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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '12

FROM MEETING ON RAILWAY ENGINEERING - 1984 TO CONFERENCE RAILCON - 2012

Dušan STAMENKOVIĆ [1]
Miloš MILOŠEVIĆ [2]

Abstract *– The first Conference on Railway was held in Niš in 1984 under the name "Meeting on Railway Engineering" and has traditionally been held every second year in Niš, organized by Faculty of Mechanical Engineering, University of Niš. For 28 years of existence the Conference has changed the name, involved in their work and organization many experts and scientists, and passed through different phases in order to have a modern concept and become an international RAILCON Conference today. This paper provides an overview of all previous conferences stating the most important statistical information about the participants, the authors, the exhibited works, discussed current events, and other. Given the complexity of the social, economic and political situation in the region, the paper especially analyzes the situation of the railway, the railway vehicle industry and university in the eighties when the Conference originated, as well as the changes that occurred during the period of nearly thirty years and their impact on the Conference. Despite the problems caused by the unstable political conditions in the region of South Eastern Europe, the economic crisis, the decline in economic activity, and the slow transformation of the Serbian Railways, the Conference on Railway persevered and successfully continued the tradition of being held, and this year it is its fifteenth anniversary. Its mission is to bring together scientists and experts from the region, to observe the ongoing changes in developed railways and suggests directions for further development in Serbia and the region.*

Keywords – RAILCON, railway, industry, univesity

1. INTRODUCTION

This year the Conference on Railway is held for the fifteenth time – it is a jubilee. It has been 28 years since the first Conference was held. During this period in various domains of science and technology many discoveries occurred, and the railway, inevitably, was the area in which a part of the significant changes was reflected. New scientific findings, the globalization of the world market and rapid technological developments introduced changes in industry, transport and education.

From the first scientific-expert gathering called "Meeting on Railway Engineering" until now, the range of themes and thematic content have been expanded. Mutually dependent and equally important components have been changing and adapting to the needs of society and science. The aim was to better organize knowledge and connect all areas in order to achieve the defined range of practical objectives.

This year's scientific-expert gathering has, in a very real sense, the international character. Accordingly, the official language of the Conference is English, and the current title is – "XV INTERNATIONAL SCIENTIFIC-EXPERT CONFERENCE ON RAILWAY RAILCON '12". The modern concept of the RAILCON Conference includes numerous sections: Vehicles, Traffic and Transportation, Infrastructure, Maintenance, Strategy and Policy, etc.

Today's Conference structure retains many good features from all periods of development. The mission of RAILCON Conference is to bring together scientists and experts from the region, to monitor ongoing changes in developed railways and suggests directions for further development of the railway in Serbia and in the region. Seeing it as an expression of the great will of the organizers and participants, as well as the enthusiasm in their approach to work and commitment to the part of mechanical engineering dealing with railway, it can be concluded that this gathering is primarily plentiful in capacities which should be cherished and developed.

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2. FROM THE FIRST TO THE FIFTEENTH CONFERENCE

The first gathering of experts who deal with railway vehicles "Meeting on Railway Engineering" was held on October, 02-03 1984 in Niš, organized by the Faculty of Mechanical Engineering, University of Niš, and Machine Industry Niš (Figure 1a). Direct reason for organizing this meeting was a double anniversary - a hundred years of existence of the railway in Serbia, and a hundred years of work of the Machine Industry Niš.

The initiator and president of the organizing committee was Professor Stojadin Stojičić (Figure 1b).

a) 

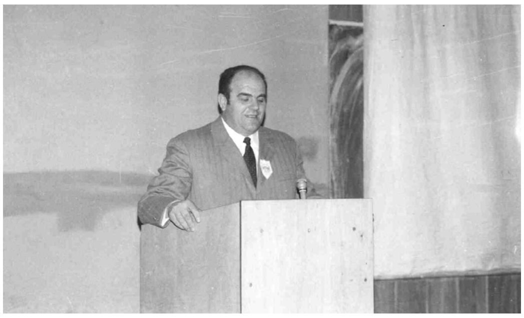
b) 

Fig.1. Participants of the first "Meeting on Railway Engineering" held on 2-3 October 1984 in Niš (a) and Professor Stojadin Stojičić at the opening ceremony of the event (b)

As the initiator, founder and organizer of the first scientific meeting of Railway Engineering in this region Professor Stojičić founded the idea of the importance of gathering representatives of science and profession in the field of railways, and with further organization of next gatherings the idea of the importance of continuity as well.

Professor Stojadin Stojičić, PhD (1930-1991) began his successful professional career in 1957, as a design engineer in the wagon factory GOŠA in Smederevska Palanka. Since 1962 he worked at the Technical Bureau of Machine Industry Niš. He was elected assistant professor at the Technical University of Niš in 1965 and until the end of his life he worked at the Faculty of Mechanical Engineering in Niš. In the period from 1973 to 1975, he served as the dean of the Faculty of Mechanical Engineering in Niš. Professor Stojičić formed and organized teaching program at the Department of Railway Engineering at the Faculty of Mechanical Engineering in Niš. Along with the educational work in his career he actively collaborated with the industry where he designed and examined railway vehicles (diesel-hydraulic locomotives, wagons, etc.)

The first gathering of scientists and experts in the field of mechanical engineering and railways met the expectations. The developmental direction of the Meeting was defined. Summing the results, the main message of the first "Meeting on Railway Engineering" was drawn - need for better coordination and cooperation between the railway operators, manufacturers, overhaulers, academic and research institutions.

The next two meetings were held under the revised, or more precisely, amended title "Yugoslav Meeting on Railway Engineering", as well as the subsequent, fourth gathering that was carried on with a new correction of the title – "Scientific-expert Meeting on Railway Engineering".

The fifth gathering was held in 1992. Since then, the Faculty of Mechanical Engineering has appeared as the main organizer. Once again the title was changed and it became "Scientific-expert Symposium on Railway Engineering". The next four gatherings got till then the broadest determinants "Scientific-expert Symposium ENGINEERING OF RAILWAY VEHICLES".

From the tenth meeting the concept has changed and "Conference on RAILWAY ENGINEERING" has extended its action including a number of experts from the region and abroad, and thus transformed into a conference with international participation.

The following four conferences were held under the same title "Scientific-Expert Conference on Railway ŽELKON/RAILCON" and with already established principles of organization. RAILCON Conference has become a recognized scientific-technical Conference on railways. With expanded content and thematic scope, and with the participation of numerous experts from abroad, RAILCON represents an important regional gathering of scientists and experts who observe the development of the railway in Serbia and achievements of railways in developed countries.

This year's gathering of scientific and experts has, in a very real sense, the international character with the Program Committee consisting of eminent scientists and experts from 11 countries. In line with that, the official language of the Conference is English and the actual title is "XV INTERNATIONAL SCIENTIFIC-EXPERT CONFERENCE ON RAILWAY RAILCON '12".

Table 1 provides a summary of information of all fifteen conferences, starting from the first "Meeting on Railway Engineering" in 1984 until the fifteenth Conference titled RAILCON '12.

Table 1. Basic information on all conferences from 1984 to 2012

No.	Date of event	Title	Organizer	Organizing Committee President	Papers number	Authors number	Participating countries number	Participants number
1.	October, 02-03 1984	Meeting on Railway Engineering	Faculty of Mechanical Engineering Machine Industry Niš	Prof. dr Stojadin Stojičić	**29**	30	1	150
2.	October, 02-03 1986	Yugoslav Meeting on Railway Engineering	Faculty of Mechanical Engineering Machine Industry Niš	Prof. dr Stojadin Stojičić	**34**	39	1	
3.	September, 29-30 1988	Yugoslav Meeting on Railway Engineering	Faculty of Mechanical Engineering Machine Industry Niš	Prof. dr Stojadin Stojičić	**36**	50	2	
4.	October, 04-05 1990	Scientific-expert Meeting on Railway Engineering	Faculty of Mechanical Engineering Machine Industry Niš	Prof. dr Stojadin Stojičić	**21**	31	3	
5.	October, 01-02 1992	Scientific-expert Symposium on Railway Engineering	Faculty of Mechanical Engineering	Prof. dr Ranđel Bogdanović	**46**	55	1	
6.	October, 05 1994	Scientific-expert Symposium Engineering of Railway Vehicles	Faculty of Mechanical Engineering	Prof. dr Ranđel Bogdanović	**38**	48	1	
7.	October, 01-02 1996	Scientific-expert Symposium Engineering of Railway Vehicles	Faculty of Mechanical Engineering	Prof. dr Ranđel Bogdanović	**49**	56	2	
8.	October, 29-30 1998	Scientific-expert Symposium Engineering of Railway Vehicles	Faculty of Mechanical Engineering	Prof. dr Slavko Kepdžija	**47**	82	2	
9.	October, 26-27 2000	Scientific-expert Symposium Engineering of Railway Vehicles	Faculty of Mechanical Engineering	Doc. dr Radisav Vukadinović	**48**	78	3	
10.	October, 24-25 2002	Conference on Railway Engineering	Faculty of Mechanical Engineering	Doc. dr Dušan Stamenković	**46**	82	4	161
11.	October, 21-22 2004	Scientific-Expert Conference on Railway ŽELKON/RAILCON '04	Faculty of Mechanical Engineering	Prof. dr Miroslav Đurđanović	**67**	117	8	220
12.	October, 19-20 2006	Scientific-Expert Conference on Railway ŽELKON/RAILCON '06	Faculty of Mechanical Engineering	Prof. dr Dušan Stamenković	**97**	174	8	280
13.	October, 09-10 2008	Scientific-Expert Conference on Railway ŽELKON/RAILCON '08	Faculty of Mechanical Engineering	Prof. dr Dušan Stamenković	**88**	162	10	190
14.	October, 07-08 2010	Scientific-Expert Conference on Railway ŽELKON/RAILCON '10	Faculty of Mechanical Engineering	Doc.dr Miloš Milošević	**93**	188	12	220
15.	October, 04-05 2012	International Scientific-Expert Conference on Railway RAILCON '12	Faculty of Mechanical Engineering	Doc. dr Miloš Milošević	**88**	178	13	

Patrons of the traditional gathering of scientists and experts from railway, university and industry were: Ministry of Science of the Republic Serbia, Serbian Railways and MIN Niš. The holding of these meetings has been enabled by many national and foreign companies and their financial support, such as: MIN Lokomotiva Niš, Bratstvo Subotica, GOŠA Smederevska Palanka, ŽELVOZ Smederevo (former Heroj Srba), TIGAR Technical Rubber Factory Pirot, CIP Transportation Institute Beograd, Institute Kirilo Savić Beograd, Railways of Montenegro, SIEMENS Beograd, ALTPRO Zagreb, KONCAR Electric ehicles Zagreb, MIN AD Svrljig, and many others.

Over the past 28 years, from the first meeting until now, in the areas of engineering, economics and politics changes were taking place. The Conference on Railway Engineering has survived, but it was transformed into a gathering that follows current trends in all areas of railway. In order to improve the gathering, some innovations were constantly introduced. Thus, from the XI Conference onward, thematic areas, apart from railway vehicles, have been extended to railway infrastructure, traffic and transport policy. Since 2004, the Conference has been known for its abbreviated name ŽELKON/RAILCON.

In the framework of the previous conferences, the Faculty of Mechanical Engineering published accompanying historical publications which in a special way deal with the history of rail traffic in our region:

- "A hundred and twenty years of railway in Niš" by Nenad Govedarović and Zoran Bundalo, 2004;
- "Private narrow gauge railroads in Serbia 1881-2006" by Nenad Govedarović, 2006;
- "Trams in Serbia 1892-2008" by Nenad Govedarović, 2008.

One of the innovations has been the inclusion of students in the work of the Conference through the section the young and the future of Railway. The section was founded in 2008 with an aim to get young professionals interested in the railways. Within this section, the successful graduate students' theses from universities in the region are presented.

Figure 2 shows some details from the previous conferences.

In order to discuss certain current topics in more details, the practice to organize Round Tables has been introduced. There, introductory speeches are given by distinguished experts from different Railways fields, with open discussions thereafter. The topics that were presented within the introductory speeches at the Round Tables at conferences so far are:

- "Railway traffic and integration processes in South Eastern Europe" - 2004;
- "The needs and opportunities for the introduction of modern trams - light rail system in the city of Niš" - 2008;

- "Regulations of rail transportation: status, problems and harmonization with EU regulations" - 2010;

and the following two topics that are at this year's RAILCON '12:

- "Certification of entities in charge of maintenance of railway vehicles" - 2012;
- "Rail passenger transport: Where are we and how to continue? " - 2012.

2002

2004

2006

2010

Fig.2. Details of the previous conferences

By selection of topics for the Plenary Sessions, Organizing and Program Committees have pointed out priority activities related to the development of railway in the country and in the region. Technological improvement of railway, regional integration processes, restructuring of the railway company into the market-oriented economic entity, sustainable development, joint and coordinated action of the relevant authorities, and the like, have had the primary significance.

The thematic topics of the Conference include railway vehicles, transportation, infrastructure, maintenance, information technology, economics, politics and everything else that has to do with Railway. Because of the interdisciplinary nature of the railway technology the meetings were always attended by experts of different profiles: mechanical engineering, electrical engineering, civil engineering, transportation, electronics, metallurgy and others.

3. WHAT HAS BEEN CHANGED IN SERBIA IN THE LAST THIRTY YEARS

We live in an age of intensive changes that occur in human consciousness, education, access to information, and therefore in all areas of life. All of these have been caused by the rapid rate of development of new technologies that are changing the way of life, communication efficiency, productivity, production methods, models of learning, etc. Accordingly, globalization and rapid technological development affect significant change in industry, transport and education.

3.1. Changes at the University in Serbia

The system of traditional higher education was established during the twentieth century, but since the signing of the Bologna Declaration in 1999 it has began changing significantly across Europe. The main goal of the Bologna process is to establish a single European area of higher education. The reform of higher education in Serbia should provide more efficient and flexible studying adapted to European quality standards. The Law on Higher Education of the Republic of Serbia was adopted in 2005 and since then, numerous activities have been conducted at universities.

Today in Serbia there are 18 accredited universities, of which 8 are state-owned and 10 private. Thirty years ago, all the universities in Serbia were state-owned, and there were 6 in total. The first private university in Serbia was founded in 1992 (Braća Karić University).

Considering new scientific discoveries and extremely rapid development of engineering and technology, constant and continuous changes in the education system are necessary. The goals that were set for the engineers some fifty year ago were directed to increase productivity and product quality, whereas today these aims, among other things, are oriented towards the requirements of energy efficiency and ecology.

With this relation, it should be noted that, because we live in a time of rapid change, there is a need for innovation of expertise, specifically for continuous learning throughout working life. The University should provide experts who are able to continuously communicate, to constantly upgrade their knowledge, to dedicate their professional skills to contemporary issues and to use modern IT tools.

In order to illustrate the changes that have been occurred in this area in recent thirty years, Table 2 presents some data related to the studies at the Faculty of Mechanical Engineering, University of Niš. The implementation of the curriculum that was accredited in accordance with the requirements of the Bologna process began with the school year 2007/08.

Table 2. Comparative data on studies at the Faculty of Mechanical engineering in Niš

School year	**1984/85**	**2011/12**	
	graduate studies	basic academic studies - Bachelor	graduate academic studies - Master
Duration of teaching semesters	10	6	4
Number of study profiles	6	1	5
Number of examinations (subjects)	39	32	19
Number of subjects of all study profiles (required + optional)	32 + 40	17 + 95	8 + 127
Number of students enrolled in the first year	320	252	46
Number of graduates	125	23*	74**

Note: * Data related to the school year 2010/11
** Data related to the school year 2010/11 and to students who began studies according to the old studying program that was in force before the Law on Higher Education of the Republic of Serbia

In contrast to previous two-semester subjects, today, in accordance with the Bologna Declaration, all subjects are one semester and there are a number of optional electives that students choose according to their preferences and interests. Former after graduate studies are now replaced with doctoral (PhD) academic studies that lasts 3 years.

It may be concluded that the University for the last 30 years has undergone some significant changes in terms of the ownership structure, the model of education and the system of financing.

3.2. Changes at the Railway in Serbia

Taking into account the steady decline of railway in the share at the transport market, twenty years ago a process of restructuring of European railway has started. Experiences of EU states and their railways show that it is possible to put the railway sector on stable basis only by restructuring it.

The process of restructuring the Railway in Serbia has been launched after the year 2000 and has been being implemented very slowly, consistent with unstable political situation in the country. This process involves: restructuring of the railway company, restructuring of the state administration in this domain and restructuring of the relationship between the state and the railway company, in order to enable the railway company for the market oriented way of doing business.

The Railway Law was passed in 2005 and it clearly defined the process of restructuring the railway sector. The Directorate for railways was formed, the Strategy and policy of development of the transport sector in Serbia was adopted, the joint-stock company Serbian Railways was established which is composed of the Directorate for Infrastructure, Directorate for Transport, etc.

The restructuring process of Serbian Railways is performed in the framework of the following activities: legislative framework, organizational structure, rationalization of unprofitable sections of the network, the separation of secondary activities from the company, reducing the number of employees, improving the quality of the relationship between the State and the Railway. Certain aspects of the restructuring (reducing the number of employees, legal framework) are increasingly further away than the other (organizational structure, the relationship between the State and the Railway, etc.) [12].

However, the process of restructuring takes place very slowly and a number of substantive changes are yet to come. This can result in that the railway sector in Serbia remains unprepared for the opening of the market, which will be established by the pressure from EU, by the international financial institutions [13].

In order to compare the efficiency of the railway today and thirty years ago, Table 3 provides an overview of some comparative data on the Railway in Serbia in 1984 and today, i.e. in the business year 2011.

Table 3. Comparative data on business years 1984 and 2011

	1984.	2011.
Volume of passenger transport (passenger-kilometers)	3580 x 10^9	590 x 10^9
Volume of freight transport (tonne-kilometres)	9,11 x 10^9	3,61 x 10^9
Length of slow running (km)	N/A	982
Inventory status of traction rolling stock (pieces)	671	417
Inventory status of passenger cars (pieces)	1254	530
Inventory status of freight cars (pieces)	15888	8844
Number of employees	46777	18557

In 1984, on the territory of the Republic of Serbia there were three independent railway companies (ŽTO Beograd, ŽTO Novi Sad and ŽTO Priština). In accordance with the law, together with other railway companies on the territory of Yugoslavia, they were associated as the so-called Union of Yugoslav Railways, which coordinated the process of making timetables, bringing technical regulations and was in charge of international cooperation. Serbian Railway today is organized as a joint-stock company 'Serbian Railways', which even though is composed of the Directorate for Infrastructure and Directorate for Transport, is essentially a single enterprise.

Numerous changes are pending within Serbian Railway in terms of organization and technology, and what is necessary for that, in addition to investments in infrastructure and rolling stock, are also the political will and persistence.

3.3. Changes at the Industry in Serbia

In the last three decades the world railway industry has undergone a process of concentration so that several large international industrial systems represent the leading global provider of services in the railway infrastructure and rolling stock. Because of that, the possibility of smaller independent companies to successfully enter the world market has been reduced.

Railway industry in Serbia has over 120 year long tradition. National railway industry has developed its capacities primarily according to the needs of the national railway and major mining-metallurgical companies in the country. It includes companies involved in the production and repair of traction rolling stock MIN Lokomotiva Niš and ŠINVOZ Zrenjanin, then factories that produce and repair freight wagons Bratstvo Subotica, MIN Vagonka Niš, FVK Kraljevo, as well as GOŠA Factory of rail vehicles Smederevo Palanka, which produce and repair passenger and freight wagons, and ŽELVOZ Smederevo, which deals with repairing of passenger and freight wagons and electric and diesel multiple units. In addition to these, many companies from mechanical, electrical, metallurgical and other industries have been producing parts for rolling stock and rail infrastructure. These are MINEL Beograd, EI Niš, Tigar Pirot, PPT Trstenik, Livnica "Požega", Livnica "Kikinda", FIAZ Prokuplje, Krušik Valjevo, Sever Subotica, Novkabel Novi Sad, FASO Vladimirci, MIN Skretnice, MIN Svrljig and so on. It is estimated that the industry, which was linked directly or indirectly to the railway in Serbia, had about 25,000 employees in the early eighties of the last century.

The period from 1980 to 1990 was characterized by stagnation and even a slight decline in gross domestic product. However, a period of an extremely difficult situation of the Serbian society and economy came from 1990 to 2000. The disintegration of Yugoslavia, wrong economic policy with hyperinflation, lack of necessary reforms, sanctions and NATO bombing caused great damage and caused a profound disruption in the economy and the railway traffic. In this period there was a large narrowing of the market of transport services and the economic downturn of railways. The condition of the infrastructure deteriorated, age structure and technical obsolescence of transport vehicles became even more pronounced. In particular the immobilization of transport capacities was striking because of irregular maintenance. Such state of the economy in the country, especially the situation at the national rail market, was reflected to the activity and status of the railway industry. Volume of production declined rapidly and unemployed facilities were partly engaged in overhaul operations, reconstruction and production of spare parts and other some jobs.

Serbian Railways, preoccupied with its own reorganization, neglected relationship to the national industry. Purchase of new vehicles, reconstruction of the old and investment repairs are carried out through tenders. In new construction jobs, because of severe commercial conditions, national industry cannot be employed, except that to a lesser extent, it may possibly be involved as a subcontractor. Thus, larger investments in the field of railways ‘‘circumvent" Serbian economy [14].

The working capacities of all national factories producing wagons in the last 15 years have decreased many times; therefore most of the factories became poor in personnel (manufacturing, engineering, commercial staff left companies). Because of the process of privatization, which the factories encountered, investments were halted and production capacities of most of the factories are considerably reduced. The equipment is mostly outdated. Unfortunately, neither with privatized factories there were no substantial investments by new owners. In this situation, there is enormous inertia of the employees, which manifested itself through the lack of interest to engage in marketing contest with the competition. In the course of the privatization process the state did not undertake incentive measures to facilitate this process [14]. In factories for production and repair of railway vehicles privatization was conducted unsuccessfully. Table 4 shows the condition of the railway vehicle industry of Serbia in the process of privatization.

Table 4. Condition of the railway vehicle industry of Serbia

No.	Company name	Activity	Employees number	Ownership status	
1.	MIN Lokomotiva - Niš	Production and repair of locomotives	296	Privatized 2007	Rescinded privatization contract November 2009
2.	ŠINVOZ - Zrenjanin	Repair of locomotives and electro and diesel multiple units	100	Privatized 2004	
3.	GOŠA – Smederevska Palanka	Production and repair of passenger and freight wagons	445	Privatized 2007	
4.	BRATSTVO - Subotica	Production and repair of freight wagons	240	Privatized 2004	
5.	MIN Vagonka - Niš	Production and repair of freight wagons	275	Privatized 2007	Rescinded privatization contract November 2009
6.	ŽELVOZ - Smederevo	Repair of passenger and freight wagons and electro and diesel multiple units	1240	Privatized 2007	Rescinded privatization contract November 2011
7.	FVK - Kraljevo	Production of freight wagons and steel structures	750	Privatized 2006	Rescinded privatization contract November 2010

In order to illustrate the unfavourable situation in factories for production and repair of railway vehicles, the analysis of productivity of the factory MIN Lokomotiva is given here. Figure 3 presents a comparative graphical analysis of data related to the repair of locomotives and production of new vehicles. It shows the average annual volume of work in the repair of locomotives and production of new maneuver locomotives and track cars, for the period 1984-1986 and the period 2009-2011. It may be noted that the volume of work today is five times lower than it was thirty years ago.

Today's factory MIN "Lokomotiva" a.d. in the restructuring has 296 employees. 28 years ago it was called OOUR Remont, it operated within enterprise MINTRANS in the frame of SOUR MIN and had 820 employees.

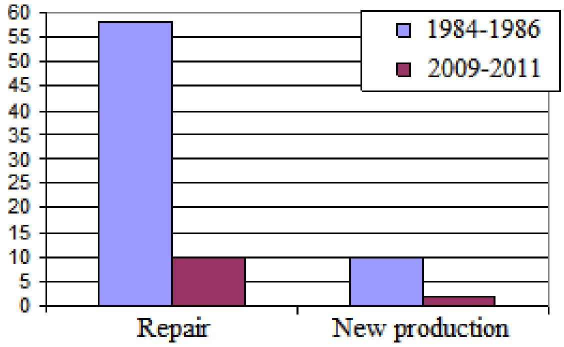


Fig.3. Ratio of the average annual volume of production of repair and new production in MIN Lokomotiva

Factory MIN Vagonka achieved the largest volume of production in 1984/1985 with the production of 845 wagons of the type Hais, for the transport of goods in pallets for the Iraq market. Today there is no production of new wagons and reconstruction of old wagons is rarely performed. The facilities of this factory are partially employed by regular current repairs of freight wagons.

Based on the above it can be concluded that changes in the railway industry of Serbia in the last 30 years were extremely unfavourable. The process of ownership transformation is not conducted in a satisfactory manner, the volume of production and the number of employees are reduced several times. These were mainly influenced by adverse political circumstances and a very unstable market. The hundred year old tradition of national railway industry does indicate that there are professional resources that can achieve higher production in a regular economic environment.

4. CONCLUSION

The processes of globalization and the creation of a global free world market marked the beginning of a global society that has led to significant changes. In addition to the formation of multinational manufacturing companies, the globalization of the world economy brings also multi-national companies in the areas of transport, services, banking, investments and the like. However, apart from positive experiences, today the production potentials of the world industry are considerably higher than the demand and the possibility of placement.

Extremely rapid technological advances caused changes in almost all spheres of life. Road and air traffic in the last 50 years have experienced a great expansion and repressed the rail service. On the other hand, that led to enormous energy consumption and alarming pollution levels. The railway, due to its advantages in terms of transport capacity, speed, energy efficiency, and particularly in terms of ecology has good perspective. Unfortunately, due to the high investment costs, the railway is now successfully developing only in rich countries, whereas this is not happening in less developed countries.

Despite the numerous problems in the last thirty years caused by unstable political conditions in the region of South Eastern Europe, the economic crisis and the decline in economic activity in recent years, and the slow transformation of the Serbian Railway, the Conference on Railway Engineering has remained and transformed into well known international RAILCON Conference which will in the future still be an event that will bring together scientists and experts in the field of railway, keeping the hope of the organizer that the Railways in the region will be improved.

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COMPETIVENESS OF THE EUROPEAN RAILWAY INDUSTRY AND THE PARTNERSHIP INDUSTRY-ACADEMIA: A MUST

Daniel L. CADET [1]

Abstract *– The Railway Industry can be separated between the Supply Industry offering products and the Operating Industry (Operators and Infrastructure Managers) maintaining the Railway System at nominal operating conditions and offering services for the transport of persons and goods. The Railway Manufacturing Industry is a world leader supplying more than 50% of the world production with a large part of the production located in Europe, but this position is being jeopardized by the entrance of new players, mainly from Asia. Concerning the Service dimension, Rail transport is also vital for the European economy. For the sustainable development of the European economy for the next years and decades, railway transport must play a key role with a drastic increase of the % of freight and passengers transported by that mode as it is stated in the European Commission's 2011Transport White Paper. To keep its world leading role as a manufacturing industry with a large number of jobs in Europe, the Rail Supply Industry must increase its competitiveness through innovation. To support the growth of the rail mode in Europe i.e. to meet the users' needs, operators and infrastructure managers must be able to provide high level of services i.e. reliable, affordable and sustainable, and being able to meet the demand for a massive increase in capacity, whilst providing increasingly seamless mobility keeping the very high level of safety of that mode. During the last decades, the Rail Sector has demonstrated its capacity to innovate. Suffice to mention the Very High Speed Trains, the Tilting Trains, the ERTMS signaling System, the catenary-free tramways, etc…However, in that Industrial Sector which is "project oriented", there are limitations preventing long-term R&D investment for different reasons : low operating margins, short series with high level of customization, long cycles (a rolling stock product can be operated for more than 50 years), conservatism favorable to proven technologies and leading to a slow penetration of innovation, cost pressure, etc… To take up the challenges that the European Rail Sector is facing, there is no other issue than a step-change investment in R&D to exploit all the potential of innovation taking place in Academia labs as well as the Research and Technology development in other sectors through adaptation of solutions to the railway needs. In that endeavor, Academia has an important role to play because Industry which is not the place where new ideas can emerge, be explored and be nurtured, does not have the resources to perform that task and all the necessary expertise. Thus, Partnership between Industry and Academia is a MUST.*

Keywords – Railway, Competitiveness, Academia, R&D.

1. INTRODUCTION

The Railway Transport Industry has two main components: the Manufacturing Industry offering solutions of transport and the Transport Industry offering services to passengers and freight operators and keeping the system at nominal operating conditions.

The European rail supply industry is one of the few industrial sectors in which Europe still leads at the world level. The global rail market is estimated at €136 billion (Europe accounts for more than €45billion) with a predicted annual growth of 2-2.5% for the next few years. The UNIFE (UNion des Industries Ferroviaires Européennes) member companies supply more than 50% of the worldwide production of rail equipment and services. Throughout Europe it is estimated that 400,000 people are directly and indirectly employed by the supply industry.

The supply industry has manufacturing and R&DI facilities throughout the EU and the sector is characterized by stability and robustness. During the last two decades, consolidation took place and a

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number of key actors are major players on the global market while keeping their position of national champions in their home territories.

Railway transport of persons and goods is vital for the European economy. To address the challenge of climate change and the need to reduce "addiction" to carbon, the rail transport represents one of the key solutions for a sustainable transport system. Modal shift is becoming a primary policy objective that will be achieved if rail is becoming the mode of choice for passengers and freight forwarders. Rail must be responsive to users' needs and infrastructure managers and operators must deliver high quality services. The operation of the railway system employs more than 1,350,000 people in Europe. Employment on urban railways is about of equal number. The business environment has changed. Railway operators who were acting as the National Operators in their home countries in the past are being challenged by local private operators but they are also becoming private operators in other countries exporting their expertise to Cities/Regions/Countries and creating jobs.

However, the Rail Sector is at a turning point of its history. In this paper, we will review the challenges lying ahead and discuss how it is possible to meet them and why the Industry-Academia partnership is a MUST for the European Railway Industry to keep its world leading role.

2. THE SECTOR AT A TURNING POINT OF ITS HISTORY

The European leadership has been made possible by a significant investment in key high-technology products (not only high-speed trains, but also in urban transport, such as control, command and signaling, e.g. ERTMS, Driverless Metro). This leadership position is being challenged by a growing competition from overseas suppliers, in particular from Asia. Those suppliers, operating from a closed domestic market, have and continue to enjoy strong governmental support. The growing investment in Research & Innovation by foreign countries is a significant challenge to the EU stake holder's worldwide leadership.

The European rail industry cannot compete with foreign rivals on price only. Long-term competitive success depends on continuous introduction of completely mastered innovation in the products as well as the enhancement of the quality of the products.

Similarly, rail infrastructure and operators are faced with major challenges to make rail transport the most attractive mode of transport i.e. become the first choice of travelers and freight operators. Rail currently has about 6% share of the passenger market and around 16% of the inland freight market, both dominated by road transport. The European Commission set up objectives for modal shift towards rail and the underlying growth of transport for the next decades. For example for 2050, it means an eightfold increase in freight moved by rail and a twelve fold increase in passenger travel. This is an opportunity but also a challenge for rail. How to respond to that demand?

To achieve those objectives, besides behavioral changes and securing physical means with which to attract, manage and retain the anticipated future new volumes of demand and still remain safe, there is no doubt that in addition to policy measures, innovation will be a major driver behind the growth of the railway sector. Railway manufacturing industry, operators and infrastructure managers must come with solutions to meet the users' needs, ensuring high level of services i.e. reliable, affordable, sustainable, and being able to meet the demand for a massive increase in capacity, whilst providing increasingly seamless mobility and keeping safety at the present level.

So two main challenges lie ahead: keep the competitiveness of the Railway Manufacturing Industry and respond to the increasing demand for transport of persons and goods in Europe. With no compromise on safety while increasing its green credentials, the railway sector must embrace new technologies. There is a need for a step-change in railway research, similar to what the automotive industry has demonstrated in response to the challenge to internal combustion engine.

The specificity of the railway business must address a number of barriers to innovation such as low margins, long product renewal cycles, small product runs, lack of standardized products and rail's complex system interfaces.

3. IS RAILWAY INDUSTRY INNOVATIVE?

Yes it is! Here are a few examples, taken from ALSTOM, demonstrating that the Railway Industry is innovative.

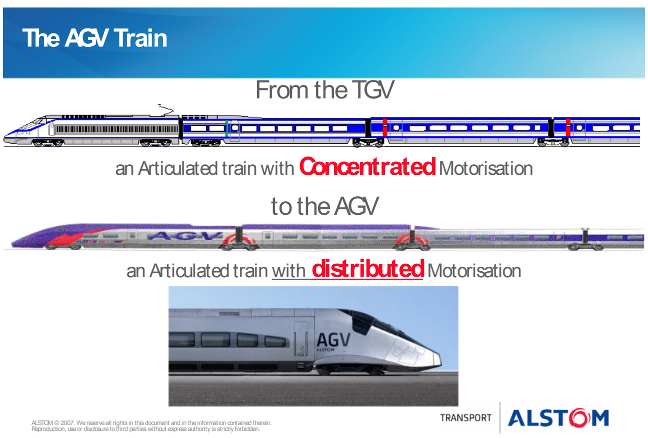
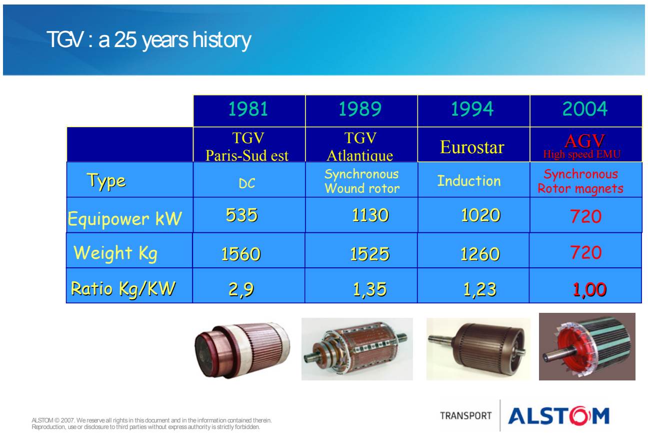


Fig.1. AGV, an articulated Very High Speed (350km/h) train with distributed motorization incorporating innovation (Permanent Magnet Motors)



	1981	1989	1994	2004
	TGV Paris-Sud est	TGV Atlantique	Eurostar	AGV High speed EMU
Type	DC	Synchronous Wound rotor	Induction	Synchronous Rotor magnets
Equipower kW	535	1130	1020	720
Weight Kg	1560	1525	1260	720
Ratio Kg/KW	2,9	1,35	1,23	1,00

Fig.2. 25 years of innovation in Traction Motors. High Power Permanent Magnets Motors for traction is a genuine innovation

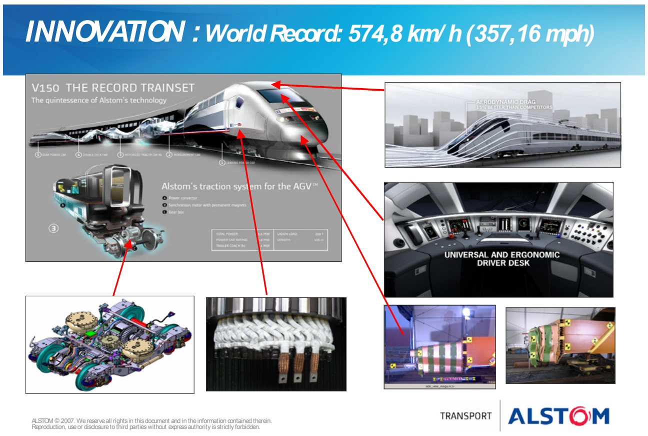


Fig.3. A series of innovation made possible the World Record 574,8 km/h

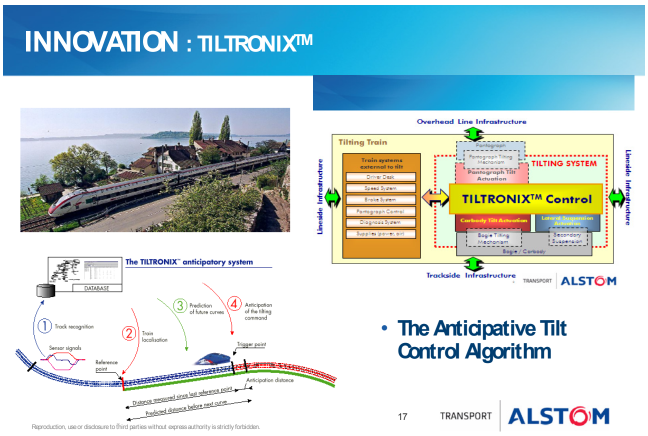


Fig.4. Tilting Train (Pendolino). The introduction of that technology was a major breakthrough allowing increase of speeds on conventional lines

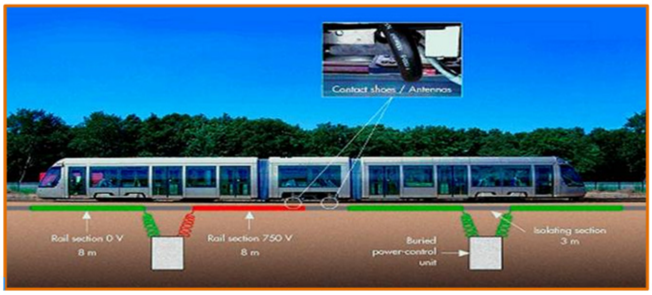


Fig.5. The APS (Aesthetic Power Supply) catenary free power system for Tramways for a complete insertion in cities. The powered section under the tramway is shifted as the tramset is moving.

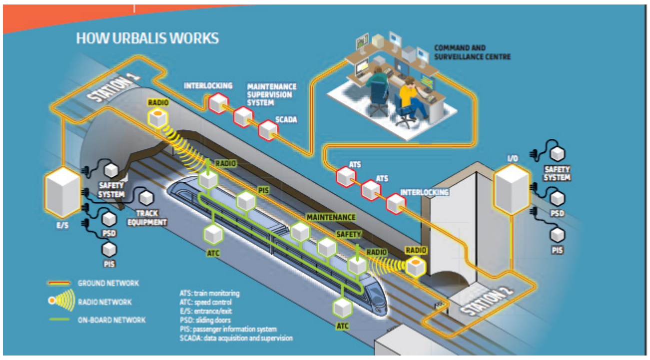


Fig.6. The URBALISTM CBTC (Communication Based Train Control) for Driverless Metro Operation

4. WHAT ARE THE LIMITATIONS FOR R&D LONG-TERM INVESTMENT

There are limitations to investment in long-term R&D in the Railway Sector.

The Railway Industry is "project oriented" and characterized by the putting in service of a small series of vehicles, designed to meet the inherent constraints of unique infrastructure, electrification or control-command systems i.e. answering the specific needs of customers. In addition, the customers request "proven technologies" with warranty over several decades.

The supply industry tries to compensate the market fragmentation by the development of "platform solutions" for rolling stock and the adoption of highly standardized architectures for control command.

Because most orders are short series specific for a customer i.e. high level of product customization, this leads to low operational margins that do not allow to invest into speculative technology-oriented research.

Rail products are characterized by very long renewal cycles. A rolling stock can be operated well beyond 50 years. This does not help to introduce innovative technologies.

Another feature of the sector is the strong and complex interaction between all the components of rail system i.e. infrastructure, control-command, electrification, vehicles. Thus, it is difficult to introduce innovative technologies that can really impact the efficiency and the competitiveness of the whole system.

Lack of standardized products prevent also the introduction of innovative technologies. Other sectors (e.g. aeronautics, automotive) are driven by suppliers' offers, whereas the railway sector is mainly driven by customer/operator demands.

5. WHY IS PARTNERSHIP WITH R&D CENTERS A MUST?

The spectrum of expertise that a railway Manufacturing Company has to encompass is wide. It covers (not exhaustive) core business topics such as Material Science (for carbody-shell and bogies construction, wheel-track interaction and wear), Traction Motors, Power Electronics (for Traction Drives), to enabling "technologies/subjects" such as aerodynamics, noise & vibrations, electromagnetic compatibility through the New Technology of Information and Communication for Signaling and Passenger Information and Rolling Stock Maintenance to Industrial Design (Aesthetics) to Human Machine Interaction (Driver Cab; Traffic Management Center) to qualitative and quantitative understanding of the passenger comfort.

Considering the very wide range of expertise that a Railway Integrator must master and/or have a sufficient level of knowledge, it is easy to understand that the industry cannot invest in terms of R&D activities into all the fields as some of them are not in its core business and some fields are pushed by other sector businesses and moving very fast. Furthermore, the Manufacturer job is not to carry out research but to deliver high quality products while keeping ahead of competition for which innovation is one component but not the only one. However, it is important that the Industry be aware of new ideas popping up in laboratories, in start-up companies, in Small ad Medium Enterprises and being developed up to the level of prototype or as a product in other sectors. Scouting for new ideas, innovations within Academia as well as within public and private applied research centers is important for the Industry.

Thus, Relation/Partnership with Academia is a MUST!

To be kept updated on research activities within Academia and other R&D Centers in the domains of interest, tools are available nowadays through Internet, proceedings of Conferences. Usually, the problem is not a lack of information but too much information that leads to poor efficiency to collect the relevant ones. In the domains of the core business, one additional solution is to become a member of the Industry Liaison Program offered by a University or an Academia Group so that all of their information on Research activities and results are accessible, giving also first access to patents and licenses. This is a first level of partnership.

For the domains that are within the Core Business of an Integrator, R&D Projects are carried out by the Integrator. Those Projects are not "Engineering Projects" for which no research activities are needed. Referring to the European Union definitions, two types of Research activities are carried out by the Railway Industry: Industrial Research corresponding to TRL (Technology Readiness Level) 1 to 4 and Experimental Development corresponding to TRL 5 to 7.

Most R&D Projects span over the two activities. For Industrial Research, more basic expertise is needed and Academia Laboratories are frequently partners in the Projects. There is less participation from Academia laboratories in the Experimental Development.

Industrial sectors are more or less secretive and conservative. This is particularly true in the Railway Transport sector. The specificity of the business is such that most R&D activities have an 3-5 years time objective in terms of products or market uptake. It is a not exploratory research but it can rather be classified as competitive research. Consequently, there is a tendency to carry out such projects totally internally.

Other projects needing more basic expertise are carried out in partnership with Academia. There are several advantages to that scheme:

- Complement the expertise of industry engineers (a company has the best engineers but. there are smart and knowledgeable people outside!);
- Open the perspective of industry engineers through a genuine interaction with scientists more knowledgeable in basic spects;
- Permit more basic research work that does not appear as necessary from an engineer perspective but that can bring a deeper knowledge that helps later to understand some issues that may pop at a certain point during the course of the project;
- Give an opportunity to both sides to understand each other (different culture, different way of working), thus building up a confidence relation for the future.
- Give Academia information on future needs of Industry in terms of Research so that University R&D is more tuned to Industry needs.

As a synthesis, this a reciprocal benefit for Industry and Academia to interact.

It is good for researchers to get out of their labs and for engineers to interact with researchers who are not tight by too much economic pressure.

6. EXAMPLES OF PARTNERSHIP PROJECTS WITH ACADEMIA

ALSTOM Transport has a large portfolio of Contracts and Research Projects with Academic

Laboratory.

A contract has a different objective. For example, there is problem appearing on a product after certain time of operational service. Understanding the root cause, means the physical/chemical/etc… phenomenon behind the problem must be identified and hopefully understood. Expertise from Academia is a must.

There are different kinds of Cooperative Research Project.

- The Industry has identified a domain in which it has to beef up its expertise. The Industry is funding a PhD student who is going to work part time in the Academia Lab as well as at the Industrial Site on a subject decided by Industry but needing an important Research work so that it can lead to the defense of a PhD dissertation. In some countries, e.g. France, the Industry is partly funded for the student salary. This is a national policy to enhance relationship between Industry and Academia. Most of the time, after getting his PhD, the young doctor is recruited by the Industry.
- The Industry decides to initiate a 3-5 year Research Project for which the expertise/ knowledge of an Academic Lab is necessary because it does not exist within the Industry. The two partners engaged into a collaborative work sharing their resources. Such a Project is organized, as all Projects within the Industry i.e. with Gate Reviews with potential NoGo at the end of a phase if the results are indicating that the development will not lead to a market uptake within a reasonable time scale.
- To boost Partnership between Industry and Academia, several Countries have established Research Programs with annual Calls for Proposals. For example, in France the Agence Nationale de la Recherche (ANR) has set up Thematic Programs, one criteria of acceptance of a proposal being that it is a joint proposal between Industry, Academia and at least one SME (Small and Medium Enterprise) if the leader is a Large Group. An accepted Proposal is funded : 25-30% Grant for a Large Group, 50% for a SME and 100% of the marginal cost of the Academic Partner.

The European Projects (funded at 50% by the European Commission) represent another kind of Cooperative Projects between the Industry (Large Groups, SMEs), Applied Research Centers and at Academic Groups. However, in EU Projects, the large number of partners does not facilitate an "intimate" relationship between an Academic Group and one of the Industry partner.

Here are some Projects carried out in partnership between ALSTOM Transport, other Industrial Companies and University Groups.

The driver of the ULTIMAT (UtiLisaTion Innovante des nouveaux MATériaux dans la construction ferroviaire) Project is the Energy Efficiency of the Mass-Transit Transport system. Metallic materials are used for carbodyshell construction. New lighter materials have emerged and are being used by other transport industries e.g. aeronautic, automotive. The objective of the ULTIMAT Project was to reduce the mass by 20%, the number of parts by 20% and the final cost by 30% while achieving the same performances in terms of resistance and reliability than a metal carbodyshell. The monitoring of the health status of such a structure was also a key issue. The Project was a joint effort between ALSTOM (Leader), Arcelor-Mittal, EADS/Sogerma Services (manufacturing composite parts), a railway supplier of thermoplastics parts and several universities (Université de Valenciennes; Ecole des Mines de Douai and the Université de Technologie Compiègne). Those university groups with a large expertise on composite materials based on years of research brought their knowledge to select the right materials, to test samples, to derive numerical models, etc… This Project that ended with the construction of a carbodyshell was successful in term of research but also in term of partnership between Industries and Academia groups.

Traction Drives are one of the core sub-systems of a Railway Integrator. ALSTOM manufactures Traction Drives i.e. Motors and Power Electronics equipment. The Power Electronics components installed on trains are using IGBT (Insulated-Gate Bipolar Transistor) that are Power Semiconductors devices made of silicon materials characterized by high efficiency and fast switching and able to control large amounts of power, for example to drive motors. They have limitations in terms of acceptable maximum temperature. Other materials are being looked at such SiC (Silicon Carbide), GaN Gallium Nitride) but also Diamond for the future. In partnership with Academia Groups that are leading the Project, Industrial companies and Semiconductor SMEs are working at exploring the potential of the Diamond material. The scientific work is on mastering the growing process of diamond monocristal doped with bore ions.

The STEEM (Tramway System for Maximum Energy Efficiency) is another project carried between ALSTOM Transport, RATP (the mass-transit operator in Paris) and IFSTAR (French Research Institute on Surface Transport). The objective was to develop an Energy Storage System using Supercaps supervised by an Energy Management System to operate a Tramway between stations without using a power line. The technology was successfully tested on Line T3 in Paris in commercial service i.e. with passengers onboard.

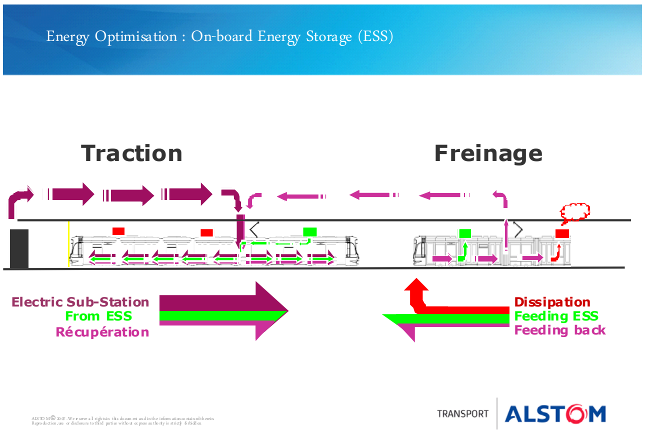


Fig.7. With an Energy Storage System onboard a Tramway, part of the Braking Energy can be recovered, stored and reused for Traction

The new technology of Urban signalling system is called CBTC (Comunication Based Train Control). It is based on high-rate communications between the trains and the wayside. This communication system must be robust, adaptative, providing high rates while using minimum radioelectric ressources. The environment of mass transit is complex as trains are operated mostly in tunnels and other confined zones. The MOCAMIMODYN (MOdeling of DYNnamic MIMO ChAnnels) Project studied the potential of new technology such as MIMO (Multiple Input Multiple Output) as a promising technology. More specifically, as performances depends on the characteristics of the propagation channel (the tunnel), it is necessary to take into account the dynamics characteristics and the variability of the propagation channel.

The partners were ALSOM Transport, IFFSTAR, Xlim SIC (University of Poitiers) and Telecom Bretagne (Engineering School in Information and Communication S&T).

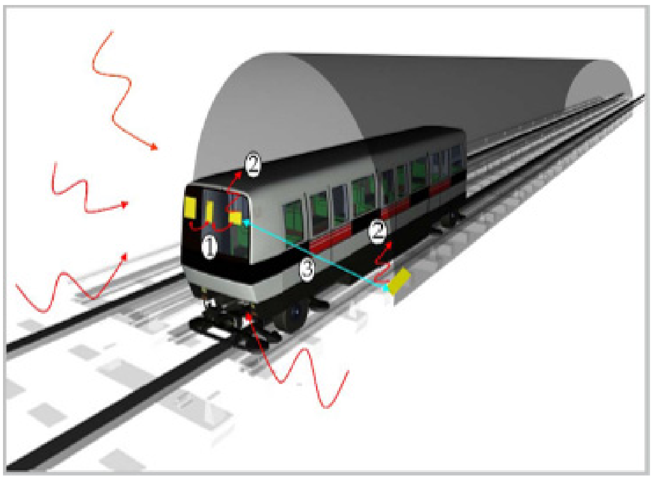


Fig.8. Schematic illustration of radio-propagation in a tunnel in presence of moving trains

Projects are also carried at the European level through funding by the European Commission (Frame Work Program). Here are examples stressing cooperation between Academia and Industry.

Several Projects funded by the European Commission are tackling the issue of certification of trains. Certification against EN standards together with the relevant technical annexes of the High Speed TSI (Technical Specifications for Interoperability) extend train delivery times for months. Therefore, certification adds to the cost of the product. Furthermore, the physical tests that are performed do not capture all operating conditions. Thus there is a risk of failure or unsafe approximation in such tests. In addition, uncontrolled environmental and other boundary test conditions can influence results. The costs and duration of tests performed in such conditions are also often increased by the need to do these tests several times so as to explore as much as possible all the range of environmental and boundary conditions and secure the results.

Three years ago, 3 Projects were submitted accepted by the European Commission (7th Frame Work Program) and clustered into the TRIOTRAIN "holding", an acronym for "Total Regulatory acceptance for InterOperable TRAIN". The three Projects (DYNOTRAIN, PANTOTRAIN and AEROTRAIN) were dealing with key railway interoperability issues. The objectives were to propose an innovative methodology that will allow multi-system network and route approval in Europe to become a faster, cheaper and better process for all involved stakeholders.

For the DYNOTRAIN Project (still going-on), the work is leading to improvement in cross-acceptance of track test, introduction of a certain level of Virtual Certification and the definition of the track loading limits related to network access.

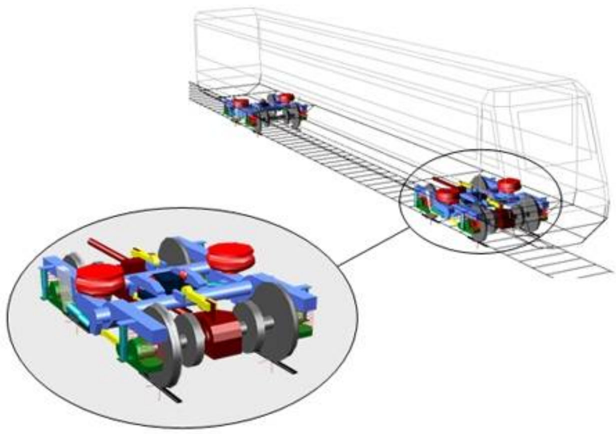


Fig.8. The DYNOTRAIN Project deals with Railway Dynamics

In the AEROTRAIN Project (closed in June 2012), the following results were achieved :

- Propose harmonization of European and national standards to reduce costs and time of certification;

- Propose the replacement of existing cross-wind and slipstream tests with new alternatives without reducing safety;
- Introduction of virtual testing for head pressure pulse loads and corss-wind aerodynamlic loads;
- Closing of open points in the High Speed and Conventional Rail (limit values and new certification procedures).

The PANTOTRAIN Project was dealing with the Pantograph-Catenary Interaction.

Two new Projects were initiated on other domains : ACOUTRAIN (Acoustics) and EUREMCO (ElectroMagnetic Compatibility).

These five R&D Projects are genuine examples of cooperation between Railway Stakeholders (Manufacturers, Suppliers, Railway Undertakings and Infrastructure Managers) and University Groups.

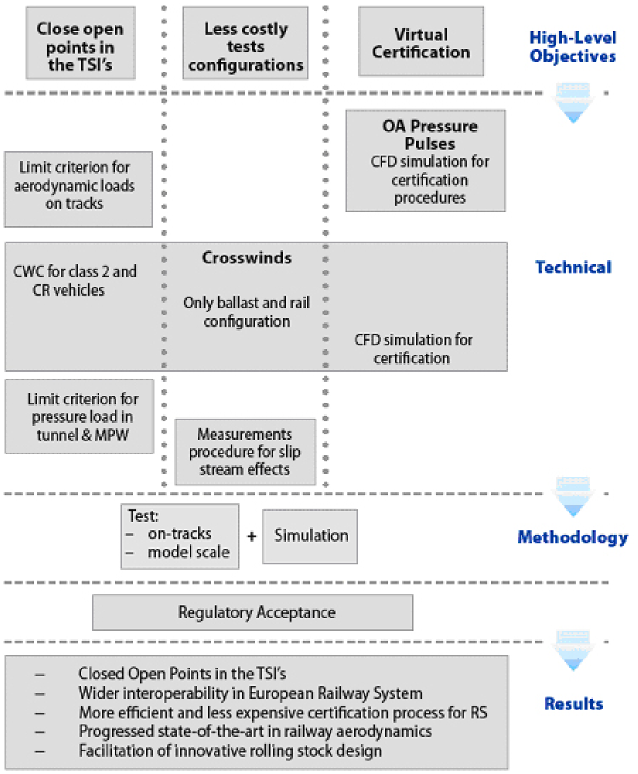


Fig.9. AEROTRAIN: from high-level Objectives to Results

7. THE PROPOSED SHIFT2RAIL JTI

The respond to challenges lie ahead the Manufacturing Industry and the Service Industry has proposed an important Program within the Horizon 2020 (the Commission R&D Program for 2014-20) through a Public-Private Partnership (PPP), more specifically a JTI (Joint Technical Initiative).

The initiative starts from what has been expressed above i.e. strong, market-driven, R&I capabilities, leading to innovative and far-reaching programs, are isntrumental to European industrial leadership and to answer the challenge of the future large increase of persons and goods mobility in Europe.

The SHIFT2RAIL JTI will tackle those challenges through a step-change in railway research and innovation and due to its collaborative nature, will allow to shorter time-to-market for key innovatiosn, positively contributing to both modal shift targets and the competitiveness of the European industry on the world market.

The SHIFT2RAIL initiative will bring together the stakeholders of Railway Research including Academia. This program will represent a real opportunity for Academia to participate to Industry R&D Projects.

8. CONCLUSIONS

To keep its world leader position, the European Railway manufacturing industry must invest into R&D to be able to offer products and systems that are affordable in terms of acquisition costs and also with a low Life Cycle Cost, of the highest quality and have even better than now, the constraints of a sustainable development.

The Rail Sector has an important role to play to respond as other transport sectors to the future demand for the transport of persons and goods.

To reach those objectives, a sizeable investment in R&D has to be made by the actors of the sector. The SHIFT2RAIL Project is the Industry answer to that challenge.

A transport system can be sustainable only if all aspects of sustainable development are taken into account. By setting high vehicle requirements with respect to safety and environmental efficiency for example, cars become more expensive and thus less affordable. A policy that would lead to low income households driving in unsafe and environmentally inefficient vehicles, would have negative consequences for social sustainability. A solution to this is to provide good alternatives through public transport, but this is not always possible and may be unaffordable for the authorities.

RESTRUCTURING OF RAILWAY SECTOR IN SERBIA– HOW TO FACE REALITY

Slobodan ROSIĆ[1]
Dragomir MANDIĆ[2]

Abstract *– The world economic crisis will inevitably affect the railway sector too. Although the competent EU authorities still have not given clear guidelines or directives saying what direction the changes will take, there are some indications that they will be much more related to reduction of important investments and less to the process of reforming and restructuring itself, especially further liberalization and commercialization of the entire railway sector. As far as Serbian Railways are concerned, unfortunately, they are among rare European railways which have only started the reforms. This is probably one of the reasons for a rather poor condition of all subsystems. The only solution is to carry out urgent and fast restructuring in order to reduce the consequences of prolonging and delaying inevitable changes.*

Keywords - restructuring, railways, Serbian Railways

1. INTRODUCTION

Following great changes in the second half of the 20th century in the field of transport, which caused huge problems for railways, most countries started important reforms of that sector. While in America and Japan these changes have been completed in a relatively fast and mostly successful way, in Europe this process has been lasting for almost a quarter of century and it is not likely to be finished soon. The economic crises, which started in 2009, rendered the situation in the railway sector even more complicated. Although, at the beginning, this crisis did not seem to have such an effect, it is now clear that European railways will seriously have to face its consequences. Therefore, most of the European countries, deliberately or as a consequence of economic measures, are being changing their policy in this sector. These changes will certainly not lead to the old system of national, monopolistic railways.

2. SITUATION IN EUROPE

The main objective of the reform of the railway sector in Europe was to improve its economic situation, that is, to stop piling up of enormous debts made by railways, to improve its competitiveness or increase the share of railways in the transport market and to establish a unique railway system. After 25 years of restructuring, the first and the third objective have been partially realized, but to a much lesser extent than it was planned and with great delays. The second objective, which is the most important for the sector itself, has not been achieved. Besides great efforts and important funds which have been invested, the share of railways in the transport market has hardly been stopped from declining and its important increase in transport market, especially in freight transport, does not seem realistic.

Since the situation differs depending on the country, it is difficult to bring a uniform conclusion for all European countries. However, we may say that, besides certain structural economic changes, the main reason for failure is the fact that the reform of this sector has not been completed, having in mind that the situation can be quite different from one country to another. Taking into account important market share of international transport in the railway sector, this situation also affects the countries which have almost completed their reforms. Except several national railways which have actually realized restructuring

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provided for by the European directives, together with the competent state authorities, most of them have been avoiding or delaying the reforms. That is why European railways, in the past decade, have not based their development on the market success, but on huge and expensive investment projects which have been financed by public funds, with several exceptions. However, sever economic crisis, which has revealed the problem of over debt European countries, will make such development policy impossible in the railway sector. Besides that, in many countries, this crisis has also revealed the problem of current business activities of railway undertakings. Although the restructuring processes have importantly reduced the losses in the past several decades, due to the uncompleted reform, that problem has not been completely eliminated. When economic situation was better, for most governments it was easier to allocate additional funds to railways than to finish the implementation of a difficult and unpopular reform. In present circumstances, such policy is no longer possible.

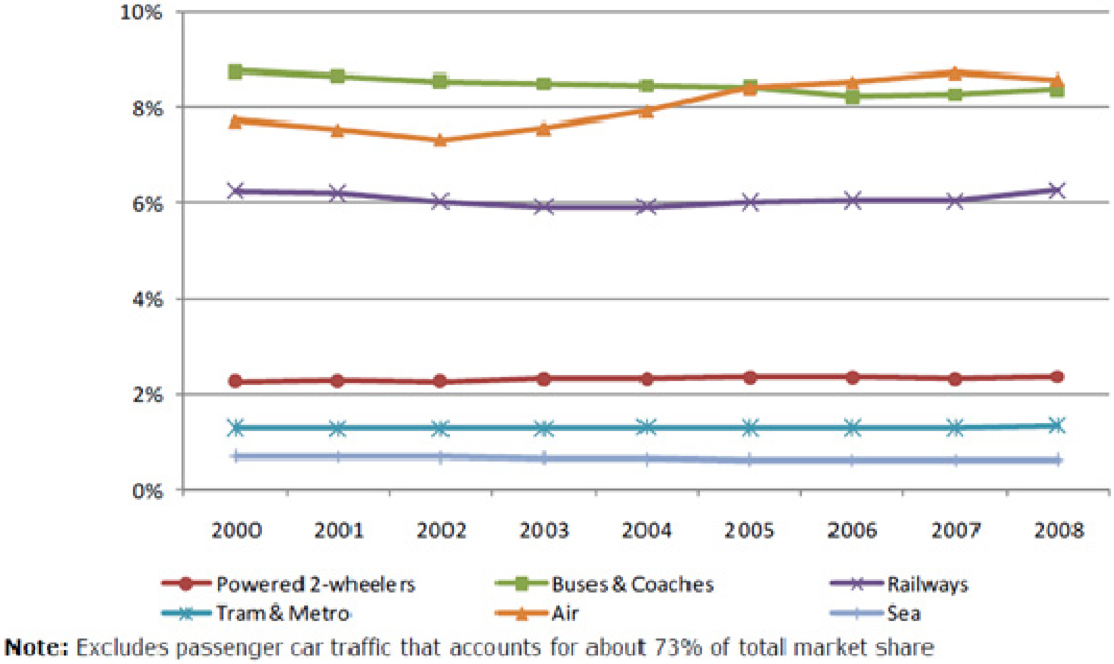

Fig.1. Market share of passenger transport modes (in passenger_km, EU-27, 2000-2008)

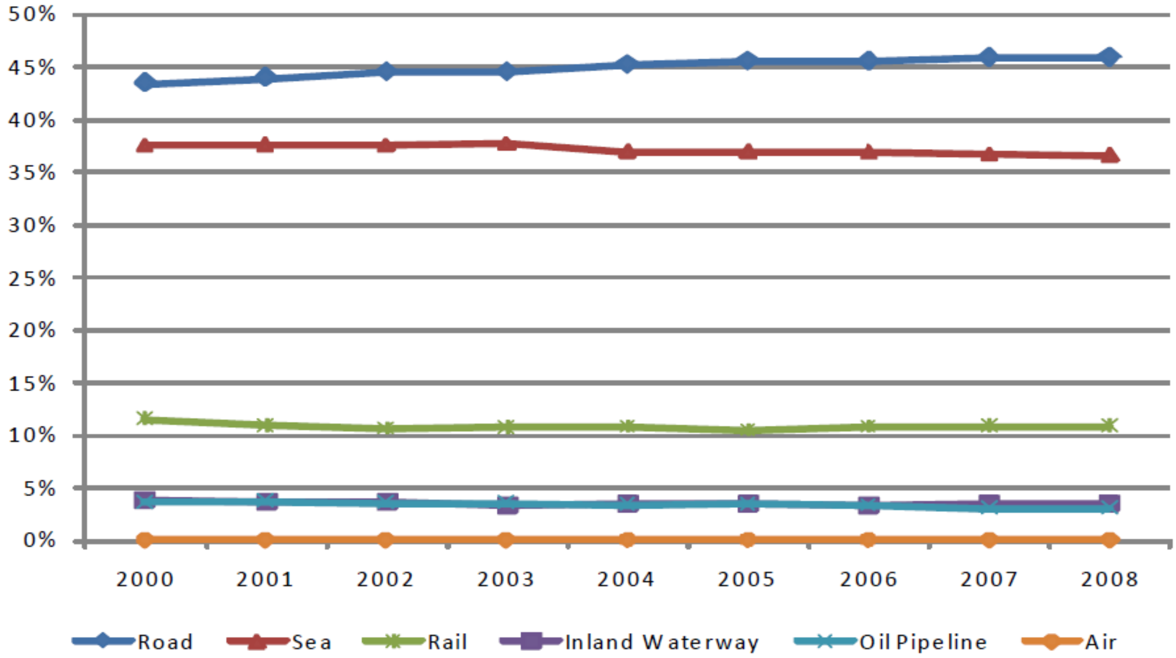

Fig.2. Market share of freight transport modes (in tonne_km, EU-27, 2000-2008)

Although there are still no official changes in European agendas in the field of railway transport and that in most documents everything is the same as it was before the crises, the first changes can already be seen. The countries highly affected by the crisis and with weak economy cannot finance this sector as they used to. Besides the traditional attempt to reduce the costs by suspending some of the unprofitable services and by reducing the number of employees, the only source of additional funds is sale of parts of the railway system. Besides a number of non-core activities, this time, many countries are forced to sell even their core business, first of all, freight transport. At the moment, Slovakia, Romania and Bulgaria are selling their national freight companies, while Greece has to try to sell the whole railway transport. Moreover, in many European countries, large investment projects in the field of railways are either reduced or prolonged.

It is still difficult to foresee the consequences of the economic crisis for the future of the railway sector in Europe. It is clear that the development will have to be based on the improvement of efficiency, instead on gigantic investments. Construction of new railway lines will become an exception and much more attention will be paid to the maintenance of the existing network. In the field of passenger transport, there will be more possibility for development in local and urban traffic, which is stable even in time of crisis and, with appropriate policy at the level of government and local authorities, it has quite a good financial result for railway undertakings. The most important changes are expected in the field of freight transport. Due to the market pressure, there will be probably a similar process as in America where, after the reform, activities were concentrated in several big companies operating long distance services and a great number of small undertakings were established to provide local and specific services. It is considered that smaller national railway undertakings cannot subsist on the market on a medium term basis without grouping.

3. SITUATION IN SERBIA

Due to the recent events, Serbia is one of the last European countries which started restructuring of the railway sector. That process started more than ten years ago and included the following activities: rehabilitation of infrastructure and wagon fleet mostly through "European" loans, reduction of the number of employees, separation of non-core activities and institutional reforms. Regardless of the quite bad situation in the railway sector, Serbia has opted for gradual implementation of reforms, without radical moves, such as total separation of activities and privatization of some of the basic activities. The main reason for that was the fact that railways were not highly positioned at the list of priorities and the government did not want to enter into difficult and unpopular processes including instant reforms of this sector. However, during the first several years, there were made certain steps and, according to the report of the World Bank, from 2000-2004, Serbia was the leader in the reform of this sector in the region. The most important measures were the new law on railways and reduction of the number of employees. However, during the following years, except for the institutional reforms, the rest of this process was almost stopped and Serbia fell to the bottom of the World Bank's list. The most important process, restructuring of the national railway undertaking, Serbian Railways, has been practically suspended. This undertaking still has the same structure as in the 1990s, although, according to the law, it should have been changed seven years ago. Several months ago, new organizational structure of Serbian Railways was finally adopted, but those acts have not been approved by the Government yet. The only improvement consists of reduction of the number of employees and separation of non-core activities. The changes were almost symbolic. The process of restructuring was practically suspended and, besides that, the strategy of infrastructure development has been changed. For main lines, it has been decided to realize reconstruction with geometric parameters for speeds of 200km/h or more, instead of rehabilitation up to the level of designed state.

Cautious policy regarding reforms and ambitious policy regarding the development of infrastructure, unfortunately have given very bad results. In practice, it has stopped both reforms and improvement of infrastructure and the consequences are really bad. Serbian Railways are still an inefficient company whose situation is being declining, besides the enormous resources the Government has been invested for its operation. For years, 120 to 150 million euros have been allocated to the railways from the government budget in order to ensure their functioning. However, this company has more and more difficulties to finance its business activities. During the period form 2000-2004, besides the maintenance of the rolling stock, Serbian Railways financed also a part of procurement of new rolling stock and reconstruction of the existing rolling stock by its own resources. During the following four years (2005-2009), only maintenance was financed by its own resources, while all procurements and reconstruction activities were financed by international loans. Since 2009, Serbian Railways has not been able to finance maintenance no longer, which is now being funded exclusively by special programs established by the Government or the city of Belgrade. It is obvious that in such a situation, the rolling stock is in an extremely poor condition. In the last four years, only 19 investment repairs have been done on electric locomotives, respectively 2 on diesel locomotives and 5 on shunting locomotives, that is, roughly, the number of reparations which, ten years ago, used to be done per year. As far as maintenance of infrastructure is concerned, the situation is similar. Therefore, during the last several years, railways have been ruining themselves more and more rapidly.

Contrary to the prevailing opinion that subventions for railways in Serbia are insufficient, comparing to other countries, they are not so small. If we compare the amount of annual subventions for railways in Serbia with their amount in Romania (which is the leader in restructuring of the railway sector in this part of Europe), we will see that in Romania, in absolute amount, subventions are 3 times higher (in 2010, Serbia got about 133 million and Romania about 390). However, their freight operation is 4 times higher, and their passenger service is almost 10 times higher, which means that Serbian Railways get more state aid per working unit.

The results are not much better in the development of infrastructure and renewal of the rolling stock. The last capital reparation was finished in 2009 and, in the following four years, besides loan contracts and huge government guarantees, not even one kilometer was done (table 3). Taking into account the provided resources, such bad results are rather unexplainable. Besides bad organization (unprepared design documentation), the main reason is that we are waiting for changes which are inevitable, as we all know, but they do not happen.

Table 3. Guarantees for loans intended for railways in the budget of the Republic of Serbia in 2011

Loan	Amount
EBRD Public enterprise Serbian Railways – infrastructure projects City of Belgrade – upgrading of suburban railways	 200 million euros 30 million euros
EIB Public enterprise Serbian Railways– infrastructure projects	 200 million euros
Spanish Government procurement of freight and passenger trains	 37 million euros
German Government modernization and electrification of the railway line Pančevo-Vršac	 45 million euros
Czech export bank Public enterprise Serbian Railways– infrastructure projects	 120 million euros
Polish Government infrastructure, rolling stock and equipment	 70 million euros
Russian Government railway line Valjevo-Loznica rehabilitation of the line Belgrade-Bar construction of the II track Belgrade-Pančevo other projects	800 million euros

The choice of project is also very problematic. Most of the current projects, although they are very expensive, will not have positive impact on business activities of railways, not even on long term basis, while some of them, like for example the line Valjevo-Loznica and some of the projects in Belgrade and Niš railway node will only bring new losses. Therefore, the latest initiative to transfer the greatest part of the "Russian loan" into the budget is not surprising.

Hence, unreformed railway sector, first of all Serbian Railways, is not able to improve its operation, even with subventions. They are not able to identify the real priorities and adequate projects, and, finally, they are not able to realize them without huge delays. This also confirms the rule that the absence of real activities and their unjustified delay makes the situation even more difficult and complicated.

4. CONCLUSION

Serbia is one of the countries where the consequences of the economic crisis will be among the most difficult ones. Therefore, it will be even more difficult to solve the problems in its railway sector. It is obvious that there are no more possibilities for slow changes. It is necessary to create a sustainable economic situation in the Serbian Railways as soon as possible. In order to realize this objective, it is necessary to increase the income and decrease the expenditure, and not to increase budget funds. This objective cannot be achieved unless the restructuring of the company has been completed. It shall be kept in mind that during economic crisis, it is very difficult to increase the revenues and that the main task will be to reduce the expenditures as much as possible.

Gigantic projects concerning high-speed lines have never been realistic and in the situation of economic crisis they have become impossible. Resources for development of infrastructure, as well as of other technical subsystems of Serbian Railways, will be very limited and they shall be used for the most important priorities, which shall be defined by competent and qualified professionals, without political pressures. It is indispensable to prevent the increase of expenditures related to the operation of Serbian Railways, even during a short period of time.

XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '12

DEVELOPMENT OF THE FUTURE RAIL FREIGHT SYSTEM TO REDUCE THE OCCURRENCES AND IMPACT OF DERAILMENT

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Andreas SCHÖBEL [3]
Björn PAULSSON [4]
Mark ROBINSON [5]

Abstract *– This paper provides an overview of D-RAIL, an EU FP7 project that focuses on freight train derailments. The project will identify root causes of derailment of particular significance to freight vehicles, which have a wider range of operating parameters (as a result of the huge range in loads, speeds and maintenance quality) than passenger vehicles. D-RAIL will extend this study to include the expected demands on the rail freight system forecast for 2050, such as heavier axle loads, faster freight vehicle speeds, radically new vehicle designs, or longer train consists. A set of alarm limits will be specified which can be selected as appropriate by infrastructure managers, depending on local conditions. Current monitoring systems and developing technologies will be assessed with respect to their ability to identify developing faults and potential dangers. Where current systems are shown to be deficient, the requirements for future monitoring systems will be specified. D-RAIL will also examine vehicle identification technologies. Integration of alarm limits, monitoring systems and vehicles across national borders and network boundaries will be examined and a deployment plan set out based on RAMS and LCC analyses. D-RAIL results will input to standards, regulations and international contracts.*

Keywords – derailment, freight trains, monitoring, vehicle and track inspection.

1. INTRODUCTION

Rail freight, as part of an intelligent and integrated logistic system, is of strategic and economic importance to Europe. To achieve this, railway infrastructure and vehicles should be well-maintained, and system upgrades and innovations coordinated with the aims of reducing accidents and operating costs, as well as congestion, pollution and noise.

Derailments cause major network disruption, and can have significant societal impact. In Europe, there are still a large number of low-cost derailments (typically in shunting yards) and a small number of high-cost ones. In the EU during the past 10 years, 691 freight train derailments have been reported – the true number is likely to be much higher. The European Railway Agency (ERA) estimates that open line freight train derailments cost EU 27 countries more than 200 million Euros per year [1]. Although the number of fatal train accidents is declining in general (by 6.3% a year [2]), derailments are still a major problem, especially when trains with dangerous goods are involved.

Regulations covering reporting of accidents are now in place in the European Union, but there is still significant variation in the quality of reporting across the Member States. Detailed information on derailments, their causes and costs, in each country is generally not publicly available. Costs, in particular, are very difficult to estimate since different financial procedures are implemented in different countries, and the aftermath of derailments (including accident investigations and public inquiries) can often last

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several years.

There is a need for new research into freight train derailments. Given the projected freight market growth in Europe, it is important to ensure the number of freight train derailments is reduced – this is a key driver for the present research. The EU FP7 project D-RAIL provides the approach, structure, and technical content to improve prevention of freight train derailments, and mitigation of derailment impact. The project started in October 2011 and its duration is 3 years.

Figure 1 shows a derailment, of a freight train, consisting of a Class 66 locomotive and a set of stone wagons, at Brentingby, UK, in 2006.

Fig.1. Brentingby derailment, UK, 9.2.2006. [3]

2. PROJECT AIMS AND OBJECTIVES

The aim of D-RAIL project is to significantly reduce the number and impact of freight train derailments. The project seeks to provide cost-effective solutions to support this key objective. This will have a dramatic impact on the disruption and associated cost of derailment to the freight industry and improve the competitiveness of rail freight operation against other transport modes within Europe.

3. CONSORTIUM

The D-RAIL consortium consists of twenty partners from ten European countries. This is a global project and includes the International Union of Railways (UIC), Russia (RZD) and the USA (Harsco). Many of our partners have significant international rail experience outside the EU.

The project is led and managed jointly by UIC and NewRail. The team consists of experts in railway engineering, vehicle and track dynamics, and risk assessment and risk management, teamed with railway users and experts with practical knowledge of the derailment problems and implementation issues. Experts in measuring and condition monitoring form part of the team. A good balance has been achieved between the railways, industry partners and academia.

Wider involvement of European railways is ensured through the involvement of UIC which represents an additional number of railway partners such as Network Rail, ProRail, RFI and ADIF. In addition, broad industry involvement is obtained thorough the inclusion of UNIFE as a member of the Steering Committee.

List of D-RAIL partners:

R&D organisations & Universities

- NewRail, Newcastle University
- RSSB
- Vienna University of Technology
- NEA Transport
- Chalmers University
- Politecnico di Milano
- Huddersfield University
- VUZ Railway Research Institute

Railways

- Deutsche Bahn
- SNCF
- SBB
- ÖBB
- Trafikverket
- UIC

Industry Partners

- Lucchini
- MerMec
- Faiveley Transport
- TelSys
- Oltis Group
- Harsco Rail

4. RESEARCH PROGRAMME

The research programme targets an improved understanding of the fundamental issues associated with freight derailments, the economic impact and the means with which to address and mitigate future occurrences. Here is a short description of the project's work packages (WP).

WP1 'Derailment Impact' has provided a comprehensive review of recent freight derailments to identify the principal root causes. The severity and impact on railway operations was also assessed to understand the economic implications for damage to vehicle and infrastructure, and disruption to network operation.

WP2 'Freight Demand And Operation' has evaluated trends for rail freight towards the target freight system of 2050. This embraced European rail policy and strategy for future freight including movement, logistics, sector economics and the likely impact on forward operation of technologies.

WP3 'Derailment Analysis And Prevention' is identifying and evaluating, through modelling and simulation, the key contributory factors associated with derailment including combined causal effects (e.g., a slight track twist and a failing bearing) for the freight vehicle and track system. The study is evaluating these factors to provide cost-effective solutions and to demonstrate a step change in prevention.

WP4 'Inspection And Monitoring Techniques' is reviewing and assessing current technologies related to derailment prevention and mitigation. One example is shown in Fig. 2. Inspection and monitoring are being considered for both the freight vehicle and the track, since it is the interaction of these that is important. Cost-effective methods to improve the existing monitoring systems will be developed.

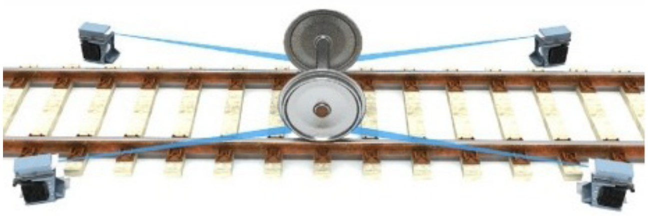

Fig.2. Measuring system for wheel surface defects [4]

WP5 'Integration Of Monitoring Techniques' will develop and integrate different wayside and on-board monitoring concepts (including vehicle identification) related to derailment prevention and mitigation. Suitable concepts are to be developed and selected on the basis of RAMS and LCC analysis to support wider industrial implementation.

WP6 'Field Testing And Evaluation' will validate improvements to track and freight vehicle(s) through field testing and to measure the combined interactions. Both existing and new technologies, including telemetry and monitoring outputs, will be evaluated to determine the step changes in safety performance required for derailment prevention.

For field testing and validation, D-RAIL will have access to VUZ's test track in the Czech Republic, which will be used for testing of wayside and vehicle-mounted monitoring technologies, and also to Barrow Hill (a heritage site and freight locomotive maintenance yard in the UK) for initial implementation and testing of new wayside monitoring technologies. The goal of the wayside monitoring is to study each passing vehicle's response to a variety of stimuli and therefore identify vehicle faults with greater certainty.

WP7 'Operational Assessment And Recommendation' will use RAMS analysis to identify the impact of vehicle monitoring on the reliability, availability and safety of the railway system. Economic assessment of monitoring concepts including migration with regard to LCC and social economic effects and risk assessment for relevant vehicle states and monitoring scenarios will be undertaken.

WP8 'Dissemination And Exploitation' will ensure that the findings of the research are widely disseminated, and that new products and technologies are fully exploited by the industry. This will be undertaken by the consortium members who already form a wide geographical, demographic and industrial spread across Europe. UIC are also part of the consortium and will be able to provide assistance in promoting and disseminating the findings of the research on a pan-European and international basis. Outreach and marketing of the research findings will occur throughout the project to a wide variety of stakeholders and engineers to ensure industry awareness.

5. EXPECTED FINAL RESULTS AND OUTCOMES

A key output from the activities will be:

- The ability to define the causes of derailment (combined or otherwise).
- A quantifiable step change in the number of freight derailments.
- Recommendations for monitoring systems based on technical and economic grounds.
- Reliable implementation scenarios and guidelines for national and international use.
- New technological developments and innovations for industrial applications.

The expected benefit is to reach a reduction of derailment impact which would at least balance the mechanical effect of the expected railway traffic increase on accident numbers. Other project outcomes will be to:

- Define and describe the foreseeable (macro-) features of the railway freight system towards a target freight system in 2050, taking into account the European Transport Policy, available studies and research on freight logistics and relevant trends of sector economics as well as railway technology developments.
- Define cost-effective scenarios, integrating system changes and new safety measures, in order to reach the proposed target system(s) and the expected reduction of derailment occurrences and impacts.
- Demonstrate (through field tests) the feasibility of the most innovative system changes and safety measures within the proposed time scale.

6. IMPACT FOR STAKEHOLDERS

Any reduction in the number or severity of the derailments represents a significant benefit to all railway parties (train operators, infrastructure owners, vehicle owners, terminal operators, shippers, etc.).

For train operators

- The more advanced monitoring systems developed or implemented through D-RAIL will result in lower levels of derailment which will in turn reduce service disruptions, train delays, loss

of equipment and goods, incidents involving dangerous goods (RID), fatalities and maintenance costs. The resulting improved levels of reliability will reduce the number of incidents which have serious implications for the whole railway system.
- D-RAIL will also integrate existing and new monitoring technologies with existing railway control and operating systems to facilitate implementation and use throughout Europe.
- D-RAIL will provide added insight into vehicle conditions that affect *operating* costs, using criteria developed through state-of-the-art simulation and field tests.
- Vehicle identification will allow for tracking and removal of unsafe vehicles.

For infrastructure owners
- The ability of D-RAIL to allow vehicles to run at higher speeds with reduced risk of derailment will result in a reduction in the complexity of operation of a mixed-traffic railway. Better use of existing infrastructure will result in increased capacity and increased traffic flow.
- Identification of vehicles that generate excessive or unbalanced loading that might cause derailments (and consequently damage to the track structure) will reduce maintenance requirements.
- Reduced risk of hazardous environmental incidents.
- At border crossings and other network access points the wayside monitoring systems will identify and stop unsafe vehicles before entering the connected network.

For vehicle owners
- D-RAIL will provide added insight into vehicle conditions that affect *maintenance* costs, using criteria developed through state-of-the-art simulation and field tests.
- Identification of recurring vehicle problems associated with certain classes of vehicles.
- The reduction in derailments should reduce vehicle repair costs.
- Identification of vehicles that generate excessive loadings will allow for better long-term management of vehicle maintenance.

For terminal operators
- The more advanced monitoring systems developed or implemented through D-RAIL will result in lower levels of derailment which will in turn reduce service disruptions in the terminals.
- D-RAIL will help improve loading practices that can result in the safe even loading of freight vehicles to limit imbalance and loss of products.
- D-RAIL will create a more competitive environment for freight logistics solutions on rail.

For shippers
- Improved safety will increase the attractiveness of rail transport by reducing loss and damage due to derailments.
- Improved safety will result in more efficient and reliable movement of goods and reduce costs.

7. CONCLUSIONS

The project is aimed towards providing significant improvements in derailment prevention, detection and mitigation of the subsequent effects.

Recommendations for improvements to existing European standards for freight operation will be assessed and provided.

The research will be reported in relation to the target freight system for 2050 and how findings will benefit economic and technological developments in future rail freight operation.

ACKNOWLEDGEMENT

This paper is done within the FP7 D-RAIL project 'Development of the future rail freight system to reduce the occurrences and impact of derailment' (www.d-rail-project.eu; Grant Agreement No.:285162;). Authors gratefully acknowledge the European Commission for part-funding the project. Thanks also to Dr Francis Franklin for technical assistance.

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[4] Figure from MerMec presentation by François Defossez

THE ROLE OF RAIL IN PROMOTING EU SUSTAINABLE TRANSPORT

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Abstract *– This paper demonstrates the potentials of rail in promoting sustainable transport. Considering the various negative effects of transportation, the main challenge is to develop a comprehensive, global approach in a low carbon scenario that combines different programmes and initiatives addressing issues such as access to transport, climate change and energy, air pollution, noise and resources, congestion. The Eropean Union (EU) has recognised that increasing rail's share of passengers and freight will substantially reduce the transport sector's carbon emissions and dependence on imported energy. In order to turn rail into a serious transport alternative, the European Commision (EC) encourages research funded through the EU Framework Programmes.*

Keywords - sustainable transport, transport impacts, European rail

1. INTRODUCTION

Since the early 1990's when the concept of sustainable development was identified as a global priority, transport as a sector affecting environment and quality of life has been gaining attention increasingly. There are various definitions of what is meant by sustainable transport, but not a universally accepted one. [1] Following Brundtland Commission's world-wide accepted definition on sustainable development **(UN World Commission on Environment and Development, 1987)**, sustainable transport can be defined as 'satisfying current transport and mobility needs without compromising the ability of future generations to meet these needs' **(Black, 1996)**. According to the officially adopted EU definition, sustainable transport system is the one that: 'allows the basic access and development needs of individuals, companies and societies to be met safely and in a manner consistent with human and ecosystem health, and promises equity within and between successive generations; is affordable, operates fairly and efficiently, offers choice of transport mode, and supports a competitive economy, as well as balanced regional development; limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and, uses non-renewable resources at or below the rates of development of renewable substitutes while minimizing the impact on land and the generation of noise' **(Council of the EU 2001).** This is an adaptation of the definition developed by the Canadian Centre for Sustainable Transportation (CST). (for details see **Bojković et al., 2010)**

Considering the various negative effects of transportation, a definition of sustainable transport should include social, environmental and economic dimensions. In addition, as a fourth dimension, reflecting the experiences in implementing the Agenda 21 on a local level, the process towards a sustainable transport system should be participative and involve not only key stakeholders, but also the general public. [2] Based on a numerous relevant international organizations (CST 2005), it is possible to define sustainable transport system as one that "allows the basic access and development needs of people to be met safely and promotes equity within and between successive generations" (*social dimension*), "is affordable within the limits imposed by internalization of external costs, operates fairly and efficiently, and fosters a balanced regional development" (*economic*

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dimension), "limits emissions of air pollution and GHGs as well as waste and minimises the impact on the use of land and the generation of noise (*environmental dimension*), and "is designed in a participatory process, which involves relevant stakeholders in all parts of the society (*degree of participation*)[1].

2. TRANSPORT IMPACTS

Transport generates a wide range of emissions that influence air quality on a local level, and plays a significant role in global GHG emissions, with most of its share originating from burning of fossil fuels. Road transport contributes 17% global CO2 emissions, a third of future emissions. Overall, transportation is responsible for 13% of global GHG emissions and 23% of energy-related CO2 emissions. Industrialized countries are currently the main contributors in climate change – global GHG emissions, but 80% of projected increase until 2030 is related to road transport in developing countries, mainly the countries with emerging economies like e.g. China[2]. Traffic congestion causes a significant amount of time lost which could have been used for other purpose, and increases operating costs (for vehicle owners and freight operators). Current transportation relies heavily on fossil fuels - the generally rising costs of crude oil and the limited number of supplier countries pose significant threats for energy security especially in the developing world. Under a business as usual (BAU) scenario projections for global freight and passenger transport show that much of the increase in transport activities will be in the most energy intensive modes like aviation, private motorized transport and road freight. This runs counter to the principles of sustainable production and consumption, which, amongst others, call for a significant increase in energy efficiency to limit the need for natural resources. Transportation consumes 25% of world energy, 67% of world petroleum use, transportation's fuel consumption has doubled. Road transport is responsible for 74%of this consumption because of rapid motorization.[3]

Additionally, a transport system increasingly centered on motorized individual transport reduces such access for low income groups – this seriously threatens equity, and efforts for poverty reduction. Transport infrastructure is a major cause for the partition of ecosystems and/or habitats of plant and animal populations into smaller, more isolated units. Also, the huge area taken up by roads and rails reduces valuable urban space otherwise available for living, recreation and businesses. Traffic noise and road traffic accidents are seriously problems related to transport sector on local, regional and global level as well - accidents incur a dominant share of overall external costs of transportation on the society, such as the costs related to medical care for the victims.

In conclusion, "low-carbon, sustainable transport reduces short and long term negative impacts on the local and global environments, has economically viable infrastructure and operation, and provides safe and secure access for both persons and goods". (**Dalkmann and Huizenga, 2010**). [2]

According to the above mentioned definitions, the common idea behind the implementation of sustainable development strategy in transport could be expressed as balanced development that integrate economic, social and environmental objectives ensuring the interests of each. As a relatively clean mode, rail is a key pillar of Europe's efforts to encourage sustainable transport and mobility, esspecialy in terms of limiting greenhouse gas emissions and reducing the EU's dependence on imported energy. Rail also provides a 'green' answer to congestion on Europe's roads [4].

3. SUSTAINABLE TRANSPORT – GLOBAL STRATEGY AND EU PERSPECTIVE

Sustainable transport in the perspective of the UN Environment Programme[3] is intergovernmental processes with focus on removing barriers for a wider uptake of sustainable transport approaches trough setting standards, institutional capacity building, advice on technical policy, technology transfer, infrastructure investments. The main challenge is to develop a comprehensive, global approach in a **low carbon scenario** that combines different programmes and initiatives addressing issues such as access to transport, climate change and energy, air pollution, noise and resources, congestion. The strategic approach to sustainable low-carbon transport originally developed for urban transport is combination of interventions: **'AVOID'** – reduce the need for transport while still serving to facilitate overall mobility of people, goods and information through better transport planning, design and innovative schemes, **'SHIFT'** – reduce specific energy consumption (per passenger / unit goods transported) by promoting a shift from high polluting modes to less polluting modes (e.g. private vehicles to public and non-motorized transport) **'CLEAN'** – improving energy efficiency, promoting clean and alternative fuels [4,11].

Transport sustainability is in focus of the European Union Sustainable Development Strategy (EU SDS)[4], which is an update of a European Council strategy adopted in Gothenburg in 2001. It aims to improve the

[1] Adapted from CST 2005 [2]

[2] Projections - CO2 from transport tol grow by 120% by 2050 (with respect to 2000 levels) [2,3]

[3] UNEP Transport Programme: clean- efficient- safe-affordable, http://www.unep.org/transport/index.asp

[4] http://ec.europa.eu/research/sd/index_en.cfm?pg=renewed-sds, Council of the European Union, 2006

quality of life and well-being for present and future generations by promoting a dynamic economy with full employment and high levels of education, health, social and territorial cohesion and environmental protection. The key environmental objective is to prevent and reduce environmental pollution and promote sustainable consumption while breaking the link between economic growth and environmental degradation. The EU SDS identifies set of sustainable development indicators (SDI), has been adopted by European Commission to monitor and support EU sustainable development strategy**.** The SDI framework covers ten themes, reflecting key challenges of the strategy. These themes are further divided into sub-themes. The indicators are allocated across corresponding themes and hierarchically organized as a three-level pyramid (Fig.1). The Level 1 of the pyramid consists of indicators related to the "overall objectives" of the EU Sustainable Development Strategy (SDS). These indicators are considered as the headline indicators. The second level in most cases consists of indicators reflecting operational objectives, while the third level usually consists of indicators related to actions described in the EU Strategy **(**for details see **Bojković et al., 2011).** [5]

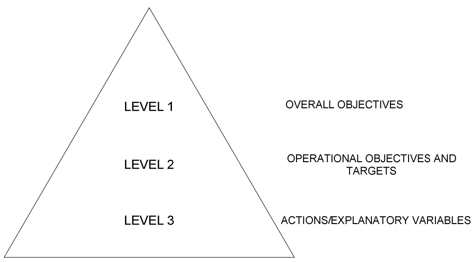

*Figure 1. The SDI pyramid (**EC 2009**)*

*Table 1. The sustainable transport themes (**EC 2009**)*

LEVEL 1	LEVEL 2		LEVEL 3		
ENERGY CONSUMPTION RELATIVE TO GDP	*TRANSPORT AND MOBILITY*				
	Modal split of freight transport	Modal split of passenger transport	Volume of freight transport relative to GDP	Volume of passenger transport relative to GDP	Investment in transport infrastructure
	TRANSPORT IMPACTS				
	Greenhouse gas emissions from transport	People killed in road accidents	Average CO_2 emissions per km from new cars	Emissions of ozone precursors from transport	Emissions of particulate matter from transport

Sustainable transport is recognized as one of the key challenges of SDS, therefore it is among the ten themes of SDI framework. The sustainable-transport themes are structured as shown in Table 1.

The European Commission during last two decades is working towards a form of mobility that is sustainable, energy-efficient and respectful of the environment, which means, promoting co-modality, and i.e. optimally combining various modes of transport within the same transport chain, as a solution for the future freight transport. Technical innovation and a shift towards the least polluting and most energy efficient modes of transport — especially in the case of long distance and urban travel — will also contribute to a more sustainable mobility. Recent document regarding EU sustainable transport policy is **“**Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system”[5]. The European Commission adopted a roadmap of 40 concrete initiatives for the next decade to build a competitive transport system that will increase mobility, remove major barriers in key areas and fuel growth and employment. At the same time, the proposals will dramatically reduce Europe's dependence on imported oil and cut carbon emissions in transport by 60% by 2050. By 2050, key goals will include:

- No more conventionally-fuelled cars in cities;
- 40% use of sustainable low carbon fuels in aviation; at least 40% cut in shipping emissions;
- A 50% shift of medium distance intercity passenger and freight journeys from road to rail and waterborne transport;
- All of which will contribute to a 60% cut in transport emissions by the middle of the century.[6,7]

Work on sustainable transport is well in progress, both in the research field and in policy-oriented studies, concentrating primarily on emissions of air pollutants (health problems) and greenhouse gases (climate change) and expanding to other sustainability concerns such as congestion, noise and accidents. Because of the inherent complexity of this sector in comparison to most other branches of economic activity due to the millions of travellers involved, policy measures often have to be taken at local scale and respecting local particularities. In such cases, “instead of concrete quantified proposals, it is possible to provide policy guidelines only, pointing to successful pilot projects around the world; in this context, because of the variety of sustainability problems and the uncertainties associated with them, cost-effectiveness analyses are crucial for the assessment of transport policies. Such studies have been extensively used in Europe in the last two decades, oriented basically either towards case studies in selected cities or towards specific issues such as pollutant emissions, CO2 emissions or noise” (for details, see **Bongardt at al**., **2011**). [2]

4. EUROPEAN RAIL: A MUST FOR SUSTAINABLE TRANSPORT[6]

The EU has “recognised that rail is a lynchpin in the European transport system, particularly

[5] White Paper, EC 2011. http://ec.europa.eu/transport/strategies/2011_white_paper_en.htm,

[6] On track to a sustainable future - EU-funded research for a safe and efficient European rail system, EU 2010.

considering its green credentials. Increasing rail's share of passengers and freight will substantially reduce the transport sector's carbon emissions while also decongesting the highways and facilitating trade throughout the single market". [4,8]

4.1. An environmentally friendly mode of transport

With very low CO2 emissions and very high energy efficiency, rail offers strong environmental advantages over other forms of transport. Rail's market share is 6% of passenger traffic and 10% of freight traffic; however, its share of the European transport sector's total energy consumption is only 3% [7,8]. Transport by rail is twice as energy efficient as by road and up to 20 times more efficient than by air. It is at least four times less CO2-intensive than travelling by car, accounting for less than 2% of transport emissions within Europe. Considerable efforts have gone into reducing that number still further. (Figure 2)

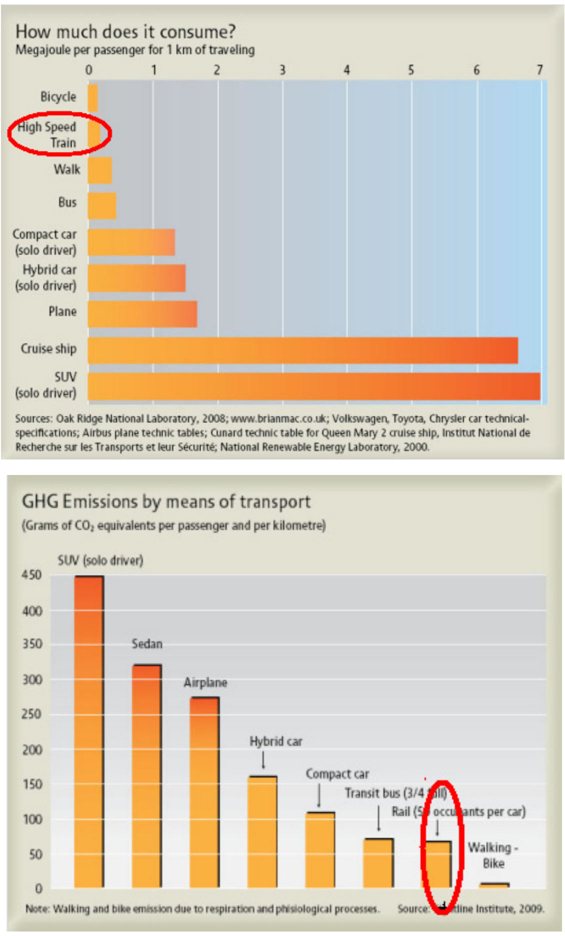

Fig. 2. Energy performance and GHG emissions by means of transport (consumption in megajoule per PKM/ grams of CO2 per PKM)[8]

From an operational perspective, electrified rail, with the appropriate energy generation mix, can be virtually carbon free. The rail sector is committed to cutting its greenhouse gas emissions by 30% compared to 1990 levels by the year 2020, and to making rail transport even more energy efficient. Since the 1970s, Europe has seen a doubling in transport activity, both of passengers and goods, and greenhouse gas emissions from transport continue to rise. Although rail emissions are low responsible for less than 2% of the transport sector's emissions, noise and vibration from railways continue to be an environmental issue that hinders the wider expansion of rail services, particularly for freight and within urban areas, as far as land use. Rail research consistently seeks further energy savings, reduced pollution, optimised land use and reduced noise and vibration. But while technical and management solutions certainly help to promote the case for rail, competitiveness remains pivotal. The biggest impact on CO2 emissions can be made by simply attracting more road traffic to the rails. [4,8]

Over the past two decades competition has intensified for better and safer rail components and infrastructure. Many of the projects funded through the Framework Programmes have succeeded in reducing the costs of manufacture and maintenance without compromising safety. These projects have enabled, and greatly benefitted from, the new drive for interoperability and the adoption of modular design and manufacture. Their strong participation in European rail research helps to maintain the sector's lead against increasingly sophisticated foreign competition, supporting European employment in the transport sector. As such, rail research and development (R&D) encompasses a wide range of technologies, safety aspects, economics and management, as well as work on efficient pricing and increasing competitiveness and customer satisfaction, as figure 3 presents.

4.2. Sustainable and competitive mode of transport – fairy tale?

Despite a number of strengths relating to the concept of sustainable transport, "there is still a certain lack of dynamism, reliability, flexibility and customer orientation on the part of railway undertakings. At times the political influence on the railway business is too strong, while there is still insufficient interoperability between national rail systems as well as insufficient — and decreasing — investment. In addition, rail is often hamstrung by outdated business and operational practices, by the presence of too much ageing infrastructure and rolling stock and by a financial situation that is often weak.

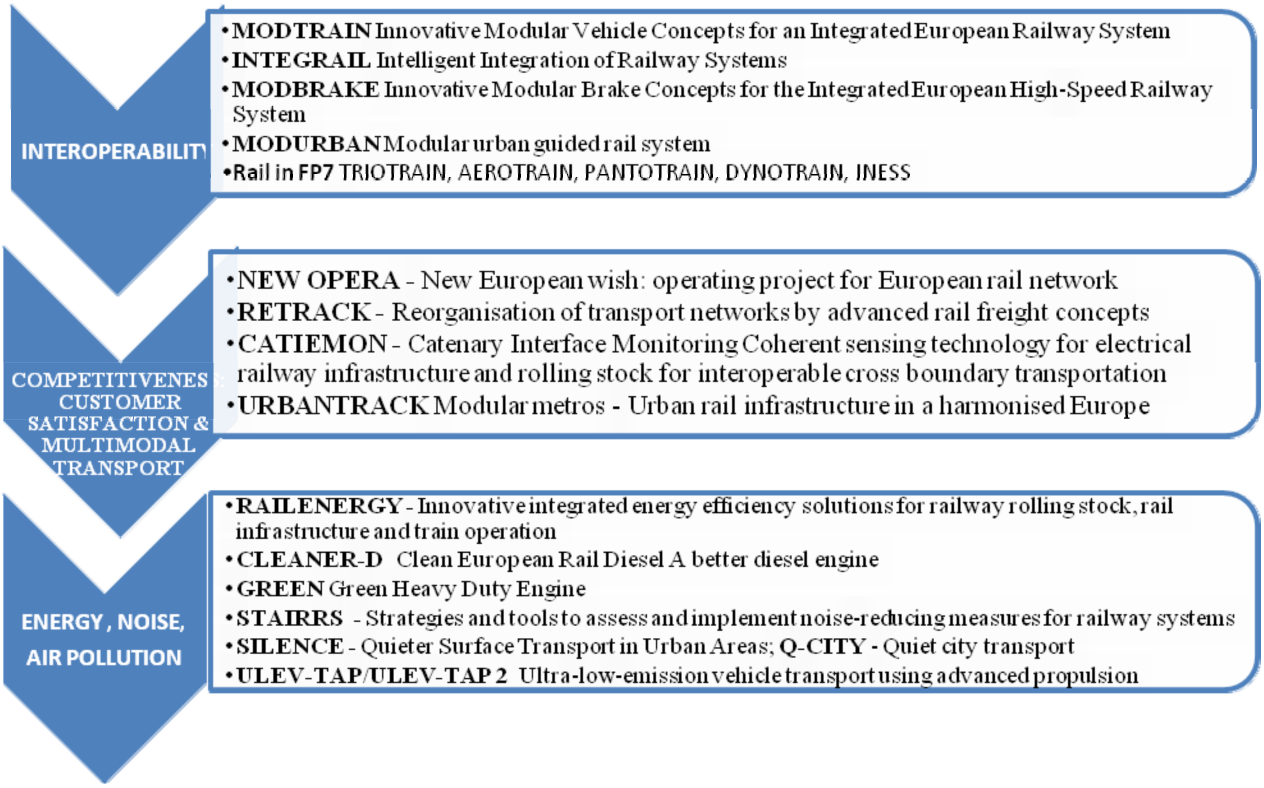

Fig.3. EU funded R&D for promoting sustainable European rail system

Rail's relatively small share of the overall transport market is another threat that has to be addressed". [10]

Making rail more customer-oriented is a big part of making rail more competitive. A good quality of service and meeting customers' expectations should be in focus in both - passenger and fright transport. The EU's legislation on passenger rights is in force from december 2009, setting out minimum quality standards that have to be guaranteed to passengers. Safeguarding the rights of rail passengers and improving the quality of rail passenger services will make rail more user-friendly and should help to increase the share of rail transport in relation to other modes.

Regarding fright transport, rail is rarely able to move goods door-to-door, which is why research into **seamless** 'multimodal' transitions is so important. For that matter, it should also be simple for passengers to connect between trains or to planes, buses or light rail, and to get up-to-date information on potential delays. This involves cooperation between competing modes of transport as well as between competing interests within those modes. [10]

Systematic sustainability management approach: Declaration – Strategy – Tools, supported by guidelines and tools - UIC Sustainability Indicators Guideline, EcoPassenger, EcoTransit, UIC Energy & CO2 database[7], is a promising framework for railways undertakings in Europe for promoting sustainable transport. To be "green" and market oriented in same time, is a new business paradigm for modern rail in Europe.

5. CONCLUSIONS

Considering the various negative effects of transportation, the main challenge is to develop a comprehensive, global approach in a low carbon scenario that combines different programmes and initiatives addressing issues such as access to transport, climate change and energy, air pollution, noise and resources, congestion.

With very low CO2 emissions and very high energy efficiency, rail offers strong environmental advantages over other means of transport. The Eropean Union has recognised that increasing rail's share of passengers and freight, will substantially reduce the transport sector's carbon emissions and dependence on imported energy. Research and development (R&D) in rail sector funded through the EU Framework Programmes are oriented on interoperabilty, environmental issues, and competitiveness, quality of service and customer satisfaction and multimodal – seamless transport.

According to the UNEP strategy for Sustainable urban transport (ASI), EU Susainable Development Strategy, EU Sustainable transport policy, The UIC Declaration Sustainable Mobility & Transport, The UIC Sustainability Strategy and Systematic sustainability management approach, table 2 presents

[7] For measuring GHG emissions and energy consumption by

links between interventions/strategies, rail strenghs (environmental performance) and weakness (market-customer orientded performance).

Table 2. Strategic Approach to Sustainable Transport – potential role of the rail [4,8,11]

Intervention/ Strategy	Potential role of the rail
AVOID	Intermodality: Air/Rail connectivity for passenger transport
SHIFT	Road to rail substitution for fright transport
CLEAN	Improving energy efficiency reducing emissions from nonrenewable fuel sources, and use of alternative fuels
Additional interventions: service quality and efficiency, operating capacity, comfort, green marketing	

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Rolling stock

XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '12

THE HYBRID TRACTION - THE WAY OF FUEL UTILIZATION IMPROVEMENT

Daniel KALINČÁK [1]
Ľuboš BARTÍK [2]
Juraj GRENČÍK [3]

Abstract *– The utilization of installed power capacity of internal combustion engines (ICE) in motive power units (especially in shunting locomotives and locomotives for industrial transport) is very low. The mean power of ICE in this operational mode is about 15 – 20 % of its installed power. The result is that most of the time internal combustion engine works in regimes that are far from optimum mode. It means that specific fuel consumption is high. Some examples of measured operational regimes of locomotives in shunting operation and other motive power units are given in the paper. Kinetic energy of a classic diesel locomotive as well as the DMUs and trains is transformed into thermal energy during braking process. Normally it is not possible to utilize this kinetic energy in a reasonable way. The kinetic energy should be transformed into a suitable form and stored for following use.*

The improvement can be achieved by using of the unconventional traction drive of rail vehicles. One of possible ways is using of the hybrid traction drive. The hybrid drive includes the ICE and the energy storage device. In this case the power of ICE can be substantially lower than in the classic traction. The parameters of such traction drive must be based on analysis of real operational regimes of vehicles. These parameters are particularly: power of ICE, power of traction motors, capacity and power of energy storage devices (accumulators).

There are other ways how to improve fuel utilization at railway vehicles, e.g. by better utilization of heat released from the fuel.

Keywords – hybrid traction drive of rail vehicles, utilization of power of ICE, fuel utilization, accumulation of energy.

1. INTRODUCTION

Problem with fuel savings and air pollution in the rail transport should be solved at the present. A significant number of diesel locomotives with various installed power and age are in operation in the industrial transport and in shunting service on railways.

It is known that the use of installed power capacity of ICE in motive power units (especially in shunting locomotives and locomotives for industrial transport) is very low. Average usage of engine power is usually less than 20 % of the installed power capacity and nominal engine performance is used only during minimal period of the total time of engine operation (at the level of approx. 1%). The result of this is that most of the time the internal combustion engine works in regimes that are far from optimum mode. It means that specific fuel consumption is high. At this type of locomotives operation the frequent and fast changes of engine regimes occur, which result in increased fuel consumption and insufficient fuel combustion with increased quantity of harmful emissions.

Kinetic energy of a classic diesel locomotive as well as the DMUs and trains is transformed into thermal energy during braking process. Normally it is not possible to utilize this kinetic energy in a reasonable way. The kinetic energy should be transformed into a suitable form and stored for following use.

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If a vehicle or a train is at standstill very often the engine continues working. The reasons are various, but mostly it is the continuous operation of auxiliary equipment (braking compressor, lighting, preheating etc.).

Besides mechanical energy (approx. 40% of the energy released from the fuel in optimum regime of the engine operation) internal combustion engine produces considerable amount of thermal energy, utilization of which is poor. Possibility of utilization of this waste thermal energy is limited also because of its varying quantity during engine operation.

Presently the motive power units operating under normal regime almost do not use alternative fuels, with exception of natural gas or biogas, but it also happens in very rare cases. Economically not acceptable concepts of engines operating on classic fuels prevail and alternative solutions are considerably neglected. Thus increased production of harmful emissions continues.

The improvement of the present state can be achieved by unconventional traction drive of rail vehicles. Such unconventional traction drive can be a hybrid drive.

We have been studying these problems for a long time and some results were published for example in [1, 2, 3] etc.

2. OPERATIONAL UTILIZATION OF THE ENGINE POWER

2.1. Industrial and shunting locomotives

The character of utilization of installed engine power in the industrial and shunting locomotives are similar. It was shown in many measurements in different times and at different locomotives. Since the operational conditions may significantly vary in different cases, the results of measurements can vary as well. We will show some results of such measurements.

The distribution of engine power on locomotive class T 419.0 (ČKD) at shunting service in the company NH a. s. Ostrava is shown on the Fig. 1 [4]. In this case idling of engine does not comprise idling during standstill of locomotive.

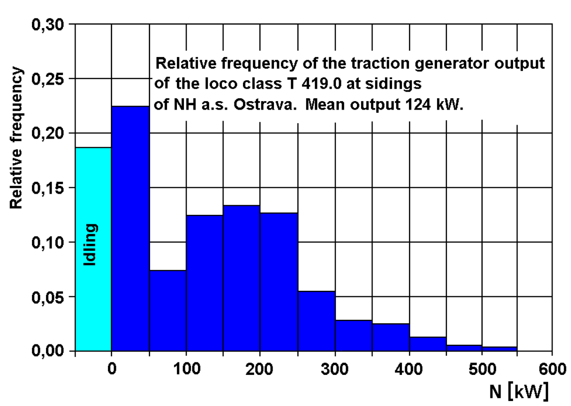

Fig.1. The distribution of the traction generator output of locomotive class T 419.0 at shunting operation at sidings of NH a. s. Ostrava

Mean output of the engine is 124 kW in this case. Nominal output of this locomotive is 600 kW. The mean output of the engine is almost 21 % of the nominal output of locomotive. This is relatively great value and it is caused by relatively smaller output of the engine. Usually idling represents more than 70% of the total time of engine activity in similar cases of operation.

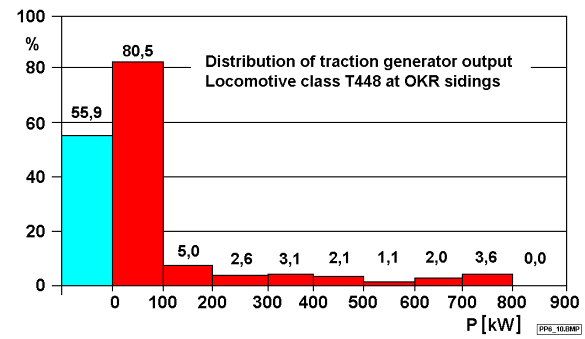

Fig.2. The distribution of the traction generator output of locomotive T 448.0 at shunting operation at sidings of OKR a. s. Ostrava

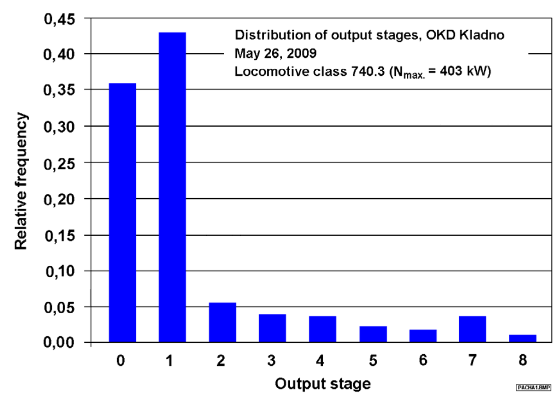

Fig.3. The distribution of engine output stages at the sidings of OKD in Kladno

Another example is from measurements at the OKR sidings in Ostrava. The measurements were carried out on the locomotive class T448 (ČKD). This locomotive has maximum output of internal combustion engine 883 kW. The distribution of traction generator output is shown on the Fig. 2 [6]. In the graph several various regimes of locomotive work were included. The left column (55.9 %) shows relative duration of idling run. About 7.1 % was idling run with consumption of power by auxiliaries (braking compressor and/or fans of cooler). The mean value of the traction generator output was in this case approx. 121 kW, which is about 14 % of maximum output of locomotive. It is evident that in this case utilization of maximum engine output is worse than in the previous one.

The part of results of measurements on locomotives class 740.3 at sidings of OKD Kladno is shown at the Fig. 3 [7]. The class 740.3 (CZ LOKO) is refurbished locomotive class 740 (ČKD) with engine Caterpillar C15 with half output (403 kW). The mean output of engine was about 95 kW, what is about 23 % of maximum output of locomotive.

We can find similar distribution of engine output also in case of railway shuntng locomotives. An example of output distribution of locomotive class 770 (ČKD) during shunting operation on hump in railway station in Žilina is shown in the Fig. 4 [5]. The mean output of the locomotive with nominal rating of 993 kW was only 61 kW in this case, what represents only 6 % of nominal output.

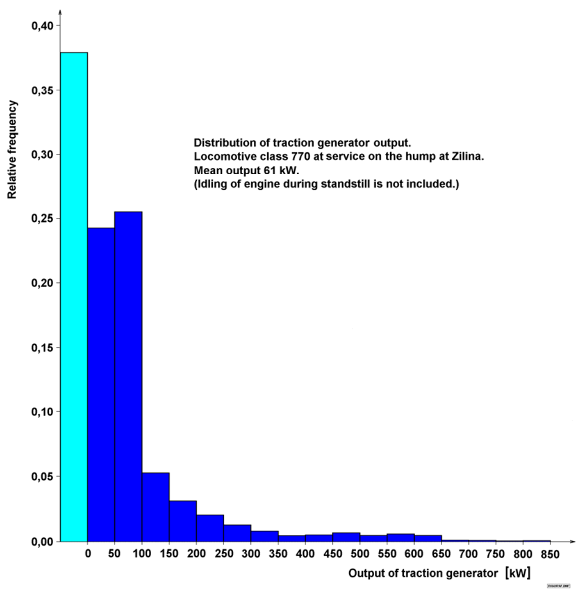

Fig.4. The distribution of traction generator output of locomotive class 770 at service on the hump at Žilina

Another example of locomotive operational regimes is taken from railway station Trencianska Tepla. The measurements were carried out on the locomotive class 742 (ČKD) [8]. This class of locomotives has nominal output of 883 kW. The distribution of traction generator output is in the Fig. 5. The mean output of traction generator was only about 102 kW, which represents about 11.5 % of nominal output.

From demonstrated examples we can conclude that the greater is nominal output of locomotive the poorer is using of installed power. This observation is valid only for locomotives designated for shunting operations in railways and for using in industrial transport.

In the Fig. 6 an example of time behaviour of output power measured on locomotive class 740 is shown [8]. The measurement comprises shunting of

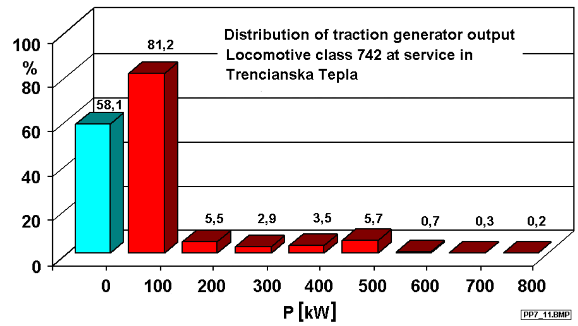

Fig.5. The distribution of traction generator output of locomotive class 742 in the shunting service at Trencianska Tepla

empty wagons at the Trencianska Tepla railway station. The mean value of output was about 80 kW in this case.

2.2. Diesel multiple units

The character of operational using of diesel multiple units is different from shunting and industrial locomotives. Example of time behaviour of velocity and power output of light diesel unit at the regional railways VLTJ in Denmark is in the Fig. 7 [9]. The peak output at driving wheelsets was 250 kW in this case. The mean output was about 105 kW without idling at the stops.

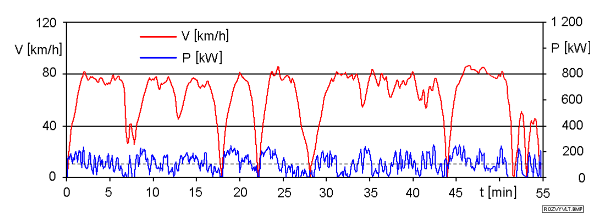

Fig.7. The course of power on wheelsets and velocity of DMU at the railways VLTJ

3. HYBRID TRACTION DRIVE

As it was mentioned above, one of possible ways is using of a hybrid traction drive. This system comprises the ICE or fuel cells and the energy storage device (flywheel type storage device, electrochemical batteries, double layer capacitors, flow batteries etc.).

Hybrid traction drive enables:

► storage of energy gained by electrodynamic braking and its next exploitation,

► installation of a primary power source with significantly lower output as in the case the of classic traction drive,

► operation of primary source of energy in optimum regime from the point of view of fuel consumption and emissions,

► utilization of accumulated energy for auxiliary systems in standstill regime of vehicle (engine not running),

► improvement of conditions for alternative fuels and fuel cells using.

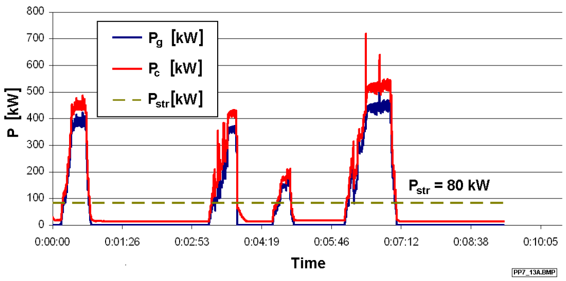

Fig. 6. Output power of locomotive class 740 on shunting operation at Trencianska Tepla

Principle of hybrid traction drive is simple. In those regimes of operation which require smaller traction power as produces the primary source of power, the surplus energy would be accumulated at proper accumulator and on the contrary in case of higher traction power demands as primary energy source offers, missing energy would be drawn from accumulator (in such way it is also possible to use energy acquired from electrodynamic braking). Using of kinetic energy of train which can be transformed by electrodynamic braking is very important and leads to much better energy balance.

Possibility of significantly smaller engine using brings reduction of fuel consumption while idling, what is important in case of industrial locomotives and locomotives for shunting operation. As was shown, idling takes about 60 - 80% of total time of engine operation in cases of industrial and shunting locomotives.

The energy stored in accumulators can be used for acceleration in case of multiple diesel units. The requirements laid on the energy storage device in case of locomotives and diesel multiple units are different. Greater importance is laid on power of energy storage device as on its capacity in case of diesel multiple units.

Another possibility for hybrid drive is utilization of solar energy [10] using of moving and stationary photovoltaic panels.

4. CONCLUSION

At some types of motive power units the utilization of the output of internal combustion engines is very poor. As was shown the mean output in many cases is below 15 % of installed output. This leads to uneconomical operation. One of the possible ways how to solve the problem is using of the hybrid traction drive. Knowledge of operational regimes of locomotives is necessary for right choice of parameters of hybrid traction drive.

It is possible to gain about 15 – 20 % savings in fuel consumption of shunting locomotive by introducing hybrid traction drive. It was proved by measurements at the first hybrid locomotive class TA 436 in the former Czechoslovakia [11]. This locomotive has engine output 189 kW instead of 600 kW of compared locomotive.

Another way for better utilization of fuel is using of SteamTrac technology [12]. This technology is based on waste heat recovery from exhaust gases. It can bring about 5-9 % fuel savings.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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EXPERIMENTAL AND NUMERICAL ANALYSIS OF FLAT CARS CONNECTIONS BETWEEN PIVOTING STANCHIONS AND MAIN LONGITUDINAL BEAMS

Dragan MILKOVIĆ [1]
Jovan TANASKOVIĆ [2]
Goran SIMIĆ [3]

Abstract *– This paper presents experimental and numerical strength analysis of some existing designs of connections between pivoting stanchions and main longitudinal beams of flat cars, pointing out the problem of possible appearance of high contact stresses at some contact surfaces, that might cause some local deformations within plasticity range. Criterion set in the applicable standard requires that two side stanchions fitted to the wagon and positioned opposite each other, shall be able to withstand, without residual deformation, a force of 35 kN acting at 500 mm from the bearing centre of the stanchions in a horizontal direction towards the outside of the wagon. Meeting this criterion and staying inside the limited available space, leaves only minor changes of dimensions of moving parts in a contact as a possible solution of this problem.*

Keywords - Pivoting stanchions, flat car, strength analysis.

1. INTRODUCTION

Elements of connections designed for supporting heavy loads and at the same time for providing relative motion between connecting parts are often subjected to high contact stresses at contact surfaces. This paper presents numerical and experimental analysis of connection between pivoting stanchion and main longitudinal beam of freight flat car type Regns(s)-z manufactured by Railway Vehicles Factory "GOŠA". The scope of this analysis is to find reliable design solution which has relatively lower contact stresses at the contact surfaces.

In Figure 1 is presented exisiting design of the connection between pivoting stanchions and main longitudinal beam on the flat car [1]. Pivoting stanchion is made of steel grade S355. Connection is provided using a bearing pin (figure 2, pos. 1) and U-shaped securing element with cotter pin (figure 2, pos. 2 and 4). In such a way is enabled easy assembling and dismantling of the stanchion in service. Motion stops placed on the outer side of the main longitudinal beam are using as prevention of rotation about bearing pin in locked position.

Fig.1. Side stanchion

Within static strength test of the wagon construction, besides other load cases, strength testing of the connection between pivoting stanchion is

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required according to valid standards [2, 3 and 4]. Pivoting stanchion should withstand force equal to 35 kN at height of 500 mm from the bearing centre in horizontal direction towards the outside of the wagon.

During testing of the side stanchion appeared a problem with U-shaped securing element (figure 2, position 2) which suffered deformation in the plasticity range, jeopardizing safety of the connection (figure 3).

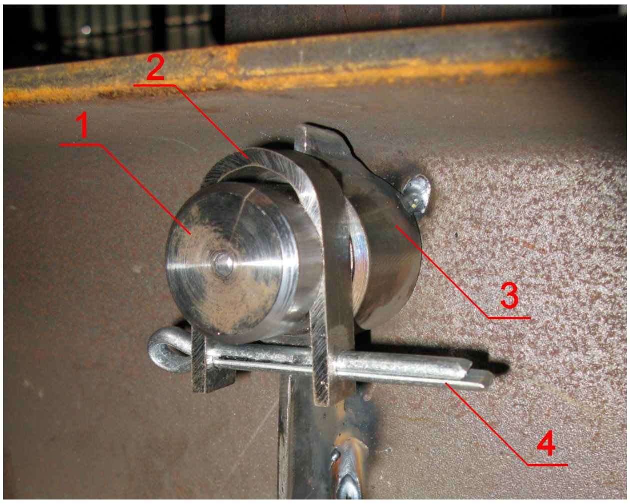

Fig.2. Details of the connection

Fig.3. Deformed U-shaped securing element

To solve the problem, numerical and experimental analysis were performed with the aim to find a solution, which will enable reliable connection between stanchion and car frame.

2. NUMERICAL ANALYSIS

Numercal analysis using finite element method and 3D model with contact elements was performed using commercial software ANSYS, figure 4. Model made in accordance with available technical documentation, provided by manufacturer, has 55465 nodes and 32561 elements. 3D solid elements from the software elements library were used, and for contact modelling special 3D elements (type CONTA and TARGA) were applied. Bilinear isotropic hardening material model of the S355 structural steel was used considering yield strength 355 MPa and tangent modulus 580 Pa.

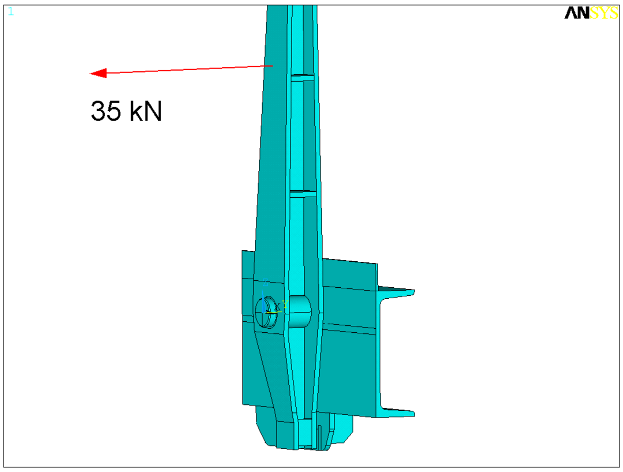

Fig.4. Model of the stanchion connection for FEA

In figure 4 is presented model of the connection between stanchion and the main longitudinal beam with marked required load case.

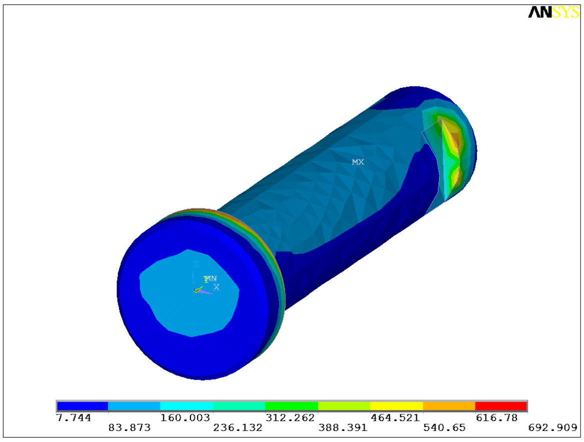

Fig.5. Von Misses stresses of the bearing pin in MPa

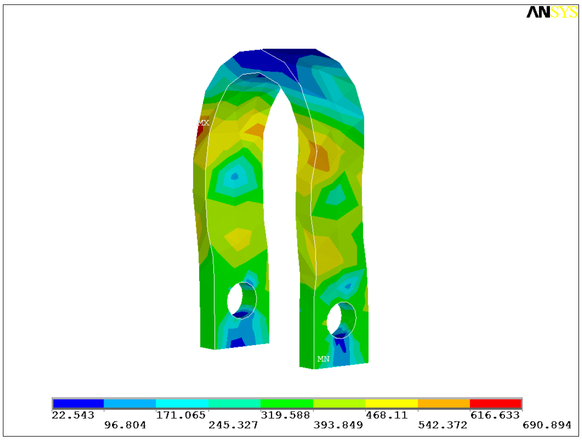

Fig.6. Von Misses stresses of U-shaped securing element in MPa

In figure 5 and 6 could be noticed that the maximum calculated stresses are above yield strength for steel grade S355 which is equal to 355MPa. Stress value of 690MPa, which appeared in some regions of the securing element implies on permanent deformations within plasticity range which may affect funcionality of the connection between stanchion and the main longitudinal beam. Cause of appearences of such high contact stresses are small contact surfaces between bearing pin and stanchion, figure 5.

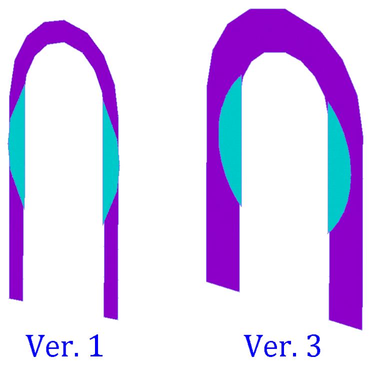

Fig.7. Contact surfaces in case of version No. 1 and version No. 3

Considering the fact that design is already built on several cars, selected connection securing principle was impossible to change. Possible solutions and modifications of the existing design were focused on increase of the contact surfaces between the parts in contact. In figure 7 is presented contact surfaces on existing version No. 1 and modified version No. 3.

The version No. 2 of the design included increase of the securing element thickness from 5 to 12 mm and increasing of the diameter of the bearing pin head from 55 to 60 mm. Thus increasing of the the areas of the contact surfaces towards the outer side. Performed FEA showed that contact stresses between bearing pin head and stanchion were decreased and are below yield strength. Stresses at the contact surfaces between securing element and bearing pin were also decreased but were still above yield strength.

Since the second version did not show satisfactory improvement, in the third version (version No. 3) besides increase of the bolt head diameter, thickness of the securing element was increased to 13 mm and, groove on the bearing pin was deepened from 6 to 7 mm. Thus the contact surfaces were increased towards the inner side.

With one such solution maximum stress value obtained using FEA on very edge of the contact surfaces was 370MPa. This value is insignificantly above yield strength of the steel grade S355. As a side-effect by deepening of the groove, cross section area of the bearing pin was reduced. FEA showed that this modification does not jeopardize bearing pin function i.e. stresses of the bearing pin body were increased for less than 10% and were still far bellow allowable value.

Since the experimental results are decisive for approval of the design, after numerical analysis test of the connection was performed.

3. EXPERIMENTAL VERIFICATION

Test was performed in the laboratory conditions in the workshop of the Railway Vehicles Factory "GOŠA" [1]. Three versions of the design of connection between pivoting stanchion and main longitudinal beam of Regns(s)-z wagon were tested.

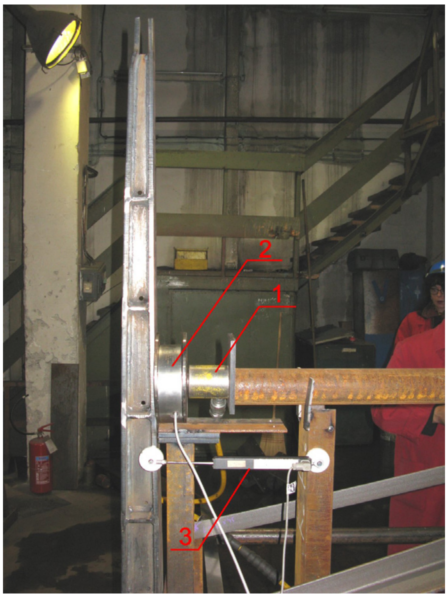

Fig.8. Measurement equipment

Test was performed according to requirements defined in [2] by applying pressure force between the two opposite stanchions at 500 mm above pivoting centre (figure 8). Force equal at least 35 kN was produced using hydraulic cylinder (position 1) placed in series with force transducer (position 2). Pressure in the cylinder was achieved using hand hydraulic pump and permanent deformations of the stanchions were measured using displacement transducer (position 3).

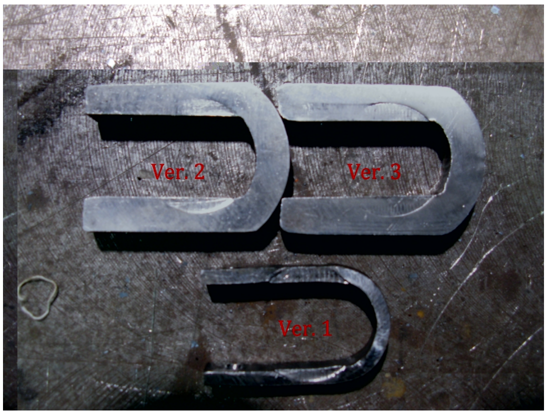

Fig.9. U shaped securing elements after testing

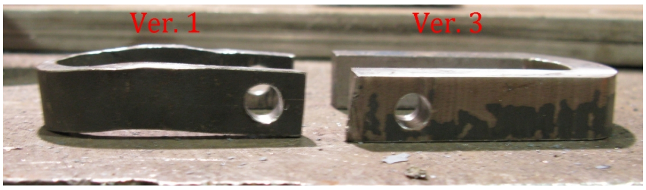

Fig.10. U shaped securing elements after testing

Version No. 2 with increased thickness of the securing element showed relatively lower surface damage, while version No. 3 with improved U-shaped securing element and replaced bearing pin with the aimo of increasing of the contact surfaces between bearing pin and securing element showed minor surface settlement of all contact surfaces. It should be mentioned that surface damage of the version No. 3 in figure 9 and 10 is a result of a force equal to 50 kN and not under required 35 kN. The reason for that was to check additional safety margin of the connection design. Version No. 2 and No. 3, besides minor surface damage did not suffer other damage which may jeopardize function of the connection between the pivoting stanchion and the main longitudinal beam. Measured deformations of the stanchions using displacement transducer for all three versions of design (if appropriately fastened) were within accuracy range and were less than 1 mm, measured at the point of application of the required load equal to 35 kN.

4. CONCLUSIONS

The scope of this paper was to propose a way for overcoming the problem noted on the connection between pivoting stanchion and the main longitudinal beam of Regns(s)-z wagon. Used methods for solving the problem were based on numerical analysis using FEM and experimental research on a full scale object. Based on the obtained results could be concluded that all three version of the design are exposed to high contact stresses between the contact surfaces. Level of deformations are such that for the version No.1 after repeated number of loads equal to maximum force 35 kN, may eventualy produce unfastening of the U-shaped securing element i.e of the connection as a whole.

Permanent deformations of version No. 2 design may not produce failure of the connection. Only minor increase of the gap between the elements may appears.

Connection formed using design version No. 3 is significantly reliable comparing to previous two versions and permanent deformations are insignificant.

Based on the previous stated could be concluded that reliability of the connection between pivoting stanchions and the main longitudinal bemas could be significantly improved by increasing of the contact surfaces between elements in relative motion and by using materials having better mechanical properties and appropriately heat treated. In earlier phase of design development, possible solution of the problem could be selection of different design principle, which is less sensitive to contact stress appearance.

ACKNOWLEDGEMENT

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WAYS TO IMPROVE THE ADHESION BETWEEN WHEELS AND RAILS FOR RAIL VEHICLES

Vasko NIKOLOV [1]

Abstract *– An analysis of the effectiveness of braking of railway vehicles and the factors that determine the coefficient of adhesion between wheel and rail during braking are presented in the paper. The dependence of the coefficient of adhesion on the speed and braking distance is shown. The behavior of axles during braking is analyzed. Methods for enhancing the adhesion between wheel and rail as a way to increase the effectiveness of the brakes of rail vehicles are given.*

Keywords – adhesion, brake system, braking, coefficient of friction.

1. INTRODUCTION

Increasing the masses and speed of railway vehicles is directly related to increasing the effectiveness of brake systems. Increasing adhesion between wheels and rails is one of the key factors for reducing brake distance as the main objective measure of braking efficiency.

2. ANALYSIS OF THE ADHESION OF WHEELS TO THE RAILS

A key indicator of the effectiveness of braking systems for rail vehicles is the length of the brake distance and in the most general form it can be represented by the dependence [5]:

$$S_{д} = 3,94(1+\gamma)\sum_{V=V_{н}}^{V=\Delta V}\frac{2V\Delta V-\Delta V^2}{w_o+i_c+1000\theta\varphi_{к}} \quad (1)$$

where:

V – speed of the train, km/h;

ΔV – intervals of speeds used in the calculations, 10 km/h;

θ – brake coefficient for a train consisting of different brake units;

w_o – basic specific train resistance, N/t;

i_c – longitudinal profile of the track, ‰;

$\varphi_{к}$ – coefficient of friction between blocks and wheels;

γ – coefficient taking into account the influence of inertia of rotating masses.

We see (1) that the effectiveness of the brake is characterized by two main parameters – brake coefficient θ and friction coefficient of the brake blocks $\varphi_{к}$. This statement is true only within certain limits, i.e. when the entire speed range of a given work unit Rolling Stock $\theta\varphi_{к}$ does not exceed the coefficient of adhesion of wheels to the rails $\psi_{к}$, which can be realized when braking. Thus, the main indicator of the braking system $S_{д}$, which characterizes the efficiency of the brake depends on the coefficient of adhesion of wheels to the rails.

The coefficient of adhesion has a complex physical character determined by the specificity of tribological processes in the contact between wheel and rail, and varies widely. Since the material and shape of the interacted surfaces are generally standardized, and are also invariant to any particular vehicle, then its value will depend mainly on:

- Climatic conditions;
- The presence on the surface of the rails of various pollutants (oxides, thin films with the addition of various amounts of adsorbed water, oil and mineral particles);
- Sporadic load distribution on the axles while driving and braking (redistribution of the weight of crew in braking, axles imbalance, unevenness of elasticity and uneven rails);
- The speed of the train.

The coefficient of adhesion is significantly reduced at the beginning of rain, when the dispersed droplets on the surface of the rails is dissolved but not yet washed away dirt. The heavy rain washes rails so that on separate sections of the rails coefficient of adhesion was even higher than before the rain. In areas close to yards where freight trains are composed, often rails are contaminated with grease and other substances that reduce friction between wheel and rail. In these areas low adhesion occurs

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even in dry sunny weather.

The values of the coefficient of adhesion obtained in traction mode are unacceptable for calculations of braking systems for several reasons. Brake systems should not be calculated for limiting values of the coefficient of adhesion, as any brief reduction in adhesion during braking causes sliding of the wheels on the rails. This is associated with increased brake distance and can cause damage to the wheels. The maximum possible coefficient adhesion during braking depends on both the estimated and allowable coefficient of adhesion during braking, and the characteristics of the brake, mostly on the shape of the curve $\varphi_к = f(V)$, as well as the static deflection and unloading of axle during braking.

The average coefficient of adhesion ψ_p, which can be determined throughout the period of braking from starting speed to full stop, can be determined assuming the brake distance [5]:

$$\psi_p = 394\frac{V^2}{s}10^{-5} \tag{2}$$

where:
V – speed of the train at the beginning of the braking, km/h;
S – brake distance, m.

If the outputs of the shortest braking distances achieved in railway transport, then from (2) we get the maximum value of the average realized adhesion for the entire period of braking.

Shortest brake distances are obtained when the transition from rolling of the wheels to slip braking force is automatically reduced and the rotation of the wheels is restored. Such a feature have both dynamic and pneumatic brakes with anti-slip devices. The maximum value of the average adhesion of these brakes is about 0,13. In passenger trains without anti-slip devices with iron blocks this factor is usually about 0,06 to 0,09.

3. ANALYSIS OF BEHAVIOR OF THE WHEELSET DURING BRAKING

In order to study the process of movement of the wheelset during braking, perform the following experience. On a coach are separated two axles, one of which is equipped with a braking system and the other that is not. During movement of the train without stopping for a period of time is measured simultaneously the speed of both axles of the coach with unknown diameters d_1 and d_2 using the timer. According to the number of revolutions (n_1 and n_2) and equality of the distances traveled by the two axles, is defined relationship of the diameters of these wheelsets:

$$\pi d_1 n_1 = \pi d_2 n_2 \tag{3}$$

whence it follows that

$$d_2 = d_1\frac{n_1}{n_2}. \tag{4}$$

Then the speeds of the same axles at a full stop of the coach are measured, as a wheelset with a diameter d_1 remains no braking. The new speed at the beginning of the braking to a full stop is measured. The new revolutions corresponding to diameters d_1 and d_2 are n_1' and n_2'. The distance of non-braking axle is $S_1 = \pi d_1 n_1'$, and of the braking one is $S_2 = \pi d_2 n_2'$. Then slip of the braking axle can be determined as follows:

$$\varepsilon = \frac{S_1 - S_2}{S_1}100\% \tag{5}$$

or

$$\varepsilon = \frac{n_1' - \frac{n_1}{n_2}n_2'}{n_1'}100\% \tag{6}$$

Thus the slip of the braking axle for the entire period of braking is determined, which for a coach equipped with standard cast iron blocks with a 0,63 pressure ratio is about 2%.

If the train's speed is $V_в$, the linear velocity on the surface of the wheel is $V_т$ and the speed of the wheels to the brake blocks is $V_{пл}$, so we can write [3]:

$$V_в = V_т + V_{пл} \tag{7}$$

When the sliding speed of the wheel on the rail $V_{пл}$ not exceed a specified value ($V_{пл} < V_{кр}$), in the wheel-rail contact area the force of adhesion acts, which is determined by the value of the coefficient of adhesion.

The equation of motion of the braked coaches is:

$$w_0'' + b_т = 30\frac{-\Delta v}{\Delta t}\cdot\frac{120}{\zeta} \tag{8}$$

where:
w_o'' – basic specific resistance to secession N/t;
$b_т$ – specific braking force of the vehicle, N/t:

$$b_т = \frac{\frac{\pi d^2}{4}pNn\eta}{Q_c}\varphi_к \tag{9}$$

$\frac{\Delta v}{\Delta t}$ – rate of increasing of the speed;
η – efficiency of brake lever system;
d – diameter of the brake cylinder, mm;
p – air pressure in the brake cylinder MPa;
N – number of braking coaches;
n – ratio of the parking brake;
Q_c – mass of the vehicle, t.

From (8) and (9) can be found $\varphi_к$

$$\varphi_к = \frac{Q_c\left(30\frac{-\Delta v}{\Delta t}\cdot\frac{120}{\zeta} - w_0''\right)}{\frac{\pi d^2}{4}pNn\eta} \tag{10}$$

The main specific resistance of the vehicle is determined as described above, but without applying the brake force, i.e. at $b_т = 0$:

$$w_o'' = 30\frac{-\Delta v}{\Delta t}\cdot\frac{120}{\varsigma} \quad (11)$$

Moreover, during braking the braking force does not exceed the adhesion force between wheelset and rail, so that:

$$\sum K\ \varphi_к \leq Q_o\psi_к \quad (12)$$

where:
ΣK – total compressive force of the wheelset on brake blocks, N;
Q_o – reference mass, t;
$\psi_к$ – coefficient of adhesion between the wheel and rail.
After determining the value of the coefficient of friction of the brake blocks at the moment of wedging it's possible to determine the maximum adhesion of wheels with the track during braking:

$$\psi_к = \frac{\sum K\varphi_к}{Q_o} \quad (13)$$

When the sliding speed of the wheels on the rails $V_{пл}$ exceed the critical ($V_{пл} > V_{кр}$), then between wheels and rails does not act the force of adhesion but friction force of the wheel on the rail, which is significantly less than the force of adhesion between the wheel and rail.

4. HOW TO INCREASE THE COEFFICIENT OF ADHESION BETWEEN WHEEL AND RAIL

One of the easiest and yet most affordable, efficient and acceptable method is to increase $\psi_к$ using quartz sand sprinkled on the surface of the rails under the wheels. It is widely used in the operation of locomotives and applied to increase traction when departing and moving on slopes with reduced adhesion of the rails, and in extreme braking. Sand falls under wheels and by sharp edges of its grains destroys the integrity of the film surface formed by the oxide and fatty substances on the rails, leading to reduced adhesion.

Another possible method to increase the value of the coefficient of adhesion of wheels to the rail is the application of cleaning the surface of the rails with various chemicals. It has been shown that their cleansing action is very effective in this case, if properly defined cleansing action and chemical composition of pollutants. In the overwhelming majority of cases the surface of the rails are formed and accumulate pollutants in the form of a thin layer of fatty acids.

Degreasing of these acids is necessary to apply an alkali such as sodium meta silicate [1]. By trial it is determined that the value of the coefficient of adhesion depends on the chemical composition of the colloidal solution, the composition of entering iron oxide silica and iron hydroxide. When cleaning the surface of the rails alkaline substances have detergent action, active adsorbed colloidal material found on the surface of the rails. As a result of the impact of these substances, the value of $\psi_к$ of the treated area is increased and stabilized.

Analyzing the experience of applying different chemicals to clean the rails to increase the coefficient of adhesion can be found their positive action in this case, if their composition is sand. Its fast effective action is tangible manifested in especially greasy sections of track, especially in places where lubricators are applied for lubrication of the lateral surfaces of the rails to reduce wear. In their action, regardless of the accuracy of the settings, the lubricant does not always fall on the surface of the rails, causing a sharp reduction of $\psi_к$. In this regard, the addition of different cleaning devices of the rolling stock also proper maintenance of the rails is necessary in which there was no sharp decline in the value of the coefficient of adhesion of wheels to the rail during braking. Main event should be regular cleaning of the track surface using, for example, rail grinding machine or other similar devices.

5. CONCLUSIONS

To increase the effectiveness of braking trains with high speeds and removal of cases of sliding of the axles on the rails during braking on the basis of the studies are recommended:

- Applying the brake means providing high levels of braking forces in railway vehicles;
- Implementation of effective anti-slip devices;
- Implement automatic sand supply under the wheels of the coach to increase the force of adhesion of wheels to the rails during braking;
- Rails to be treated with different chemicals, and also by rail grinding machine of the areas where the most frequent cases of sliding due to low adhesion of wheels to the rails.

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IMPROVING RAILWAY BOARDING ACCESSIBILITY

Goran SIMIĆ [1]
Bernhard RÜGER [2]

Abstract *– Regarding to EU regulations today's public transportation systems must be accessible for everyone without any restrictions. The relevant question is: How can trains be accessible for everyone? The huge variety of different vehicles and different platforms does not allow level boarding everywhere, but only in so called "closed" systems. The paper gives an overview of the requirements for new boarding assistance systems and of the recent results in development of the lift system for UIC-coaches within the EU-cofounded project PubTrans4All.*

Keywords – accessible boarding, rail vehicles, lift for wheelchairs, boarding assistant system.

1. INTRODUCTION

Very important step in the accessibility of the rail vehicles is boarding or alighting. Usually only closed rail systems can offer complete level boarding which is the best accessibility solution for all categories of the people with reduced mobility and offers the quickest exchange of travelers. In all other cases, especially for wheelchair users, boarding assistance systems (BAS) like ramps or lifts are needed. Research within PubTrans4All-project revealed that the worse accessibility is in older railway rolling stock, within them in UIC coaches.

This project is co-founded by the EU. Participation of the University of Belgrade-Faculty of Mechanical Engineering is supported by Serbian Ministry of Education and Science.

2. GENERAL REQUIREMENTS FOR A NEW BOARDING ASSISTANCE SYSTEM

The general requirements provide an overview of all relevant parameters that must be considered when designing a new boarding assistance system. Table 1 presents the importance scores used in order to rank the evaluation criteria. Table 1 summarizes the requirements. Features rated as not important, are not shown herein. In colon "importance" the notes mean:

1- Very important – critical to successful operation ("must have")
2- Important – high benefit for users and operators ("nice to have")
3- Less important – some benefit for users and operators, but not absolutely necessary

Table 1. BAS evaluation criteria - overview

Criteria	Remark	Importance
User		
User with devices	wheelchair, walking frame, baby prams	1-2
Physical impaired	Walking disabled, with crutch or sticks, elderly, diminutive people	2
User with special needs	Visual and hearing impaired	2-3
General passengers	Passengers with luggage, children, pregnant	2-3
Operation without staff	Operation by passengers themselves, automation	2
Operator		
Reliability	Prevention of Malfunction	1
Operational quality	Short dwell time, malfunctions must not influence train operations	1-2
Operational effort	Number of staff	1-2
Failure management	Problems easy to solve	1
Manufacturing/ Implementation		
Universalism	The system needs to be universal, retro-fitting allowed	1-2
Costs	Costs as low as possible	1
Manufacturing effort	The manufacturing and retro-fitting effort needs to be low	1-2
Safety		
Safety risks	No safety risks to be tolerated	1
Safety features	Optical and audio signals	1-2
Maintenance		
Maintenance effort	Number of personnel required, special tool required	1
Costs		2
All regulations must be fulfilled (currently according to TSI-PRM as a minimum standard)		

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3. DECISION MAKING PROCESS

At the beginning of the project the project consortium consciously set the bar very high with aim to find a technical solution for accessibility for *all* passengers in *all* boarding situations.

After a long research and discussion process, the consortium concluded that many restrictions are necessary and the all-in-one solution is not possible.

For all local systems (including tramways, metros, urban and suburban railway traffic) a newly developed BAS is neither necessary nor meaningful. All these systems can be seen as so called "closed systems". Here the operators provide vehicles which correspond to the existing platform height or plan to adapt the platforms and/or their vehicles to achieve level boarding Remaining horizontal gap between vehicle and platform is bridged by relatively simple technical aids.

High speed, long distance and international railway traffic will not be able to offer level boarding. The first reason is a higher floor. The lowest floor height in high speed trains is offered in Talgo-trains (760mm). All other vehicles have got higher floor.

The second reason comes from TSI regulations in which two different platform heights are defined as European standard (550mm and 760mm). The consequce is that for the next decades all international trains will need to stop at both levels!

The investigation has also shown that within the next decades a huge number of high floor vehicles will run in European countries in long distance traffic. Due to the long life cycle of railway vehicles they can't be changed in a short or medium term.

So the decision was to develop a BAS for all types of high floor vehicles. In general there are four possibilities – ramps or lifts, platform or vehicle based.

The operators' surveys clearly show that operators strongly wish to have vehicle based BAS systems. Two reasons can be identified for that. Firstly, operators want to be independent from the infrastructure and want to offer the possibility of accessible boarding everywhere. Secondly, it is very difficult to provide a platform based device at all (!) platforms in a railway network.

Comparing the ramps and lifts advantages and disadvantages it was clear that for high floor vehicles the ramps should be very long and it is not possible to find a technical solution for installing such a ramp into existing vehicles. Only different types of lifts are left in focus.

For the next steps of development two decisions have been necessary: Who the user will be and which vehicles are relevant.

The investigations show that for all types of high floor trains with an entrance door width of at least 900mm, different lift systems already exist.

But there is one very big group of high floor railway vehicles in Europe, the so called UIC-wagons. They will be running in many European countries for some decades more and in many countries form the backbone of the long distance railway traffic, especially in eastern European countries. UIC coaches have small doors with a width of only 800 mm with limited space in the entrance area. At the moment there is no vehicle based BAS for UIC coaches and only platform-based lifts can be used for boarding/alighting of wheelchair users. Therefore, the consortium came to the decision that the most important step to offer accessibility to all is to focus on UIC-coaches.

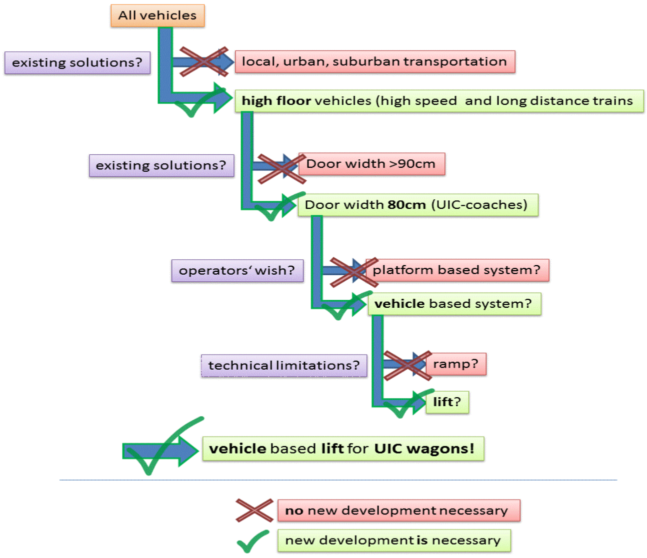

Fig.1. Decision making process

In regard to user requirements, wheelchair users are the only passengers for whom a technical solution is an absolute must. For many other groups it would be very nice to have some technical devices. But if it is not feasible, than other solutions like special services at entrance door well established in some European countries are acceptable and can be further improved.

At the end of the decision process, it came out that the most important case is to develop a vehicle based lift for UIC-coaches. Since there are many restrictions because of the vehicle design, it was necessary to define some compromise design solutions

4. TECHNICAL REQUIREMENTS FOR A LIFT FOR UIC WAGONS

Large number of technical requirements for the lift implementation into UIC coaches has been identified during the project research. The short list of most important of them is shown in Table 2.

Since there are many restrictions because of the vehicle design, it was necessary for few of stipulated requirements to make compromise solutions.

Table 2: Technical requirements for lift

Characteristic	Value	Comment
Carrying capacity	300kg	Covers 99% of wheelchair users
Minimum clear width of lift platform	720mm	Covers 96% of wheelchair users
Minimum platform length	1200mm	
Maximum working height difference vehicle floor-platform	1300mm	
Boarding/alighting parallel to the vehicle (required for narrow platforms)	recommended	Alternatively, exit sideways through lay down of the side fenders
Handrail bound to the platform on one side, should be at the height of	650 to 1100mm from platform level	
Finger pressure for activation of control buttons	≤ 5N	
Manual force to operate the lift by staff	≤ 200N	For example for emergency mechanical activation.
Manual force to operate the lift by staff at movement start	≤ 250N	Allowed only for short period at the start. For example for emergency mechanical activation.
Vertical speed in the operation	≤ 0.15 m/s	Movement should be smooth
Speed of any point of BAS without load	≤ 0.2 m/s	Up to 0,6m/s allowed by EN 1756-2. TSI PRM: maximum speed without load less than 0,3m/s is recommended.
Acceleration during operation with load in any direction and at any point of the lift platform	≤0.3 g	
Tilting speed of the lift platform	≤ 4o/s	In case of automatic adaptation to the relative angle between vehicle and platform, for example at superelevated track by platforms in curves.
Automatic roll-off protection height	≥100mm	The barrier in front and at rear side of the wheelchair lift platform should be automatically erected during lift operation.
Lateral side guards height:	≥25mm min ≥50mm preferred	Prevention of the wheelchair side roll-off from the lift platform
End of travel mechanical limitation devices	yes	
Overload protection of the main power electrical circuit		Fuse, an overload cut-out or similar
In stowed position BAS must be safe against uncontrolled displacements. Mechanical securing devices dimensioning according to the accelerations:	$a_{longitud.}$=5g $a_{lateral}$=1.5g $a_{vertical}$=1g	These accelerations can arise in the exceptional case of occasionally buffing impact at coach staying in yard (without passenger) (UIC 566)
Activation possible only at:	V = 0 km/h.	
Activation of the BAS should introduce activation of the coach brake system.	yes	Movement of the train during BAS usage must be prevented
The lift platform surface should be smooth and must have slip-resistant surface	yes	Slip resistance according to EN ISO 14122-2.
The operation control should be of type hold-to-run.	yes	Lift shall stop moving and remain motionless after the control is released.
In any case of breakdown, it is acceptable that platform may decrease with controlled speed:	≤ 0,165 m/s	For example in case of the hose or pipe failure by hydraulic systems or similar.
A stop in overload protection should be present at overload more than	25%	
An emergency stop button within reach of the user should be present	yes	Release of the emergency stop button should only be possible by the personnel
Other technical details not covered in this table should be based on:	TSI PRM, EN 1756-2, RVAR	

5. DESIGN AND TESTING

The UIC coaches have doors located at the ends. Because of the folding or sliding steps, vicinity of the buffers as well as other constraints, there is no space under the steps for the installation of a BAS. The space at the entrance is occupied by mechanisms of the head doors leading to the next coach, some electrical and pneumatic components, handbrake, firefighting equipment, etc. Typical for these coaches is that the passageway is in majority cases at one side outside the longitudinal center line of the vehicle because of the neighboring toilet cabins.

After analysis of several lift types only feasible solution was swivel lift. This lift type used in some other applications of consortial partner and lift producer MBB, was newly designed to meet the limited space conditions in entrance area of UIC coaches. The design width in the stowed position was reduced to the required aisle widths inside the car needed for free passage of wheelchair. The swivel mechanism had to be redesigned in order to lift could pass through doors with width of 800mm. The lift sliding pillar geometry was adapted to allow the lift to pass the foldable step in opened position.

The UIC wagon of the Bulgarian State Railways provided for lift prototype installation had also to be adapted. The rod representing mechanical connection between door mechanism and foldable step should be removed and replaced by pneumatic drive for foldable step in order to left enough space for lift mechanism. Appropriate new wiring was necessary too. The outer part of the double wall between side corridor and the toilet should be removed to create sufficient corridor width for passing wheelchairs. The end wall had to be moved about 40mm toward the end of the wagon to avoid interference with lift during unfolding. Installation of the lift attaching plates at three positions was necessary. The door pillar was reinforced in accordance with FME strength calculation under forces acting during lift service.

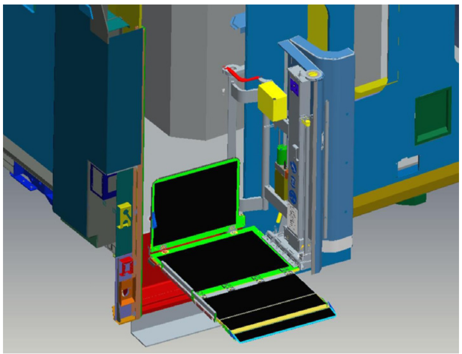

Fig.2. Virtual reality lift examination

The installation of the adapted lift was simulated using virtual reality equipment of Siemens Transportation, Vienna (Fig. 2) before the installation in the mock-up. To test the space and usability of the system and the installation a mock-up of Bulgarian State Railways UIC-coach entrance area was constructed by Bombardier Transportation, Berlin.

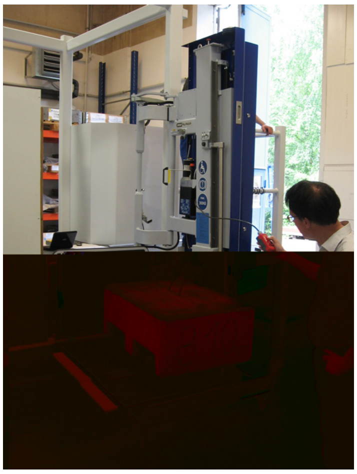

Fig.3. Lift tests in mock-up

The tests at the mock-up were performed along with required measurements, including the test of 300 kg load capacity (Fig. 3).

To test the prototype performances in real conditions of the platform and track characteristics the installation of the lift prototype in the existing UIC coach was made by Bulgarian State Railways.

During the rides on a main line route from Sofia to Pleven the boarding and alighting of wheelchair users were tested (Fig.4). Stations with different platform heights and widts covered all possible boarding situations. Some of them were in curves with different radii and track cants.

Fig.4. Tests in real service conditions

The tests have shown that the lift can be used on platforms heights down to 160 mm. For platforms in curves, there are some limitations due to superelevation of the track.

The boarding is possible with a side roll-off and roll-on at the platforms no more than 1,4m wide in the case of the hand driven wheelchairs. For motor driven wheelchairs a little bit larger platforms are needed.

From the perspective of the operator, complete usage cycle lasts in average about 2 minutes (a little bit more on very low platforms).

6. CONCLUSIONS

The main goal of the EU PubTrans4All project to choose appropriate solution, design, build and test the prototype of BAS for demanding conditions of UIC coaches was successfully completed. The coach with the lift for wheelchair user will be presented to the public at Innotrans fair in September 2012.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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SOME RESULTS FROM SIMULATING OF CONTACT STRESSES AT THE MESHING OF A PAIR OF SPUR GEARS OF ELECTRIC LOCOMOTIVE

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Abstract *–The current work presents some results of investigating the intensity of the stress on the line of contact in a pair of spur gears and its influence on the strength of the teeth of virtual models of spur gears with straight teeth. We present a 3-dimensional model of spur gears and their contact with an electric locomotive reductor in a CAD system with the SolidWorks2010 software. We investigate the influence of different parameters on the stress on contacting teeth. The results are obtained through the application of the Hertzian theory of contact.*

Keywords - electric locomotive, spur gears, CAD, CAE, simulation.

1. INTRODUCTION

The electric locomotive types owned by "Holding BDZ" EAD are shown in table 1.

The Bulgarian National Railways currently posses 575 mobile electric units, from which 405 locomotives and 170 electric railcars. From the formation of BDZ until present day, its mobile units are divided into 80 series with approximately 97 constructive variations. The most powerful electric locomotive from the end of the 90s is the series 46 imported in 1986-1987; it was constructed in the ELECTROPUTERE – Craiova factory and has a power of 5400 kW. The locomotives from this series are used predominately in the servicing of express lines. From December 2007 BDZ is in posession of 15 new tripple-car electric railcars Siemens Desiro – series 30, and from May 2008 with 10 new four-car series 31 ones.

Currently "Holding BDZ" EAD finds itself in an increasingly tough financial situation. The locomotives in its posession are on average over 25 years old [1]. The only exception are the 6 modernized electric locomotives. The annual funds necessairy for maintenance and repair of the mobile units are approximately 18 million levs.

Some of the most common malfunctions in the mobile parts of electric locomotives are damages to the gears of wheelsets' reductors[2].

The reliability of a spur gear transmission consists of assessing the reliability of the elements that make up the assembled unit [3-6].

Table 1. Editorial instructions

Series	Symbol	Model	Producer	Total	Supply
41	41.001–039	42E1	Škoda	10	04.1962–07.1962
		42E1	Škoda	31	03.1963–11.1963
		42Em	Škoda	(39)	04.1965–12.1967
42	42.001–020	46E1	Škoda	20	10.1965–01.1966
	42.021–050	46E2	Škoda	30	12.1966–03.1967
	42.051–070	46E3	Škoda	20	10.1968–11.1968
	42.071–090	46E4	Škoda	20	06.1970–08.1970
43	43.001–023	64E1	Škoda	23	08.1971–09.1971
	43.024–043	64E2	Škoda	20	02.1973–03.1973
	43.044–056	64E3	Škoda	13	02.1974–03.1974
44	44.057–070	68E1	Škoda	14	04.1975–05.1975
	44.071–100	68E2	Škoda	30	11.1976–02.1977
	44.101–115	68E3	Škoda	15	09.1978–12.1979
	44.116–130	68E4	Škoda	15	11.1979–12.1979
	44.131–145	68E5	Škoda	15	12.1980–01.1981
45	45.146–175	68E6	Škoda	30	02.1982–04.1982
	45.176–205	68E7	Škoda	30	11.1983–01.1984
	45.206–220	68E8	Škoda	15	11.1984–01.1985
46	46.001–015	1.	Electroputere	15	1986
	46.016–030	2.	Electroputere	15	1986
	46.031–045	3.	Electroputere	15	1987
47	47.001–030	75E1	Škoda	30	-
60	60.001–004	28E1	Škoda/BDŽ	4	12.1982–06.1985
61	61.001–020	56E1	Škoda	20	04.1994–07.1994

The reliability of the elements and the modal vibrations [6] in the transmissions is a function of the stress state and the number of cycles of stress.

The aim of this article is to create a 3-dimensional

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CAD model of the elements of the wheelsets reductor of an electric locomotive put under simulated stress.

Evaluating the contact resillience of the spur gears is done through determining the contact stress σ_h .

2. MODELLING THE GEOMETRY OF THE STRESS ON THE SPUR GEARS FROM A REDUCTOR IN AN ELECTRIC LOCOMOTIVE

Table 2 shows some of the main parameters of a gear transmission in electric locomotives from the 43,44,45 and 46 series, and table 3 shows the main parameters of the spur gears.

Table 2

Locomotive series	Engine power N_{eng}, kW	Trans-mission ratio, **U**	Wheel-base, a_w, **mm**	Module **m,mm**	Number of teeth	
					z_1	z_2
43-44	**785**	**3,348**	**606±0,5**	**12**	**23**	**77**
45	**785**	**3,95**	**606±0,5**	**12**	**20**	**79**
46	**900**	**3,65**	$\mathbf{580_0^{+0,14}}$	**12**	**20**	**73**

Table 3

Parameter	Electric locomotive series					
	43-44		**45**		**46**	
	z_1	z_2	z_1	z_2	z_1	z_2
Module – **m, mm**	**12**		**12**		**12**	
Teeth number - z_i	**23**	**77**	**20**	**79**	**20**	**73**
Teeth angle - **β, grad**	**0**		**0**		**6**	
Gear width, b_{wi}, **mm**	**120**		**120**		**108**	
Coefficient of displacement - x_i	**+0,793**	**-0,275**	**+0,5**	**+0,5**	**+0,478**	**+1,2775**
Maximum acceptable error of the tooth profile, f_f, **μm**	16	34	16	34	22	30
Maximum acceptable error of the tooth direction - F_β, **μm**	21	40	21	40	20	40
Mean length of the common normal - W_m, **mm**	98,94 $\binom{-0,1}{-0,2}$	347,2 $\binom{-0,16}{-0,60}$	96,03 $\binom{-0,09}{-0,17}$	354,34 $\binom{-0,16}{-0,60}$	95,91 $\binom{-0,19}{-0,28}$	394,92 $\binom{-0,19}{-0,31}$
Level of accuracy and type of transmission	6-6-6B	7-C	6-6-6B	7-C	7-6-6C	7-6-6C
Diameter of the outside circle - D_a, **mm**	318,6	941,4	274,28	982,53	272,5	933,61
Diameter of the pitch circle - D_c, **mm**	278	924	244	948	241,32	880,83
Diameter of the base circle - D_f, **mm**	265	887,4	224	930	246,1	907,21

Forming the complete unit of the pair of gears working together happens when the plains defined by the perpendiculars to the axes of the gears and the plain along the line of gearing, tangental to the initial cyllinders, match. Fig. 1 shows the gearing of a pair of gears inside the series 45 locomotive (table 3).

Because the maximum stress in the transmission of force between two gears is distributed among the pairs of teeth that take part in the transmission together, we investigate the contact between sectors of three, two or one teeth instead of the whole gears [8-15]. The model employed in the current work is the gearing of sectors of three gear teeth of an electric locomotive series 45.

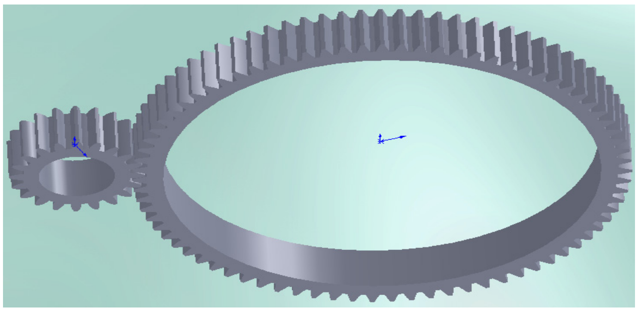

Fig.1. Gearing of a pair of gears inside the series 45 locomotive

The modelling of the forces and obtaining the values for the arising stress are done with the help of the SolidWorks' 2010 product that uses the calculation method of the finite elements when generating the results.

The generated mesh of finite elements has the following characteristics: size of elements – **1 mm**, type of mesh – frame (solid), quality of the mesh – high (every element has **10** nodes), mesh type – standard, options for the mesh generation methods – Automatic Transition off and Smooth Surface on, number of iterations for checking the level of curviture of the tetrahedric elements – **4**, approximate number of finite elements – **50000** depending on the tooth pair. We use the iteration computational method FFEPlus [CosmosWorks'2010 Online User's Gruide & Help Files].

In the simulation we used combinations of models of gears with different coefficients of height correction **x = -0,6; -0,5; -0,4; - 0,3; 0,0; + 0,3; +0,4; +0,5; +0,6** and different gear width of the larger of the two gears $\mathbf{b_2}$ **= 108, 110, 120, 122** and **125 mm** and width $\mathbf{b_1}$ **= 120 mm** of the gear with lower number of teeth – **20**, with different curviture radius of the transitional curve **R = 0,0; 0,2; 0,4 ;0,6** and **1,5 mm**. The module of the teeth in all combinations is **m = 12 mm**. In a transmission the gear with the smaller gear always has the same number of teeth – **20** and always has the same torque applied to it **M = 3.6 kNm**. Modelling of the applied torque happens with a uniform pressure **p** along the two symmetric plains of contact (see fig.2) – **1,8 kNm** on each plain, with the value of the force given by the following relation:

$$\mathbf{M/2 = \int_{r_0}^{r_f} r.p.b.dr = 0{,}5.p.b.(r_f^{\,2} - r_0^{\,2})} \qquad (1)$$

where **r** is the current radius [**m**]; **p** – the required value for the pressure [**Pa**]; **b** – the width of the gear [**m**] (chosen) $\mathbf{r_f}$ – radius of the base circle [**m**] (specified for the particular gear); $\mathbf{r_0}$ – radius of the opening of the gear [**m**] (specified for the particular gear as a part of $\mathbf{r_f}$) **M = 3,6 kNm** – torque. For the contacting involute profile tooth surfaces, the Contract Pair of type Surface option is chosen, i.e. the two contacting surfaces are guaranteed while the physical requirement to not have any pieces pervading each other is fulfilled.

The large gear is blocked along the internal cylindrical surface of the opening. This surface is assimed to be immobile and non-deformable. The small gear is allowed to rotate around its axis, simulating a transmission with a shaft.

The chosen material for the models of the gears is steel with characteristics given by the provided library applications in SolidWorks'2010, module of linear deformation (Young's) $\mathbf{E = 2{,}06.10^{11}}$ **Pa**, Poisson coefficient **μ = 0,3**, module of angular deformations **G** $\mathbf{= 7{,}9.10^{10}}$ **Pa**, density $\mathbf{\rho = 7870\ kg/m^3}$,etc.

3. RESULTS FROM THE MODELLING

The conducted simulations for obtaining the contact stress show the very apparent irregular nature of the distribution of the stress in the contact line area. Thus fig. 2 shows the distribution of the contact stress between a large spur gear with a number of teeth equal to $\mathbf{z_2 = 79}$, paired with a small spur gear with $\mathbf{z_1}$ **= 20** number of teeth. The spur gears have not been corrected, have no rounding of the transitional curve, and have the same gear width of **b = 120 mm**. In the axial direction the surfaces of the gears perpendicular to their axes match.

It is evident from the figures that the maximum contact stress measurements, $\mathbf{\sigma_{h1}}$ **=659 MPa** and $\mathbf{\sigma_{h2}}$ **=638 MPa**, are concentrated around the edges of the contact lines. This has been experimentally confirmed in [16].

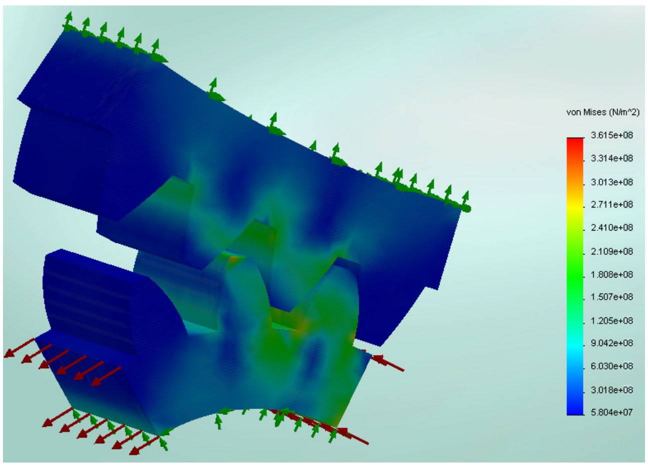

Fig.2. Distribution of the contact stress in the teeth sectors

It is established that the maximum contact stress is calculated on the basis of the Hertz formula in the case of a linear contact of two cylinders with radii equal to the radii of the curve ρ_1 and ρ_2 of the involute profiles at the pole of contact according to [17].

$$\sigma_H = \sqrt{\frac{E_{red}}{2.\pi.(1-\mu^2)}.\frac{q}{\rho_{red}}} \qquad (2)$$

where in accordance with the material of the gears from the simulations $\mathbf{E_{red} = E = 2{,}06.10^{11}}$ **MPa** a linear deformation model for steel for both gears is used; **μ = 0,30** is the Poisson coefficient; ρ_{red} $=\rho_1.\rho_2/(\rho_1+\rho_2)=\mathbf{(d_1.\sin\alpha_w/2).(u/(u+1))}$ is the radius of the curve ($\mathbf{\alpha_w = 20°}$ is the angle of contact, $\mathbf{d_1}$ and $\mathbf{d_2}$ are the separation diameters, and $\mathbf{u = d_2/d_1}$ is the transmission ratio); $\mathbf{q = (E_n/b_1).K_{H\alpha}.K_{H\beta}.K_{Hv}}$ = $\mathbf{(E_t/(b_i.\cos\alpha_w)).K_{H\alpha}.K_{H\beta}.K_{Hv}}$ is the intensity of the uniformly distributed along the length $\mathbf{b_i}$ of linear contact normal stress, with the forces $\mathbf{F_n}$ and $\mathbf{F_t}$ being the normal and tangental components of the forces at the point of contact, and the coefficients $\mathbf{K_{H\alpha}}$, $\mathbf{K_{H\beta}}$ and $\mathbf{K_{Hv}}$ being the coefficients of stress that indicate respectively the distribution of stress between the teeth, the non-uniformity of the distribution of the stress along the lengh of the contact line, and the additional dynamic stress (since the simulation performs an ideally-distributed and static in nature stress, here $\mathbf{K_{H\alpha} = K_{H\beta} = K_{Hv} = 1}$).

Thus from (2), having in mind that $\mathbf{F_t = 2.T_1/d_1}$ we obtain:

$$\sigma_H = \sqrt{\frac{E_{np}}{\pi.(1-\mu^2)}.\frac{2.T_1}{d_1 b_2.\cos\alpha_w}.\frac{2.(u+1)}{d_1.\sin\alpha_W.u}} =$$

$$= 795{,}027.10^6.\sqrt{\frac{u+1}{u}} \qquad (3)$$

Thus we obtain the calculated values in table 4 for the contact stress $\mathbf{\sigma_н}$ between spur gears with number of teeth $\mathbf{z_1 = 20}$ and $\mathbf{z_2 = 77}$ or **79** with a coefficients of correction $\mathbf{x_1 = x_2 = 0}$ or with equally shifted contact and a line of the contact line $\mathbf{b_1 = 120mm.}$

Table 4. Calculated values for the contact stress $\boldsymbol{\sigma_н}$ *depending on* ***u***

u	77/20	79/20
Contact stress $\sigma_н$ [MP_a]	666 и 722	664 и 721

With a correction of the spur gears with coefficients $\mathbf{x_1 = x_2 = +0{,}5}$, the stress at the contact points of small gears is lower than the norm for the material, alloy structural steel **37 Cr 4** (**Rm=785 MPa**) tooth face hard. If the gears are not corrected, the stress is above the allowed norm.

By using different brands of tempered steel for the manufacture of the spur gears, the stress at the contacts that arises between them change. In fig. 3 are shown the dependencies between $\mathbf{R_m}$ –strain stress, **MPa** and $\mathbf{S_H}$ – coefficient of security of the contact stress between the gears with number of teeth $\mathbf{z_1 = 20}$ and $\mathbf{z_2 = 79}$.

Both dependencies show that using steel with stress under **750 MPa** cannot provide the minimum required value of the coefficient **[S_h]=1,3**. Using different brands of steel or tempering increases the value of the coefficient of security but also raises the price of the gears as well.

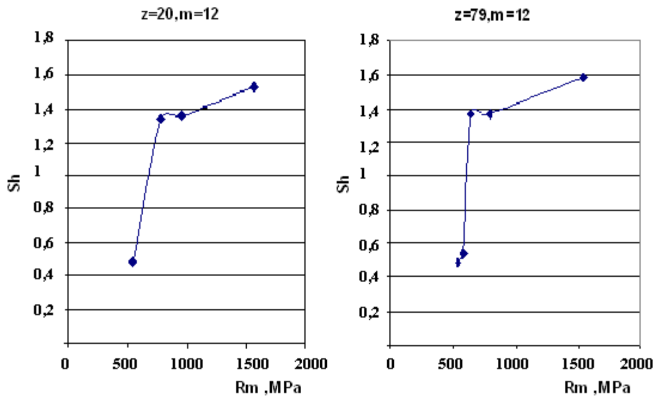

Fig.3. Dependence between R_m – strain stress, MPa and S_h – security coefficient of contact stress

4. CONCLUSION

The simulations of the contact stress in spur gears with straight teeth have shown:

1. The distribution of the equivalent stress close to the contact line has a highly non-uniform character – in all conducted simulations they are concentrated in the two ends of the contact line.

2. The values of the obtained contact stress in the simulation are approximately of the same range but a bit smaller than the values of the contact stress calculated from the Hertz formula. The increase in susceptibility of the teeth favors the shift of the stress away from the contact line and from then, a lower concentration of the stress.

3. In the pair of contacting gears, larger stress in the contact area occurs in the gear with a lower width. The maximum contact stress is found at the end points of the contact line of the teeth. To shift the stress, using corrections in the longitudinal direction of the teeth of the gears is suggested.

4. Changing the profile of the standard contour that forms the involute operational surface of the teeth and the transmission curve of the spur gear do not have any signifficant effect on the contact stress that arises in the gears.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '12

MODELING THERMAL EFFECTS OF THE BRAKING PROCESS AT BLOCK-BRAKED RAILWAY VEHICLES

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Abstract *– The modeling of thermal effects has become increasingly important in product design in different transport means, road vehicles, airplanes, railway vehicles, and so forth. Moreover, the thermal analysis is a very important stage in the study of braking systems, especially of railway vehicles where it is necessary to brake huge masses, because the thermal load of a braked railway wheel is prevailing compared to other types of loads. In the braking phase kinetic energy transforms into thermal energy resulting in intense heating and high temperature states of railway wheels. In that way induced thermal loads determine thermomechanical behavior of the structure of railway wheels. In cases of thermal overloads, the generation of stresses and deformations are occurred whose consequences are the appearance of cracks on the rim of a wheel and the final total wheel defect. The importance to precisely determine the temperature distribution caused by the transfer process of the heat generated during braking due to the friction on contact surfaces of the braking system determines a dare research task. Therefore, the thermal analysis of a block-braked solid railway wheel of a locomotive of the type 444 of the national railway operator Serbian Railways using analytical and numerical modeling of thermal effects during braking until the locomotive stops, is processed in detail in this paper.*

Keywords - railway, braking, block-braked solid wheel, thermal load, friction generated heat.

1. INTRODUCTION

Thermal analysis is involved in almost every kind of physical processes and can be the limiting factor for many processes. The modeling of thermal effects has become increasingly important in product design including areas such as electronics, automotive, aerospace, railway (e.g. wheel and rail contact, braking systems and so on), medical industries, etc. Computer simulation has allowed engineers and researchers to optimize process efficiency and explore new designs, while at the same time reducing costly experimental trials. The finite element method (FEM) has become the preferred method in performing thermal analysis on a many systems and processes in recent years [1]. A FEA thermal analysis is a finite element analysis that looks at how heat affects certain materials and engineering designs. Thermal analysis and precise prediction of the maximum temperature is needed for the design of many systems, for example braking systems [2], especially for both discs and linings, where how to handle the high speed spinning of discs is the point of the heat/structure coupled analyses [3]. The thermal analysis is a primordial stage in the study of the braking systems, because the temperature determines thermomechanical behavior of the structure. In the braking phase, kinetic energy transforms into thermal energy, resulting in intense heating of the railway wheel. This generates stresses and deformations whose consequences are manifested by the appearance and the accentuation of cracks on treads of wheels and finally fractures of wheels [4].

Many researches results confirmed dominant influence of thermal loads in regard to mechanical loads [5] and residual stresses induced by high

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thermal loads in block-braked solid wheel were registered [6]. Therefore, it is important to determine with high precision the temperature field of the braking system, as well as to emphasis that high thermal loads, in other words overloads, of wheel can occur as a result of long braking. Those are the main goals of this paper which presents results of a thermal analysis of a braking system of railway vehicles using analytical and numerical modeling of thermal effects during braking, until locomotive stops, in order to analyze damages of solid wheel braked by blocks, especially on railway vehicles of national railway operator Serbian Railways.

2. ANALYTICAL MODELING OF THERMAL EFFECTS OF THE BRAKING PROCESS AT BLOCK-BRAKED RAILWAY VEHICLES

To simulate a process of braking of railway vehicles it is necessary to define an analytical model of a thermal analysis that describes the heating transfer of the heat generated by friction at surfaces which are in contact between a railway wheel and braking blocks through the wheel and blocks, as well as heat outflow of the whole braking system due to cooling of the surrounding air. For that purposes an analytical model for analyzing thermal effects in braking systems of passenger cars [7] was utilized and its adopted procedure is presented in this paper for a braking system of railway vehicles.

The thermal analysis of the braking system of railway vehicles requires a precise determination of the quantity of heat produced by friction and as well as the distribution of this energy between the railway wheel and the braking blocks. When the braking process occurs, blocks and railway wheel are in a sliding contact. The resulting force resists the movement so the train slows down and eventually stops. The friction between the wheel and blocks always opposes motion and the heat is generated due to conversion of the kinetic energy. However, the whole braking system is exposed to the enlarged air flow for high speed braking and the heat is dissipated.

The heat flux evacuated of surfaces in contact (between blocks and railway wheel) is equal to the power friction. The heat power generated per unit contact area at the radius r of the wheel can be calculated by the following equation:

$$q(r,t) = -f_f \cdot r \cdot \omega(t) = -f_f \cdot r \cdot (\omega_0 + \alpha \cdot t) \qquad (1)$$

where f_f is the friction force per unit contact area, ω is the angular velocity, ω_0 is the initial angular velocity, α is angular acceleration of the railway wheel and t is braking time. In the following considerations, it is not the case where the wheel rotates, but the heat source.

The friction force per unit contact area can be calculated as:

$$f_f = \frac{\mu \cdot F_N}{A} \qquad (2)$$

where μ is the friction coefficient, F_N is the normal braking force on one of the braking blocks, and A is the area of the contact surface between one braking block and the railway wheel.

The wheel and blocks dissipate the heat produced at the boundary between the braking blocks and the wheel by convection and radiation. The model also includes heat conduction through the blocks and the wheel by the transient heat transfer equation:

$$\rho \cdot C_p \frac{\partial T}{\partial t} + \nabla \cdot (-k \cdot \nabla T) = Q - \rho \cdot C_p \cdot u \cdot \nabla T \qquad (3)$$

where for materials of the wheel and the blocks ρ is the density, k represents the thermal conductivity, C_p is the specific heat capacity, u is the velocity field and Q is the heating power per unit volume, which in this case is set to zero. The velocity field u involves all the points on the wheel with their local velocities of the heat transfer:

$$\vec{v}_d = \omega(t) \cdot \vec{r} \qquad (4)$$

where $\vec{r}$ is the position vector of the considered point.

At the contact surface between the wheel and the blocks, the braking process produces heat according to the expression (1). The heat dissipation from the free surfaces of the wheel and blocks to the surrounding air is described by both convection and radiation:

$$q_{diss} = -h \cdot (T - T_{ref}) - \varepsilon \cdot \sigma \cdot (T^4 - T_{ref}^4) \qquad (5)$$

In this equation, h equals the convective film coefficient, ε is the material's emissivity, and σ is the Stefan-Boltzmann constant ($5.67 \cdot 10^{-8}$), T_{ref} is the temperature of the surrounding air.

To calculate the convective film coefficient as a function of the railway vehicle velocity v, the following formula should be used:

$$h = \frac{0.037 \cdot k_a}{2 \cdot r} \cdot R_e^{0.8} \cdot Pr^{0.33} = \frac{0.037 \cdot k_a}{2 \cdot r} \cdot \left(\frac{\rho_a \cdot 2 \cdot r \cdot v}{\mu_{va}} \right)^{0.8} \cdot \left(\frac{C_{pa} \cdot \mu_{va}}{k_a} \right)^{0.33} \qquad (6)$$

Here, material properties: the thermal conductivity k_a, the density ρ_a, the viscosity μ_{va} and the specific heat capacity C_{pa} are for the surrounding air.

3. NUMERICAL MODELING OF THERMAL EFFECTS OF THE BRAKING PROCESS AT BLOCK-BRAKED RAILWAY VEHICLES

High thermal loads at railway wheels very often occur as a result of a long braking. For analyzing the process of braking it is very useful to use FEM simulations based on the adopted and presented analytical model for defining heat sources at surfaces which are in contact with blocks, and to define the simultaneous heat inflow from friction (a part of heat transferred to the wheel rim) and heat outflow due to cooling at the segments of the surface, which are not in contact. In COMSOL Multiphysics the Heat Transfer Module (Heat Transfer in Solids) is used to carry out transient thermal analysis. The Module supports all fundamental mechanisms including conductive, convective and radiative heat transfer. Using the physics interfaces in this Module along with the inherent multiphysics capabilities of COMSOL Multiphysics, the transient thermal analysis was preformed, and the temperature fields of a railway wheel during braking, until locomotive stops were determined, with different braking conditions.

The thermal analysis was performed for braking a locomotive of the type 444 of the national railway operator Serbian Railways, that ran with initial velocity of 120km/h. Two different cases of braking were analyzed, with low ($3.36 \cdot 10^5$ Pa) and high ($7 \cdot 10^5$ Pa) pressures in the braking installation. In the low pressure regime of braking, the normal braking force on one braking block was F_N =20379N, with duration t=35s of the braking until the locomotive stops. In the case of high pressure regime of braking, the normal braking force was F_N =37162N, with duration t=19s of the braking until the locomotive stops. Braking forces were introduced in the analysis throughout equations (1) and (2). The intermediate radius for the chosen locomotive wheel was r=625mm, the contact surface area between the braking block and the wheel was A=19577mm^2, and the friction coefficient for materials of the block and the wheel was μ=0.115.

Fig.1. shows the meshed 3D model of the railway wheel and braking blocks. In the meshing process this assembly was devided in 68771 finite elements.

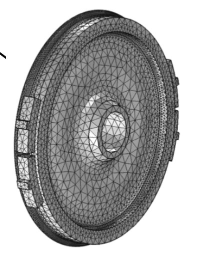

Fig.1. The meshed model of the block-braked solid wheel assembly

The material of the railway wheel is steel DIN 40Mn4 (AISI 1039, JIS S40C, Č3130) and the braking blocks is gray cast iron P10. Table 1 summarizes the thermal properties of these materials; the density of air at a reference temperature of 300 K was calculated using the ideal gas law.

Table 1. Material properties

Property	Railway wheel	Braking block	Air
ρ [kg/m3]	7850	7200	1.170
C_p [J/(kg·K)]	486	510	1100
k [W/(m·K)]	52	45	0.026
ε	0.28	0.31	-
μ_{va} [Pa·s]	-	-	1.8·10-5

4. RESULTS OF THERMAL ANALYSIS OF THE BRAKING PROCESS OF THE 444 LOCOMOTIVE

During the braking process, as the velocity of the locomotive decreases, the generated heat due to the friction between surfaces in contact decreases as well (1). At a time the generated heat becomes smaller than the dissipated heat from the free surfaces. For this analysis, at the moment t=17.8s, for the low pressure regime of braking, and t=11.8s, for the high pressure regime in the braking installation maximum temperatures were reached. After these times, as the braking process continue, the temperature starts to decrease and the wheel starts to cool down. The diagrams of the temperature distribution at the moment with maximal temperatures reached, for the examined wheel of the locomotive of the type 444 of the national railway operator Serbian Railways, are shown in Fig.2.

In order to determine positions of areas with maximal temperatures it is helpful to plot diagrams of temperature distribution versus time along with the wheel radius. These diagrams are displayed in Figure 3 for the low pressure regime of braking and for the high pressure regime in the braking installation.

According to the diagrams of the temperature distribution (Fig. 2 and 3) Table 2 is made in order to summarize, for examined cases, the values of the maximal temperatures at the points at the wheel rim at the moment when temperature reached the maximal values for the braking process of a locomotive of the type 444 of the national railway operator Serbian Railways from the initial velocity of v = 120 km/h until the locomotive stops.

Table 2. The maximal temperatures at the wheel rim

Braking regime	Low pressure	High pressure
Time of braking *t* [s]	17.8	11.8
Temperature [ºC]	170.73	220.64

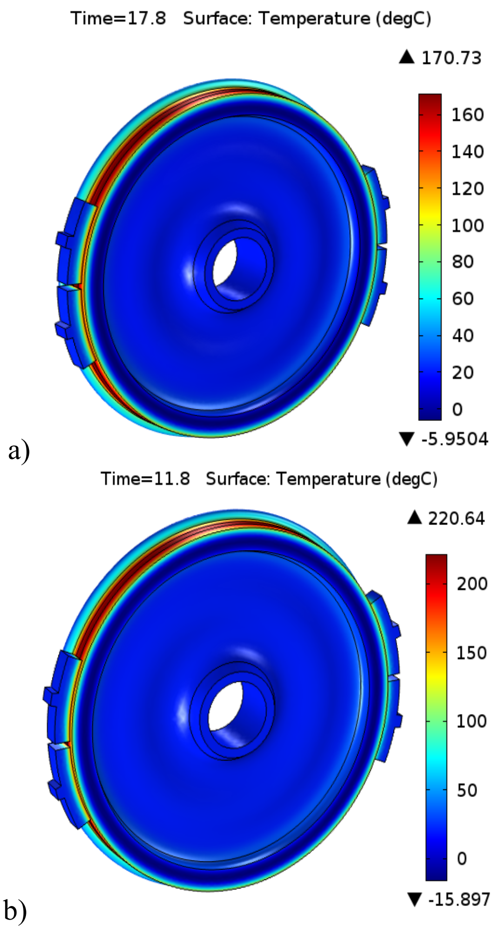

Fig.2. The temperature distribution at the wheel at: a) t=17.8s (low press.); b) t=11.8s (high press.)

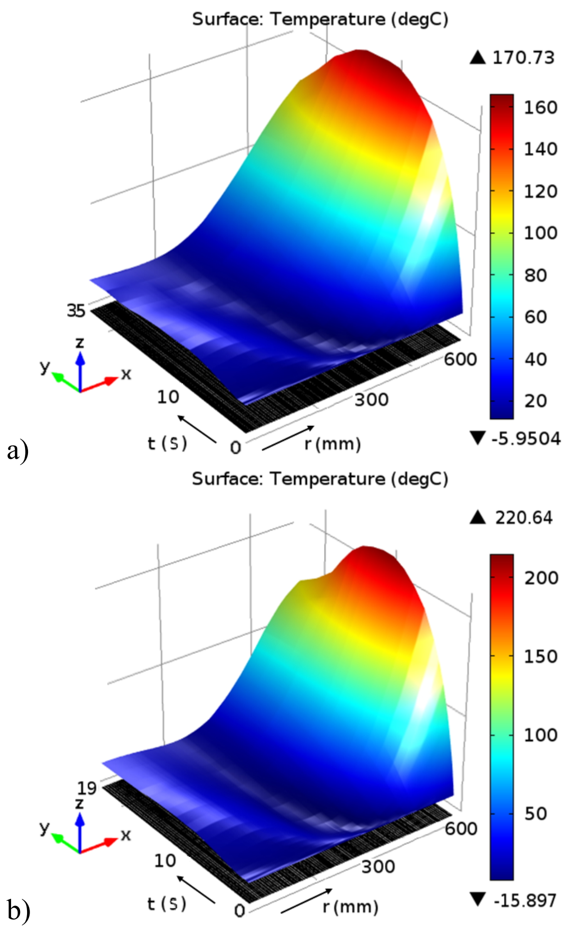

Fig.3. The temperature distribution at the wheel in function of time and wheel radius a) low pressure; b) high pressure

5. CONCLUSIONS

In this paper we made an effort to analyze a block-braked solid railway wheel of a locomotive of the type 444 of the national railway operator Serbian Railways using analytical and numerical modeling of thermal effects during braking, until locomotive stops, for two breaking regimes, with low and high pressure in the braking installation. The intention was to make the contribution in preventing the fracture of the solid wheels being braked by brake blocks caused by the thermal overloading because of the hypothesis that thermal loads are the main cause of cracks occurrence on wheel rim of railway vehicles on the rail network of Serbian Railways.

The presented modeling thermal effects of the braking process at block-braked railway vehicles is the base for the following stress analysis of the appropriate stress states as consequence of analyzed thermal loads in the simulated operation conditions. That approach could significantly decrease the probability of appearing of cracks caused by the thermal loads. This research can also help to discover on time the conditions for appearing these cracks and represents the final part of the process of solving problems concerning the solid wheel fracture due to thermal loads.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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EXPERIMENTAL RESEARCHES AND NUMERICAL SIMULATIONS OF COMBINED COLLISION ENERGY ABSORBER

Jovan TANASKOVIĆ [1]
Dragan MILKOVIĆ [2]
Vojkan LUČANIN [3]

***Abstract** – The subject of this paper is experimental researches and numerical simulations of combined collision energy absorber. The mentioned elements are parts of passive safety measures of railway vehicles. This type of absorbers works on the principle of deformation using shrinking and folding process of the tubes. The idea was to use process of shrinking and folding of the tubes in a parallel mode to absorb as much of the collision kinetic energy as possible by controlled deformation, with limited dimensions of absorber. Energy absorption occurred by elastic-plastic deformations of the tubes and friction between the tube and the cone bush. Using combined method, during the collision, energy absorption starts in the tube which is compressed into cone bush. After pre-defined stroke in the process of energy absorption the simultaneous process of folding of the outer tube starts, so both tubes deform in parallel mode during the rest of the stroke. In this way the force gradually increases without undesirable peaks during the entire stroke, resulting significant bigger amount of absorbed energy. Experimental investigations of combined absorber were realized in laboratory conditions. During experimental investigations the stroke and force were measured. The numerical simulations were used for checking the absorption power of absorption elements before the experimental researches. After the tests were completed, the recorded data were analyzed and force versus stroke diagrams of numerical simulation and quasi-static test were made. Results of calculation using FEM and results obtained experimentaly are in good correlation.*

Keywords - Experimental researches, combined absorber, railway vehicle, passive safety.

1. INTRODUCTION

The subject of this paper is analysis of results of numerical simulations and experimental investigations of combined tube collision kinetic energy absorber. Mentioned elements are a part of passive protection measures of railway vehicle. This type of absorber works on the principle of shrinking and folding the tubes. The idea to combine these two processes of deformations, stemmed from the need to increase the absorption capacity and to reduce the space required for installation, which is in the frontal part of the wagon is very limited. The reason for analysing this type of elements is further increase, of the of the protection of the structures behind the absorbers and unwanted deformations and thus to increase safety of passengers, goods and railway coaches. By using this type of absorber, energy absorption occurs by elasto-plastic deformations of the tube and friction between the tube and the cone bush. The combined method was chosen for two reasons: first, tube shrinking absorber has very good characteristics [1], and second, to exclude very high values of the force (peak) on the deformation start which characterize folding tube absorber [2]. During the collision, absorption of the energy starts in the inner tube wich is compressing into cone bush. After pre-defined stroke, the process of deformation of the outer tube will start and on the rest of the stroke both tubes will absorb collision energy in parallel mode, Fig. 1. Thus the force gradually increases without undesirable peaks during the entire stroke, resulting in a significant bigger amount of absorbed energy. During

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development of absorption elements couple, the results of experimental investigations given in [3] were used. This paper analysed influence of strain-rate on the deformation resistance.

This paper presents experimental investigations based on quasi-static test. During investigations the force and stroke were measured. Prior the experimental investigations, designed characteristics of absorption couple were checked using numerical simulations. After the tests completion, recorded data were analysed and compared with results obtained using numerical analysis.

2. NUMERICAL SIMULATIONS

Numerical simulations was performed using software package ANSYS. Following elements were involved in the model: seamless tube (pos. 1, material S355J2G3) with dimensions ∅75x2x160mm, segments tube (pos. 2, material S355J2G3) with dimensions ∅86x90mm and the cone bush (Pos. 3) from quenched and tempered carbon steel (material C45E) with dimensions ∅105/68x13°, Fig. 1.

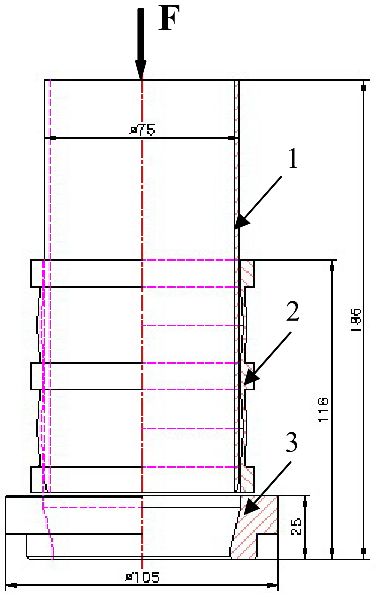

Fig.1. Working principle of combined absorber

Using the finite elements method, the nonlinear numerical simulation on the plane axisymmetric was performed (Fig. 2), using *Perzyna model* with rate dependent option.

Perzyna model requires defining key parameters which characterize rate dependent option. The key parameters are: m - strain rate hardening parameter and γ – material viscosity parameter. Results of experimental investigations, described in [3], defined next values of key parameters for quasi-static tests: m=0,23 and γ=305.

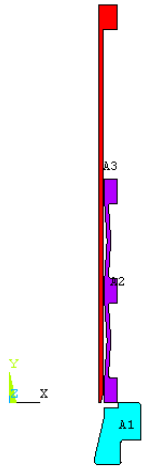

Fig.2. Plane axisymmetric model

3. EXPERIMENTAL INVESTIGATIONS

Experimental investigations were realised on the servo-hydraulic testing machine Zwick Roell HB250 at the Faculty of Mechanical Engineering, University of Belgrade (Fig.3). This machine is property of Laboratory of machine elements and systems testing.

Fig.3. Testing machine Zwick Roell HB250

The following elements were used for this investigation: seamless tubes (pos. 1, 2, 3 and 4) from structural steel (material S355J2G3) and the cone bush (Pos. 5) from quenched and tempered carbon steel (material C45E), Fig. 4.

Fig.4. Samples

Samples on the Fig. 4 are separated in five groups: a) seamless tubes with two folding segments with cone walls (pos. 1), b) seamless tubes with two folding segments with plane walls (pos. 2), c) plane seamless tubes of length L = 160 mm (pos. 3), d) plane seamless tubes of length L = 71 mm (pos. 4) and e) cone bush (pos. 5). Different geometries of the folding tubes are created to shows influence of the wall geometry on the start values of the deformation resistance.

Working principle of combined absorber is shown in the Fig. 1. Combined absorber works on the principle of compressing and folding tubes at the same time. During the collision, process of energy absorption first starts mode of tube shrinking (pos. 1) during the stroke of ≈ 63 mm. After the stroke of 63 mm, starts the second mode of energy absorption, using the folding of the tube (pos. 2). In that moment, energy absorption continues in parallel working mode, compressing and folding the tubes on the stroke of 40 mm (pos. 1 and 2). Combined principle was chosen to decrease undesirable peaks of the force at the start, which characterize the folding process. The combined process of energy absorption gives significant lower values of the force peaks at the start of the folding process and at the same time, for the same amount of absorbed energy requires lower thickness, comparing to absorber using only folding tube process. Experimental investigations were realized in two phases using quasi-static loading. First phase served for selection of the most appropriate design of the folding tube.

As expected, tube consisting of segments with coned wall (Fig. 4, pos. 1) showed better characteristics, more appropriate for the combined process of energy absorption. Geometry of the tube with cone wall allows predicting the deformation starting position (peak of the cone). This geometry shows lower values of the force at the start of the folding process what was the one of the aims of this paper. Second phase of experimental investigations, quasi-static test, was realized with speed of piston stroke of 25 mm/s.

4. RESULTS

4.1. Numerical simulations

After the numerical simulations were completed, the recorded data were analyzed and force versus stroke diagram are shown in the Fig. 5.

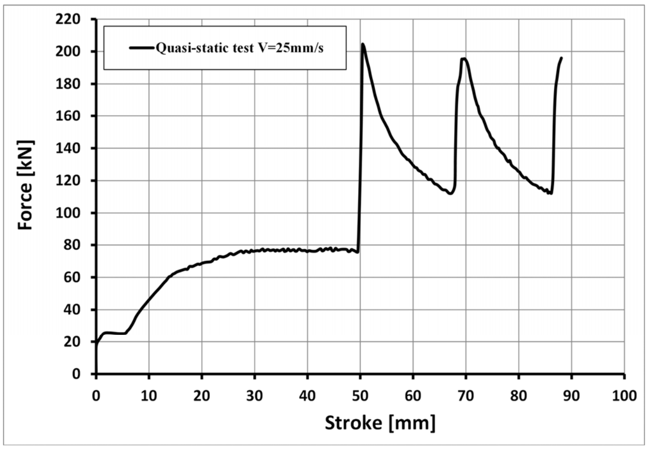

Fig.5. Force vs. stroke diagram – Numerical simulation

Fig. 6 shows shape of the combined absorber after deformation process. .

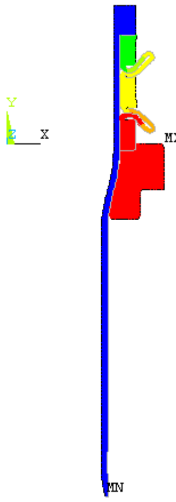

Fig.6. Combined absorber after deformation process

4.2. Experimental investigations

In this phase of the reasearches were formed assemblies, as shown in the Fig. 7. Charateristic diagram obtained by experimental investigations shown on Fig. 8.

Fig.7. Combined absorber after experimental investigations – V = 25 mm/s

This diagram characterizes two clear separated phases. The first phase is compressing of the shrinking tube into a cone bush at stroke of approximately 60 mm. The second phase characterizes parallel work of the shrinking tube and the folding tube at the stroke of approximately 35 mm.

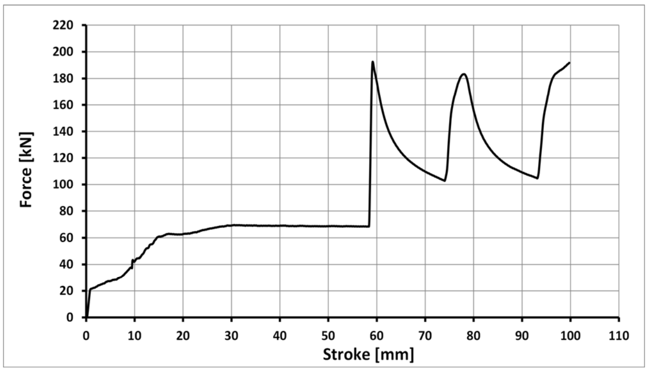

Fig.8. Force vs. stroke diagram – experimental investigations

With the aim of better review of results and their relations, in Fig. 9 are shown two curves obtained by numerical simulations and experimental investigations. The same key parameters were used for both investigations as mentioned above.

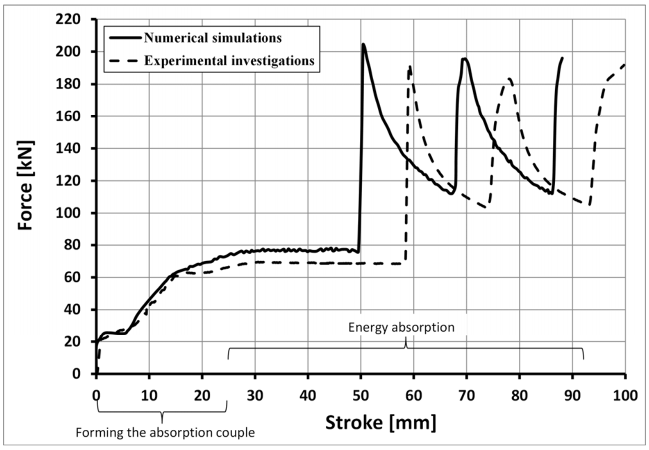

Fig.9. Force vs. stroke diagram – numerical and experimental curves

In this diagram can be clearly seen that numerical and experimental results are in a good correlations. Differences in stroke values between the curves are caused by difference in defined stroke of the first phase characterized by shrinking of the tube. Characteristic parameters which can be used for evaluation of this type of absorber are shown in the Table 1.

The aim of this analysis was to compare two types of energy absorption elements and since it was performed using scaled model, as expected, scaled values of force and absorbed energy were obtained. Bold numbers in table 1 are the values of absorbed energy in case of using only shrinking method. Using the combined absorber, amount of absorbed energy is approximately twice as higher compared to tube shrinking absorbers, at the same stroke.

Table 1. Characteristics parameter

	F_{Imax} [kN]	F_{IImax} [kN]	h [mm]	W [kJ]
Numerical	76	204	62	7,3 **[4,6]**
Experimental	69	191	68	8 **[4,6]**

5. CONCLUSIONS

Using combined principle of energy absorption, absorption element with compact dimensions can be designed. This type of absorber may absorb significant higher amount of collision energy in comparison with using only shrinking or folding process. Good corellation between results of numerical and experimental investigations indicate the possibility of using the developed numerical model for future research in this field. The next step of this researche will be experimental investigations on the full size combined absorber during collision of two passenger coaches.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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PREDICTION OF HEAT GENERATION IN RAILWAY DRAW GEAR RUBER-METAL SPRING

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Abstract *– The temperature of rubber or rubber-metal springs increases under cyclic loading, due to hysteresis losses and low rubber thermal conductivity. This well-known phenomenon, called heat build-up, is a primary reason for rubber aging. Increase of temperature within the rubber compound leads to degradation of its physical and chemical properties, increase of stiffness and loss of damping capability. The paper presents a case study of prediction of heat generation in rubber-metal spring of railway draw gear during dynamic testing in accordance with UIC Code 827-1.*

Keywords – Draw gear, Rubber-metal spring, Hysteresis heat generation, Finite elements analysis.

1. INTRODUCTION

The draw gear is a basic and extremely important subsystem of railway vehicles, which primary task is to connect vehicles in trains, i.e vehicles and locomotive and to transfer the traction force from locomotive to other vehicles in trains. Moreover, their absorption properties are of crucial influence on transferring and reducing impact loads between locomotive and rest of the vehicles by which the stability and safety of running and maneuver are affected. The malfunction of draw gear may be the cause of unstable running and derailment of a vehicle in the worst case.

Absorbing elements in draw gear are usually implemented as elastomer springs. Fig. 1 shows the assembly of draw gear with haul hook.

Rubber or rubber-metal springs have several advantages in respect to metal springs (lower price, easier installation, lower mass, reduced corrosion, no risk of fracture and no need for lubrication). However, they have one major disadvantage reflected in insufficiently reliable service life caused by rubber fatigue.

Fig. 1. The buffer assembly filled with the rubber-metal spring

When rubber is used for a long period of time it ages, becomes stiffer and loses its damping capability. This aging process results mainly from heat generated

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within the rubber due to hysteresis loss, and it affects the material properties, as well as the useful lifetime of rubber [1].

Due to the viscoelastic response of the rubber compounds, stress-strain curve of the rubber creates a hysteretic loop during the full load-unload cycle. The area in hysteresis loop corresponds to dissipated energy which is primarily converted into heat [2, 3]. Since heat generation occurs within the material and it is not easily conducted away, due to rubber thermal properties, heat generation is causing an increase of temperature inside the rubber compound which can even lead to melting of the material or to explosive rupture (blowout).

The aim of this paper is to present an efficient procedure [5] for prediction of heat generation in railway draw gear filled with rubber-metal spring. The aim of heat generation prediction is to ensure that any temperature rise inside a rubber metal spring does not exceed the design requirements in accelerated fatigue tests.

2. HEAT GENERATION PREDICTION PROCEDURE

It is found from both testing and simulation that the energy loss per cycle of the rubber spring, under fixed dynamic amplitude, does not depend on the loading frequency. Therefore, the energy loss per cycle can be more easily obtained using a conventional quasi-static loading procedure, to reduce the cost and the time, than from conducting more complicated dynamic tests [4].

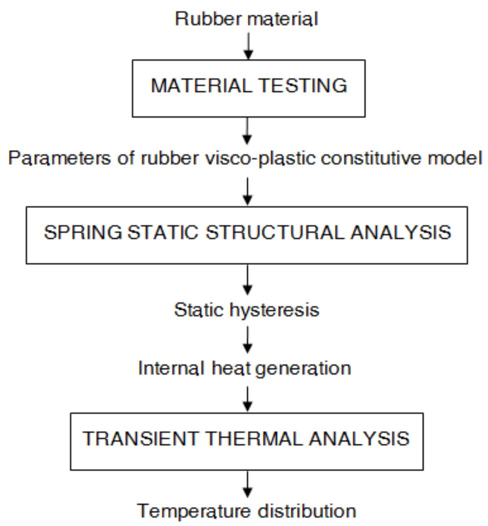

Fig.1. A schematic for new procedure for temperature distribution prediction in rubber and rubber-metal springs with FEA

A schematic (algorithm) of the new procedure for prediction of heat generation due to hysteresis loss in rubber or rubber-metal springs is shown in Figure 1 [5]. The proposed procedure is completely computational based and doesn't require determination of static hysteresis experimentally as proposed by other authors [4, 6], as static hysteresis it is determined by computer simulation (FEM).

If assumed that dissipated energy (E_D) is primarily converted into heat, the heat generation rate (H_G) can be derived from static hysteresis and total mechanical energy (E_T) or total mechanical energy and absorbed energy (E_A) as:

$$H_G = \frac{E_D}{t} = \frac{I \cdot E_T}{t} = \frac{E_T - E_A}{t} \qquad (1)$$

Due to relatively low computational demands, the proposed approach enables the time integration, thus enabling the prediction of spring heat emission during prolonged operation time i.e. establishing of thermal equilibrium.

The determination of static hysteresis (I) is enabled by application of a Bergström-Boyce visco-plastic rubber constitutive model. The high accuracy across different elastomer compounds of Bergström-Boyce material model was a primary reason for adaptation of the noted material model during investigation of heat generation in draw gear rubber-metal spring. The Bergström-Boyce material model is a phenomenologically based, highly nonlinear model used to model visco-plastic behavior of elastomers. The model allows for a nonlinear stress-strain relationship, strain rate dependence and can capture the hysteresis effect of elastomers.

3. PREDICTION OF STATIC HYSTERESIS

In order to predict heat generation due to hysteresis losses in draw gear rubber metal spring a case study was defined. The goal of the case study was to obtain temperature of the rubber metal spring during the accelerated fatigue test according to the UIC Code 827-1. UIC Code 827-1 defines fatigue testing conditions which replace the exploitation investigation of buffer and draw gear [7].

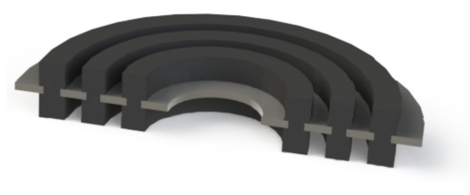

Fig.2. The basic rubber metal spring element of draw gear

The rubber-metal spring of draw gear by manufacturer MIN Svrljig from Serbia was subjected to accelerated fatigue testing. The noted rubber metal spring consist of 5 elements shown in Fig.2, serially connected into draw gear assembly. The elements are made with rubber mixture TG-B-712 by manufacturer "TIGAR technical rubber" from Serbia. TG-B-712 is a caoutchouc-butyl rubber with vol40% carbon black particles. Mechanical properties of TG-B-712 are given in Table 1.

Table 1. Mechanical properties of rubber compound TG-B-712 [8]

Test	
Hardness in Sh-A according to ISO/48	80
Strength in MPa according to ISO/37	15.3
Elongation at rupture in % according to ISO/37	379
200% Modulus of elasticity in MPa according to ISO/37	9
Compression set after 25% compression for 24 hours at 70 ºC in % according to ISO/815	12.1

As parameters of rubber constitutive model were already known [5], the next step in procedure given on Fig. 1.was to determine the static hysteresis by a static structural analysis. To lower the computational demands, due to symmetry of the spring assembly and the load, only one quarter of the model was considered. The finite element model (Fig. 3) was meshed with 3D solid hex mesh.

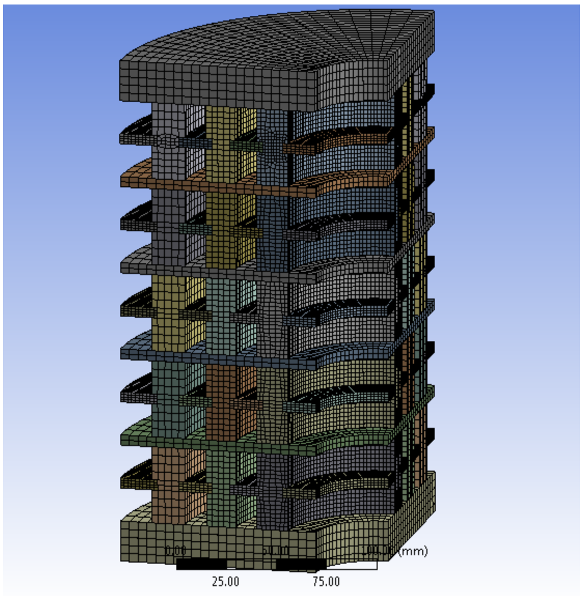

Fig.3. The FE model of basic rubber metal spring element

Finite element model consists of 128167 nodes which form 93209 3D SOLID 185 [9] finite elements. During static structural simulation value of coefficient of friction 0.5 was assumed to 0.5 [10]. The spring load was defined based on UIC Code 827-1. Draw gear assembly was compressed from stroke of 6 mm to final stroke of 36 mm at 0.75 Hz.

The simulation prediction of static hysteresis follows exactly the experimental procedure in regard to loading and boundary conditions. Furthermore, the force-displacement data was recorded during the experimental investigation in order to verify the accuracy of prediction of static hysteresis.

Figure 4 shows the comparison of load-deflection curves obtained by simulation and experimentally. It is clear that the predicted behavior has a very good resemblance with the experimental results. Table 2 gives the comparison of the values of stored energy and hysteresis obtained, both experimentally and by simulation.

Table 2. The results of the static hysteresis test

	E_T, kJ	E_D, kJ	I, %
Experiment	2.865	0.765	26.71
Simulation	2.745	0.721	26.25

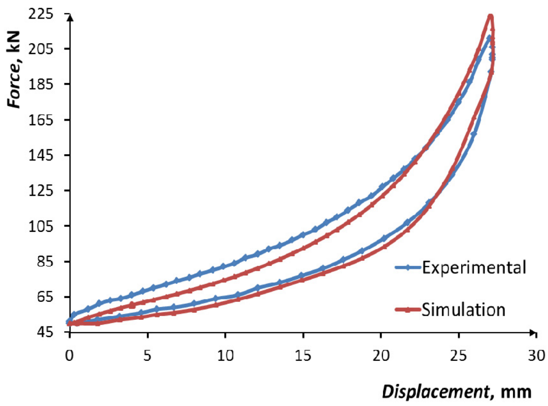

Fig. 4. Comparison between experimentally obtained and predicted behavior during accelerated fatigue testing

The difference between the simulated and experimentally obtained static hysteresis values is in the frame of 2 % (Table 2), which is rather high accuracy.

4. PREDICTION OF TEMPERATURE DISTRIBUTION

The predicted hysteresis values were used to determine the heat generation rate (H_G) according to the equation 1. Heat obtained generation rate (H_G) was applied as the major heat source via the internal heat generation load case. Furthermore, convection and radiation from the rubber and steel outer surfaces were considered also. The values of the parameters used in the transient thermal analysis are listed in Table 3. Parameter values were obtained from the relevant literature or predicted based on data extrapolation from literature.

The internal heat generation was applied to all basic rubber metal elements in draw gear assembly. The results of transient thermal simulation are shown in Fig.5. From the temperature profile the highest value is in the center of the component, which is easily understandable because the heat exchange is much quicker near the outer specimen surface.

Table 3. Parameters used for heat transfer simulation [4, 11]

Parameter	Value
Rubber density (kg/m^3)	1000
Stefan–Boltzmann constant (W/m^{2}K^4)	5.67×10^{-8}
Steel specific heat capacity (J/kgK)	434
Rubber specific heat capacity (J/kgK)	1700
Steel conductivity coefficient (W/mK)	60.5
Rubber conductivity coefficient (W/mK)	0.238
Convective heat transfer coefficient from steel to air (W/m^{2}K)	6
Convective heat transfer coefficient from rubber to air (W/m^{2}K)	8
Steel emissivity	0.2
Rubber emissivity	0.95

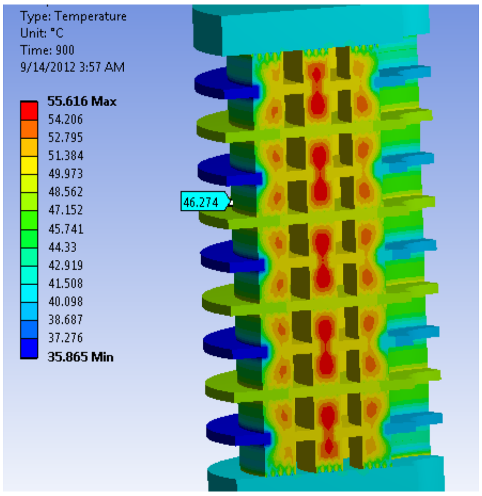

Fig.5. Temperature distribution of draw gear assembly obtained by simulation

The predicted temperature was compared with experimentally obtained, at cycle 700, which correspond to time of 15 min from start of the test. In that moment measured temperature of the rubber surface was 44 °C. The predicted temperature in the same spot was 46.2 °C which is a very good agreement.

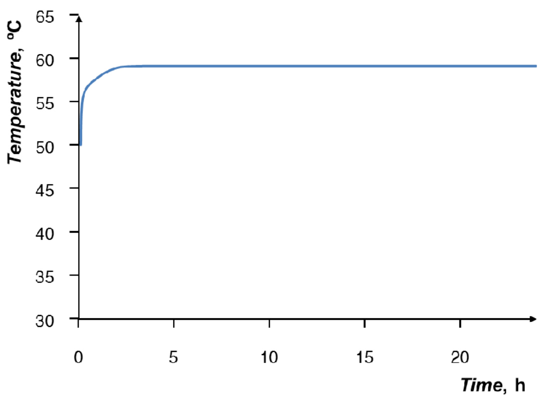

Fig.5. Maximal temperature of draw gear assembly over time of 24 h

It is clear from the obtained results that new procedure for temperature distribution prediction in rubber and rubber-metal springs with FEA gives very good results in case of object of complex geometry such is draw gear assembly. Furthermore, as maximal predicted temperature after 24 h doesn't surpass 60 °C (Fig. 6) it can be concluded that during accelerated fatigue tests, the rubber design requirement will not be exceeded i.e. no additional cooling of rubber metal spring during fatigue test is required.

5. CONCLUSION

Presented procedure for prediction of heat generation in draw gear assembly is in very good agreement with experimental results. As completely computational based, it is a valuable tool for predicting and controlling of rubber metal spring temperature during accelerated fatigue tests. Furthermore it can be employed in rubber lifetime estimation procedures based on obtained temperature data.

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IMPROVEMENT OF SUSPENSION SYSTEM OF WAGONS WITH LAMINATED SPRINGS

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Abstract *– During the exploitation of freight wagons with laminated springs, a large number of fractures of elements of suspension have been noticed. These fractures decrease efficiency of transportation and very often cause the derailment with large economic losses and sometimes with human victims. This paper presents the failure analysis and improvement of suspension of wagons with laminated springs. The technique is based on specially designed rubber elastic elements which can be subsequently installed in suspension of wagons. This solution is result of many years research of Railway Vehicles Center of Faculty of Mechanical Engineering Kraljevo in this field. The rubber elastic element is very easy to install in all existing wagons, between the laminated spring buckle and underframe. The applied methodology is based on theoretical and experimental analysis of behavior of suspension with and without rubber elastic elements. Subsequent installation of rubber elastic elements can prevent very frequent fractures of laminated springs and cracks on the underframes. This provides enormously reduced costs of maintenance of wagons and increased the efficiency of railway transportation.*

Keywords - improvement, suspension, wagon, laminated springs

1. INTRODUCTION

One of the most important parameters which determine the reliability and running safety of railway vehicles is functionality of the suspension. In addition, it affects the quality of ride comfort of passengers or cargo. Inadequate functioning of suspension causes very serious consequences and in many cases may cause derailment. For this reason, the fault of suspension is very important topic that is the subject of many scientific papers such as [1–5]. The main aims of these researches was to indicate the potential problems and to give the motivation for improvements in existing or newly-designed solutions of suspension.

Failures of elements of the suspension system based on the laminated springs are particularly frequent when the wagons are used in extreme operating conditions. Very intense loadings in exploitation caused the increasing of stresses of these elements. As a consequence, there have been very frequent fractures of elements of suspension system and cracks on the underframe. Such fractures very often cause derailment, as is for example shown in Fig. 1. The consequences of such events were huge material damage and significant decreasing the efficiency of railway freight transportation.

Fig.1. The derailment of Fbd wagon for coal transportation in thermal power plant ''Nikola Tesla'' Obrenovac, Serbia

Such events caused the need to improving the suspension system based on the laminated spring. Obtained results of improvement through subsequently installation of rubber elastic element are presented in this paper.

2. TYPICAL SOLUTION OF SUSPENSION BASED ON LAMINATED SPRING

The principal scheme of typical solution of

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suspension system based on the laminated spring is shown in Fig. 2.

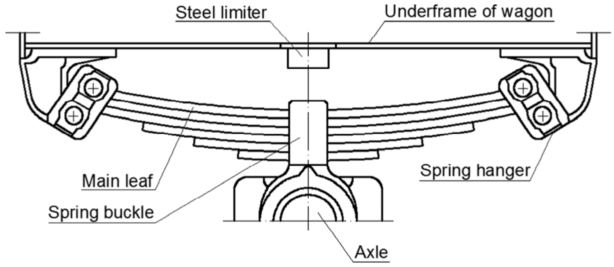

Fig.2. The scheme of typical solution of suspension system based on laminated spring

The steel limiter is fixed for the underframe of wagon and has the task to limit the stroke of laminated spring. In extreme operating conditions at maximum loads there are intense dynamic rigid impacts of spring buckle in the steel limiter which is very unfavorable for the suspension system and the underframe of wagon. As a result there are very often fractures on the underframe and elements of the suspension system.

For example, for Fbd wagon for coal transportation it is calculated that on average at the annual level, per one wagon there are almost 3 fractures on the elements of the suspension system [6]. In addition, it was noticed that the most dominant are the fractures of the laminated springs [6].

During the experimental tests of laminated springs of the Fbd wagon the following measuring equipment was used: device for dynamic testing HBM MGC Plus, inductive transducers of displacement HBM W100, and PC. Also, the following software was used: software package for data acquisition and on-line data processing - “Catman” (production of HBM), and software package for processing and displaying data - "Origin" (production of MicroCal). Using the mentioned measuring equipment the behavior of laminated spring in the exploitation was recorded. During the tests, the vertical deflection (movement) of the spring buckle was measured. The collected data from exploitation were used to form a Goodman-Smith diagram and determine the lines of operating and the critical stresses of laminated spring.

During the exploitation, the suspension system of Fbd wagon is exposed to effect of forces $F=F_{sr}+F_a$. The mean load is $F_{sr}=92.8\ kN$, while the investigation is established that the real values of the total force F range and up to 50% above average, due to the overload of wheel and dynamic effects during movement. Therefore, the effect of amplitude load F_a on the fracture of laminated spring is dominant.

The spectrum of force amplitude or stress of laminated spring corresponds to the hard working regime. Based on the characteristics of laminated spring material (51Si7 according to EN) the line of main dynamic strength was formed (dashed line on the Fig. 3), where are:

$\sigma_T=110\div125\ kN/cm^2$ – the yield strength,

$\sigma_{Dn}=60\div70\ kN/cm^2$ – the dynamic strength during the alternating variable load,

$\sigma_{Dj}=110\ kN/cm^2$ – the dynamic strength during the DC variable load.

The extreme values of these data (σ_T, σ_{Dn}) have low probability of occurrence, so in the further analysis the mean value of given areas are used.

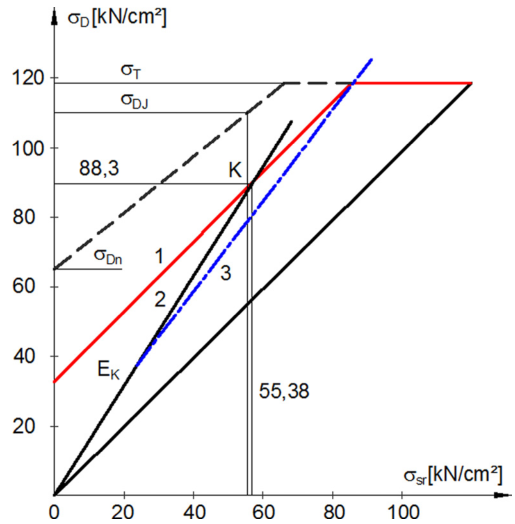

Fig.3. The Goodman-Smith diagram

The quality of the laminated spring production, the conditions of exploitation, and uniformity of loading are random variables, whose influence on the fracture was taken into account through the correction of main dynamic strength by the factor k_A. On that way, the line of critical stress of laminated spring was obtained (red line 1). On the other hand, the loads during the exploitation caused the stresses in the laminated spring of the following intensities:

$\sigma_{sr}=55.38\ kN/cm^2$ – the medium dynamic stress in the laminated spring,

$\sigma_{max}=88.3\ kN/cm^2$ – the maximal dynamic stress in the laminated spring.

Change of the operating stress of the laminated spring is linear and in the Goodman-Smith diagram it is represented by the line 2 which passes through the origin and the point K which has coordinates σ_{sr}, σ_{max}. In this case the line of operating stress of laminated spring cuts the line of critical stress. From this analysis it can be concluded that in the existing state of laminated spring the occurrence of fracture is very likely. It is also concluded that occurrence of maximal stresses mostly affected the fractures of main leafs of laminated springs.

Therefore, the main reasons for the formation of fractures were primarily increased stresses and loads, and unreliable quality of laminated spring production. In this case, increased loads arising not only due to overload of wagons by coal, but also because of their uneven loading that cannot be accurately controlled.

On of the solutions of this problem implies that, with the minimum processing and reconstruction, the existing suspension system to improve to the satisfactory level of reliability that will significantly improve the efficiency of railway transport

3. SUBSEQUENTLY INSTALLATION OF RUBBER ELASTIC ELEMENT

Respecting the existing design of the wagon, the special solution of the rubber elastic element, which can be subsequently installed in suspension system, can be designed. In concrete example of Fbd wagon this element is shown in Fig. 4. It is predicted that the life time of this element must be minimal 5 years. This enables that this element can be replaced in frame of regular servicing of wagons.

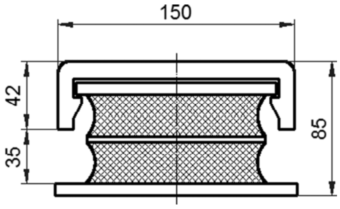

Fig.4. The rubber elastic element

The element is very easy to install in existing wagons, between the laminated spring buckle and underframe, instead a steel limiter, as shown in Fig. 5.

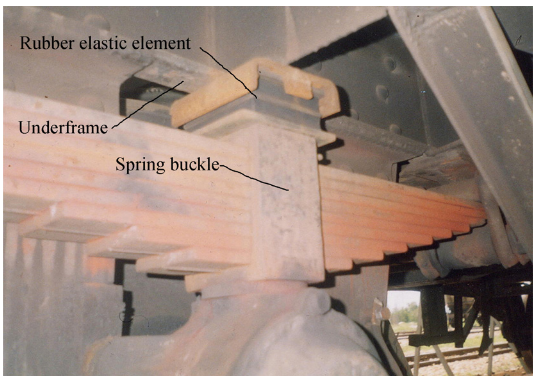

Fig.5. The rubber elastic element in suspension system

The constructive solution of rubber elastic element must be designed on the basis of free space to install in the suspension system. In order to determine the necessary characteristics of rubber incorporated in the elastic element, the main aim is to find compromise between the laminated spring relieving, the life-time of the rubber elastic element, and dynamic characteristics of the whole wagon (number of occurrences and the values of the stress amplitudes – deflection as a function of the path traveled). The diagram of stiffness of adopted rubber elastic element for Fbd wagon obtained by the experimental way is shown in Fig. 6.

In concrete example of Fbd wagon, the subsequent installation of rubber elastic element caused significant decrease of stress amplitude, and therefore a new line of operating stress of laminated spring in Goodman-Smith diagram (blue line 3 on Fig. 3).

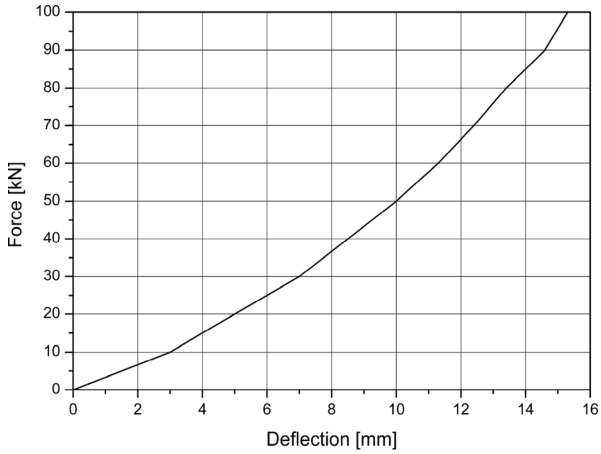

Fig.6. The diagram of stiffness of rubber element

This solution results in significantly lower stress amplitudes, and hence reduces the extent of fatigue loading. Therefore, the blue line 3 on the Goodman-Smith diagram on the Fig. 3 represents the compromise between the laminated spring relieving and load of rubber elastic element, which provide a permanent dynamic strength of the laminated spring.

4. RESULTS OF THE INTRODUCED IMPROVEMENT

The testing of suspension system with rubber elastic element in exploitation was performed with the same measuring equipment and on the same track as previously tests without it. The change of deflection of rubber elastic element z in function of time, for empty and laden wagon in exploitation conditions is shown in Fig. 7.

Based on the processing and analysis of recorded signals of behavior of suspension system elements, the quality of the projected improvement was assessed. Characteristic loads of laminated spring with and without the rubber elastic element, in the static and dynamic conditions for laden wagon are given in Table 1.

Table 1. The effect of the introduced improvement

Force on LS	Without REE [kN]	With REE [kN]	Relieving of LS [%]
Static F_u^{st}	119	61.42	48.4
Maximal dynamic F_{max}^d	157	68.06	56.6
Minimal dynamic F_{min}^d	125	53.45	57.3

LS – laminated spring
REE – rubber elastic element

From the previous table it is evident that the total static force on the one laminated spring F_u^{st} of fully laden wagon is lower for 48.4 %. This means that part of the load is taken from the rubber elastic element, and in this way, even in the static conditions, the laminated spring is relieved for almost 50 %. As expected, this was even more pronounced in wagon running at dynamic loadings. The rubber elastic element has a parabolic curve of dependence of force and deflection and a percentage of relieving of the laminated spring in dynamic conditions is increased and ranged between 56.6 % and 57.3 %. During these tests, the maximal dynamic deflection of rubber elastic element for laden wagon is equal to $z_{max}=12.2$ *mm* (Fig. 7).

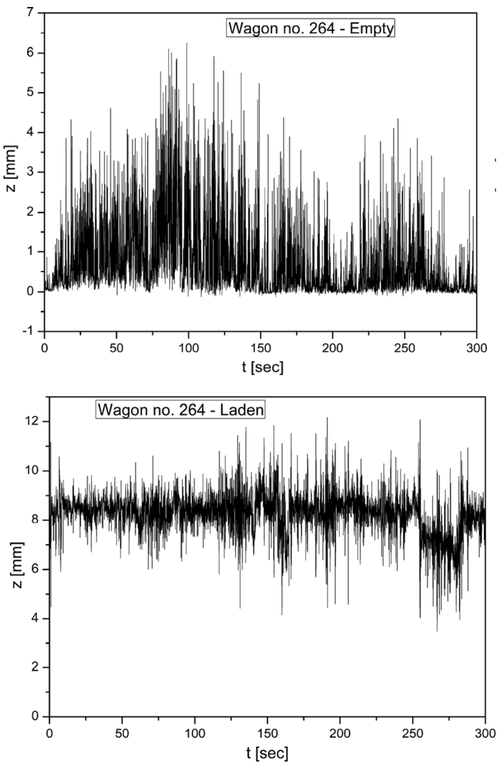

Fig. 7. The deflection of rubber elastic element

Based on those obtained results, the rubber elastic elements were installed on the over 400 wagons for coal transportation to the thermal power plant "Nikola Tesla" Obrenovac. The number of fractures was reduced by more than 90 %.

5. CONCLUSION

The paper presents the failure analysis and methodology for improvement of suspension system of wagons with laminated springs. The technique is based on specially designed rubber elastic element which can be subsequently installed in suspension of wagons. The element is very easy to install in existing wagons, between the laminated spring buckle and underframe. The methodology of identifying the causes of unwanted fractures is focused on theoretical and experimental analysis of behaviour of suspension system with and without rubber elastic elements.

In concrete example of Fbd wagon for coal transportation, the results of introduced improvement are: the static load of laminated spring of laden wagon is reduced by about 50 %; the dynamic load of laminated spring of laden wagon is reduced by over 60 %; in the eventual fracture of the main leaf of laminated spring, axle bearing do not remains unencumbered, which reducing the probability of derailment of empty wagon; the number of fractures was reduced by more than 90 %, (it should be noted that the rubber elastic elements are installed in the existing suspension systems); the reliability of transportation of coal is increased, and thus the overall reliability of the thermal power plant system.

In addition, designed rubber elastic element satisfies the following requirements: allows the behavior of suspension system which provides a permanent dynamic strength of the laminated spring; provides the required dynamic characteristics of wagon; prevents the occurrence of cracks and fractures on the underframe of wagon.

Therefore, subsequent installation of rubber elastic elements can prevent the very frequent fractures of laminated springs and cracks on the underframes on wagons with laminated springs. This can provides enormously reduced costs of maintenance of wagons and increased the efficiency of railway transportation.

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ELASTIC RUBBER ELEMENTS AS COMPONENTS OF RESILIENT LIGHT-RAIL WHEELS

Dobrinka ATMADZHOVA [1]
Emil MIHAYLOV [2]

Abstract *– The paper proposes an analysis on the influence of the elastic rubber elements as components of resilient wheels for light-rail vehicles and the state of strength and wear. This calculation leads to the establishment of a simplified form of elastic rubber elements for introduction in practice. The new elements are mounted in resilient wheels of tram wheel sets in the city of Sofia.*

Keywords – elastic rubber elements, resilient wheels, light-rail transport, trams.

1. INTRODUCTION

Resilient wheels are currently used in light rail systems such as tramways to prevent squealing and reduce impact noise. On the other hand, they are rarely found on main lines (passenger rolling stock and freight rolling stock). Although manufacturers often claim that resilient wheels are favourable for rolling noise control, there is no extensive theoretical investigation confirming this statement that has been published up to now. The rubber elastic element is used as a component of the elastic wheel of the urban transport vehicles, their suspension system or vehicles.

The advantages of using rubber are as follows [1, 2]:

- a low stress value of an elastic modulus;
- triple reduction of vibrations of mechanical energy due to the internal friction process: the damping coefficient is approximately **10%** of the critical value;
- perfect moulding properties.

The disadvantages of using rubber are as follows:

- elastic properties are strongly influenced by the temperature;
- a loss in time of mechanical properties.

Main advantages [3, 4, 5]:

- ■ High absorption of noise and vibrations
- ■ Reduction of life-cycle costs
- ■ Easy assembling and disassembling
- ■ Extended life cycle of wheel and rail
- ■ Low weight

For isotropic, incompressible material there is a relationship between Young's modulus and Shear modulus, so that **E = 3G**.

Lindley [6, 7] has proposed a table with values of Young's modulus (**E**) and shear modulus (**G**) for natural vulcanized rubber.

Classical mechanics also indicates that:

$$\mathbf{E=2G(1+\nu)} \tag{1}$$

where ν - Poisson's ratio.

Rubber, being with certain properties of a liquid, is almost incompressible. This incompressibility gives a value of Poisson's ratio that is very close to **0,5** for smaller levels of strain. If this value is substituted into the above equation, **E = 2G (1+ 0,5)** giving the same relationship again: **E = 3G**

Unfortunately, these ratios are applied only for untreated rubber and it becomes more complicated when carbon black is added.

The function of a rubber element fixed to a metal element (vulcanization procedure) when a compression loading per area takes place, the value of the longitudinal calculus module $\mathbf{E_c > E}$ will increase with the increase of the shape coefficient λ. The shape coefficient is calculated as follows:

$$\lambda = \mathbf{S_b/S_l} \tag{2}$$

where: $\mathbf{S_b}$ – element basic surface; $\mathbf{S_l}$ – element free lateral surface.

2. ELASTIC TRAM WHEEL STRUCTURE - INFLUENCE OF ELASTIC ELEMENTS

The elastic tram wheels (figs. 1, 2) used for light

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rail in the city of Sofia consists of several components (fig.3). The elastic tram wheel is part of T 81 bogie manufactured in the tram factory in Sofia in the early 1980s.

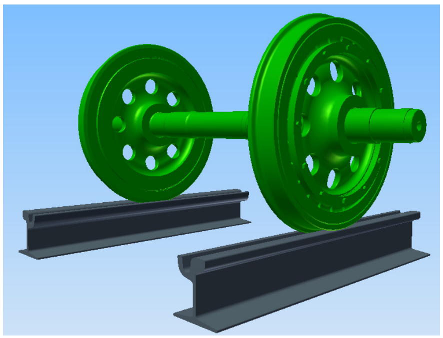


Fig.1. The tram wheelset used for light rail in Sofia.

1 - Wheel centre;
2 - Tyre;
3 - Clamping ring; 4 - Rubber segments (elastic element).

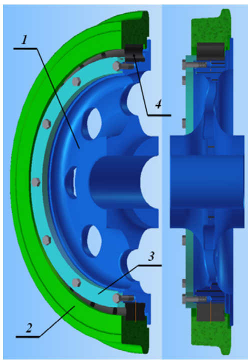


Fig.2. Cross-section of an elastic tram wheel

Fig.3. Components of the elastic tram wheel

Elastic component used in a tram wheel of type T 81 is made of oil-proof rubber with hardness of **82÷84 Sh** and has dimensions shown in Fig. 4.a, b. It is mounted between the wheel centre and tyre with tightness as the force of stress on the elastic component at mounting is **51,8 kN**. Fig. 4.c. presents the diagram of the elastic component deformation; with stress of **9 900 kg (97,1 kN)** deformation of **15 mm** should be obtained, the residual deformation with load removal is admitted to be **0,5 mm**.

After mounting the elastic component takes the shape shown in Fig. 4.b and Fig. 5.b. The elastic component height is **38 mm,** the internal stress is:

$$\sigma_z = E.\varepsilon_z \quad (3)$$

where: ε_z – elastic component of deformation.

After mounting radial σ_r and tangential σ_t stresses appear as a result of press fitting in the tyre as the equivalent stress can be determined by the expression:

$$\sigma_e = \sigma_t - \upsilon\sigma_r \quad (4)$$

where: $\upsilon = \sigma_{Sstrain}/\sigma_{Spressure}$ - coefficient considering the strength of tension and stress.

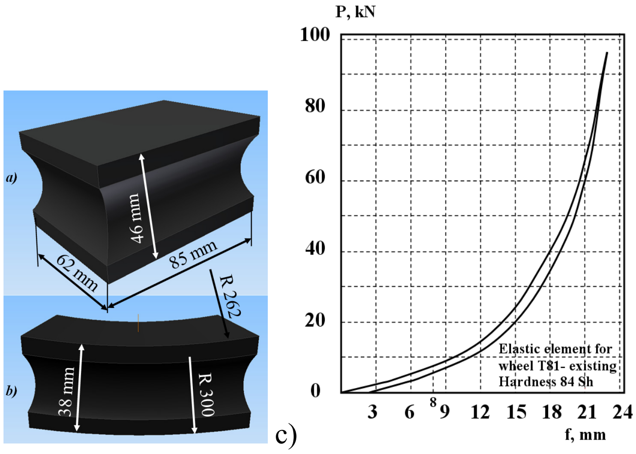


Fig.4. Rubber segments (existing elastic element)

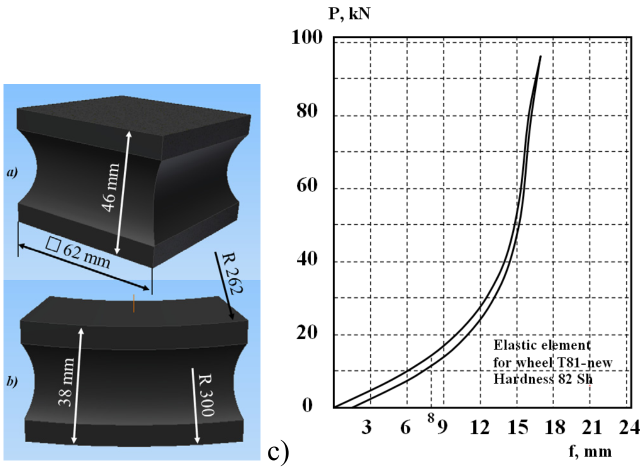


Fig.5. New rubber segments (elastic element)

The equivalent stresses with press fitting are the highest along the interior tyre diameter [8], then with $\upsilon = 1$ they are determined by the formula:

$$\sigma_{pressure} = \frac{p.2d_{inner}^2}{d_{inner}^2 - d_{outside}^2} \le [\sigma] \quad (5)$$

where: **p** – surface stress along the interior tyre surface caused by fitting tightness; d_{inner} – interior tyre surface diameter; $d_{outside}$ - rolling tyre component diameter along the circle of rolling.

As a result of conducted laboratory studies [9] it has been established that in the case of tram wheel of type T 81 **p = 1900 kN/m²**.

The distribution of static forces loading on individual elastic wheel components is not uniform. According to [8] the maximum static loading in the tyre is calculated as follows:

$$q_{0max} = 2Q_k/\pi d_{inner} \quad (6)$$

where: Q_k – static loading on the wheel; d_{inner} – interior tyre surface diameter.

The static load distribution is calculated by the formula:

$$q = q_{0max}.\cos\varphi \quad (7)$$

Fig.6 shows the distribution of equivalent stresses by Von Mises criterion. Maximum stresses by value are in the middle of the indicated component angles. For the existing element the stresses by Von Mises criterion are **48,82 MPa** and for the new element they are **62,89 MPa.**

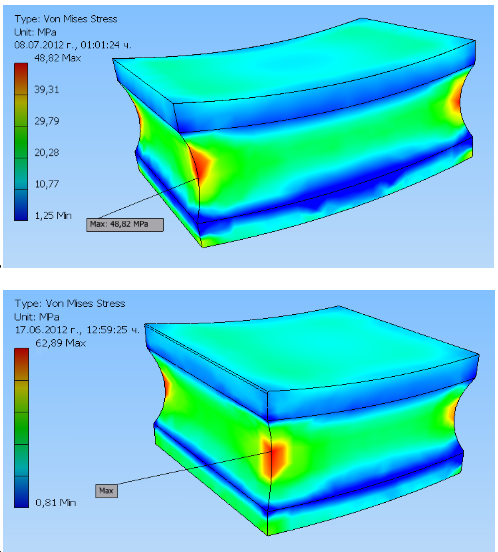


Fig.6. The equivalent stresses by Von Mises criterion in rubber segments mounted: a – existing element and b - new element

3. FINITE ELEMENT ANALYSES

The analysis has been performed using Autodesk INVERTOR 2012 code [10].The configuration of geometry for the elastic tram wheel in contact with the respective rail and the three-dimensional network is presented in Fig. 7.

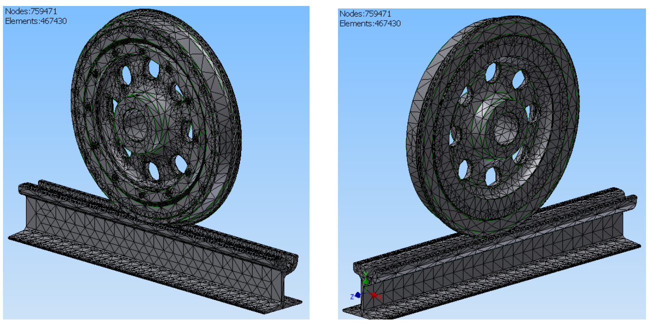
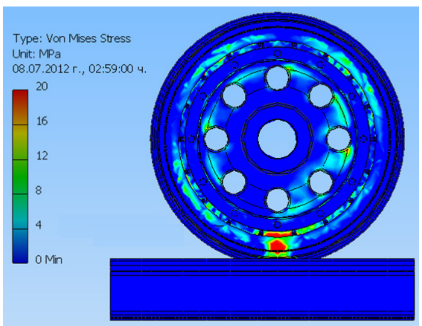
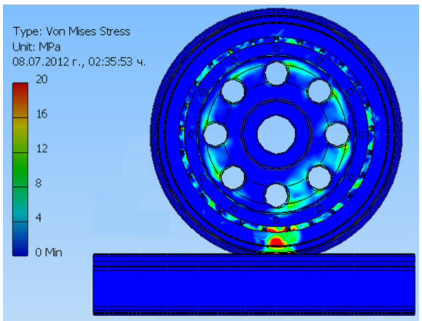


Fig.7. The finite element meshing of wheel and rail



a.



b.

Fig.8. The equivalent stresses by Von Mises criterion in wheel and rail: a – existing element and b - new element

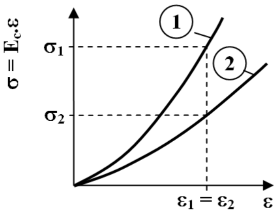
The equivalent stresses by criterion Von Mises are shown in Fig. 8. The equivalent stresses do not exceed **20 MPa** in a rubber elastic element.

The new rubber elastic element is recommended for practical applications.

4. EXPERIMENTS

The working temperature influences on the elastic properties of rubber. Internal friction presents during the deformation process, so part of the deformation work is transferred into heating energy.

Fig.9. Comparison between simplified elastic - plastic element shapes (1-for λ_1; 2 - for λ_2)



The stress increases proportionally to the increase of the shape coefficient and for the two different shapes of the elastic elements such as those presented in Fig. 9 subjected on a loading process, the following shape coefficients will be obtained:

$$\lambda_1 = S_{b1}/S_{l1} = a.b_1/[2(a+b_1)h] \quad (8)$$

$$\lambda_2 = S_{b2}/S_{l2} = a.a/[2(a+a)h] = a/4.h \quad (9)$$

so $\lambda_1 > \lambda_2$ and $E_{c1} > E_{c2}$, but with $\sigma = E\varepsilon$ at $\varepsilon = f/h =$ **constant**, it results also in $\sigma_1 > \sigma_2$.

When $S_{b1} = (b_1/a)2S_{b2}$ and $b_1 > a$, the result is $P_1 > P_2$.

For a rubber element, the elastic behaviour will change according to the relationship between the „calculated" coefficients [1, 2]:

$$E_c = \lambda_c.G. \quad (10)$$

For compression loading, which is particular for initially compressed rubber elements introduced when assembling, with a function of real cross-section area - S_f, the compression force between the both parts of the elastic tram and rail wheels - **P** will be:

$$P = \sigma.S_f = \varepsilon.E_c.S_f, \quad (11)$$

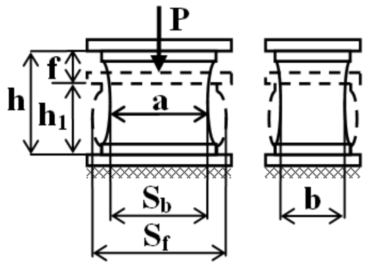
as: $S_f = S_b.h/h_1$ and $h_1 = h-f$, it results in:

$$P = (f/h).E_c.\ S_b.h/\ h_1 = E_c.\ S_b.f/\ h_1 \quad (12)$$

If there is an "n"-node of "block" shaped elastic element with parameters according to Fig. 10, it is obtained that:

$$\mathbf{S_b = ab;\ S_l = 2(a+b)h} \text{ and } \boldsymbol{\lambda = ab/[2(a+b)h]} \quad (13)$$

Fig.10. Simplified shapes of elastic - plastic elements



The relative dependency $\boldsymbol{\lambda_c = f(\lambda)}$ is presented in Fig. 11:

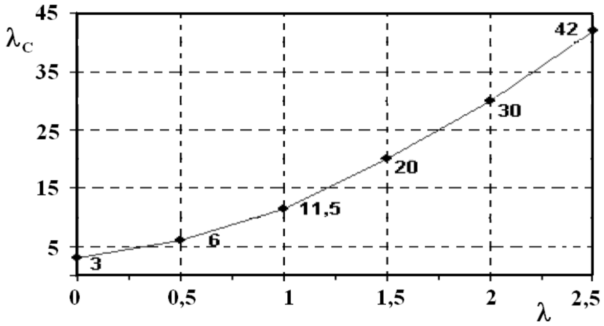


Fig.11. The dependency between theoretical and calculated shape coefficients [2]

So it results in the dependency:

$$\mathbf{P = \lambda_c.G.\ S_b.f/h_1 = \lambda_c.G.ab.f/h_1} \quad (14)$$

and the static stiffness will be:

$$\mathbf{k_\sigma = dP/df = \lambda_c.G.\ S_b.h/h_1^2 = \lambda_c.G.ab.h/h_1^2} \quad (15)$$

In conclusion, the static stiffness of a rubber element subjected under a compression test increases when the height of the element h decreases and the shear modulus **G**, the hardness and the cross-section area $\mathbf{S_b=a.b}$, prolongation (deformation) **f** will also increase respectively. All these theoretical results have been experimentally validated; the methodology is of practical utility.

The flexibility of a rubber element will be:

$$\mathbf{X_\sigma=(k_\sigma)^{-1}=h_1^2[\lambda_c.G.\ S_b.h]=3h(h_1/h)^2/[\lambda_c.E.S_b]} \quad (12)$$

For elastic elements the calculated values are:

Table 1.

Type elem.	**S_b, m^2**	**S_l, m^2**	**λ**	**λ_c**
existing	**0,0053**	**0,0135**	**0,389**	**5,334**
new	**0,0038**	**0,0086**	**0,444**	**5,664**
Type elem.	**E_c, MPa**	**P, kN**	**k_σ, MPa.m**	**X_σ, $[MPa.m]^{-1}$**
existing	**64**	**70,8**	**12,6**	**0,08**
new	**68**	**54**	**9,17**	**0,1**

The new elastic components are mounted in resilient wheels of tram wheel sets in Sofia.

5. CONCLUSIONS

The paper presents an analysis on the influence of elastic tram wheels used for light rail in Sofia on the stress state. It is emphasized on the importance of the new fixed rubber elastic element, which is recommended for practical applications. This approximation leads to new coefficients as well as to validation of the simplified shape of samples for future standardized experimental tests.

The shape coefficient is influenced by supporting or fixing of the sample system. The "calculated" shape coefficient of the elastic element $\boldsymbol{\lambda_c}$ is an accurate assessment related to flexibility in comparison with the simple shape coefficient **λ**.

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STUDY ON FATIGUE OF RUBBER METAL SPRINGS OF PRIMARY SPRING SUSPENSION OF ELECTRIC LOCOMOTIVES

Dobrinka ATMADZHOVA [1]
Nencho NENOV [2]

Abstract *– Rubber-metal springs (RMS) used widely in both primary and secondary spring suspension of rail vehicles are reliable elastic-damping elements. They are compact since they combine elastic and damping properties and do not require operational maintenance but their significant disadvantage is the process of characteristics changing known as rubber "aging". It has been found that the average lifecycle of RMS of locomotives series 46-000 in the operational practice of the Bulgarian State Railways since 1986 does not exceed 60% of the one guaranteed by manufacturers. Most probably the explanation of that fact is related both to poor features of rail network in the country and the operation of locomotives without balancing the static load on their wheels. The study presented includes a simulation analysis carried out by finite element method to predict the distribution of stress and evaluate the behavior of fatigue. Based on the nonlinear quasi-static modeling and analysis, residual stresses have been registered and superimposed and a methodology considering material fatigue has been developed to help predict RMS resource exhaustion. The results obtained in the study can be used to optimize the basic RMS design parameters and features in.*

Keywords - Electric locomotive, Rubber-metal springs, Failure analysis, Life-cycle prediction.

1. INTRODUCTION

A significant part of rail vehicles are with bogies. The calculation, design and testing of springs suspension as an important component of the bogie is a complex and highly comprehensive engineering task [1, 2, 3].

The use of RMS in spring degree (most often in the axle once) has important advantages, since RMS which have both elastic and damping properties can be used instead to mount cylindrical coil springs and hydraulic dampers. The structure of locomotives of series 46-000 is of such a type.

The bogie of the electric locomotive of series 46-000 being operated in the system of Bulgarian railways (Fig. 1) uses rubber-metal springs in their primary (axle) suspension (Fig. 2).

A RMS consists of a V-shaped metal plates (four or six) among which there are vulcanized rubber (three or five layers). The rubber parameters are appropriately chosen to ensure the required properties. The operational position of the RMS in a locomotive is set at an angle to the vertical axis, which determines the existence of loading on the rubber layers with shear and compression.

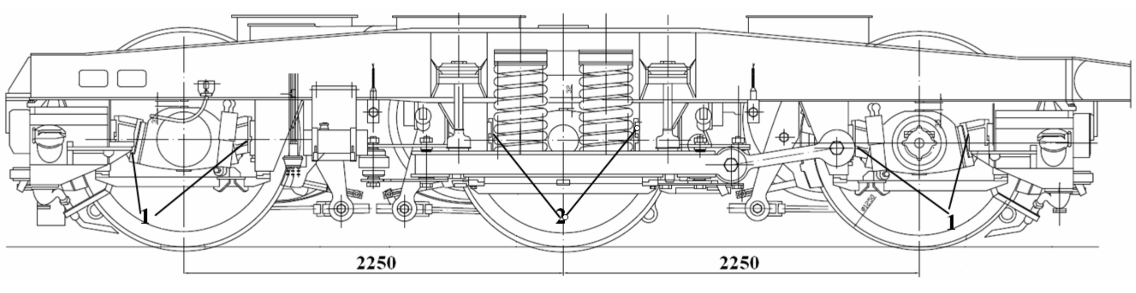

Fig.1. Bogie of an electric locomotive of series 46-000
1- RMS in wheelsets no.1 and 3; 2- RMS in wheelsets No.

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The paper [4] contains a list of the main parameters of rubber-metal elements (e.g. values of residual deformation, elastic and damping properties, etc.).The results of RMS testing for similar locomotives operated by the Serbian Railways (named series 461) are given in [5].

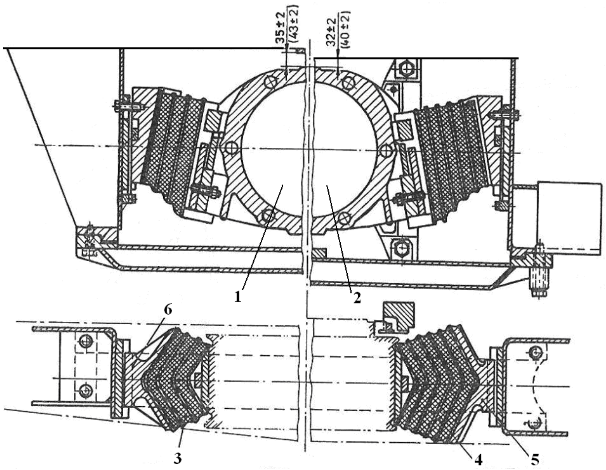


Fig.2. Primary suspension of bogie of an electric locomotive series 46-000
(1- axlebox in wheelsets no.1 and 3; 2 - axlebox in wheelsets no.2; 3 - RMS with 3 rubber springs; 4 - RMS with 5 rubber springs; 5, 6 - supporting elements)

Some studies of foreign authors [6, 7] have confirmed that the life cycle of a RMS reaches to about **0,8** million cycles with **1,5** million cycles set at the stage of design and construction, as the probable explanation is related to integral fatigue of material and the presence of residual stresses in the V-shaped metal plates.

Other studies (e.g. [8]) present the attempt made on the basis of an effective three-dimensional analysis of stress and strain state of metal plates and rubber layers to predict the timing of cracks from fatigue and tearing of the rubber layers.

2. MATERIAL PROPERTIES

To investigate and analyze the distribution of stresses and evaluate fatigue behaviour, the finite element method has been applied.

2.1. Metal material properties

The metal part (plate) is made of steel with maximum permissible stresses of **355 MPa**. The British standard code for design, calculation of fatigue and assessment of steel structures BS7608 gives the ratios between stress and number of load cycles (S/N) established by statistical analysis of experimental data [9].

The dependency below (with constant amplitudes) is in force:

$$\log N = \log C_o - d/\sigma - m.\log S_r \quad (1)$$

where: **N** – number of cycles, S_r – stresses, C_o is a constant related to the mean value of dependency S_r-**N**; **d** – standard deviation from the mean one; **σ** is the standard deviation of **log N**; **m** is the inverse slope of $\log S_r$ versus log N curve.

To determine the constant with real loading, the equation below is used:

$$\log C_d = \log C_o - d\sigma \quad (2)$$

After substitution and transformation it is obtained that:

$$S_r^m N = C_d \quad (3)$$

2.2. Rubber material properties

The elastic models proposed in [9] and applicable to rubber and other elastomeric materials (based on the potential strain energy of deformation or the density or strain energy) have been used.

Synthetic polyisoprene (IR), which has similar properties to those of natural rubber, is used in the new generation of RMSs. Despite its slightly high price it has significant advantages as slow hardening, better mixing, extrusion, moulding in RMS manufacturing.

For isotropic, incompressible material the dependency between the Young's Modulus and the modulus of shear is **E = 3G**.

Dependency **E=2G(1+v)** is well-known from classical mechanics, where **v** – coefficient of Poisson (Poisson's ratio = normal stress/lateral stress). For small levels of stresses, the coefficient takes the value of **0,5**, i.e.: **E = 2G (1 + 0,5)**

The dependencies given above are valid for pure rubber but according to [10] the dependency (e.g. for material 65IRHD) takes the type of **E = 4,2G** when adding solid carbon (soot).

In [10], the following values are recommended for natural rubber: **E = 1,5 MPa** and **G = 0,49 MPa** and for material 65IRHD **G = 1,3 MPa** respectively.

The method used to evaluate fatigue and RMS life cycle duration is based on predefined data of the material and effective stress (σ_f). The stress sensor can be easily integrated with finite elements (e.g. by using SolidWorks 2010 [11].

The rubber crack initiation is a result of the cumulative damage when visual cracks appeared [9, 12].

The appearance of visual cracks on the rubber layers is a sign of damage to the RMS and is a result of accumulated internal damages in the elastic material.

3. FINITE ELEMENT MODELS

An analysis by finite element method is made to forecast the distribution of stresses and evaluate the behavior of fatigue. With the study of fatigue the RMS is examined as a single unit. Based on the locomotive weight distribution among its wheels, the nominal load of **50 kN** is chosen.

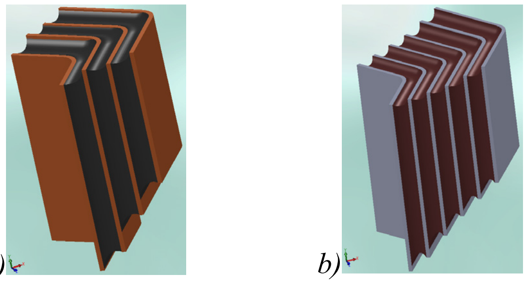
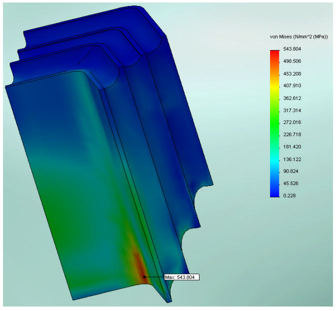


Fig.3. The models of RMS
a) With 3 packages; b) With 5 packages

*a) With 3 packages (max **543,8MPa**)*



*b) With 5 packages (max **568,1MPa**)*

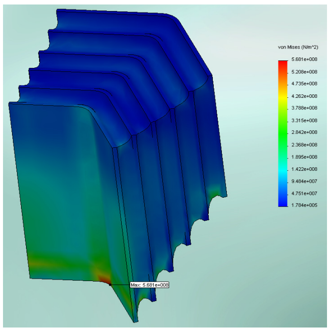
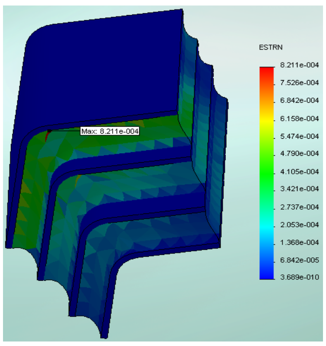


Fig.4. Stress profile of the modified part

*a) With 3 packages (max **0,82·10**$^{-3}$)*



*b) With 5 packages (max **2,01·10**$^{-3}$)*

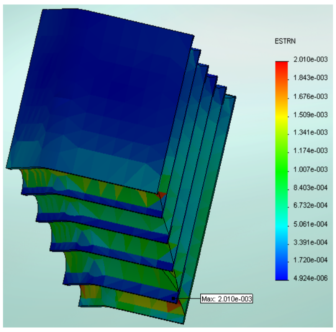


Fig.5. Strain profile of the modified part

The models in Fig. 3, and Fig. 4 show the maximum tensile stress. Fig. 5 show the strain profile of the modified part.

The survey results have justified the statement that the excessive bending moment can cause fatigue damage. Therefore, the RMS life of operation can be extended by reducing stresses.

4. STIFFNESS VERIFICATION

To evaluate the results obtained, it is crucial to test and validate the developed models.

For the needs of the Bulgarian railways a number of devices to test RMSs have been developed as one of them is shown in Fig. 6 [13]. The results of laboratory tests for 3-layer and 5-layer RMSs carried out on this device are used to validate the models (Fig. 7 shows the parameters obtained and a diagram of 3-layer RMS).

Fig.6. Stand for testing

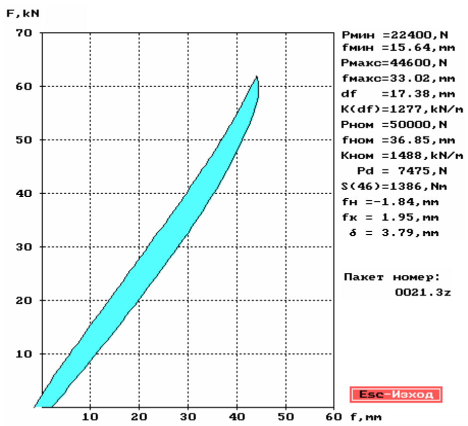


Fig.7. The stiffness and histerezis of RMS models

5. METAL FATIGUE VERIFICATION

The verification for both RMS models is performed with a nominal load (**50 kN**). The maximum values of stresses in the first metal layer with a 3-layer package are **543,8 MPa** and with a 5-layer one they are **568,1 MPa** respectively.

The check-up determination of the fatigue cycle has been carried out based on the requirements of regulations [14] and [15]. The life cycle specified in these standards depends not only on stress changes and number of loading cycles, but also on the probability parameter of fail-safe operation.

For class B probability of failure of **2,3%** is used to validate the analysis of fatigue. Steel for metal plates has a limit of **355 MPa**.

After cold forming of RMS plates, with stress of above **355 MPa**, residual stresses are created on the inner surface. Therefore stresses have to be reduced to **189 MPa** for a RMS with 3 elements and to **213 MPa** for a RMS with 5 elements. Based on the fatigue curve [14], the life cycle of a three-layer RMS is approximately $\mathbf{0{,}6\cdot 10^6}$ cycles instead of $\mathbf{2\cdot 10^6}$ cycles and the life cycle of a five-layer RMS is approximately $\mathbf{0{,}8\cdot 10^6}$ cycles instead of $\mathbf{3.10^6}$. The estimated life cycle of the order of $\mathbf{1{,}5\cdot 10^6}$ cycles shows good coincidence between simulation research and practical testing of RMSs.

6. RUBBER FATIGUE VERIFICATION

The assessment of fatigue for the rubber components of RMSs is based on a three-dimensional method of stress assessment. The effective values of stresses σ_f are **3,57 - 4 MPa** for both types of RMSs. From the curve of fatigue of the rubber component, approximately $\mathbf{75\text{-}90\cdot 10^3}$ cycles correspond to the stresses of **3,57 - 4 MPa**. Cracks due to fatigue occur after approximately $\mathbf{170\cdot 10^3}$ cycles.

7. DISCUSSION

An integrated evaluation of the fatigue of RMS components (rubber layers and V-shaped metal plates) has been made and validated. The nonlinear quasi-static variable stresses are superimposed with residual stresses and the lifecycle of the metal plates is forecasted. The prediction of life cycle of the rubber layers considering the strength fatigue is more complex due to the specific material characteristics of material. Using the three-dimensional effective method for stress evaluation the beginning of crack appearance due to fatigue can be predicted. This study on RMSs can be used in the processes of design, modeling and analysis of RMSs and optimization of their parameters in terms of material (rubber and metal).

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '12

ABOUT DYNAMIC MODELING OF SUSPENSION IN RAIL VEHICLES

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Jelena STEFANOVIĆ MARINOVIĆ[3]
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Abstract *–Dynamic modeling of rail vehicles suspension often is done by commercial software packages based on finite elements, like ANSYS. Models obtained by this method can have more than 23000 degrees of freedom. The own frequency of such systems are in the range 9 to 16 Hz. Basic forms of oscillation are the vertical and lateral extension of shape, twisting and bending. When analyzing the formation of dynamic elements that are essential for the structure of a dynamic model, it is preferable to group the whole system, i.e. present in the form of links number of relatively independent subsystems. Models obtained in this way, are more suitable for analysis and subsequent modification with the aim of further detailed study. This paper analyzes the problems of dynamic modeling in determining the static stiffness and dynamic damping factor of rubber metal elements using such approach of dynamic modeling.*

Keywords - suspension, dynamic modeling, rail vehicle, rubber spring pack.

1. INTRODUCTION

1.1. Rubber Suspension

Steel springs provide a solid and reliable cushion for vehicle suspension. Steel is heavy and requires maintenance because of wear and rust. Rubber springs however, could perform the same function and it was used for minor parts of steel suspension systems from the late 19th century. Then some trains were equipped with rubber packs replacing the steel in both primary and secondary suspension positions.

The axlebox is specially shaped, as presented in Fig 1, to allow the fitting of rubber packs at an angle which will allow the forces to be transmitted to the bogie frame. Angled rubber packs replaced the traditional steel springs and were quite successful until they were superseded in later designs by air springs.

Although successful in lighter applications, rubber suspensions can require careful design to be an effective and reliable alternative to steel.

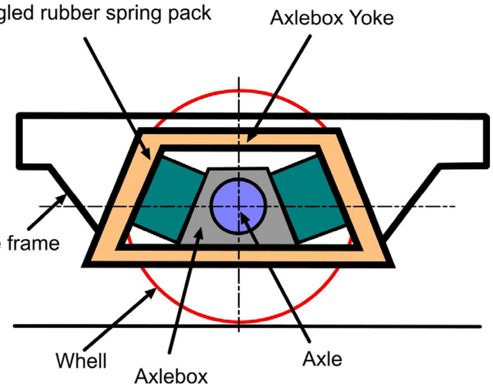

Fig. 1. Rubber spring pack suspension

1.2. Dynamic modeling

The car body is modeled by means of the commercial finite element software ANSYS [1],

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giving a model with approximately 23000 degrees of freedom. The own frequency of such systems are in the range 9 to 16 Hz. These modes are typical for an oblong box (26.4 m × 4.4 m × 3.0 m), i.e. vertical and lateral bending shapes, torsion, shear and breathing modes [2].

When analyzing the formation of dynamic elements that are essential for the formation of a discrete dynamic model, it is preferable to group the whole system, i.e. present in the form of links number of relatively independent subsystems (Fig. 2) [2]. Models obtained in this way, are more suitable for analysis and subsequent modification with the aim of further more detailed study. On Fig.2 is shown a principled approach to the division's suspension system of two subsystems:

- system **B2** – suspension system in the strict sense, with wheels and
- system **B1** – suspension system - a system of rails, track and foundation.

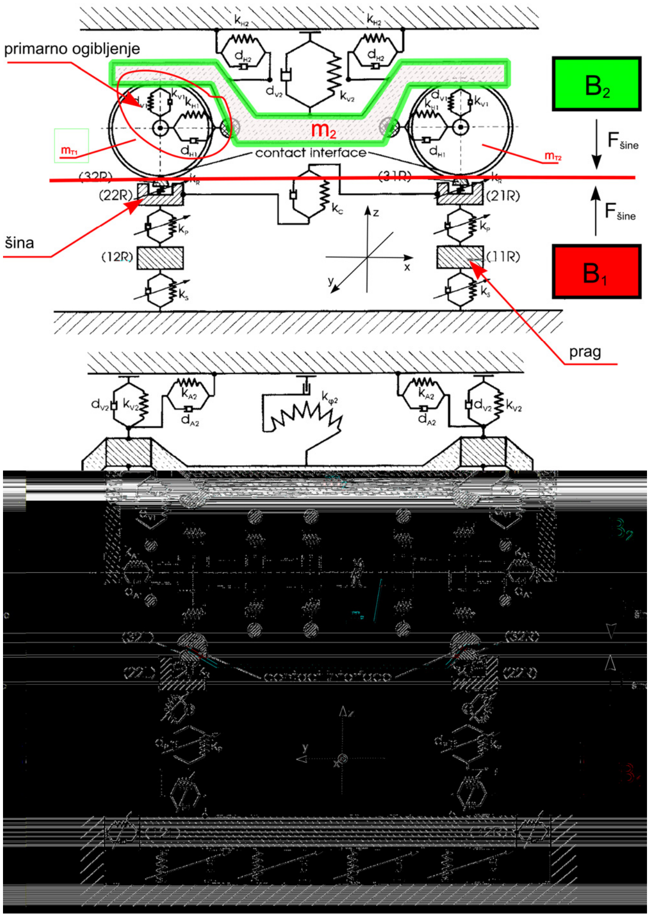

Fig. 2. Discrete dynamic model

2. DYNAMIC MODEL OF FRAME, WHEELS, RAIL AND PRIMARY SUSPENSION BASED ON RUBBER BAND ELEMENTS

The subject of consideration in the paper is a investigation of characteristic of primary rubber band suspension on modern passenger car interacting with a track making discrete mechanical model. This model is shown in Fig 3 [3] and Fig. 4.

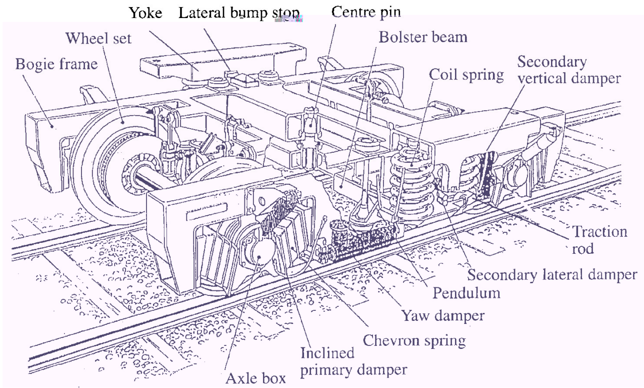

Fig. 3. The typical structure of suspension with rubber metal elements [3]

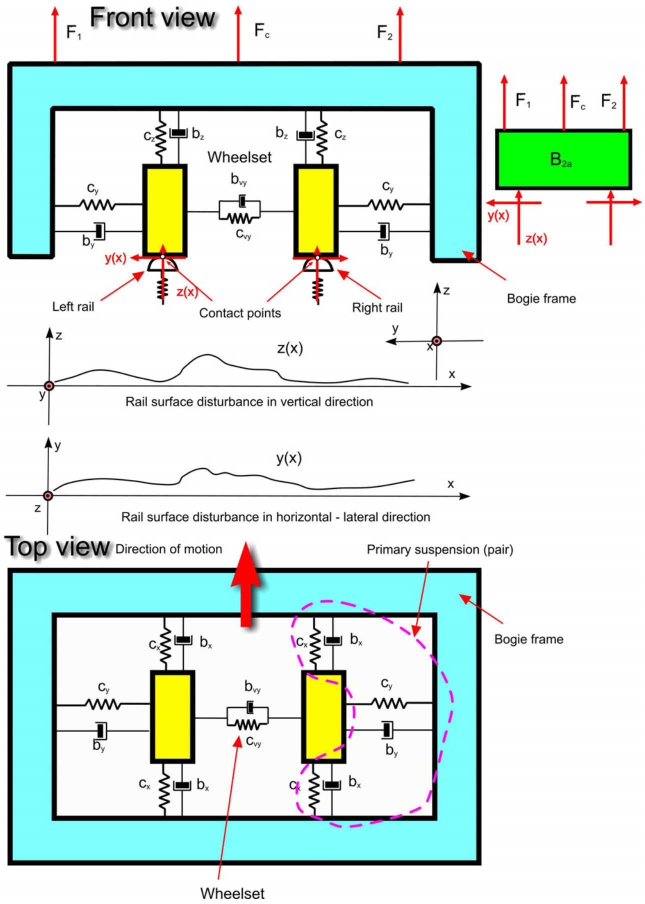

Fig. 4. Dynamic model of frame, wheels, rail and primary suspension (rubber band elements)

After the forming a discrete mechanical model, it is much easier to perform dynamic analysis and conduct laboratory tests. Simplified dynamic system, with abstraction of many parameters, separates the relevant from irrelevant characteristics. Now in the analysis only participate the stiffness and damping properties of metal – rubber packets and all other elements appear as the external influencing factors. Those factors can be relatively easy to calculate or determine otherwise.

3. THE PRINCIPLE OF TESTING DYNAMIC CHARACTERISTICS OFF RUBBER - METAL ELEMENTS

The basic assumption is that the primary rubber band suspension is presented as a visco-elastic spring with typical features – the stiffness c and the damping factor of packages b. Investigation of dynamic characteristics of rubber - elastic elements is divided into two independent segments:

1. *Testing with static force* - the goal is to determine the stiffness of the package c. The aim of study was to determine the static stiffness of metal rubber suspension. During this investigation it is considered that there is no viscous characteristics of the package b.
2. *Testing with the variable force* - the goal is to determine the damping factor of packages b. The second phase of the study aims to determine only the viscous characteristics of the package, ie. damping factor. As this feature depends on the speed of deformation of rubber metal package, it is necessary to perform testing under variable force.

3.1. Testing with static force

The basic assumption is that are ignored the stiffness and damping characteristics in the longitudinal direction x. Active force, the force of elastic and damping elements are shown in Fig. 5. The forces of inertia and damping forces do not exist, since it is a static test, i.e.

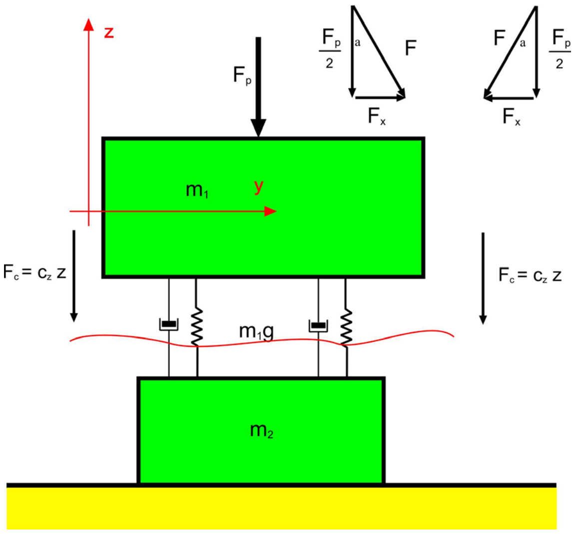

Fig. 5. Force disposition during static test

$$F_i = m \cdot a = 0$$

$$F_b = b \cdot \dot{z} = 0 \text{ where } \dot{z} = 0, a = 0$$

The goal of static tests is to determine the stiffness of the package of rubber metal elements in the vertical direction c_z. According Fig. 5

$$tg\ \alpha = \frac{F_x}{\frac{F_p}{2}} \Rightarrow F_x = \frac{F_p}{2} tg\ \alpha$$

$$c_x = \frac{F_x}{\Delta x} = \frac{1}{2}\frac{F_p}{2} tg\ \alpha$$

$$c_z = \frac{F_p}{2 \cdot \Delta z}$$

3.2. Testing with dynamic force

The basic assumption was stiffness and damping characteristics in the longitudinal direction are ignored. Active forces, the force of elastic and damping elements, forces of inertia are shown in Fig. 6. The forces of inertia and damping forces are now, since it is a dynamic test, ie.

$$F_i = m \cdot \ddot{z} \neq 0$$

$$F_b = b \cdot \dot{z} \neq 0$$

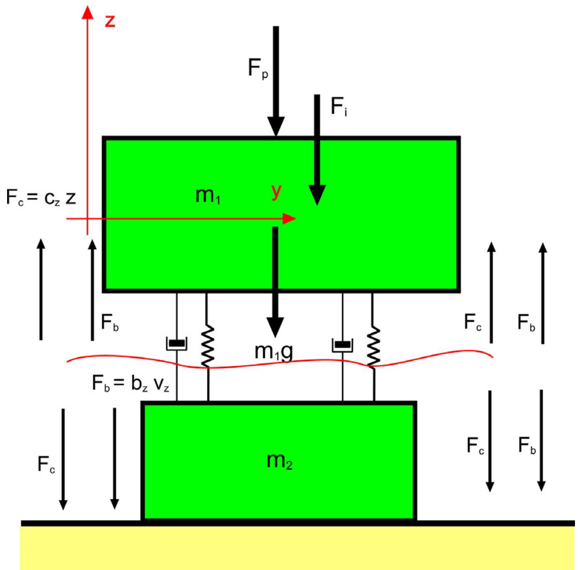

Fig. 6. Force disposition during dynamic test

Balance conditions for dynamic and other active forces, for system on Fig. 6, will be

$$-F_i - m_1 g - F_p + 2F_c + 2F_b = 0$$

ie.

$$-m_1 \cdot \ddot{z} - m_1 g - F_p + 2 \cdot c_z \cdot (z + z_0) + 2 \cdot b_z \cdot \dot{z} = 0$$

Initial conditions are

$$F_p = 0,\ \ddot{z} = 0,\ \dot{z} = 0 \text{ i } z = 0$$

and gives the possibility of determining the initial deflection of rubber metal elements

$$-m_1 \cdot \ddot{z} - m_1 g - F_p + 2 \cdot c_z \cdot (z + z_0) + 2 \cdot b_z \cdot \dot{z} = 0$$

$$\Rightarrow \; m_1 g = 2 \cdot c_z \cdot z_0$$

ie.

$$\Rightarrow \; z_0 = \frac{m_1 g}{2c_z}$$

Now, the differential equation becomes

$$-m_1 \cdot \ddot{z} - m_1 g - F_p + 2 \cdot c_z \cdot (z + z_0) + 2 \cdot b_z \cdot \dot{z} = 0$$

then

$$b_z = \frac{1}{\dot{z}} \left[\frac{m_1}{2}(g + \ddot{z}) + \frac{F_p}{2} - c_z (z + z_0) \right]$$

Since the

$$z_0 = \frac{m_1 g}{2c_z}$$

$$b_z = \frac{1}{\dot{z}} \left[\frac{m_1 g}{2} + \frac{m_1 \ddot{z}}{2} + \frac{F_p}{2} - c_z \left(z + \frac{m_1 g}{2c_z} \right) \right]$$

$$b_z = \frac{1}{\dot{z}} \left[\frac{F_p}{2} + \frac{m_1 \ddot{z}}{2} - c_z z \right]$$

Modeling of differential equations in a commercial package MatLab, ie. Simulink, is presented on the following diagram (Fig. 7).

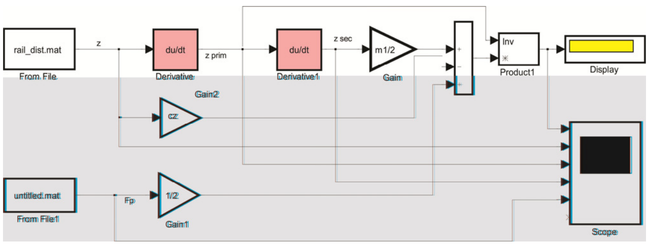

Fig. 7. Simulink diagram for determining the damping characteristics of rubber metal elements

Because of given the structure and method of mounting rubber metal elements, testing can be performed only with a pair of such elements. It is necessary to test at least three sets of rubber metal packages. Let denote the characteristics of each

stiffness	c_{z1}	c_{z2}	c_{z3}
dumping factor	b_{z1}	b_{z2}	b_{z3}

By measuring the couples package gives the mean value of each pair

c_{srz1} $\qquad$ c_{srz2} $\qquad$ c_{srz3}

where are

$$c_{srz1} = \frac{c_{z1} + c_{z2}}{2} \qquad c_{srz2} = \frac{c_{z1} + c_{z3}}{2}$$

$$c_{srz3} = \frac{c_{z2} + c_{z3}}{2}$$

From these equations it is easy calculate the stiffness values of each package separately (c_{z1}, c_{z2}, c_{z3}).

4. CONCLUSIONS

The formation of dynamic elements are essential for the structure of a dynamic model. In this paper the whole system is presented in the form of links of relatively independent subsystems. Simple model, obtained in this way, are suitable for analysis. This paper has analyzed the problems of dynamic modeling in determining stiffness and damping factor of rubber metal elements using such approach. The proposed method for determining these factors is simple and easily applicable. According [4], the damping factor of the primary suspension optimal value can be about $b = 75\,kN\frac{s}{m}$. The considered case study [4] refers to a TGV locomotive running with a constant speed of $120\,\frac{km}{h}$.

ACKNOWLEDGEMENT

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '12

NEW GENERATION OF VACUUM CIRCUIT-BREAKERS FOR RAILWAY TRACTION VEHICLES 25KV, 50HZ

Vladimir LAZAREVIĆ [1]

Abstract *– Main Circuit-Breaker, as one of the most important electric components of railway traction vehicles, was improved through modern technical and technological solutions to the optimal solution for manufacturers and operators of traction vehicles. At the same time special attention has been paid to improve the reliability and safety of the operation, to extend the service life of the device with much higher mechanical and electrical durability, thus lowering the total LCC. New-generation Circuit-Breakers are with small dimensions and lightweight, their installation is simpler, and at the same time compatible with the standard devices existing on vehicles.*

Keywords – railway vehicles, AC circuit-breaker, BVAC, MACS.

1. INTRODUCTION

Beginning with the introduction of electric traction at Serbian Railways, (around year 1970) the high-speed Circuit-Breakers mounted on the traction vehicles roof were used. Their purpose is to protect and switch ON and OFF the traction power and auxiliary electric circuits of locomotives and train sets supplied with 25kV, 50Hz network.

2. EXISTING TECHNICAL SOLUTIONS

From the first delivery of electric locomotives series 441, the main switch type DBTF 30 i 250 manufacturered by BBC [1] was incorporated as a standard.

Operation of this switch is electrical and pneumatic (air compressed at 8.5 bar is necessary for its operation). When switching off, i.e. the main movable contact separating from the fixed one, the compressed air passes by main contacts, extinguishes the arc caused by interruption of electrical current and exits into the atmosphere (***air-blast*** type of circuit-breaker). Quicker extinguishing of the arc is supported by non-linear resistor connected in parallel with main contacts.

If compressed air pressure is lower than a certain value this would jeopardize the safe operation of the main switch. So it has to be controlled by special device which blocks the main switch in such cases.

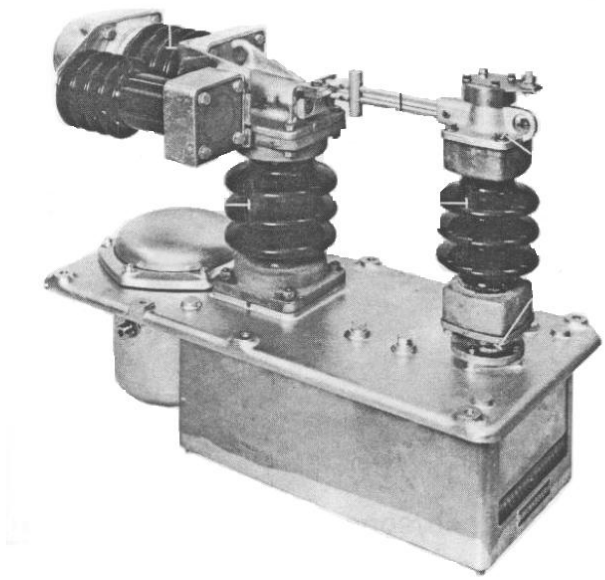

Fig.1. Main Circuit-Breaker, type DBTF

Together with the Main Switch, functionally and/or constructive as his additional component, Earthing Disconnector and high voltage Surge Arrester are mounted.

The main protective device of the electric trains series 412/416 is also a high-speed pneumatic switch, type BOB-25, with the arc extinguishing chamber which opeartes in similar way as with DBTF (electric arc is blown-out and extinguished by compressed air) [2].

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Fig.2. Main switch type BOB-25

Existing devices, with some solutions older than 40 years, are nowdays successfully replaced by modern equipment during the modification and modernization of the vehicles.

3. MAINTENANCE AND SUBSTITUTION

The maintenance of older circuit-breaker types requires regular replacement of parts that wear out in service, and damaged one as well. Also with each revision the complete sealing material should be replaced. Today, having in mind the age of the individual devices, procurement of necessary parts and materials are more and more difficult. Spare parts are manufactured only for a known customer with special order and because of small quantities the delivery times are long and prices are high.

Circuit-breakers in cases when the repair/regeneration is not possible or not commercially justified should be replaced by newer types of devices.

At modernized locomotive series 444 the main switch type DBTF was replaced by the vacuum circuit-breaker type BVAC [3]. On that occasion the locomotives of Serbian Railways were equiped with thirty BVAC switches, which are in operation for over six years already.

Also ten locomotives series 441 with old type switches DBTF were equiped by BVAC during the investment repair.

4. MODERN TECHNICAL SOLUTIONS

4.1. Vacuum Circuit-Breaker type BVAC

As a replacement for the main switch type DBTF, Swiss manufacturer Sécheron in 1990. launched the first generation of vacuum circuit breaker type ***BVAC***.

Fig.3. Circuit-Breaker type BVAC

BVAC is a single pole device for switching single-phase alternating current, which is mounted on the roof of a railway vehicle. It is equipped with a vacuum switch tube, pneumatic closing, electromagnetic holding and opening through spring induced force. BVAC is used as the main line breaker to switch ON and OFF the traction power circuit, as well as to interrupt the overloads and short-circuit currents.

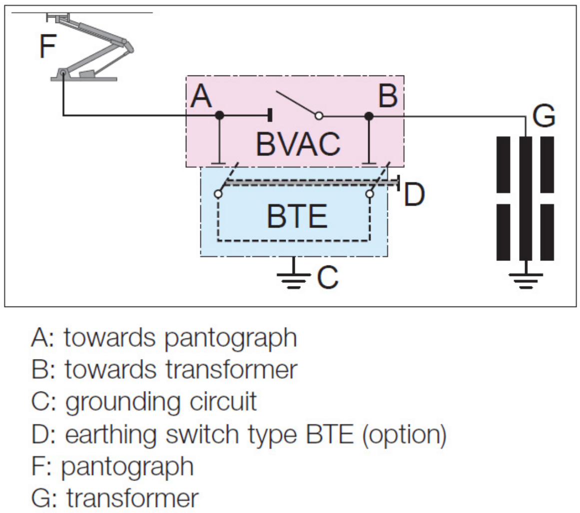


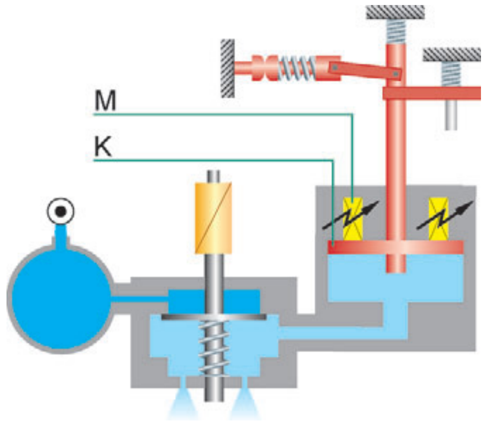
Fig.4. BVAC function in a main circuit

BVAC can replace DBTF circuit-breaker without modification on the roof. As an option, the Earthing Switch type BTE 15/25.04. can be added.

The operation of the BVAC circuit-breaker includes 3 steps:

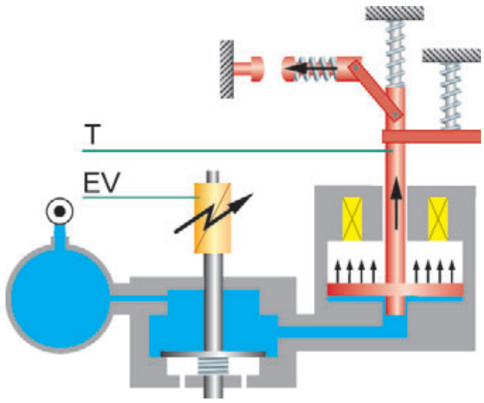
Closing (pneumatic)

The BVAC is closed by actuation of the solenoid valve (EV). Moved by the piston (K) and the isolating rod (T), a mecanism closes the the main contacts inside the vacuum switch tube (VST) and prestress the opening springs:



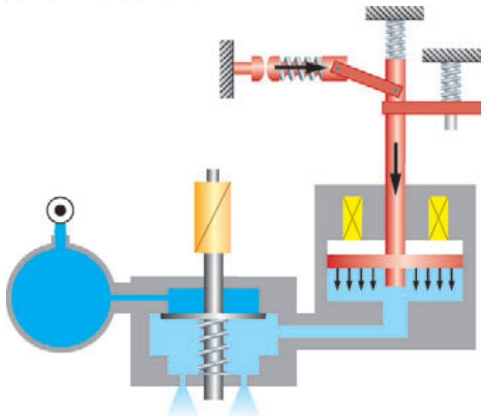
Holding (electro-magnetic)

The pneumatic cylinder is equipped with a holding electro-magnet (M), which holds the BVAC in the closed position, without air pressure:



Tripping

The opening of the BVAC is caused by the prestressed springs release, which occurs when the holding current is cut off:



4.2. Vacuum Circuit-Breaker type MACS

With the experience in operation of thousands of circuit-breakers type BVAC worldwide, Sécheron has come to a new generation of vacuum Circuit-Breakers type ***MACS***, an optimal solution for manufacturers and operators of railway vehicles running on 15 kV and/or 25 kV AC networks.

Table 1. Circuit-Breaker type MACS

Features
Suitable for 15 kVAC and/or 25 kVAC networks
Conventional free air thermal current: 1000 A
Rated impulse withstand voltage (1.2 / 50 µs): Uimp = 125 kV or 170 kV
Indoor or outdoor installation
External creepage distances > 1000 mm
Vacuum interrupter
Electric operation (closing and holding)
High safety thanks to the automatic opening through spring release in case of interruption of supply voltage (no need of stored auxiliary electrical energy)
High mechanical and electrical endurances (at Ie = 1000 A): > 200'000 operations
Vertical or horizontal mounting
Low height: 563 mm (for Uimp = 125 kV) above the roof and 140 mm below the roof
Low weight: < 100 kg for the AC Circuit-Breaker
Usable in various ranges of ambient temperature from -40°C to +70°C (-50°C to +70°C in option)
Reference standards: IEC60077-1 /-2 /-4, IEC61373, EN50121-3-2, NF F16-101 /-102

MACS is a multi-functional switch for railway traction vehicles, which comes in three variants: AC Vacuum Circuit-Breaker (AC VCB) as a basis, to which an Earthing Switch (ES) and/or a Surge Arrester (SA) can be integrated, making a unique compact unit with small size and weight:

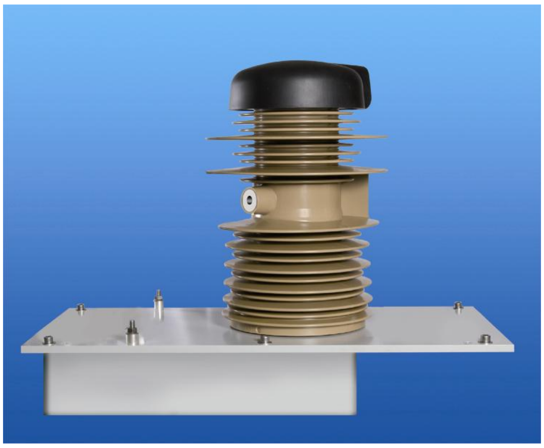


Fig.5a. AC breaker type MACS

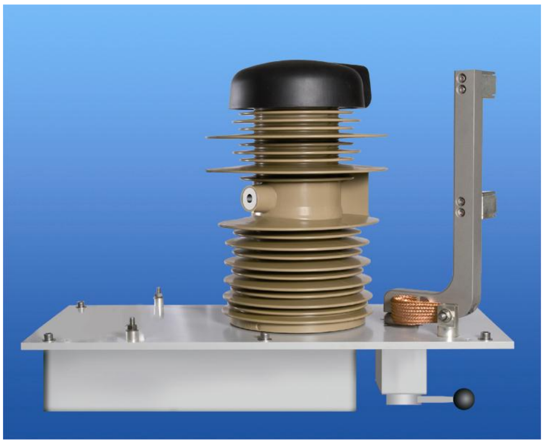


Fig.5b. Integrated Earthing Switch, with manual and electric operation

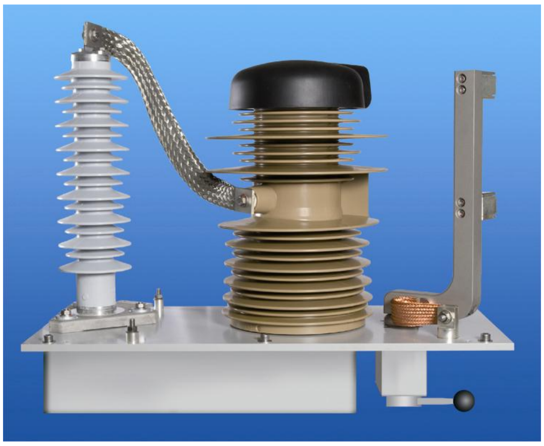


Fig.5c. Surge Arrester integrated

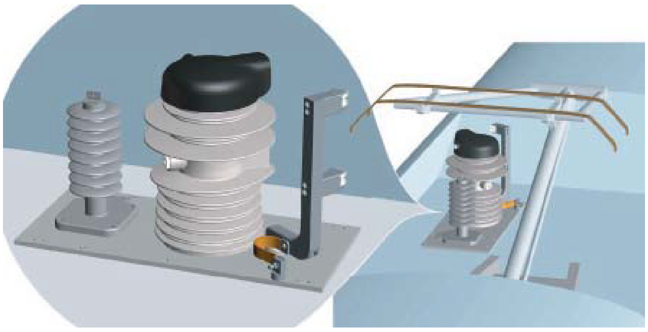


Fig.6. Vertical mounting on the roof

There is a variant in aluminum housing type AC MODBOX integrating also other high voltage functions such as current and voltage measurement, disconnectors, filters, transient inductors and all the low voltage corresponding control equipments.

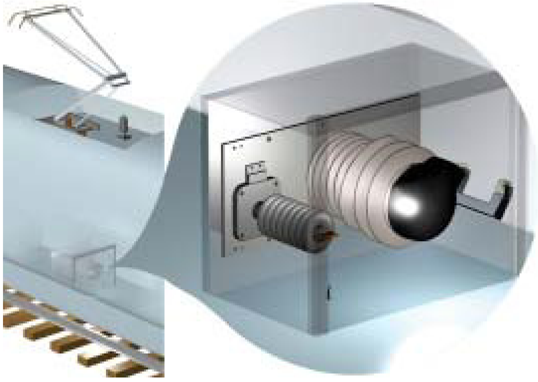


Fig.7. Horizontal mounting

5. CONCLUSIONS

New and unique features of the new generation circuit-breaker type MACS are: complete electric operation (no need for compressed air installations, pipes, filters, etc..), automatic opening through spring release (not bi-stable), integrated grounding switch (manual operation or electrical) and possible vertical or horizontal installation.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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HARDWARE-IN-THE-LOOP SIMULATION OF THE LABORATORY MODEL FOR ADHESION FORCE EMULATION

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Dragutin KOSTIĆ [2]
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Abstract – *It is presented a simple hardware-in-the-loop simulation model of the motor-generator test unit, suitable for laboratory development and implementation on the real controllers of slip control algorithms for vehicles with electric traction. Such HIL simulation is important step in physical realization of the adhesion control test unit. After developing some slip control algorithm, it should be tested in a laboratory before eventual implementing in a railway vehicle. Lab model consists of motor–generator group, directly connected and controlled independently. Induction motor unit represents traction motor while DC generator emulates load, with load torque proportional to adhesion (traction) force, at the wheel-rail contact. Train running is emulated in controller's program code. Appropriate computer simulation model is realized in Matlab/Simulink as well as real-time lab unit model.*

Keywords - Adhesion, Hardware-in-the-loop, Slip control, Motor-generator group.

1. INTRODUCTION

Adhesion characteristic depends on various conditions at the wheel-rail contact and influences to the traction and braking control of the vehicle. In order to improve safety, energy efficiency, and durability of infrastructure, traction and braking forces/torques must be controlled in accordance to adhesion conditions.

After developing some slip control algorithm [1], it should be tested in a laboratory before eventual implementing in a railway vehicle. The simplest laboratory experimental model consists of: electric motor (traction motor), driving axle, control unit and (the most critical for practical realization) mechanical system for adhesion phenomena simulation [2]. The last part produces load torque for traction motor, proportional to traction/adhesion force, which under real conditions depends on several factors: normal force at wheel/rail contact, outer conditions, wheel/ground material, slip velocity etc. Therefore, it is obvious that such mechanical system is difficult for realization and maintenance.

Much simpler for realization, more flexible for usage, adhesion simulation system can be realized with motor-generator group with load torque simulation [3]. Such simulator using DC motor – DC generator unit is proven as reliable in development of slip control algorithms [4]. Some adhesion characteristic must be mathematically modeled to describe various rail conditions. Based on those predefined slip-adhesion characteristics, adhesion force signal is obtained, as load torque reference for DC generator.

Before physical realization, real-time performance of the proposed lab motor-generator unit should be verified by real-time simulation, followed by proper hardware-in-the-loop simulation with control unit brought out from the computer model to the real microcontroller platform.

2. SIMPLE ELECTRIC VEHICLE MODEL DESCRIPTION

Proposed laboratory system is the most suitable for simulation of a vehicle with one driving axle. Following equations describe dynamic of such vehicle:

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$$J\frac{d\omega_m}{dt} = T_m - iT_{adh} - K\omega_m \quad (1)$$

$$M\frac{dv}{dt} = F_{adh} - F_{res} \quad (2)$$

where: J is moment inertia of all rotation parts, ω_m is traction motor rotor angular velocity, T_m - traction torque of the motor, i - transmission gear ratio, $T_{adh} = F_{adh} \cdot R$ - adhesion torque, proportional to adhesion force developed at the wheel-rail contact, R - wheel radius, K - coefficient of the frictional resistance, M - mass of the vehicle, v - vehicle's velocity, F_{adh} - adhesion force, F_{res} - resistant forces.

Adhesion force is proportional to adhesion coefficient μ_a and normal force N at wheel-rail contact:

$$F_{adh} = \mu_a N \ . \quad (3)$$

Slip velocity is difference between wheel rim and vehicle velocity:

$$v_s = \omega_w R - v \ . \quad (4)$$

Often, instead of slip velocity only (relative) slip is used:

$$s = \frac{v_s}{\max(\omega_w R, v)} \ . \quad (5)$$

Adhesion characteristic is a curve that describes connection between adhesion coefficient and slip (or slip velocity) and its shape depends on the various factors. But, it always looks similar in stable and unstable zone, as shown in the Fig. 1.

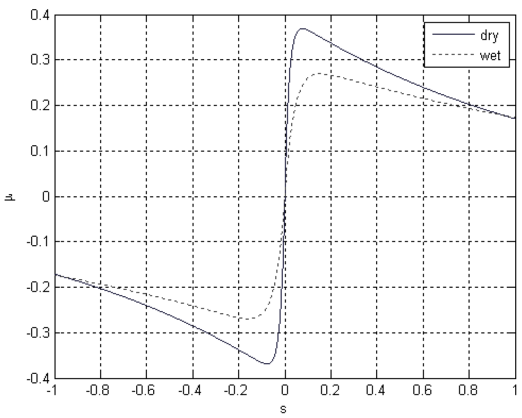

Fig.1. Typical shapes of the adhesion curves

The adhesion characteristic is unpredictable and variable, but always of similar shape. The aim of proper slip control is to keep the working point on the top of the curve, regardless of its shape.

Several different mathematical models are developed for analytical description of the adhesion curve, in the various different realistic conditions on the track. Simple expression gives adhesion coefficient value in terms of relative slippage:

$$\mu_a(s) = \mu_{\max}\operatorname{sign}(s)\left(-e^{-k_1 s} + e^{-k_2 s}\right) . \quad (6)$$

Variation of the parameters k_1 and k_2 modifies shape of the curve, as shown on the Fig 1.

Finally, simple model of one-motor electric vehicle is given on the next figure.

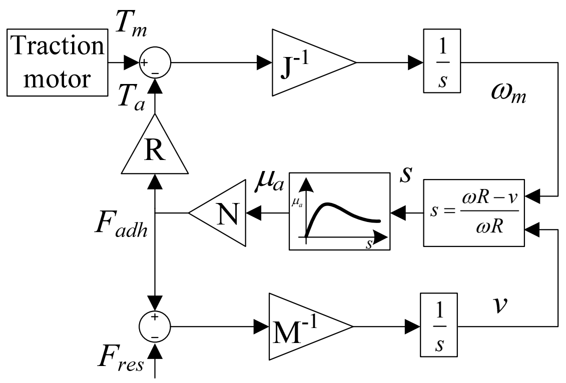

Fig.2. Model of the simple one-wheel vehicle

3. SIMULATION MODEL OF PROPOSED LABORATORY SYSTEM

The controller unit implements slip control algorithm. Block scheme of the proposed system is presented on the Fig 3.

Basic motor-brake model already exists in the laboratory, and it is supposed to be upgraded with a proper control and converter units.

Simulation model of the proposed system is realized in Matlab/Simulink. Previously developed model of vector controlled AM drive is used as torque actuator.

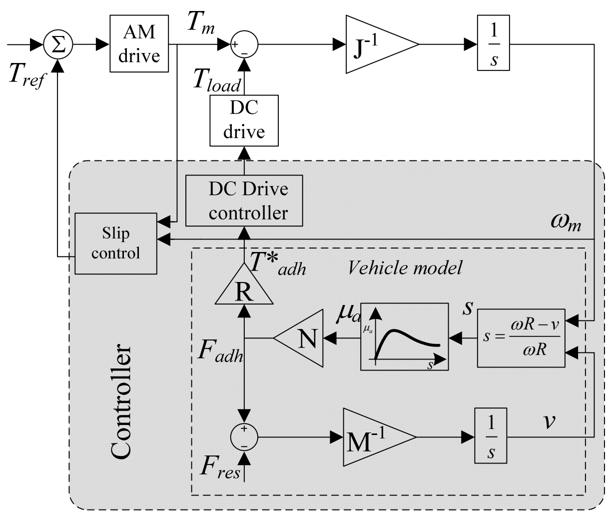

Fig.3. Block scheme of the proposed laboratory system

Traction motor is asynchronous, controlled by the three-phase inverter with implemented indirect vector control, with appropriate current regulator in *dq* system.

The DC generator, which will be used for load emulation, must be controlled in that way to develop load torque between 0 and the load torque that corresponds to theoretical maximum of adhesive force.

For the purpose of proving the reliability of the model, some simple slip control algorithm should be applied. It is based on the adhesion force observer, more precisely described in [3]. The aim of the observer is to estimate immeasurable adhesion force/torque, which is proportional to adhesion coefficient μ_a.

Optimal control of traction torque means that operation point is located in the stable area of the adhesion characteristic, near to the peak. Also, control algorithm must be able to respond adequately in the case of sudden occurance of bad track conditions.

3.1. Simulation results

In order to verify validity of the proposed laboratory motor-generator model, simple simulation is performed. The vehicle motion parameters are scaled to meet nominal torque and speed values.

Duration time of the simulation is 5 seconds, starting angular velocity of the traction motor is $\omega_{start} = 15\,\text{rad/s}$, and that corresponds to vehicle velocity $v_{start} = 9\,\text{km/h}$. At moment $t = 2\,\text{s}$ bad rail condition (wet rail adhesion characteristic at Fig.1.) occurs, which last for 1.5 seconds.

Reference and estimated adhesion torque time diagrams are given on the Fig.4 and more detail described in [3].

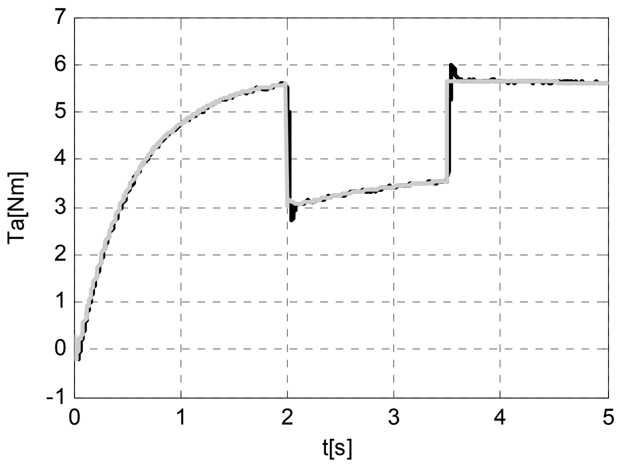

Fig.4. Reference (gray) and estimated (black) adhesion torque

Proposed slip control algorithm easily handles with sudden drop of the adhesion coefficient (at $t = 2\,\text{s}$). Also, estimated (from adhesion observer) and developed (generator current control block) adhesion force signal diagrams are satisfying.

4. HARDWARE-IN-THE-LOOP SIMULATION MODEL

By analyzing the simulation results, it could be noticed that small change of control parameters (observer bandwidth, controller gains), or even more simulation configuration parameters, can greatly affect performances. Therefore, it was concluded that proposed simulation model should be physically implemented. In order to validate basic functionality of the proposed lab system (estimating of the adhesion force and controlling generator's load torque), a simple hardware-in-the-loop system has been designed. The plant process (motor-axle-load) behavior is emulated, based on the developed and described Simulink model, by using appropriate Real Time Windows Target resources.

It is noticed high influence of simulation step value on the results in the previously presented simulation. For the complete model, with modeled PWM drivers and voltage converters, simulation fundamental step time should not exceed $2\,\mu\text{s}$ for relevant and meaningful results. Appropriate real-time application is almost impossible to be built on the standard PC. For such high demanding task, some powerful real-time platform must be used.

For basic analysis, voltage converters modules can be omitted and replaced by controlled ideal voltage sources. Such simulation model can operate with much lower simulation step time, e.g. $20-50\,\mu\text{s}$. In this case real-time application is fully realizable.

Finally, based on the previously realized real-time simulation model, simple hardware-in-the-loop system can be realized according to the next block diagram (Fig.5.), using inexpensive and available elements:

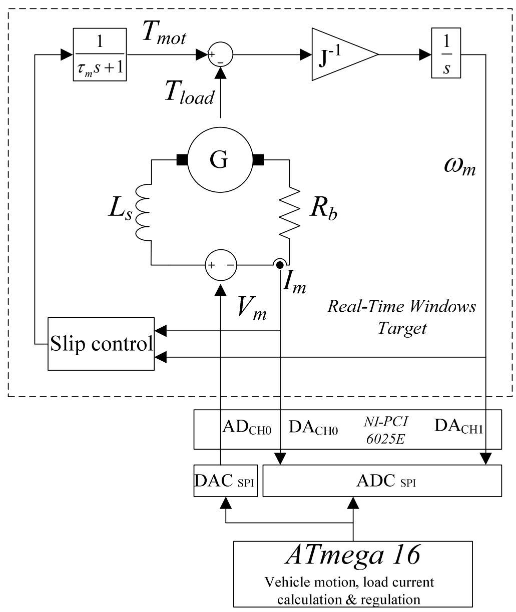

Fig.5. Proposed simple HIL simulation model of the test adhesion unit

Real-time model, realized in the Simulink, using the Real-Time Windows Target, emulates the plant, i.e. traction AC motor coupled with adhesion load DC generator. The complete control process for the adhesion load simulation (vehicle running, adhesion phenomena, DC machine load current calculation and regulation), is brought out from the simulation model and realized on the 'real' controller ATmega16

Communication of the real-time model with a external controller is provided by I/O board PCI 6025E, manufactured by National Instruments. It possesses both analog input and output channels for signal interconnection between RT plant model and real controller. Based on the motor-generator angular velocity signal, obtained from RT simulation, vehicle motion is emulated and vehicle velocity calculated in the controller code. Also, DC machine load current calculation and regulation are performed. Simple hysteresis current controller is implemented.

4.1. HIL simulation results

HIL simulation parameters are similar to those from Chapter 3. Complete simulation lasts for 5 seconds, with a sudden drop of adhesion coefficient.

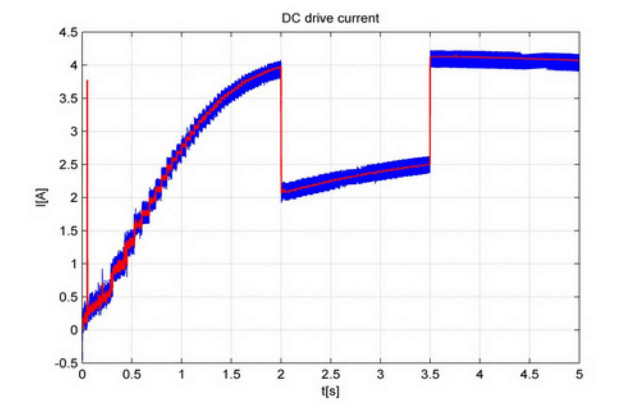

Fig.6a. Load current reference (red) and meaasured current of DC generator

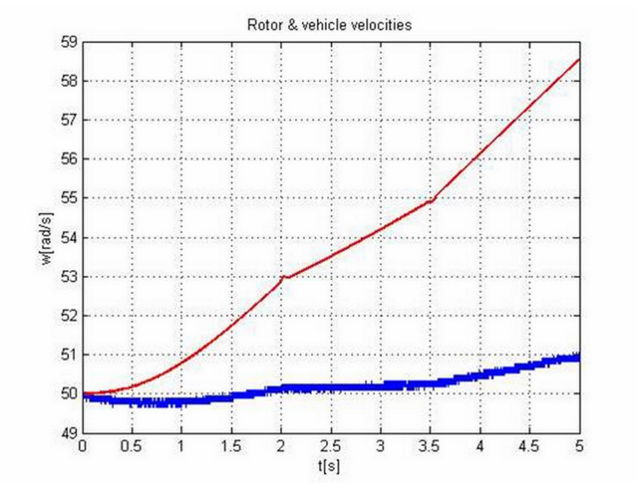

Fig.6b. Measured velocity of the driving axle (red) and emulated vehicle's velocity (blue)

HIL simulation couldn't be performed with simulation step time (for real-time motor-generator group model) smaller then 100ms on the used platform.

Despite limited performances of the used components, HIL simulation results confirmed reliability of controller-based vehicle running emulation, necessary for proper adhesion force (load torque reference) signal obtaining.

5. CONCLUSION

Simulation results verify that proposed model is suitable for laboratory research of slip control algorithms.

Simulation results are affected by simulation configuration parameters, so improving of the real laboratory model is necessary for further research in this area.

Important step toward practical realization has been composing of the proper hardware-in-the-loop simulation system.

Presented hardware-in-the-loop simulation model can be used as a base for development of more complex railway vehicle HIL simulations, but with obsolete using of more advanced platforms, both for real-time simulation and controller's tasks.

ACKNOWLEDGEMENT

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '12

LED LIGHTING IN RAILWAY ROLLING STOCK

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Vladimir PEJIĆ [2]

Abstract *– Today, the most efficient energy source of light is LED lighting. The abbreviation LED comes from Light Emitting Diode.It has long been known that the LED diodes were used in indications and signs of electronic devices. Now, due to their characteristics, they are used in addition to environmental and spatial lighting, traffic lights, information panels, traffic signs, decorative architectural designs, sports traffic lights, street lighting, etc. Auto industry has already instaled complete illumination of all segments of the car with LEDs: cabin lighting, instrument panel, front and rear LED lights. New rail vehicles are also equipped with LED lighting. It is rationally and appropriate to reconstruct the traditional lighting of the Serbian Railways locomotives using LED technology. This paper represents examples of LED lighting company INGEL from Nis, which are installed on locomotives series 441, 461, 661 and 745.*

Keywords - LED technology, LED lighting, rolling stock, energy efficiency.

1. INTRODUCTION

Today, LED technology has a significant role. Manufacturers of LED products are competing with each other almost weekly in product innovations with increasing light output. Characteristics of LED lightings are:

- energy efficiency,
- long lifetime,
- small dimensions,
- minimal thermal light sources,
- immunity to vibration,
- aesthetics.

Fig.1. Different types of LED diodes

Tehnicaly, the LED diode is a semiconductor diode. PN connection is transmitting photons by direct polarization, i.e. emits light. Color of the light emitted by the LED depends on the materials from which it was made and the current through the diode in the forward direction.

Current and voltage of the PN connection of LEDs, as well as in other diodes, have the exponential characteristics. That means that very small changes in voltage result in large changes in current, and thus the change of the emitted light.

Figure 1 shows the different types of LEDs, which differ in strength.

2. PARAMETERS FOR THE MEASUREMENT OF LIGHT

When the light falls on the object surface it reflects to the human eye (Figure 2).

Luminous flux [lm] is the total amount of light emitted from the light source and is expressed in lumens. Lumen [lm] is the amount of light falling on the unit angle per steradian from the light source of one candela 1 lm = 1 cd sr. Candela [cd] is the unit light and it is the amount of light emitted in a certain direction 1 cd = 1 lm/sr, i.e. the value in candela is equal to the value of lumens per steradian.

Due to the color and quality of the object surface, the light reflected from the surface which reaches the human eye can be different. Lumination [cd/m^2] is a

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measure of object surface brightness expressed in cd/m^2 and depends on the structure of the surface exposed to light (darker or brighter area of the surface). Lux [lx] is a unit that represents the brightness or intensity of light (1 lx = 1 lm/m^2). This unit is important in real life. The intensity of light is important in schools, offices, workplaces and other venues. The recommended amount of light in the workplace is 500-600 lux.

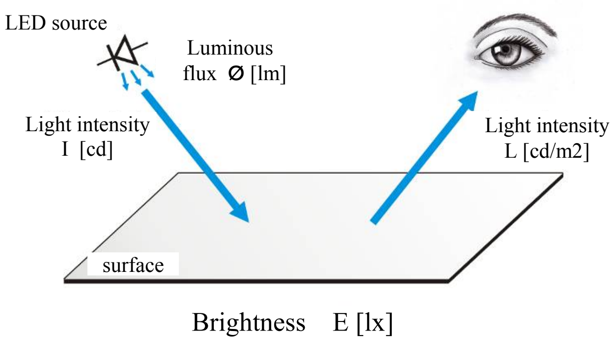

Fig.2. Schematic representation of light parameters

Lux – meter is the instrument which is used to measure the illumination, i.e. light intensity. Lux-meter is measuring the amount of light needed in the workplace.

3. ADVANTAGES OF LED TECHNOLOGY

Although classical tungsten filament bulbs are in use for the past 125 years, they are slowly going to the past. They are replaced by so-called "energy saving light bulbs " and now by even more efficient LEDs. The numbers are always the most valid and the strongest argument for the evaluation, se here are some interesting facts. Australia already banned the use of incandescent light bulbs. It is estimated that this will have the effect of reducing gas emissions (causing global warming) up to 260,000 tons in period of one year.

Households will be saving up to 75% of the total cost for lighting by using the new bulbs. California and Cuba also legislate the use of new lighting.

According to European studies, EU could reduce carbon dioxide emissions by 35 million tons per year, if households and public institutions used LED light bulbs instead of traditional.

The International Nuclear Energy Agency (NEA) estimates that lighting consumes up to 20% of the total produced electricity, which is much more than the total capacity of all nuclear power plants.

The Climate Group director Mark Kenber estimates that LED technology represents a revolution in clean energy and that the conventional lighting consumes 19% of global electricity generation,. According to him, LEDs could reduce annual emission of gas to 670 million tons.

"Philips" developed a pilot project of LED street lighting in the 12 largest cities in the world and presented it to the UN summit, showing that this would save 85% of energy.

LED lighting lasts about 15 times longer than conventional bulbs. LEDs consume 10-15 times less energy and provide the same light. The life expectancy of LED lighting is from 50,000 to 100,000 hours. During 6,000 working hours of LED technology failures are 1%, and in conventional lighting failures are 10%.

If one compare the consumption of traditional light bulbs with LED light bulbs in the household, it is possible to save up to 28 KWh just on one bulb point.

It is expected that LED bulbs will take 60% of the market by year 2020. year. Replacing one bulb in each household Serbia would save about 1 billion kWh, with market value of about 60 million euros.

Will the Serbia issue their own standards and adopt needed laws?

It could easily happen to us that tehnicaly developed countries "make us a favor" and sell us surplusage of incandescent light bulbs for “an affordable price” as used cars.

Beside exceptional energy efficiency, LED lighting has other advantages too. Conventional tungsten filament bulbs need about 200 ms (130 - 200 ms) to shine. LEDs emit light almost immediately. If the car speed is 60 km / h, for 200 ms it will go over:

$$s = v \cdot t = 60\,\frac{\text{km}}{\text{h}} \cdot 200\ \text{ms} = \\ = 60 \cdot \frac{1000\ \text{m}}{3600\ \text{s}} \cdot 200 \cdot 10^{-3}\ \text{s} = 3.33\ \text{m} \tag{1}$$

At a speed of 100 km/h it will take 5.55 m. Accordingly, after the pressuring of the brake pedal, the driver behind, sees brake lights before and has 3.33 m that is, 5.55 m more for stopping of his vehicle.

Unbelievable but significantly, how little technical phenomenon increases traffic safety.

LEDs have great potential to achieve significant cost savings due to the lower level of consumption, and at the same time delivering more light [2]. Furthermore, they have several times longer product lifetime, reduced need for maintenance and also drastically reduced costs of replacement parts of bulbs or tubes. LED lamps are in this respect only the beginning of their development cycle. Current intensity of LED lamps light power is around 100 lumens per watt. Since it is expected that in the future the intensity will reach 200 lumens per watt, this new technology has great potential.

LEDs emit light at specific angle, and reduce losses due to absorption and reflection. Lifetime of LED bulbs is much longer, and the whole lamp is made of high quality materials that are suitable for recycling.

4. LED LIGHTING PRODUCTS ON RAILWAY VEHICLES

For Serbian Railways locomotives, the Ingel company from Nis has developed and produced several products with LEDs that replaced the previous classic lighting and the signaling control panels.

4.1. Head Position Lamp

Head position lamp is located at the both ends of the locomotive, and its color depends of locomotive movements. For forward drive front head light is white, while back head light is red. Figure 3 shows the current position lights with two bulbs (white and red).

Fig.3. Red and white locomotive position lamps

Fig.4. Front position LED light

Figure 4 and 5 show the new position light with LED diodes, which designation is LD (B + C) 110V/9W POZ.

Lighting automatically changes color (white or red) depending on locomotive direction. LED Light power with is 9W, while the classic parking lights power is 100W.

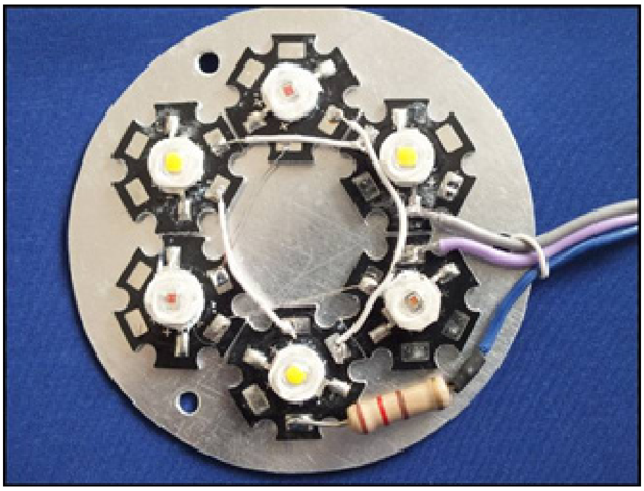

Fig.5. Front position lamp LD (B+C) PO

4.2. Control desk signal repeaters in the cab

Control desk signal repeaters, located in the cab are information repeaters and their use is to inform about failures, or to display information such as: traction motor electricity, traction motor voltage, heating current of the train, main transformer electricity, compressor motor temperature, ground failure, autostop switch failure, short curcuit with the mass, ride with braking, excess electricity of eletric consumers, explosion in voltage selector, the main transformer overheating , fuse blowing, exceeding of the primary current, selection of the train type, EP contactor failure, midpole selector etc.

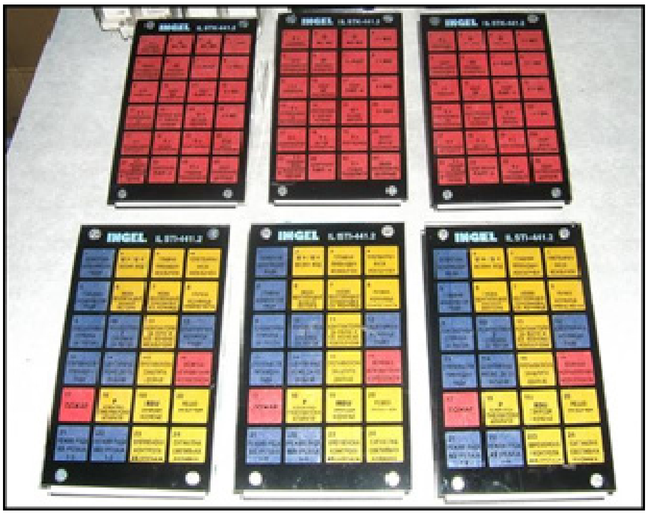

Fig.6. Control desk signal repeaters in the driving locomotives

Control desk signal repeaters of electric locomotive series 441 are marked with IL-STI 441.1, 441.2-IL STI and STI-IL 441.3, and they are shown in Figure 6, and their appearance on the back side are shown in Figure 7.

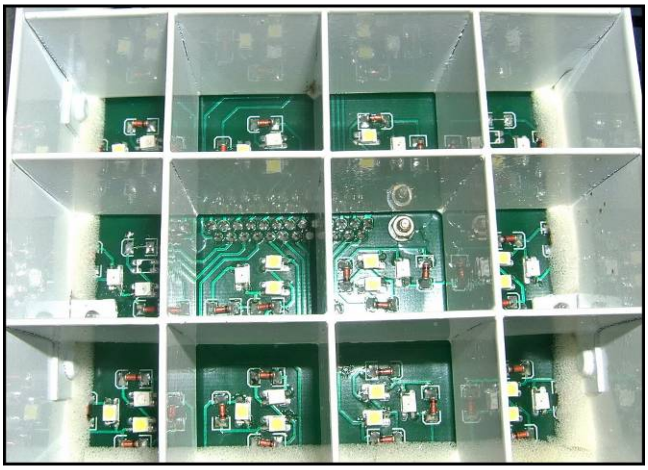

Fig.7. View of segments with LED signal repeater

4.3. Driver's cabs and engine room lighting

Driver's cab and engine room lighting is important to train drivers so they could comfortably and safely serve their locomotives.

Classic lighting has a power of 25 W per light bulb, while LED lighting power is 3W (Figure 8).

Fig.8. Driver's cabs and engine room lighting, type LDB -MP- 130V / 3W

Fig.9. Segment with a powerful LED diodes

Figure 9 showes lighting segment with powerful LED diodes, while Figure 10 illustrates switching supply.

Fig.10. Switching supply for some LED diodes

Beside these, there are some more developed products for railway vehicles such as control desk lighting in the driving locomotive with labels LDZ 305-24V/70 mA - Model 1 and LDZ 618-24V/140 mA - Model 2.

5. CONCLUSION

LEDs have long been used in indications and signs of electronic devices. Today, however, their use is extended to the spatial lighting, information panels, traffic signs, sports scoreboard lights, etc. Recently, they are also widely used in the automotive industry and the industry of railway vehicles. Given the many advantages of LED lighting compared with conventional lighting in terms of energy efficiency, it is possible provide significant energy savings using LED technology. Therefore, it is reasonable to reconstruct the traditional lighting of the Serbian Railways locomotives with LED lighting.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '12

ANALYSIS OF THE MOTOR TRACK CAR STABILITY UNDER EXTREME POSITION OF THE TRACK CAR CRANE

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Borisav BOGDANOVIĆ [3]
Milan PLAVŠIĆ [4]

Abstract *– In this paper stability of the heavy motor track car under extreme loads and cran position on track has analysed. The analysis was done by measuring of the vertical wheel forces in stationary condition. On this occasion the superposition of extreme working conditions of the track car crane and maximum value of twisted track was checked. In particular how this superposition was reflected on vehicle stability was cheked.*

Keywords - heavy motor track car, stability, track car crane, twisted track, wheel forces.

1. INTRODUCTION

Heavy motor track car type: *DHD - 200 DK* made for the railway construction works (figure 1) has been manufactured by MIN "Lokomotiva" - Nis.

Fig.1. Heavy motor track car type DHD - 200 DK with the crane

In front of the car, closer to axle No.2 is placed railway crane manufactured by: "PALFINGER" type: PK15002 A/SA, which is designed for handling the load transported with this vehicle, during the works on the railway.

Considering the fact that this crane can lift the significant loads of up to 1,6t [1] there was a need to check the vehicle stability on track, when crane is working in extreeme working conditions. These conditions are when the crane is holding the heaviest possible load and in maximum crane lenght position, both in the vehicle direction, heading foreward (*x* axis) and in transverse direction (*y* axis) regarding the vehicle.

2. METHOD OF MEASUREMENT

During the test it was used the measuring method with vertical wheel forces. – Q_{ij}. Testings were done in stationary condition using manufacturer weighbridge.

First were weighed wheel forces for unloaded wehicle with crane in assembled (travel) position (figure 2), and then with crane in working positions.

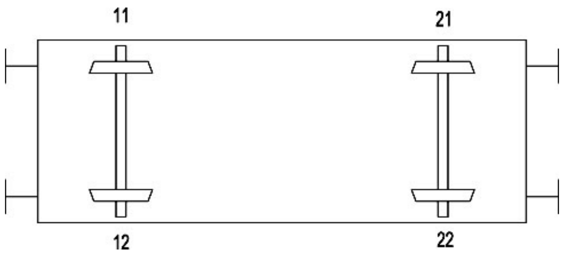

Fig.2. Scheme of heavy motor car on weighbridge in unloaded condition

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The measuring results of wheel forces for unloaded vehicle are given in table 1.

Table 1. Wheel forces for unloaded vehicle [kN]

Wheels	Axles 1	Axles 2	Difference per axle
1	57,2	53,46	3,74
2	58,37	54,45	3,92
Side difference	1,17	0,99	

3. TEST CONDITIONS

The heavy motor car is placed on weighbridge which simulates streight and flat railroad, without stabilizers situated. Wehicle stability is tested for two extreme positions *A* and *B*.

Measuring position *A*: The crane is loaded with 1640 kg which is maximum weight for maximum arm length of 7.9m, and arm is drawn in a vehicle longitudinal direction, in *x*-axis direction (figure 3).

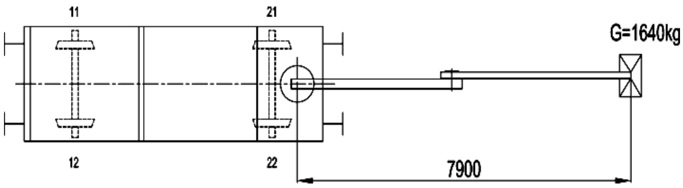

Fig.3. Heavy motor car in measuring position A

Measuring position *B*: The crane is loaded with 1640 kg and arm is drawn in transverse direction (in *y*-axis direction) at length of 2,865m due to a limited space around weighbridge as shown at figure 4.

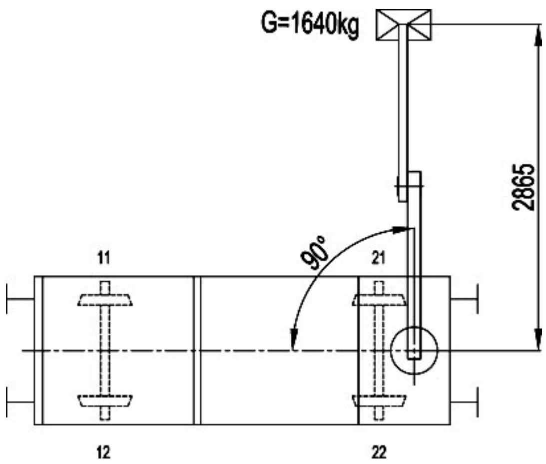

Fig.4. Heavy motor car in measuring position B

The wheel force value Q_{ij}, on the oposite side from the loaded axle or side of the vehicle, is taken as the acceptance criteria. That value should not decrease to zero, i.e. axle or wheels to become relieved.

4. TEST RESULTS

4.1. Measuring on plain and straight track

In tables 2 and 3 are shown the measuring results for extreeme positions A and B respectively:

Table 2. Wheel forces in measuring position A in kN

Wheel	Axle 1	Axle 2	Difference per axle
1	36,8	84,86	48,1
2	36,59	82,89	46,3

Wheel forces on unloaded axle are:

$Q_{11} = 36,8$ [kN]

$Q_{12} = 36,59$ [kN]

Table 3. Wheel forces in measuring position B in kN

Wheel	Axle 1	Axle 2
1	74,46	113,3
2	36,89	16,58
Difference per side	37,57	96,72

Wheel forces on unloaded side are:

$Q_{12} = 36,89$ [kN]

$Q_{22} = 16,58$ [kN]

These measuring results are valid if the heavy motor car is placed on plain and streight railroad. However, in the case when car is running on twisted track with track twist value – *g* then, it is necessary to check the vehicle stability by subtracting the value of wheel force deviation caused by track twist - ΔQ_{ij} from critical wheel forces value – Q_{ij} .

4.2. Calculation of wheel forces deviation caused by the track twist

Track twist value – *g,* is determined according ORE B55 /RP 8 [2] (point 3.4.2), as:

$$g = 7 - \frac{5}{2a} \quad [‰] \qquad \text{(2a in meters)} \qquad (1)$$

where 2a – wheelbase, for this heavy motor car it is 4,3m.

When substituted in the formula (1), track twist value equals:

$g = 5,84$ [‰]

Using this value, the total lifting heigh for one wheel can be calculated as the simulation of the track twist:

$$h_1 = g \cdot 2a \quad \text{[mm]} \qquad (2)$$

When values are substituted in formula (2):

$h_1 = 25,112$ [mm]

Wheel force deviation due to the track twist value is the difference between mean static wheel force per axle - Q_{oi} and minimum wheel force $- Q_{ij,\ min}$ from the following calculation:

$$\Delta Q_{ij} = \overline{Q}_{oi} - Q_{ij,\min} \tag{3}$$

Mean static wheel force per axle is arithmetic mean value of measured wheel forces at one axle. Minimum wheel force can be obtained from the track twist diagram.

Track twist diagrams or functional dependence *Qij=Q(zij)* are obtained from testing of vehicle torsional stiffness by measuring the lifting on one wheel at height which simulates track twist and by measuring the wheel forces on stationary axle. Figure 5 shows the track twist diagram when wheel 12 is lifted at bearing housing and forces at oposite axle 2 Q_{21} and Q_{22} are measured.

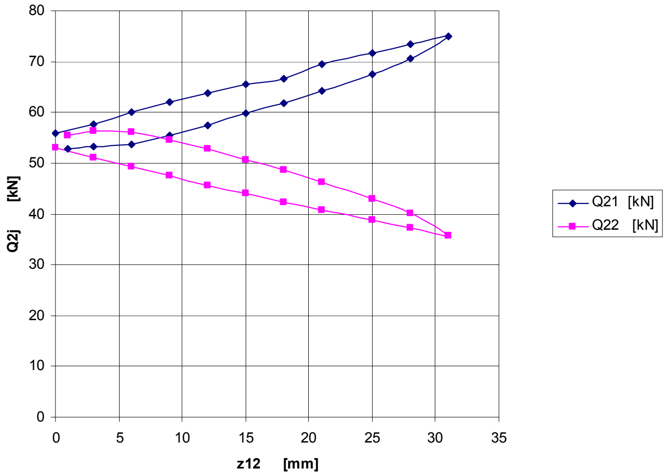

Fig. 5. Track twist diagram Qij = Q(z12)

From the diagram (figure 5) it can be obtained the minumum force $Q_{22,\ min}$ for the 25mm lifting height, which simulate the testing track twist. This force equals:

$Q_{22,\ min}$ = 38,74 [kN]

The mean static force for axle 2 is:

$Q_{0,2}$ = 54,3 [kN]

Wheel force deviation on wheel 22 due to track twist on wheel 12 is:

ΔQ_{22} = 54,3 – 38,74 = 15,56 [kN]

Total reduction of wheel force on wheel 22 during the extreme position A on plain and streigth track – Q_{22} and due to crossing over the track twist - ΔQ_{22}, is gain as the difference between these values:

$Q_{22,i} = Q_{22} - \Delta Q_{22}$ = 16,58 - 15,56 = 1,02 [kN]

In the same way were calculated the forces on the other critical places for both measuring positions, which is shown in table 4:

Table 4. Wheel forces in loaded condition due to the track twist influence in kN

Wheel	**ΔQ_{ij}**	**Q_{ij}**	**Q_{ij}**	**$Q_{ij,i}$**	**$Q_{ij,i}$**
1	**2**	**3**	**4**	**5=3-2**	**6=4-2**
Measuring position	**-**	**A**	**B**	**A**	**B**
11	16,09	36,8	-	20,7	-
12	16,09	36,59	36,89	20,5	20,8
21	19,38	-	-	-	-
22	15,56	-	16,58	-	1,02

5. DISCUSSION

The differences of wheel forces with unloaded crane are small and balanced by the sides and by the axles. For the measuring position *A*, those differences are almost equal. Axle 2 is 2,3 times more loaded than axle 1 (figure 3, table 2). Wheel forces on axle 1 have not fallen to zero, (figure 6) so the heavy motor car remained stable.

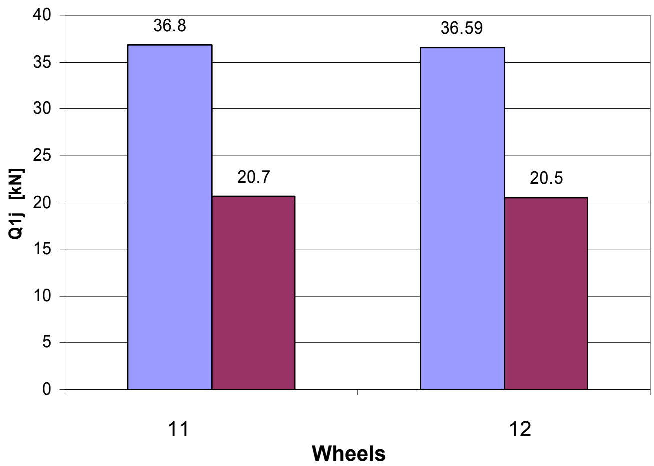

Fig.6. Wheel forces Q1j at axle 1, measuring position A

The wheel force differences for measuring position *B* are uneven. Left side is much more loaded in comparison with the right side. On wheel 21 is measured the highest force value, and on wheel 22 the smallest (figure 4, table 3). The whel 21 is loaded 6,8 times more than wheel 22.. Although, force value Q_{22} approached zero (figure 7), the wheel forces on the side 2 of the vehicle have not fallen to zero.

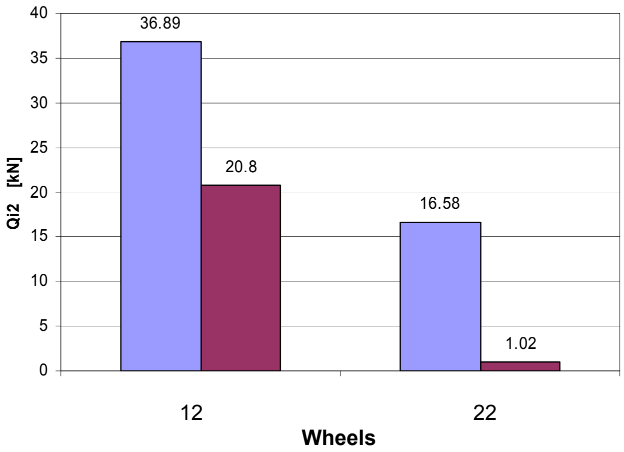

Fig.7. Wheel forces Qi2 on side 2, measuring position B

During the test, the overload alarm set on and the crane arm couldn't draw any longer due to the crane blockade. The vehicle remained stable in this position, also.

6. CONCLUSIONS

Based on the heavy motor car type *DHD - 200 DK* stability analysis regarding the extreeme working conditions, it can be concluded that the vehicle remined stable during the testings for both of the crane extreeme positions, under maximum permited load and without stabilizers situated.

In case of driving the vehicle in measuring position *B* on twisted track, wheel force on wheel 22 can fall to zero (figure 7). The measured value is 1,02 kN which indicate that heavy motor car cannot be driven with maximum loaded crane as in position *B,* due to possibility of derailment and loss of stability.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '12

ANALYSIS OF THE TRACK CAR UNDERFRAME STIFFENING IMPACT ON THE TORSIONAL STIFFNESS

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Abstract – *In this paper the modification of the underframe construction of heavy motor track car has been analysed. This modification was done to increase the stability of running on twisted track and to improve safety against derailment. The parameter, such as torsional stiffness, was analysed. This parameter, related to the vehicle, directly affect the safety of motor track car regarding derailment.*

Keywords - heavy motor track car, twisted track, torsional stiffnes of the vehicle, derailment.

1. INTRODUCTION

The locomotive manufacturer MIN "Lokomotiva" from Niš, Serbia, has produced heavy motor track car type: DHD-200 DK for track construction needs (Fig. 1). The underframe of this type of track car is based on previous type of two-axle track car: DHD-200. This underframe was made of standard steel perfils and sheets as welded grid [1]. During the exploatation of the previous track car type DHD-200, there were some cases of derailment during running on twisted track. In order to solve this problem, there was a need for constructive modification of the vehicle underframe.

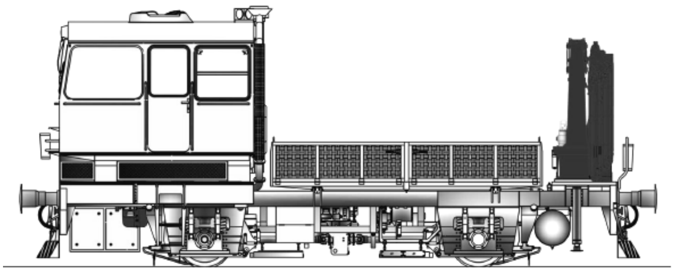

Figure 1. Heavy motor track car of type DHD - 200 DK

Appearance of derailment is complex phenomenon, which is associated with numerous factors related to the vehicle as well as to the track. This paper will limit its analysis to the factor related to vehicle. That is torsional stiffnes of the railway vehicle.

As constructive measure in order to overcome the derailment problem, manufacturer has stiffen underframe above axle 2, ie. above crane position. This stiffening is carried out by welding of three square steel plates linking longitudinal and cross beams of the frame. Apart of stiffening the dead mass of the vehicle was increased by 841 kg at the place of axle 2. The dead mass of the vehicle was increased in totally for 3,7%. This was done due to equilization of axle loads, which were quite uneven because of asymmetric construction of the vehicle.

The aim of this paper is to analyse validity of given consructive solution in order to overcome the problem of derailment.

2. THEORETICAL BASIS

Knowing the vehicle torsional stiffnes coefficient, from the point of view of safety against derailment for railway vehicles running on twisted track, is substantially.

The vehicle with high torsional stiffnes coefficient can be threatened by derailment during running on twisted track, since it can happen that one wheels diagonal could relieve of load. In this way, the quotient Y/Q may be unfavorable.

Derailment appear when the quotient Y/Q is greater then 0,8 for the curves radius R ≥ 250 m [2]. Which means when the guiding forces Y_i are high and wheel forces Q_i are low. This situation appears when unladen vehicle negotiate the curves with very small radius. At the outlet of transition curves with very

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small radius, there are design track twists at the joint with straight track parts. In particular freight wagons, when empty, are threatened by derailment.

Track twist is deviation of reliance point of one wheel from the plain determined by other three wheel's reliance points. When track car with its suspension system is on the twisted track, at the one wheel diagonal load increases and at the other wheel diagonal load decreases.

For this analysis, the phenomenon of load decrease is significant, because it leads to reduced wheel forces Q_i for certain amount ΔQ_i. Value ΔQ_i depends on suspension stiffness and on torsional stiffness of car body as well. All these components does make one system, which determins overall torsional stiffness.

With the lower torsional stiffness coefficient of car body, relief of wheel load is lower ΔQ_i, that means that a vehicle is more safer against the derailment.

3. VEHICLE TORSIONAL STIFFNESS CRITERION

3.1. Measuring positions

Measuring is done in stationary condition. Motor track car was relies to the wagon weighbridge with its wheels. Because of uneven distribution of weight in track car, measuring was done with four measuring positions (A, B, C, D) depending on lifting post and measured wheel forces (Fig. 2) according to [3].

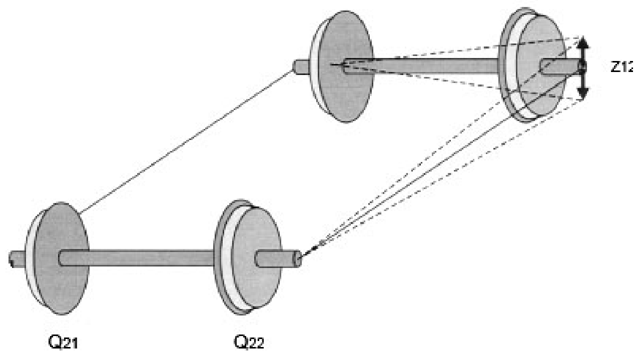

Fig.2. Reliance of motor track car at wagon weighbridge

3.2. Measurement principle

At vehicle reliance posts out of measuring points, location of jack is enabled. By means of jack, vehicle was lifted to the height that simulate maximum twisted track height - h_1. Vehicle was lifted at middle of axle box. Before measuring, the vehicle was protected against movement. Measurement was performed gradually while lifting (loading) and while lowering (relief).

3.3. Measuring values

Values measured during testing are wheel forces: Q_{11}, Q_{12}, Q_{21} and Q_{22}, using wagon weighbridge, and lifting height of axle boxes: 11, 12, 21 and 22, z_{11}, z_{12}, z_{21} and z_{22} respectively using displacement transducer. Based on measurement results, twist diagrams $Q_{ij} = Q(z_{ij})$ are evaluated for all four measuring positions A to D. Only two diagrams, for measuring position „A", are shown for example. First diagram (Fig. 3) applies to underframe before reconstruction and the second one (Fig. 4), applies to the underframe after reconstruction.

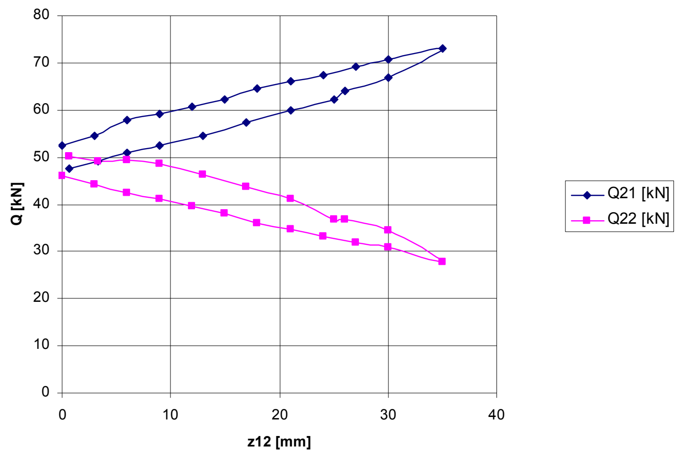

Fig.3. Twist diagram for measuring position A for underframe before reconstruction

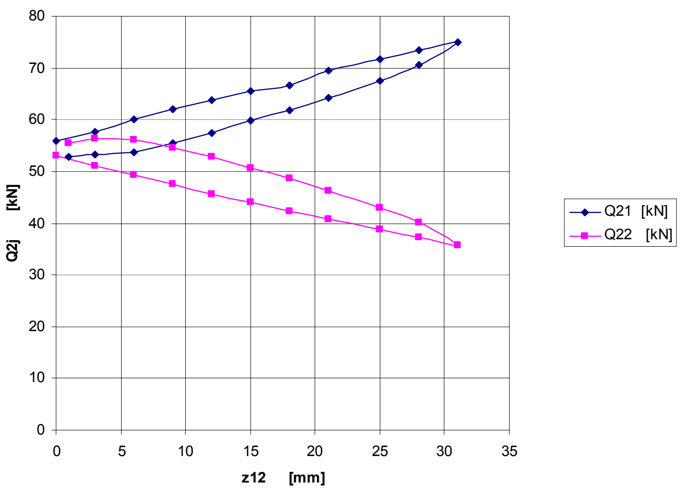

Fig.4. Twist diagram for measuring position A for underframe after reconstruction

For measuring position „A" force changes were registered by the wheels 21 and 22 depending on the lifting of wheel 12. Hysteresis loops in twist diagrams are result of friction in the vehicle body.

3.4. Assessment quantities

For several measuring positions, torsional stiffness of the vehicle - c_{tA} was calculated according to the formula indicated in [3].

$$c_{tA} = \frac{\Delta Q_t}{g^*} \quad [\text{kN/‰}] \qquad (1)$$

where: ΔQ_t is wheel force change during twist tests, taken from twist diagrams (fig. 3 and 4) for determined value of vehicle twist g*

g* is vehicle twist, calculated according [3] as:

$$g = 7 - \frac{5}{2a} \ [‰] \quad (2a \text{ in m}) \qquad (2)$$

for 2a = 4,3 (m), it becomes:

$$g = 7 - \frac{5}{4,3} = 5,84 \ [‰]$$

These values are shown in tables 1 and 2 for the case before and after stiffening the frame respectively.

Table 1. Wheel force change during twist test before stiffening the frame

Quantities	Measuring position			
	A	B	C	D
ΔQ_t [kN]	15,94	13,74	16,98	15,9
c_{tA} [kN/‰]	2,729	2,353	2,91	2,723

Mean value of torsional stiffness of the track car, taken from four measuring position is:

$c_{tA} = 2,679$ [kN/‰]

Table 2. Wheel force change during twist test after stiffening the frame

Quantities	Measuring position			
	A	B	C	D
$\Delta Q'_t$ [kN]	15,69	17,56	20,21	17,96
c'_{tA} [kN/‰]	2,687	3,007	3,461	3,075

Mean value of torsional stiffness of the track car, taken from four measuring position is:

$c'_{tA} = 3,058$ [kN/‰]

3.5. Calculation of limit values of torsional stiffness

Limit values of torsional stiffness of two axle vehicles will be determin according to the formula indicated in [3].

$$\lim C_{tA} \cong \frac{\lim \Delta Q_t}{g^*} \qquad (3)$$

where: $lim\Delta Q_t$ is permissible difference of wheel forces, because of twisted track and is calculated according to the formula indicated in [3] as well.

$$lim\Delta Q_{t,j} = lim\Delta Q_j - \Delta Q_{fzo} \qquad (4)$$

where: ΔQ_{fzo} is wheel force change of empty vehicle, calculated according [3] as:

$$\Delta Q_{fzo} = \Delta q_o \cdot \overline{Q_{0\,j}} \qquad (5)$$

where: Δq_o is mean value of the wheel force change rate of empty vehicle

$\overline{Q_{0\,j}}$ mean value of wheel force of empty vehicle

Substituting measured values in to formula above, becomes:

1) *for the vehicle before stiffening the frame*

$lim\Delta Q_{t,1} = lim\Delta Q_1 - \Delta Q_{fzo} = 42–17,34 = 24,66$ kN

$lim\Delta Q_{t,2} = lim\Delta Q_2 - \Delta Q_{fzo} = 35,98–17,34 = 18,64$ kN

2) *for the vehicle after stiffening the frame*

$lim\Delta Q'_{t,1} = lim\Delta Q'_1 - \Delta Q'_{fzo} = 41,31–16,84 = 24,47$ kN

$lim\Delta Q'_{t,2} = lim\Delta Q'_2 - \Delta Q'_{fzo} = 39,69–16,84 = 22,85$ kN

Considering that for axle 2 permissible difference of wheel forces due to negotiating twisted track is less than for axle 1, then the limit values of torsional stiffnes of the vehicle are calculated in relation to axle 2, as more severe criterion.

$$dozC_{tA} \cong \frac{doz\Delta Q_{2t}}{g^*} = \frac{18,64}{5,84} = 3,192 \quad [kN/‰]$$

$$dozC'_{tA} \cong \frac{doz\Delta Q'_{2t}}{g^*} = \frac{22,85}{5,84} = 3,913 \quad [kN/‰]$$

3.6. Evaluation of the measuring results of torsional stiffness of the track car

All measured and calculated values of torsional stiffness, for all measuring positions, are below limit values. Torsional stiffness coefficient mean value is consequently below limit value, as for track car, both before reconstruction and after reconstruction of underframe.

3.7. Discussion of the measurement results

Preview of a margins of safety of mean values of torsional stiffness of the track car is given in table 3.

Table 3. Margins of safety of torsional stiffness before and after reconstruction of underframe of track car

MS [%]	MS' [%]	ΔMS [%]
16,1	21,85	+26,3

Margins of safety regarding torsional stiffness coefficients are quite large. The situation after stiffening of underframe is, somewhat, more favorable. Increase of margin of safety for 26% is recorded. At a glance it could seems paradoxically, because after stiffnening of underframe more favorable situation occurs regarding torsional stiffness. It is because the limit value of torsional stiffness is sliding value and depends on mean value of wheel force change rate of empty vahicle, which is lower after reconstruction of the underframe because of more equal distribution of wheel forces in this case. The torsional stiffness coefficient of the vehicle after reconstruction is, however, higher for 12,4% as expected.

4. CONCLUSIONS

Based on the analysis of the constructive solution to overcome the problem of derailment, it can be concluded that, the track car had satisfying characteristic of torsional stiffness even before reconstruction of underframe. Thanks the reconstruction, performance of track car stability is improved but at the cost of increasing the mass of the vehicle.

Reasons of derailment of previous type of track car: DHD-200, which is the same in terms of car body as a new type of track car: DHD-200 DK, should be further research.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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55 YEARS OF TYPE DVM2 LOCOMOTIVES EXPLOITATION

Marko DJUKIĆ [1]

Abstract *– In 2012 it will be 55 years from the beginning of the exploitation of diesel-electric locomotives type DVM2. It is a basic type of shunting locomotives that are manufactured in factory Ganz MÁVAG for the needs of railways and industrial companies in Hungary but mostly for export. In the beginning of the 1960's (JŽ 641.0) and later in the beginning of the 1970's (JŽ 641.1 and 641.2) the locomotives were supplied by the former Yugoslav railways and they were for the needs of ŽTP "Beograd". The paper shows a brief history of supply, the introduction into traffic and exploitation of locomotives type DVM2.*

Keywords - diesel locomotive, exploitation, history, remotorization.

1. INTRODUCTION

The locomotives type DVM2 (hun. *Dízel-Villamos Mozdony 2*) represent the leading type of diesel-electric locomotives manufactured in factory *Ganz-MÁVAG* in Budapest, for railways and industrial companies in Hungary but mostly for export *<Hungarian State Railways Machine Factory MÁVAG (Magyar Állami Vas-, Acél- és Gépgyárak). In 1959 MÁVAG merged with the Ganz Wagon and Machine factory under the name Ganz-MÁVAG, that worked until December, 1987 when it was divided into many independent companies.>*. They are designed for shunting service although they can be used both for traction of light freight and passenger trains on plain lines without train heating. The first locomotive was manufactured in 1954 and up until 1977 which is the year the last one was made a total of 926 locomotives were manufactured (table 1.) so they are among the largest manufactured types of diesel-electric shunting locomotives in the world.

2. THE DEVELOPMENT OF LOCOMOTIVES TYPE DVM2

In the beginning of 1949 within the modernization program and in cooperation with the Relevant Ministry, the Hungarian State Railways (MÁV) ordered from MÁVAG the making of projects for: 130 hp light diesel shunting locomotive with a mechanical power transmission, 600 hp heavy diesel shunting locomotive with an electrical power transmission, and 2000 hp diesel locomotive designed for the traction of trains on main lines, with an electrical power transmission. During the 1950's the development of locomotives type DMM2, DVM2 (class MÁV M424) and DVM3 (class MÁV M601) began in *MÁVAG* based on their own concept and the *Ganz-Jendrassik* diesel engine *<György Jendrassik (1898-1954)-engineer, scientist, academician. He worked in the Ganz factory as the main engineer (1927) and then the executive director (1942). In 1924 he began to explore the development of diesel engines in order to design the first version of diesel engines for railway vehicles under the name Ganz Jendrassik in 1928. In 1943 he was elected a corresponding member of the Hungarian Academy of Science.>*. Unlike the first two types that had the serial manufacturing *<According to MÁVAG project, the locomotives type DMM2 were developed in factory Wilhelm Pieck Vagon és Gépgyár, Győr (type Rába M.030 and M.033, class MÁV M275/M28).>* the third one had only a prototype made since the project of locomotive for train traction on main lines proved unsuccessful. Therefore, MÁV later made the decision to purchase the locomotives class M61 and M62 that were manufactured in factories *NOHAB* (Sweden) that is *LTZ* (USSR) respectively.

In the March of 1954 two locomotive prototypes type DVM2 with a 16-cylinder Ganz-Jendrassik XVI Jv 170/240 diesel engine rated at 600 hp (441 kW) *<This type of diesel engine was built for the first time into the locomotives BHÉV 7400 and 7401 that were manufactured in Ganz for Budapest suburbian railway (BHÉV) in 1943.>* and *Ganz* electric equipment were finished in *MÁVAG*. They got the numbers M424.5001 and 5002 according to MÁV numbering scheme of that time. In 1955 and 1956 a detailed research of both prototypes was made after which a serial manufacturing of locomotives began and it lasted 20 years.

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Table 1. List of delivered locomotives type DVM2

Purchaser	Year of manufacture	Number of locomotives	Locomotive numbering
Prototype	1954	2	M424.5001, 5002
Hungary-MÁV	1957-1969	166	M44.001-166
	1969	5	201-205
	1970	24	501-524
Hungary-GySEV	1969-1971	5	M44.303-307
Hungary-industry	1963-1977	89	A25.004-013, 017-020, 022-040, 042-085, 088-099
Czecho-slovakia-ČSD	1957	5	T455.001-005
China-CR	1957-1959	17	ND15.101-117
	1965	8	unknown
China-industry	1959	1	unknown
Albania-HSH	1959	1	unknown
Poland-PKP	1958	10	Lwe58.01-10
	1961-1968	263	SM41.01-263
Poland-industry	1961-1968	31	S101-131
	1963-1968	11	SM41.A-I, K-L
	1966	2	SL-3,4
	1966-1971	64	SM41.979, 1016-1020, 1154-1160, 1164-1169, 1263, 1274-1276, 1325-1334, 1380-1383, 1422-1434, 1577-1586, 1602-1605
	1963	1	unknown
Yugoslavia-JŽ	1960-1961	15	641.001-015
	1971-1972	45	101-145
	1970	20	201-220
Bulgaria-BDŽ	1965-1968	65	51.02-66
Bulgaria-industry	1962-1970	41	DE60.01-41
	1965	1	DE60.01
	1971-1973	29	51.108-136
Turkey-industry	1976	5	TCDF 9-13
	Total:	**926**	

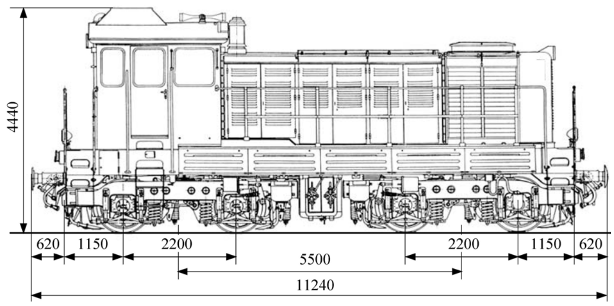

Fig.1. Locomotive type DVM2

In order to improve the constructive solutions during the manufacturing there were differences in the types of equipment that was built in and certain functioning schemes so the locomotives were manufactured in many varieties beginning with DVM2-1 in which two prototypes were placed and then from DVM2-2 to DVM2-69 for the rest of the locomotives.

At the same time with the manufacturing for MÁV there was also the manufacturing of locomotives for export mainly to the countries of the former "Eastern" bloc. By the end of 1957 the delivery of locomotives to Czechoslovakia and China started, in 1958 to Poland, in 1960 to Yugoslavia, in 1962 to Bulgaria, etc.

3. THE LOCOMOTIVES DELIVERED TO HUNGARY

The first locomotives were delivered at the end of 1957 to MÁV. They had numbers M44.001 and 002, in accordance with the new numbering scheme that was introduced to MÁV at the end of 1950's. One of those locomotives was presented in Czechoslovakia and in Poland. Unlike the two prototypes with the mass of 58,65 t and the maximum speed of 65 km/h, these locomotives were with the mass of 61,76 t and the maximum speed of 80 km/h, and there were also the differences in the vehicle dimensions. In 1957 both prototypes were bought by the Hungarian oil and gas industry - OKGT (today's MOL) that sold them to BHÉV in 1963 and then in 1977 they were bought by MÁV. Their numbers changed in the following way: M424.5001→OKGT A25.001→BHÉV DL XVI L732→MÁV M44.209 and M424.5002→OKGT A25.003→BHÉV DL XVI 731→MÁV M44.211.

The Hungarian State Railways acquired 195 locomotives, about 4/5 of which were arranged in Budapest (depots Ferencváros, Hámán Kató, Rákos and Déli), Szombathely, Miskolc and Debrecen.

Fig.2. MÁV M44.522 (Photo: Marko Djukić)

The industrial companies in Hungary acquired 89 locomotives most of which for the Diósgyőr-Miskolc, Ózd and Dunaújváros metallurgical complex, OKGT, Pétfürdő nitrogen fertilizer factory, etc.

The Győr-Sopron-Ebenfurt railway (GySEV) acquired 5 locomotives. In 1963 MÁV gave its GySEV locomotives M44.001 and 025, and in 1989 - M44.088, 018, 073 and 122 that were renumbered into

M44.301, 302 and 308-311 respectively. During the 1990's GySEV bought the industrial A25.070, 080 and 025 that were renumbered into M44.312-314, so today there are 14 locomotives type DVM2 in GySEV and they are all of Sopron depot.

During the exploitation the locomotives delivered to Hungary often changed owners between MÁV, BHÉV, GySEV and the industrial companies. Today there are about 1/3 of delivered locomotives in exploitation that are mostly remotorized.

4. THE LOCOMOTIVES DELIVERED TO POLAND

Following the world trends in the middle of the 1950's Polish State Railways (PKP) decided to gradually withdraw the steam locomotives from the exploitation. Having in mind that the Polish industry of that time was not prepared for the manufacturing of the adequate diesel locomotives the only solution was to import them provided that only manufacturers from the countries of former "Eastern" bloc could be considered. Since the Hungarian industry already had a certain experience in the manufacturing of diesel traction units, the locomotives type DVM2 were chosen. After the testing in 1957 PKP made the decision to purchase 10 locomotives of which the Lwe58 class was formed, that is SM40 from 1960 when the new numbering scheme was introduced to PKP. Since the electro-pneumatic equipment on them was not reliable, the following locomotives were delivered to PKP with certain modifications (class SM41). In order to reach the level of the locomotives class SM41 the modification of locomotives class SM40 was done later but their numbers remained the same.

The Polish State Railways acquired 273 locomotives, 10 of them class SM40 and 263 class SM41. They were mostly arranged in Kraków, Szczecin, Gdańsk, Poznań and Katowice depots. During the 1960's they were the leading type of diesel locomotives in PKP. With the manufacturing of locomotives type SM42 in Polish factory *Fablok*, Chrzanów (1822 locomotives delivered to Poland, 1156 of which for PKP and 666 for the industry), the locomotives class SM40 and SM41 slowly started to be less important. Because of the unreliability in service the withdrawal of the locomotives from exploitation began in the middle of the 1980's and then rapidly in the beginning of the 1990's. From 1988 to 1994 PKP dismissed about 200 locomotives of that type and the last one (SM41.226) in June, 2000. The locomotives SM40.01 and 10, that is SM41.01, 43, 126, 164, 175, 190 and 226 (111) were saved for the museum.

The industrial companies in Poland acquired 109 locomotives mostly for the Nowa Huta (Kraków) steelworks, Płock and Trzebinia oil rafinery, Tarnobrzeg chemical industry, etc. One locomotive was given to PKP where it was numbered SM41.264. What is interesting is that the numbers of the industrial locomotives SM41.979-1605 were formed from their *Ganz-MÁVAG* manufacture numbers.

5. THE LOCOMOTIVES CLASS JŽ/ŽS 641

The former Yugoslav Railways (JŽ) acquired 80 locomotives type DVM2 for ŽTP "Beograd", now Serbian Railways (ŽS). The locomotives were classified into 3 subclasses: 641.0, 641.1 and 641.2 which were each slightly different. Locomotives 641.111-145 were manufactured in the factory *Djuro Djaković*, Slavonski Brod in cooperation with *Ganz-MÁVAG* that was the main deliverer of the equipment. During the 1970's and 1980's they were the leading type of shunting locomotives of ŽTP "Beograd" although they were often used for the traction of light freight and passenger trains on lines with a lower axle load. They were arranged in all depots of ŽTP "Beograd". The withdrawal of the locomotives from traffic began during 1990's. Today there are 8 locomotives in ŽS active fleet: 641.012, 116, 118, 135, 142, 144, 208 and 215, although only 641.215 of Ruma depot operates. Locomotive 641.005 was given to the Railway museum, while 641.218 and 219 were sold in 2005 to company *Šinvoz*, Zrenjanin.

Fig.3. ŽS 641.208 (Photo: Marko Djukić)

Based on the concept of locomotives type DVM2 the locomotives type DVM12 (subclass 641.3) were developed in *Ganz-MÁVAG* during the 1980's.

6. THE LOCOMOTIVES DELIVERED TO BULGARIA

The first locomotives type DVM2 were delivered to Bulgaria from 1962 to 1964 for Metalworking Company Kremikovtzi (MCK) that ordered in that time 14 locomotives (DE60.01-14). The first 5 locomotives were delivered in 1962 and one of them (DE60.01) was taken for a test in 1963 by Bulgarian State Railways (BDŽ). This locomotive was used for shunting in station Yana mostly to exchange coaches with the MCK. In 1965 BDŽ made the decision to purchase 10 locomotives type DVM2 (51.02-11) and after their delivery they officially became the owner of the tested locomotive that got the number 51.01. The next locomotive delivered for the industry in 1965 got the number DE60.01. The locomotives delivered for BDŽ in the first and mostly the second delivery of 25 locomotives that were delivered in 1966 were arranged in Sofia depot where they changed one part of the shunting steam locomotives in Sofia railway junction. By the end of 1968, 30 more locomotives were delivered to BDŽ.

The industrial companies in Bulgaria acquired 71 locomotives mostly for MCK, Maritsa Iztok and Varna thermal power plants, Pernik steelworks, Burgas oil refinery, Pleven cement factory, non-ferrous metals smelter in Plovdiv, etc. In 1968 the locomotives DE60.19, 27 and 32-35 were given to BDŽ after which they were renumbered to 51.67-72 respectively, and later also 51.110, 136 and 172. In 1970 the renumbering on the industrial DE60 into class 51 started which was formed from locomotives of that type on BDŽ. The locomotives that were manufactured after that for the industry got the numbers 51.108-136 and class DE60 that were then in the industry were renumbered to 51.150-161, 163-168 and 170-186.

BDŽ had 75 locomotives type DVM2, that were mostly arranged in depots in the North part of Bulgaria (Ruse, Gorna Oryahovitsa, etc.) and a smaller part in Sofia. The withdrawal of the locomotives from traffic began in 1989 with the locomotive 51.26 and rapidly in the beginning of the 1990's. Today there are 6 locomotives in exploitation in BDŽ and they are all of Ruse depot. The locomotive 51.01 was given to the Ruse Railway museum.

7. OTHER DELIVERED LOCOMOTIVES

The Czechoslovakian State Railways (ČSD) acquired 5 locomotives that were arranged in station Čierna nad Tisou (border station between Czechoslovakia and USSR). Considering that in the late 1950's the Czechoslovakian industry of that time began to manufacture the locomotives of similar characteristics the locomotives class T455 operated very shortly so they were withdrawn from traffic already in the late 1960's.

PR China acquired 26 locomotives, 25 of which for China Railways (CR) and one for the industry.

In 1959 one locomotive type DVM2 was delivered from Hungary to Albanian State Railways (HSH) besides the locomotives type T435.0 from Czechoslovakia, for traction of trains on lines Durrës-Tirana and Durrës-Elbasan-Kraste.

The Karabük steelworks in Turkey acquired 5 locomotives.

8. THE REMOTORIZATION OF LOCOMOTIVES

The remotorization programs were done in order to decrease the immobilisation and to enable more locomotive reliability.

The locomotive JŽ 641.012 was remotorized in 1982 in *Ganz MÁVAG* by SEMT Pielstick 8PA4V-185VG diesel engine manufactured in the mentioned Hungarian factory, while 641.118, 135, 142 and 208 were remotorized from 1990 to 1992 in *Šinvoz* by SEMT Pielstick 6PA4V-185VG diesel engine manufactured in factory *Uljanik*, Pula.

In the late 1980's, 20 MÁV (M44.5) and 5 locomotives of industrial companies in Hungary were remotorized by Ganz 16VE17/24R diesel engine and in the beginning of the 1990's seven more locomotives of industrial companies in Hungary by SEMT Pielstick 6PA4V-185VG diesel engine manufactured in *Ganz*. From 1994 to 2000 the remotorization of locomotives GySEV M44.3 was done by Deutz TBD604BL6 diesel engine and from 1999 to 2004 forty more MÁV locomotives by Caterpillar CAT 3508 DI-TA diesel engine, of which the class M44.4 was formed (M44.401-440).

Besides the lowering of the maintenance costs, the remotorization of the locomotives resulted in significant savings in energy costs since the above diesel engines have a lower fuel consumption.

9. CONCLUSIONS

The locomotives type DVM2 were delivered to 8 countries of the world and in most of them they had a significant role during the introduction of diesel traction in the exploitation at the end of 1950's and in the 1960's. Except in Hungary to some extent they are about to stop operating, or they stopped operating in the rest of the countries. Having in mind that they are almost all amortized the remotorizaton seems to be the only solution in order to continue with operating.

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Traffic and Transport

XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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ORGANIZATIONAL MEASURES IN FUNCTION OF INTERMODAL TERMINAL CAPACITY ENHANCEMENT

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Abstract *– With intensive implementation of the intermodal transport techniques and the tendency of constant growth of intermodal transport share, since the 80s of the last century to today, capacity needs of the intermodal terminal were also growing. The terminal capacity can be increased not only by investing in its infrastructure, but also trough implementation of certain organizational measures. In this respect, it is necessary to prepare preview of this measures, also known as "the best EU practice", already shown to be successful and adapt them to the market of our region, which is yet to develop in this direction.*

Keywords – intermodal terminal, capacity, organizational measures.

1. INTRODUCTION

Operators of intermodal terminals from Europe, which were primarily designed for accommodation of a certain number of intermodal transport units (hereinafter: ITU), very often find themselves in a situation when there is saturation of terminal physical capacity. In that moment any subsystem inside the terminal, as well as the applied operational technology, cannot meet the requirements of intermodal transport operators (hereinafter: ITO), customers, as well as the requirements of railway undertakings (hereinafter: RU) and road transport carriers.

When it is impossible to enlarge terminal infrastructure, terminal operators (hereinafter: TO) are in situation to look for a pragmatic solutions in order to eliminate the obstacles on short-time basis and continue with their regular operations. On the other hand, many TOs holding the leading positions in the Europe, have developed mechanisms for process optimization and efficient terminal capacity management that can be classified within the scope of *"the best EU practice"*, and as such represent guide models to be followed during the design of modern intermodal terminal in Serbia and its integration into the intermodal transport market in Europe.

2. TERMINAL CAPACITY BASIC DETERMINANTS

Terminals are the basic components of an integrated intermodal transport network and as such should be able to respond to the requirements in terms of capacity, in order to ensure transhipment between road-railway on efficient and safe way.

Transhipment capacity of the terminal is determined by several basic factors:

terminal position in the rail and road network;
size and organization of the terminal;
length of handling tracks and
type and number of the handling equipment (mobile or fixed equipment[1]).

With more intensive implementation of intermodal transport techniques, followed by a tendency of constant growth of intermodal transport shares, from the 80-ies of the last century to the present time, characteristic *modular* type of terminal layout has been developed, and usually applies as such during the terminal design.

Transhipment terminal capacity can be increased in two ways:

1. physical enlargement of terminal infrastructure (increasing the number and length of handling tracks; expansion of interim storage space or by switching to more efficient handling mechanization); or

2. with implementation of organizational measures, which are primarily related to the optimization of technological processes.

Since the economic situation and still on-going crisis greatly affect the transport sector - optimization

[1] According to generally accepted standards, mobile handling equipment can meet requirements of up to *70,000 ITU/ year*. Above these values the fixed handling equipment is needed.

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of technological processes with implementation of organizational measures will get more and more importance.

3. INTERMODAL MARKET IN SERBIA AND REGION

The project of Pan-European transport corridors, defined in 1994 in Crete, and later amended in Helsinki in 1997 is of great importance for the countries of South Eastern Europe. From ten corridors in total, the six of them passes through the region of Southeast Europe, which valorises the transport position Serbia as a transit country.

One of the basic principles of arrangement within defined corridors is *intermodality*, which provides a choice between integrated and interrelated forms of transport. Basically defined corridors are being further developed through the concept of *TINA* (Transport Infrastructure Needs Assessment) transport network which belongs to the specific corridors, and represents a continuation of already established functional Trans-European Transport Network- *TEN-T* on the territory of the European Union.

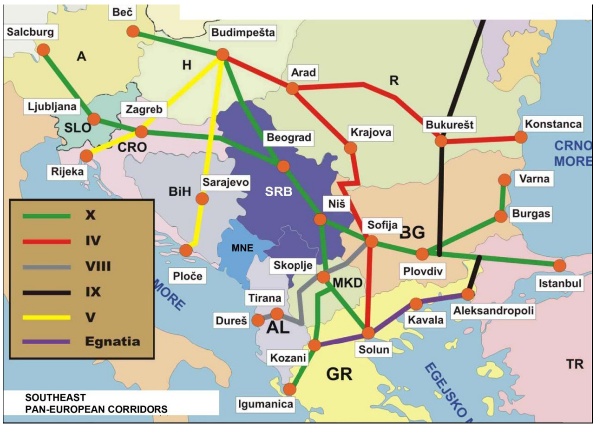

Fig.1. Distribution of Pan-European corridors

Focussing on Serbian intermodal transport market, the very first impression would be that intermodal transport is very poorly developed and is primarily related and identified as continental transport of containers in import, i.e. with their further distribution in hinterland of the ports.

According to available information[2], general conclusion of stakeholders is that needs and the current state of affairs of the Serbian economy correspond to the volume of around 50,000 TEU per annum. In that structure 40" containers are predominate (with a share of about 70%), while the ratio of containers in import and export is 80%:20%. Due to this disparity in the exchange of goods, containers are in most cases returning empty to port, in order to avoid container demurrage charges.

[2] Material of the Project: "Facilitating intermodal transport in Serbia", EGIS / DB International, 2012.

Dominant directions are ports of the Adriatic Sea, firs of all Port of Rijeka with a share of about 70% of the total flow. The port of Bar currently serves the Serbian market with about 20% of container flows, while the remaining 10% goes through the ports of Koper, Constantza and Thessaloniki. Intermodal transport stakeholders have a general consensus that this trend will dramatically change with joining of Croatia to EU (in mid-2013.), which will result in a significant redirecting of flows that gravitate to countries outside the EU to the port of Bar.

There are also some potential for transport of swap bodies which could seem interesting as well.

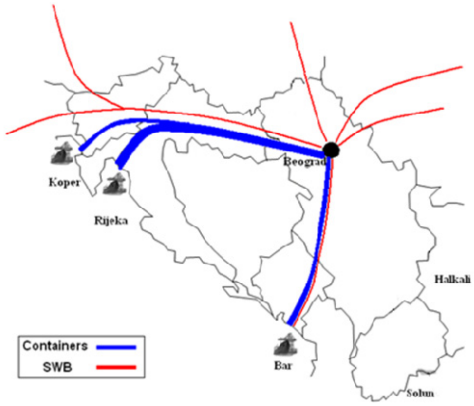

Fig.2. Potential of Serbian intermodal flows

Presence of other intermodal transport techniques (except road - railway transport of containers) in total intermodal flows is negligible, primarily due to the lack of modern terminals equipped for transhipment of these ITUs.

Attractiveness of Serbia on the international intermodal transport market will be substantially changed with construction of modern intermodal terminal in Batajnica (suburbs of Belgrade).

4. THE CHARACTERISTICS OF THE FUTURE TERMINAL

As mentioned above, so-called modular type of terminal is composed of several functional units. Manipulative area is the most important entity and in the case of Belgrade Intermodal Terminal (hereinafter: BIT) will consist of:

- 2 transhipment tracks for loading/unloading of ITUs and 1 bypass track for shunting locomotive rides;
- 4 truck lanes: 2 bypass lanes, 1 loading/unloading and 1 emergency lane and
- interim storage space: 3 rows for temporary storage of ITUs (containers, frigo-containers, swap bodies and containers with dangerous goods).

Planned layout of the future BIT terminal, which was designed according to the principles and guidelines of *"the best EU practice"*- provided by DB

International experts with world-wide experience in this field , is shown in the following figure.

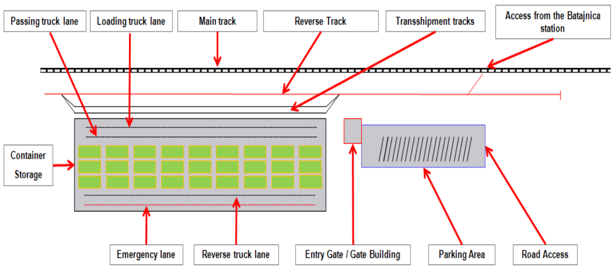

Fig.3. BIT layout

Step-wise development of Belgrade Intermodal Terminal would ensure economic and financial sustainability of investment and ensure planned iterative capacity expansion fully in accordance with the growing demands coming directly from the market and potential clients.

5. PREVIEW OF ORGANIZATIONAL MEASURES

Bearing in mind that there is no modern intermodal terminal of this type in Serbia and region - a question arises: ***which organizational measures should be implemented after terminal construction in order to ensure adequately managing of its capacity and positive influence on increase of ITU flows?*** Organizational measures, implemented by TO, would also represent a form of incentive for development of intermodal transport in general.

There is a whole set of measures, rising from the practice of successful and well operating intermodal terminals in EU, but only certain number of them could be applicable on a market conditions currently existing in Serbia and region.

Implementation of this measures should be aimed at positioning of an intermodal transport as a fully competitive to traditional and today in a vast majority used road transport.

Among the measures, which could be seen as the *best EU practice,* but still applicable on a Serbian market, the following could be distinguished:

5.1. Shunting services controlled by TO

The RU engaged by ITO with the main rail haul is also usually used for inside terminal manoeuvring rides, as well as for carriage of wagons taken out or wagons to be included in the composition (small shunting rides).

In order to ensure efficiency of these operations it is necessary to establish good and smooth coordination, which seems to be hardly possible in the present working environment. Practice of successful European terminals shows that shunting operations are managed by TOs, totally independent or in cooperation with RUs. Positive effects of this approach are:

operational processes facilitation and reduction of losses between involved stakeholders,
TOs are enabled to reduce train delays,
raising of operational flexibility and
higher prioritisation level of operations.

This measure ensures not only terminal capacity and efficiency enhancement, but also brings a benefit to RUs since they don't need to provide their own equipment and personnel in every terminal.

5.2. Bonus/malus pricing system

Interim storage capacity management in a proper way, as the most vital entity, is essential for a smooth functioning of a whole terminal. Inland port terminals (usually operating as *dry-ports*) are generating a considerable share of their revenues from storage of containers. On the other hand, rail-road terminals are facing the problem when ITUs are staying placed inside terminal interim storage for more than 24 hours. This is particularly owing to the fact that these terminals were originally designed for direct rail-road transhipment - in practice only 10-15% of transhipping operations are done directly.

Bonus-malus pricing system, as incentive at the same time, represents a measure for interim storage capacity management which foresees a reward (*"bonus"*) for a customer who picks up his shipment early - for example in the first three hours after the time of availability of the train. Customers picking up their shipments after 24 hours are being extra charged trough a penalty (*"malus"*). TO is invoicing interim storage services to his clients on a monthly basis and their costs can significantly vary depending on number of *"bonuses"* or *"maluses"* they have collected in a previous month.

Estimations are that such measure ensures a total terminal capacity increase effect of about 5%.

5.3. Increase of the *flow factor*

If the inside terminal track capacity, on a daily average, is occupied by only 1 train (inbound or outbound) then this terminal applies a static capacity management concept. In this respect it is necessary to introduce a term of so-called *"flow factor"* which has a value of 1.0 when each usable meter of a handling track is used by a train being processed. Following the same approach, a flow factor of 2.0 means that every meter of handling track is being used by 2 different trains (inbound or outbound) on average daily basis.

It is obvious that introducing of such a dynamic operational concept is one of the most effective measures to enhance the capacity of a given terminal infrastructure. Raising this flow factor from 1.0 to 2.0 implies theoretically a chance for doubling of the transhipment capacity.

With implementation of this measure usage of transhipment tracks is doubled on a daily basis since train sets or *shuttle* trains are being hauled on a tracks dedicated for parking (manoeuvring rides).

Implementing costs for this measure are primarily related to incensement in cost of manoeuvring services that will drastically participate in the final price which TO invoices to the clients.

5.4. *„First/Last mile*“ trucking services

Similar reasons as for shunting operations have led some of TOs to offer, as part of their service package, ITUs pick up/delivery service on relation intermodal terminal-client (and vice versa). This type of service completely fits into one of the very basic principles of intermodal transportation - *"door to door"* transportation service.

With provision of adequate and sustainable services of this type, a *win-win* business relationship can be created bring a direct benefit to all involved stakeholders.

Although direct impact on the total transhipment capacity of a terminal may be marginal, trucking services can also be used to increase a capacity of interim storage space and to facilitate accessibility to usually crowded handling area of a terminal.

5.5. Extension of terminal opening time

Opening time of intermodal terminals differs from site to site, but it could be said that some typical schedules have evolved in Europe over the years. Only a very few intermodal facilities are working on a single-shift-basis and are open for 8 - 10 hours. Most of them apply a two-shift scheme with 12-16 opening hours in total, from Monday to Friday. Considering a 24-hours economy these terminals are on average open to customers with 53% of the maximum available time.

Extension of terminal opening time can be done in two ways:

- with enlargement of opening hours for operating part of terminal (rail-side),
- with extension of the opening time also for road-side part for pick-up/delivery of ITUs.

Extending the terminal opening time could mean increasing the daily opening period (up to 24 hours) or that terminal will be opened also on Saturdays or even Sundays.

Implementation of extension of customer-related opening times could bring about an increase of transhipment capacity of at least 10 - 20 % compared to the initial situation.

5.6. Sustainable and punctual railway timetable

Terminals that are already congested with ITUs or operating at their capacity limits have a very few or no further *buffer* time to compensate delayed trains. Only in case that trains are running with a high rate of punctuality, and timetable is due to this sustainable, terminal can operate smoothly - both in terms of its capacity and customer relationships. On the opposite, unreliability of a timetable can have a significant negative effect on terminal technical capacity.

Experience of TOs around the Europe leads to the conclusion that lot of joint efforts have to be given in order to induce a change of behaviour of RUs. As an instrument for that they foresee *bonus-malus incentives* and *priority rules* - *"punctual trains are served first"* - priority is given to trains running to according Timetable on force. *"Time windows"* for train arrivals are defined in accordance with the length of train routes, in order to absorb small delays and avoid greater negative impact on the operation of terminal.

Successful implement of this concept needs interaction and close cooperation between TO, RU and ITO. Today this can be seen only in a very few terminals in Europe. But still, this represents a base on which should be built in the future in order to achieve full interaction of all stakeholders in intermodal transport chain. Implementation of this measure could bring up to 20% of terminal capacity enhancement.

6. CONCLUDING REMARKS ON THE EXAMPLE OF BIT

The focus of the region towards EU accession and integration in European transport flows and trends, provides a significant opportunity to enhance intermodal or combined rail-road transport in our region as well. It should be primarily seen as response to demands of the economy in the region, in terms of positioning of their products to various markets (especially in the EU market), then in response to the issues of competitiveness of our carriers and, ultimately, as the answer to the ever-present and actual problems related to environmental aspect of transportation.

Design, construction and management of modern intermodal terminal in Serbia can be completely seen as *"ground-breaking" or "pioneer"* project, so guidelines and examples of the *"the best EU practice"*, followed by experience and expertise of international experts in this field, are more than welcome.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '12

STANDARDIZED MANAGEMENT SYSTEMS (SMS) IN THE FUNCTION OF IMPROVING THE BUSINESS PERFORMANCE OF SERBIAN RAILWAYS

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Abstract *– Many factors influence the development of the organization and its ability to maintain business performance in the long-term and to develop them constantly. Creating a sustainable balance between economic – financial, social and environmental interests is the goal of any transportation organization today, which can not be realized without the use of standardized management system. Experiences of organizations that have done so, indicate that harmonization of the management using ISO requirements, has a positive impact on business performance of transportation organizations. The paper promotes the idea for a more serious approach to standardization of the existing management system and implementation of ISO standards in the Serbian Railways, in order to improve business performance and to increase effects of the process of restructuring.*

Keywords - transportation, sustainability, standards, business performance.

1. INTRODUCTION

In the past ten years or so, there have been significant changes on the market of transport services. Processes of globalization, liberalization, deregulation and harmonization of the market are gaining momentum, so a very important question arises on how to use the positive effects of these processes and accelerate the integration of the transport systems of Serbia into the European systems.

The answer to this question is not an easy one, because today all of the transport organizations in Serbia are facing an increasing complexity of the market, technological, financial, organizational and social demands, which often puts them in a situation where they can not satisfy the interests of all engaged participants, who are directly or indirectly involved in the transport process. Global economic crisis additionally makes the position of the domestic transport organizations more difficult and together with a series of subjective weaknesses which manifest themselves inside the organizations, significantly influences the multiplication of the factors, which diminish the sustainability of the organizational development, that is, its possibility to maintain and continually develop its business performance in the long run. Overcoming this condition requires great efforts, primarily of the state, in whose authority is the legal regulative, but neither should the role of the transport organizations be negligible, because they should adopt and implement the contemporary achievements and recommendations of those who succeeded and had results in the improvement of the business of organizations, that is, their performance.

Improvement of the business performance is becoming a great challenge for great transport systems, such as Serbian Railways for example, which should, for their survival, in a very brief time period suggest a strategy, by which an organization that operates at a great loss, could be transformed into an organization that adopts modern principles of business and makes profit. Bearing in mind the fact that the basic product of the transport organization is the transport service, one might say that Serbian Railways should follow the example of

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European railway authorities, which implement the rules of business conduct where quality has become the key word, and the beneficiary of the transport service has become the quality measurement of the service offered [3]. The application of SMS and their implementation in the existing management system of the railway, requires a completely new way of managing an organization, whose goal should be: optimal functioning of all business processes, application of adequate information and communication technologies, adequate valuation of working features on one hand, and the results achieved on the market on the other. Through defining, measuring, planning and managing performances, with support and SMS application, conditions are created that business processes in railway are organized in proper manner, which could improve the position of the organization on the transport services market and satisfy the expectations of service beneficiaries.

2. PREVIOUS RESEARCH AND EXPERIENCE

The result of SMS implementation and tracking their influence on improving the business performance of the organization is the existence of a great number of published books, analyses, studies, articles in expert magazines, and the complexity of the matter and they could be seen on the basis of significant differences in viewing this matter. The goal of most of the analyses is to shift the questions tied to the practical use of SMS from the area that handles the ways and experiences in implementing into the area of determinations of the effect of their application [2]. Analysis of literature shows that researchers have been handling different aspects of the influence of certain models of quality management, such as the impact on product/service quality, business expenses and achieved profit, human resources management, relations with interested parties… Short review has been given in this paper, considering the research performed at universities in some countries of Europe and Serbia. Researchers at the University of Perugia (Italy), in the industrial engineering department had gathered 3024 articles, based on which they performed the classification of different influences of the application of ISO 9000 standards on organizations performance. Basic influence division is into internal (quality system, productivity, product/service quality, competitiveness, human resources development and organizational climate) and external (international trade, suppliers, product/service beneficiaries and other interested parties and the market) [4]. Incurred results, as a consequence of this research approach, show the significant influence of the applied SMS on every stated category of organizational performance. The University of the Basque Country (Spain) has performed the research of the influence of ISO 9000 certification on the profitability of Basquian organizations, in the province that is considered one of the regions where ISO certification has mostly come to life. By comparison of the data between 400 certified and 400 uncertified organizations a link has been determined between the implementation of ISO 9000 standard and the quality system of the organization, improvement of product/service quality, reducing the costs of production, enhancing the possibilities for the sale of product/service and improving profitability [5]. University of Macedonia in Thessaloniki (Greece) has, by researching the influence of ISO 9000 standards on TQM, analyzed their influence on leadership, strategic quality planning, data quality and their analysis, HR management, supplier relations, relations with product/service beneficiaries and quality and design of the product [6]. Research in Serbia began several years ago at Faculties of the University of Belgrade and Novi Sad, Vinča Institute and at several private companies that deal with certification. They are based on researching the influence of QM principle on good practice QMS I IMS – and in our country the research for the level of maturity of QMS as the basis for the change of TQM in Serbia [3]. Key indicators of the research in progress should show the relation between the level of QM practice and achieved business performance.

3. INTRODUCING SMS INTO THE OPERATIONS OF SERBIAN RAILWAYS

Bearing in mind the results and experiences of developed European railway authorities in relation to introducing SMS, when it comes to modern business operations of Serbian Railways, it is necessary to search for the answers to the questions – when and how to start the project of implementing SMS, and to avoid, above other things: the unnecessary dissipation of one’s own resources, cost increases, exposing co-workers to stress, increase of dissatisfaction of the transport services beneficiaries, and with the shortest time period for the realization of the project. The best way for the successful implementation of SMS, which has for its goal the improvement of the railways business operations is studying the requests tied to: transport policy in the EU and standardized management systems.

Demands of EU transport policy – based on increasing the overall transport efficiency, cost reduction and ecological acceptability of the transport system, and these are the key spots on the way to the necessary transformation of the railway system, in the area of: interoperability, service quality, security and opening the national market. The essence of changes refers to creating the conditions for getting the prescribed licences for managing the public railway infrastructure and performing transportation in the railway traffic. Disregarding the specificity of the requests that should be fulfilled by the licenced infrastructure manager and transporter, their essence is based on applying standards regarding:

- quality and level of railway infrastructure services and quality of transport service,
- environment protection and protection and concern for the health and safety of the employees,
- risk management and information safety.

Requests of SMS – related to the requests that certain management systems contain, regarding: quality management, environment protection, health and safety of the employees, socially responsible business and information safety. By implementing SMS into the existing management system of the organization, requests of European transport policy could be realized and also significant effects on all levels of organizations processes could be achieved. As the most significant effects of certain management systems one may put forward [7]:

QMS (ISO 9001:2008)

- gaining and/or establishing business trust with known and potential clients,
- improving the business capability and productivity,
- focus on achieving business goals and expectations of the product/service beneficiary,

EMS (ISO 14001:2004)

- identifies, controls and improves the influence of the activities of the organization and its products/services on the environment,
- implementing a systems approach, through which evidence could be given that the organization has realized the desired goals.

OHSMS (OHSAS 18001:2007)

- injuries in workplace are reduced to a minimum or completely eliminated,
- bestoves trust upon beneficiaries/buyers that there is commitment to managing the health protection and work safety that could be proven.

CSRMS (ISO 26000:2010)

- strengthening the competitive advantage and morale boost, commitment and productivity of the employees,
- improving relations with companies, governments, media, suppliers, colleagues, beneficiaries and the community where the activity is performed.

ISMS (ISO 27001:2005)

- improving competitive advantage, reducing the risk from damaging and losing information, and incurred costs,
- achieving compliance with the existing regulations, and strengthening the trust of clients, employees, co-workers, institutions and all interested parties for knowing that their data is safe.

Table 1. Description of steps to sustainable success – levels of organizational maturity [1]

Character and level of maturity	**Organization beginner**	**Proactive organization**	**Flexible organization**	**Innovative organization**	**Sustainable organization**
Elements of maturity	**Level 1**[1]	**Level 2**	**Level 3**	**Level 4**	**Level 5**
Focus on	Products	Buyers, requirements from laws and regulations	Additional interested parties	Balanced focus on existing interested parties	Balanced focus on incoming interested parties
Approach	Reactive	Based on process management	Process management enables flexibility	Approach of effective interrelated processes based on innovations	Approach of effective Interrelated processes which include ties to important interested parties
Improvement drivers	Reclamation& financial indicators	Data on customer satisfaction	Inputs from suppliers, partners and employees	Inputs from other interested parties	Inputs from all other interested parties
Activities and systems	Basic working procedures	QMS applied	Effective and integrated management system	Agility (speed, flexibility and nnovation) supported by management system	Management system supported with a benchmark
Results	Negligible (random) keeping of the results	Some stated results	Stated results	Consistent, positive results and sustainable trends	Performances developed and maintained in the long run
Learning	Individual and negligible	Systematical learning on mistakes	Spreading knowledge inside the organization	Continual improvements based on learning and culture of spreading knowledge	Learning spreading with important interested parties
Implementation of PDCA	Random usage of certain PDCA quadrants	Initial usage of PDCA cycle in some processes	PDCA cycle is applied and is completely embedded in key processes	Self-initiating PDCA cycle is applied inside the organization,	PDCA cycle is initiated by the interested parties

[1] Every next level contains features of previous levels.

Insight into the mentioned effects of implementing the standardized management systems indicates that they significantly contribute to the strengthening of business performances of the organization, and additional effort that could be invested into the sistematization of the effects, would show that it helps gain elements of the strategy for the development of the organization, whose goal is the long term enhacement of the organizations performances, as seen from the financial perspective, perspective of the beneficiary, business processes and development. For Serbian Railways the implementation of SMS is inevitable, based on experience of European railway authorities, which were accompanied by the railway authorities from the neighbouring countries, which should contribute to the creation of successful railway transport organization and its equal participance on the European market of transport services.

4. ASSESSMENT OF THE POSSIBILITIES OF SERBIAN RAILWAYS FOR INTRODUCING SMS

Serbian Railways are at the time in the finishing phase of the restructuring process, that represents the chance to enhance and redefine the operations and relations inside the organizational units. The success of this process should mostly depend on the way in which Serbian Railways will manage their operations, that is, the processes inside the system. Introducing SMS is at the same time the chance to know at any time: who, how, when and where is performing the activities related to the optimal functioning of the business system.

Creating a sustainable organization is a job which requires additional effort, as from the state, and also from the railway, and the beginning of this process and the necessary step could be the estimate of the level of organizational maturity. In table 1. levels of organizational maturity have been shown and steps toward sustainable succes with defined elements and criteria of maturity [1].

Serbian Railways according to the elements of maturity could be named an Organization beginner, whose approach to business processes is far from the requests and possibilities which have organizations that are on higher levels of maturity.

Bearing in mind the fact that Serbian Railways are a joint-stock company, whose only stockholder is the state, a logical conlusion emerges to launch an initiative for changes in the way and the principles of business, a great business system such as Serbian Railways, which should be started by the state, with significant effort and an honest intention of the management, whereas all of the employees should be included.

5. CONCLUSION

The highest management of the organization has the obligation to establish a comprehensive management system, which could follow and manage all of the elements of the business system, with the goal to satisfy the demands of all interested parties, including legal regulations which determine the operations of an organization. Bearing in mind the fact that Serbian Railways are an organization with negative business results, the change of business philosophy imposes as a condition for survival.

A new approach requires dramatic changes where the lead role should belong to the state and the railway management, where neither the role of the employed workers is not negligible. One of the ways to approach changes is to introduce SMS as a powerful tool for improving business performances of the organization.

A new time is coming, all of the European railway managements have for years been preparing for the battle on the market of transport services, and the question that inevitably imposes is as follows: Will there be place in this new time for Serbian Railways?

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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POSSIBILITIES FOR INTEGRATED TIMETABLES WITHIN THE NETWORK OF SERBIAN RAILWAYS

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Sanjin MILINKOVIĆ [3]
Andreas SCHÖBEL [4]

Abstract *– Timetables are key control elements for railways. They determine all costs for operation but also have a great effect on a railway company's revenue, because the utilization of trains depends largely on travel times and available connections. Within this paper, a fully functioning system of so called integrated timetables within Serbia's present inter-city railway network is developed. The big difference to common timetables is, that all lines are served several times daily with a fixed interval of two hours and all trains serving one junction have the ability to be connected to all other directions there within short transfer time. So it is possible to reduce total travel time between several Serbian towns up to three hours without major investment for improving the tracks' maximum speed. The two-hour-interval has been decided to perform the balancing act between working out ways to increase the attractivity of railway networks while making best use of the modest rolling stock and infrastructure which are now available. Going along with renovation of the tracks it might even be possible to shorten the intervals to one hour, to increase the trains' speed and to integrate local traffic within this system in the future.*

Keywords – Railway Operation, Integrated Timetable, Passenger Transport, Simulation.

1. INTRODUCTION

The idea of this paper was to develop a system of integrated timetables within the network of Serbian Railways. The focus is placed on Inter-City connections as well as links to surrounding countries. The following concept is based on considerations published in Fischer, 2012 [1] and gives an overview on a possible system of integrated timetables that can be realized quick and affordable. By introducing an integrated timetable, the total travel times can be reduced without upgrading the tracks to higher speed that involves a large amount of investments and years of realization. Together with an adequate number of punctual and reliable trains, image and signification of railways in Serbia can be clearly increased. If tracks are renewed yet, these ideas can easily be transferred to the new configuration, as they are not an interim solution but a fully working concept.

2. DEVELOPING AN INTEGRATED TIMETABLE

First of all, several terms going with timetables have to be defined: A *clock-faced timetable* is a timetable with constant intervals between the single trains. A *symmetric clock-faced timetable* extends this definition on both directions. And, at last, an *integrated timetable* takes this into account for the entire network made up of junctions (hubs) and lines (so called edges) between them.

Such a timetable can only be realized, if two mathematical boundary conditions are satisfied, the *edge-* and *circle-equations*. The edge-equation requires the travel time between two hubs to be half of the interval or a multiple of that. To fulfill the circle-equation, every ride from one hub through the network back to this one must be a multiple of the

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interval [2].

Of course it is often not possible to realize this *ideal integrated timetable*, as hubs should not only be chosen by mathematical reasons but of their notability (bigger towns, junctions). Then it can be slightly modified so that, for example, in this hub some connections have a longer time for interchange.

The main slogan for the traffic on a network of integrated timetables is “as fast as required” unlike common timetables where it is “as fast as possible”. To provide good connections it might be useful even to stretch travel times on single sections, if this measure leads to better connections. In general is to be said that in this concept, time is much more important than distance.

Another important factor is the design of the hubs. As several lines meet together there, an adequate number of platforms must be provided and trains must not obstruct each other during arrival or departure. By using one platform with two tracks for up to four trains (with intermediate switches), the necessary interchange time can be reduced as people don’t have to change platforms.

For the timetable development itself a top-down-system is essential. After setting lines and hubs, travel times have to be calculated and the lines can be linked. Single lines should be determined by their length and long-distance-lines have a higher priority than regional or local lines as latter are much easier to be linked in. After that, the demand of rolling stock can be estimated and circulation plans can be developed. The last step is to check the plausibility of the concept by examining tracks’ and stations’ capacities, especially on single track sections. Problems found by this evaluation can be solved in a further step of iteration [3].

Two factors are essential for a functioning system of integrated timetables: Reliability and punctuality of the trains. As all lines are well connected, the delay of a single train can cause lots of delays throughout the entire network. So it must be careful proved whether a train has to wait for a delayed connection or not. All in all integrated timetables increase the attractiveness of a railway system more than any other comparable effort.

3. CONCEPT FOR SERBIAN RAILWAY’S NETWORK

As mentioned in chapter two, the first aim was to set the individual lines and connections between them. Based on today’s network of long-distance trains, seven lines were chosen to make up the core of the concept (Table 1). Five of them are domestic ones (although several trains may be extended across the borders) and two are almost exclusively meant for international transport. The domestic ones should get typical local toponyms for marketing reasons and all lines are assigned colour codes. All lines run in a two hour interval, which is the result of the balancing act between working out ways to increase the attractivity of railway networks while making best use of the modest rolling stock and infrastructure which are now available.

Table 1. Projected Inter-City lines

Name	Route
IC1 Vojvodina	Beograd – Novi Sad – Subotica
IC2 Morava	Beograd – Lapovo – Niš
IC3 Zlatibor	Beograd – Požega – Užice
IC4 Raška	Stalać – Kraljevo – Užice
IC5 Šumadija	Lapovo – Kragujevac – Kraljevo
EuroCity	Beograd – Sr. Mitrovica – Zagreb
EuroCity	Beograd – Vršac – Timişoara

IC-Lines 1 and 2 as well as the Eurocity connection with Croatia are today’s core of the network with serving four of Serbia’s five biggest towns (Beograd, Novi Sad, Niš and Subotica) and being part of the European Corridor X. IC-Line 3 is part of the important connections with Montenegro’s port of Bar. The IC-Lines 4 and 5 are set up to establish proper connections around the junction of Kraljevo and require special consideration.

The first idea was to establish a direct connection Beograd – Kraljevo via Lapovo but this wasn’t considered well because according to the boundary conditions mentioned in chapter two, short transfer times would not be possible within this configuration. So it was decided to establish a connection Stalać – Požega (extended directly to Užice) with good connections to Beograd at Požega, as well Niš and Beograd at Stalać (Fig.1). To explain the time format in this figure, x and y stand for even and odd hours. The single numbers are minutes for interchanging trains. As the timetable is symmetrical, these times are valid for both directions.

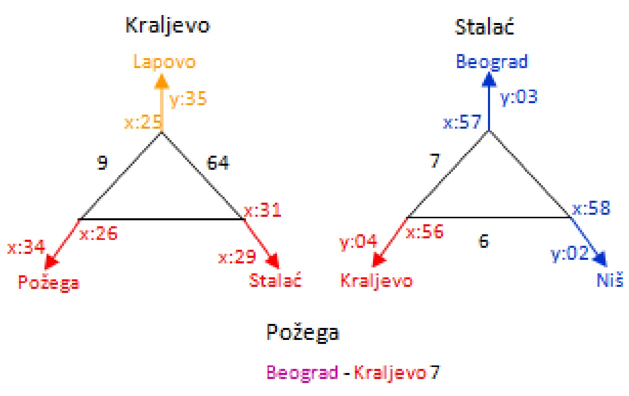

Fig.1. Examples for interchanges at several hubs

The remaining gap between Lapovo and Kraljevo is filled by an additional IC-Line tendering proper connections to nearly all other directions and providing a larger number of intermediate stops. Tough the lack of a direct connection, the total travel time from Čačak and Kraljevo to Beograd via Požega (PO) can be significantly reduced in comparison to the direct route via Lapovo (LA). This is one of the biggest efforts of an integrated timetable (Table 2).

Table 2. Comparison of selected travel times

Connection	via PO	via LA
Beograd – Kraljevo	3h 47min	4h 15min
Beograd – Čačak	3h 20min	4h 45min
Beograd – Vr. Banja	4h 19min	4h 50min

The network is completed by the second EuroCity line linking Beograd with Timişoara in Romania also serving some important towns in Vojvodina like Pančevo. An overview of these seven lines and some regional lines that might be linked in is shown in Fig.2. The same time format is used as in Fig.1.

All intermediate stops are shown in Fig.2. It turned out to be useful to introduce only one category of fast trains as, caused by the low speed in the entire network, additional stops take not so much time. To avoid additional stops for crossing, southbound trains on IC-Line 2 run via Mladenovac as trains heading towards Beograd serve Mala Krsna.

For calculating travel times of the trains, timetable documents of ŽS were used [4]. So it came out that the travel times between two stations are almost the same like in today's timetables. All travel times were calculated with one class 441 locomotive and up to eight carriages. Intermediate stops take mostly two minutes time, unless engine or direction are changed. Recovery margins recommended by the UIC in leaflet 451-1 [5] were specified.

As mentioned in chapter one, the goal was to develop a fully functioning system on today's infrastructure. Nevertheless, some investments have to be made to provide a reliable supply, but they are locally restricted. The two biggest projects are the refurbishments of the tracks between Kraljevo and Stalać, where there is no traffic at the moment and the completion of Beograd Centar railway station. This is necessary to guarantee the shorter travel times in comparison to the route via Beograd's main station. A small but effective measure is also to build a double track section with a length of two kilometres at Mali Iđoš to enable crossing trains without an additional stop (Fig.2).

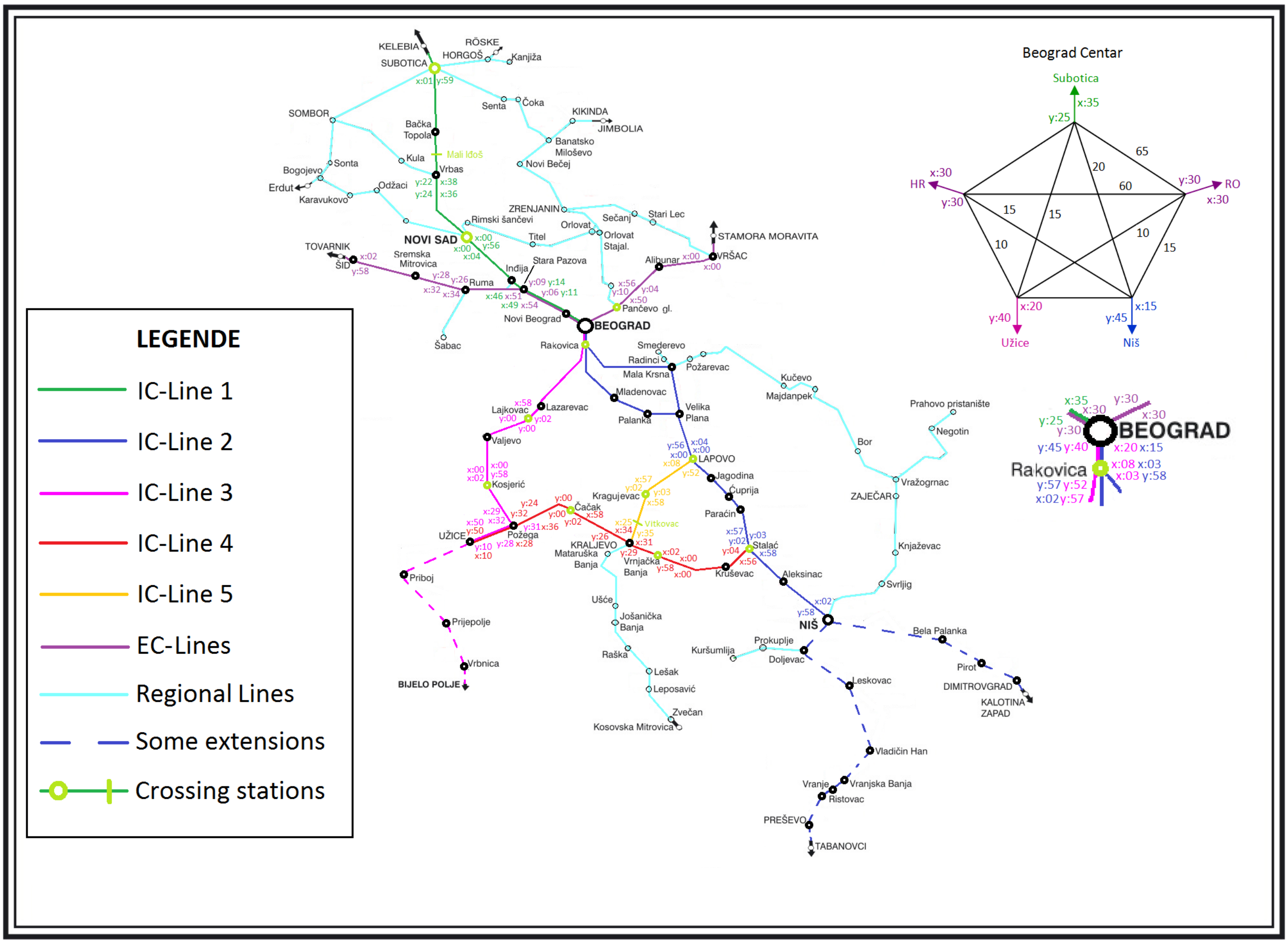

Fig.2. Overview on all seven lines with intermediate stops, travel times and possible regional connections

4. VERIFICATION OF THE RESULTS BY USING A SIMULATION PROGRAM

The manually calculated results from chapter three underwent verification with OpenTrack, a simulation program for railway systems developed at ETH Zurich. By using this tool it is possible to simulate different operation conditions on railway networks e.g. regular timetables, impacts of delays or occupancy of tracks and stations. After running the simulation, the results can be used for the next step of iteration to optimize the timetable.

The train configuration was worked out more in detail, so travel times were calculated with following train compositions: IC-Line 1 and EC to Zagreb with ŽS 441.7 and six carriages; EC to Timişoara with ŽS 661 and five carriages, IC-Lines 2/3 with ŽS 461 and up to nine carriages and for the remaining two lines, diesel multiple units ŽS 712 were taken in account because of the request to change the direction quickly at Stalać, Lapovo and Požega. Of course, trains can be made up with a lower number of carriages or the class 712 DMUs can be substituted by newer class 711.

The simulation run showed that the elaborated timetable concept is fully working. Small delays up to ten minutes could easily be made up between two hubs and along the line from Lapovo to Beograd, that is especially susceptible for delays, even 15 minutes can be obtained, which is essential to guarantee all connections at Beograd Centar station (Fig.2).

Experiments with higher delays showed that connecting trains should not wait longer than five to ten minutes, as otherwise they would carry on the delay to the next hub. So dispositions done by the dispatchers at the single hubs belong to the most important tasks.

Not part of the simulation was an investigation of the track capacity, because the exact location of signals and blocks was not known. As Fig.3 for the example of the line Beograd – Novi Sad – Subotica and an interval of two hours shows, there seem to be enough slots available for regional and freight trains. Within this figure, recovery margins can be made out by comparing the ideal (black) with the real (purple) lines.

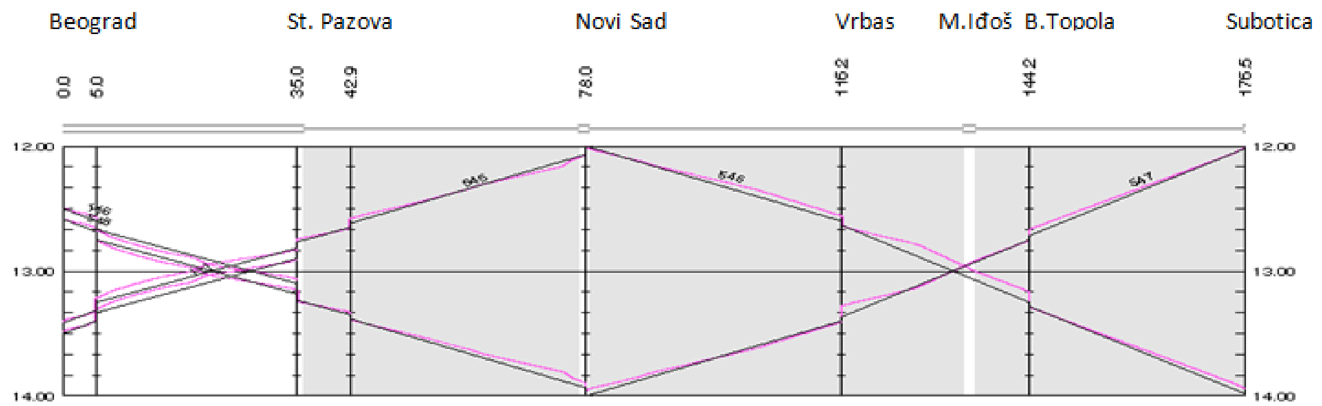

Fig.3. Timetable extract for Beograd – Subotica from 12:00 to 14:00 with IC and EC trains (OpenTrack)

5. CONCLUSIONS

The introduction of an integrated timetable on Serbia's railway network could be the first step to improve the situation of passenger transport in the country. As indicated in chapter four, the profitable freight traffic is not affected from the improvements in passenger traffic, as the tracks seem to have sufficient capacity to handle today's freight traffic.

The next step might be to adapt regional lines to fit into the timetable system. At hubs like Subotica, Novi Sad or Niš, the interchange time should be low and connecting trains should easily being reached on foot. Regional traffic on main lines should be adapted to the times of IC trains, so that there is also a good connection between faster and slower trains. After that, the target of an integrated timetable throughout the network is realized.

The third goal might be to modernize the tracks as well as the rolling stock. With rising of the actual speed limits, travel times can further be reduced. When the whole Corridor X is improved to a speed limit of 160 km/h, travel times of about two hours between Beograd and Niš and about 1 hour 30 from Beograd to Subotica will be possible.

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METROPOLITAN IN THE PUBLIC TRANSPORT SYSTEM OF SOFIA

Rusko VALKOV [1]

Abstract *– The report analyses the preconditions for building the metro in Sofia, as well as outlines the advantages of the metro as a kind of railway transport. Metro construction takes place in the central city part, in the conditions of continuous movement of the public transport lines, which requires the application of various methods of construction, presented in the report. Different public urban transport lines operate in Sofia – tram, trolleybus, bus, fixed-route taxi vans, and since 1998-2003 – the first radius of the metro as well. During rush hours large passenger flows are formed in the city. Along the main directions they reach 30 000 passengers per hour, and projections are that they will increase to 38 000 passengers per hour. World practice shows that the only solution for the quick and effective service of these large passenger flows and for easing traffic in the city is the speedy development of an off-street high-speed public transport with a big transportation capacity.*

Keywords - metropolitan, metro diameter, metro radius, transportation capacity.

1. INTRODUCTION

During the second half of the 20th century greatly increased worldwide the number of cities with over 1 million inhabitants. Over 450 cities in the world are in this category, a few dozen of these cities are with more than 10 million inhabitants. The huge number of residents and guests of these cities leads to almost insurmountable difficulties in solving their transport problems.

The transport systems of these cities are very complicated and usually combine several types of transport: railway transport – metropolitan, trams and light railway, and automobile transport – bus, trolleybus, cars and minibus.

In some cities, thanks to natural resources (Venice, Amsterdam, Hamburg etc.), is used water transport as well.

The increased auto mobilization and the low capacity of the street network, particularly in the central part of the city, cause a lot of traffic and ecological problems. In order to resolve them, various approaches are applied: traffic along isolated routes, usage of underground spaces, construction of overpasses, widening of the street network etc.

The goal is to reduce loss of traveling time, to rise at a higher level safety of passengers and vehicles, to increase the transport capacity on the most loaded destinations and to minimize the damaging effects on the environment.

Different transport modes of public transport system cover these requirements to different degrees. The most efficient solution to the problems of movement of large passenger flows by using speed railway – metropolitan, proven its indisputable advantages since its establishment in 1863 until now, namely:

- big transport capacity;
- high safety in movement of vehicles due to lack of contact with other vehicles and pedestrians;
- use of ecologically clean energy – electricity, for all types of activities: movement of vehicles, signaling and telecommunication, lighting, ventilation, repairs, etc.;
- does not occupy open spaces which significantly facilitates the process of operation, servicing of passengers and protection of environmental sites and historical values.

2. METROPOLITAN IN SOFIA

For those reasons in the last few decades are continuously built metropolitans, and more than 50 % of the operating 180 subways worldwide are under development and supplement.

The development of the metropolitans is carried out in three directions:

- building new lines to the existing general scheme;

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- extension of the already built lines;
- renovation and upgrading of various systems and elements of the metropolitans: improvement of the construction of the rail roads and the systems for electricity supply and signaling, improving the level of safety and passenger services, etc.

The intensive development of the metropolitans is accompanied by the application of different contemporary methods, technologies and equipment.

The beginning of the urban public transport in Sofia was set in 1880, a year later after the city was announced for capital of the Republic of Bulgaria. The first public transport carriages initially drove from the current “Sveta Nedelia” Squire to Sofia railway station (now Sofia Central railway station), which at that time was outside the city, and later on other routes. With the expansion of the city constantly increases the public transport lines and their length. The main lines of public transport are now tram, trolleybus, bus, fixed-route taxi vans.

In the 1960s, when started the application of industrial methods of construction in the residential areas, Sofia and all major cities in Bulgaria, grow rapidly.

In less than two decades in Sofia are already formed the largest residential complexes: Lyulin, Mladost, Nadezhda, Druzhba, Ovcha Kupel, etc., considerably distant from the city center and from each other. In a short time, regardless the administrative restrictions, the residents of the capital exceed one million. As a consequence, huge passenger flows are formed, which requires increasing the number of public transport lines and the number of vehicles. Significantly increases as well the number of automobiles.

The increased number of residents and vehicles, as well as the extremely exhausted traffic capacity of a large part of the historically formed street network, significantly worsen the transport and environmental situation in Sofia. The travel speed by public transport on weekdays in the rush hours (7:30 – 9:30 and 16:30 – 18:30) is under 10 km/h. Big traffic jams are daily occurrence in the city.

For solving the transport problems in Sofia are taken early measures. In 1968 the Council of Ministers of the Republic of Bulgaria decided to explore opportunities to build speed tram lines. The rapid growth of the capital and the forecasts for its further development led in 1972 to the decision for construction of subway which to become backbone of public transport with a share of over 50 % of passenger transportation in the city. Different versions of the general metro scheme had been discussed and proposed. The original concept was to be built a loop (8-shape), which serves the center of the town, and at the same time combines the advantages of the closed loop from operational standpoint. Long time prevailed the idea for diametric-circular scheme similar to Moscow metro.

The formed passenger flows on the basis of location of the large residential complexes, and a thorough analyses of economic and technical feasibility, predetermine the metro construction to be carried out in diametrical scheme with 3 lines, which scheme allows extension of lines and deviation from them. According this scheme the total length of the three lines is 56 km with 48 metro stations, and the lines cross in the central part on three nodal stations: Serdika, Sofia University and National Palace of Culture. This scheme facilitates the passengers as any point can be reached with maximum one change of the lines. It is accepted in the central city part the location of the metro stations and the section tunnels to be with shallow underground deployment, and in peripheral areas – open-air. Diametrical scheme is applied mainly in cities with star-like structure of the residential areas and comparatively dense construction.

For Sofia metropolitan with utmost length is the metro diameter East-West (length 21 km and 17 metro stations (1-39), which connects two of the largest residential complexes in Sofia – Mladost and Lyulin, through the city center. This metro diameter is most important for unloading the city center and therefore with it began the construction of the metropolitan in Sofia in 1979. For faster execution of the construction works, the west part or so called metro radius, is divided into 4 sections. The first of the 4 sections with a length of 6,4 km and five metro stations is entered into operation on 28.01.1998. The next sections are put into operation in 1999 and 2000. In April 2003 started to operate section “Slivnitza” – “Obelya”, which appears as an extension of the metro radius. The length of this section is 1,9 km, as 1,2 km is underground and the rest is above ground. Metro station “Obelya” is quite different from the others on that metro radius. It is the only metro station in curve, with two side platforms, unlike the others, and above ground, situated partially on a bridge.

The main parameters of track and engineering equipment are connected with the requirements for radius of the curves in plan 1-63 and maximum longitudinal gradient (1-64). The adopted minimum radius of the curves of the main lines is 600 m (1-63). Curves with radius up to 300 m are exceptionally allowed in complicated geological conditions, need for building demolition, reconstruction, etc. For curves with radius less than 2000 m are applied transition curves (1-63 below). Maximum permitted longitudinal slope of the lines is 0,04 for underground sections and 0,035 for sections above ground. Engineering-geological conditions, under which the construction is done (1-68), most of the built lines and the presence of exceptionally variable underground communications, require application of different methods of construction. The above ground method is the least costly, so this method is used mostly in the construction of all metro stations and of most of the section tunnels.

3. CONCLUSIONS

Sections in the city center cannot be built by above ground methods, as in this part are the largest and most important state buildings and many cultural monuments. To avoid much of the excavation and to reduce to minimum possible disruption in the normal rhythm of the city, it is adopted construction to be carried out underground, by shield method using modern automated shield. Shield complex secures simultaneously digging of the tunnel tube, installation of the tunnel structure and injection of the concrete mixture behind the structure. The insured by the shield counter pressure provides stability to the located near the track buildings and facilities.

Sofia metropolitan is the largest construction and transport facility in the capital of Bulgaria. It accepts great part of passenger flows and unloads the heavy traffic situation in the city.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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QUALITY MANAGEMENT IN TRANSPORTATION OF DANGEROUS SUBSTANCES BY RAILWAY

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Abstract: *This paper explores the issue of transportation of dangerous substances as one of the services provided by a railway company. The service is defined as classical logistic service. The paper takes the very concept of logistics – the logistics as a subject in which the service is created – as a cetrepoint in the process of defining the transportation of dangerous substances as one of logistical services. The logistics of transportation of dangerous substances by railway is seen as a process of planning, organisation, control, and the factual path of dangerous substances on their journey by railway – from the point of loading to the point of unloading. Quality management of logistical service of transportation of dangerous substances by railway includes planning, security and quality improvement.*

Keywords - transportation, dangerous substances, quality, management.

1. INTRODUCTION

In view of potential hazards and adverse effects, management of dangerous substances transportation flows is an activity of general interest. Management of railway transportation of dangerous substances should be viewed as implementation of measures required for handling of dangerous substances during their transportation from the point of loading, placing them in temporary storage if necessary, loading, transportation/ haulage, unloading, placing in storage and delivery to the user, including monitoring of such activities.

Railway transportation of dangerous substances takes place within a system where a logistics process, comprising a set of specific, interconnected or interactive logistics activities, is carried out.

Railway transportation of dangerous substances offers a service provided by the railway to its users, where such type of service is defined as a standard logistics service.

The railway, or its management, aims at increasing the scope of service and improving its quality without considerably increasing the costs thereof.

2. DANGEROUS SUBSTANCES RAILWAY TRANSPORTATION SERVICE

Transportation of dangerous substances by railway should be viewed as a system. Railway transportation system of dangerous substances comprises input elements, internal logistics process, logistics activities, output elements, external influences and regulatory aspects, Figure 1.

Input activities of railway transportation system of dangerous substances, in addition to dangerous substances, include various resources: material resources, infrastructure, technological resources, human resources, financial and other resources.

The internal or logistics process performed within the railway transportation system of dangerous substances can be defined as a set of interconnected or interactive activities through which resources, as input elements, are transformed into output elements of logistics services.

The result of logistics process of railway transportation of dangerous substances is the logistics service of dangerous substances railway

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transportation, which represents the output element of dangerous substances transportation system.

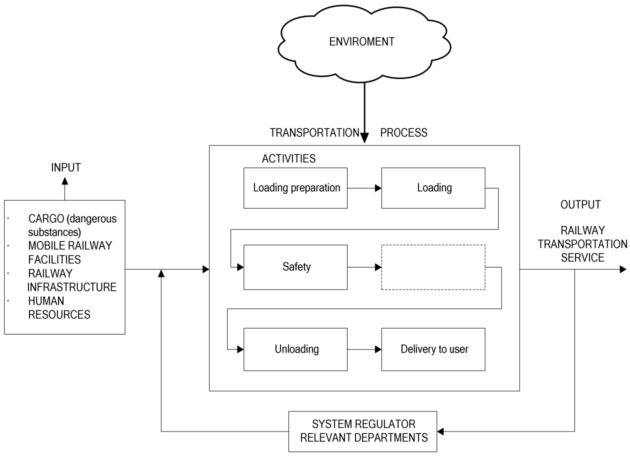

Fig.1. Railway transportation of dangerous substances as a system

Railway transportation system of dangerous substances is a process of planning, organizing, control and implementation of flows, processes and activities of dangerous substances transportation, from the point of receipt and loading thereof, to the place of storage or delivery to the user, for the purpose of meeting user demands with minimum costs and minimum adverse effects to people and environment.

Organisation and management of the logistics process of railway transportation of dangerous substances must be based on the quality principle, where the process of railway transportation of dangerous substances should be focused on user demands in order to establish and maintain high quality level of the logistics process within the system. For a more successful organisation and management, railway transportation system of dangerous substances should be user-oriented, it should consider user needs and requirements and it should monitor specific changes in requirements arising from advanced systems.

Logistics process control of railway transportation of dangerous substances is an activity requiring constant monitoring, measuring, testing, comparing, analyses, checkups, detecting errors, omissions and inconsistencies and causes thereof, for the purpose of defining actions for improving transportation quality.

Railway transportation of dangerous substances can be viewed as a service provided by the railway to the users, which is a standard logistics service. Starting from the concept of logistics, the logistics of railway transportation of dangerous substances is defined as a process of planning, organisation, control and the factual path of dangerous substances on their journey by railway – from the point of loading to the point of unloading and delivery to the user.

3. SERVICE QUALITY OF DANGEROUS SUBSTANCES RAILWAY TRANSPORTATION

The issue related to the quality of logistics service of dangerous substances railway transportation represents the difference between the planned (desired) and reasonable (implemented) condition of service. The issues related to the quality of logistics service of dangerous substances railway transportation are detected by comparative analysis of such condition.

The quality of logistics service of dangerous substances railway transportation directly depends on the quality of logistics process or individual activities of such process.

Considering the fact that a typical feature of the logistics service of dangerous substances railway transportation is the complex structure of service providing activities and of external and internal connections, quality monitoring and improvement requires a methodological approach based on system analysis.

Quality assurance process is preformed by implementation, supervision, monitoring of implementation of dangerous substances railway transportation service and by elimination of the causes which may lead to unwanted discrepancies. Implementation of quality assurance process requires registering and monitoring of external and internal quality indicators of dangerous substances railway transportation.

External quality indicators should include features of logistics services required and expected by the users (safety, time, reliability, availability, acceptability, price, etc.), whereas, internal quality indicators should include features of logistics service related to the railway where the logistics service is actually implemented (utilization of facilities, efficiency, effectiveness, etc.).

Logistics activities are performed in order to provide a good quality of logistics service of dangerous substances railway transportation. Generally speaking, the quality of logistics service, including the logistics service of dangerous substances railway transportation, is measured by the following performance aspects: timeliness, safety, spatial targeting, timing, flexibility and professionalism.

The quality of logistics service of dangerous substances railway transportation can be viewed from the following aspect: user demands, criteria based on service, value of service, technical criteria and subjective opinion on quality.

The quality of logistics service viewed from the aspect of user demands is based on the assumption that quality is what users want and expect.

According to the service-based criteria, quality is defined as a set of features of logistics service and it supports the value of specific features. A special skill is expressing of "measurability" of such features.

The quality of logistics service based on value is the connection of purposefulness (level of user satisfaction) and price of logistics service. With respect thereto, the aim is to sufficiently satisfy user demands, with an acceptable price.

The quality of logistics service viewed from the aspect of technical criteria implies compliance with set standards and codes, or agreement with specific quality parameters. The basis of technical criteria is provided by RID.

The quality of logistics service based on subjective opinion is based on the idea of developing an image and familiarity of a logistics service and of the organization providing such service.

4. QUALITY MANAGEMENT OF DANGEROUS SUBSTANCES RAILWAY TRANSPORTATION

Quality management of dangerous substances railway transportation includes quality planning, assurance and improvement.

Figure 2 shows a quality management model of the logistics service of dangerous substances railway transportation, with input elements which, in addition to the quantity of dangerous substances, include transportation planning of such substances or dangerous substances management planning, necessary means of transportation and handling, necessary infrastructural resources and necessary human resources – personnel. Within the scope of logistics system, the logistics process of transportation and its individual mutually adjusted logistics activities are carried out at a defined logistics order.

The product of transportation logistics process, or of the functioning of such system, is the transportation logistics service, which includes all of its quality parameters and it represents the output element. The quality of such logistics service must be inspected constantly.

There is obviously a quality issue, where quality implies a difference between the planned and actual condition of logistics process and in turn, the quality of its product – the logistics service.

A process must be established to ensure constant monitoring and comparing of such conditions, so as to discover quality issues and causes of its unsatisfactory level. In practice, there are various methods of determining quality level. If the quality is unsatisfactory and does not meet user demands, necessary corrective actions are performed until, under specific material and organizational conditions, the satisfactory (expected, desired) level is achieved.

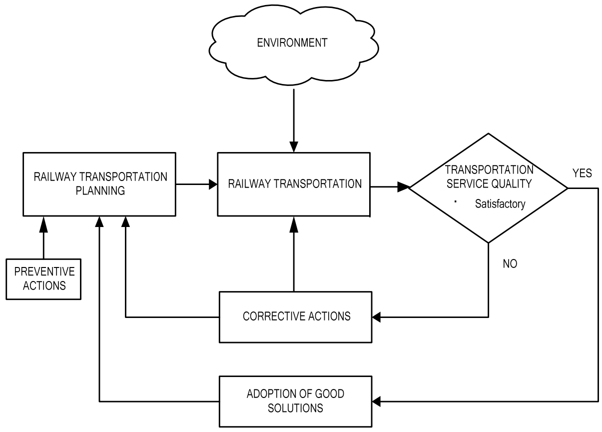

Fig.2. Quality management model of logistics service of waste material

Planning the quality of dangerous substances railway transportation service must be based on quality-related user demands. The more the users specify their service demand; the planning process is simpler and more specific. In order for the users to better express their demands, they need to be familiar with specific logistics system parameters, or available resources.

The task of logistics system management, or the railway, is to ensure the required quality. For that purpose, it must constantly supervise and monitor implementation of logistics process, activities and thereby, the service, and also to make good any discovered faults and causes which may lead to disruptions and unwanted effects. Implementation of this task – quality assurance – requires feedback from logistics processes, which reflect the existing condition.

Quality improvement of dangerous substances railway transportation service is an ongoing process, important both to the railway and the end user. Quality improvement requires taking certain steps in planning, implementation, control and inspection and enhancement of quality. The focal point of the process of quality improvement of dangerous substances railway transportation service is defining (developing) and implementation (carrying out) of corrective actions to eliminate the causes that lead to a deviation of achieved quality from the planned quality.

Since they cannot be explicitly measured or determined, the qualitative aspects of specific values of the measured quality of logistics service make the quality measuring process very complex. In most cases, logistics service users define or specify their quality expectations or demands in the previously described manner, by using various attributes. The nature of attributes is such that it provides sufficient possibilities for defining a reliable system and criterion to provide necessary absolute values of logistics service quality.

Logistics service providers, in their efforts to meet logistics demands or desires and expectations of their users as much as possible, regularly face such issues. This is the reason for development of specific/suitable procedures and models for monitoring and measuring logistics service quality.

Measuring of logistics service quality is the main precondition for improvement of the process of providing such service. It is generally known that if one cannot measure something, one also cannot improve it.

Essentially, the issue of measuring logistics service quality lies in the lack of standards which could be successfully applied to such needs. Standardization process in the area of logistics services, and especially their quality, is very difficult to achieve. This is mostly due to a high level of heterogeneity of logistics services. By conducting specific investigations, numerous research and educational institutions worldwide are making efforts to find the answer to the question: how to determine the measures of quality of logistics service.

Measurement system needs to enable identification of the issues related to quality of specific activities within the logistics service process and focusing on resolving the key issues. Such issues are mostly related to insufficient knowledge of important facts on which the implementation of services depends and which may cause considerable negative effects.

Quality assurance process is put into practice through implementation, supervising, monitoring and eliminating the causes which may lead to unwanted discrepancies.

5. CONCLUSION

The railway, as a complex system, due to its technical and technological features, takes a special place in the transportation system or transportation services market with respect to the issue of dangerous substances transportation. In terms of providing services to its users, the railway is making efforts to meet user demands as much as possible. In this, it is regularly faced with the issue of the quality of the provided service of dangerous substances transportation.

For the purpose of contributing to a more successful quality management of logistics service of dangerous substances railway transportation, this paper provides the concept of a potential quality management model of such service. The proposed model implies implementation of a few steps: transportation planning, transportation implementation, measuring the quality of provided transportation service, taking corrective actions for quality improvement (in the event of deviation from the planned or expected quality) of provided service.

A specific issue of implementation of the proposed model is the measuring of quality of dangerous substances railway transportation service. This issue also exists in any other type of logistics services and its main cause is the lack of adequate standards. In addressing this issue, further research in the area of logistics services quality, which also includes the dangerous substances railway transportation service, should be focused on standardization.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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A NEURO-FUZZY APPROACH FOR URBAN RAIL PASSENGER DEMAND FORECASTING

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Abstract – *Neuro-fuzzy techniques are finding a practical application in many fields such as in model identification and forecasting of linear and non-linear systems. This paper presents the application of an adaptive neuro-fuzzy inference system (ANFIS) to urban rail passenger time series modeling, and is illustrated by an application to model the rail passengers flow on Belgrade urban railway network. An introduction to ANFIS modeling approach is also presented. The advantage of the method is that it does not require the model structure to be known a priori, in contrast to most of the time series modeling techniques. The results showed that the ANFIS forecasted flow series preserves the statistical properties of the original flow series.*

Keywords - Neuro-fuzzy, forecasting, railway, passenger demand.

1. INTRODUCTION

Passenger flow forecasting is a vital component of rail transportation systems which can be used to fine-tune travel behaviors, reduce passenger congestion, and enhance service quality. The forecasting results of passenger flow can be applied to support rail system management such as operation planning, and station passenger crowd regulation planning. In some cases, it is used for establishing the daily train timetables which have direct impact on resource allocation and utilization. The success of strategic and detailed planning of public transportation highly depends on accurate demand in formation data. Also, passenger flow forecast represent a basic work for urban rail transport project investment decision analysis.

The transportation forecasting approaches can be generally divided into two categories: parametric and non-parametric techniques (Wei and Chen, 2012).

In general, the traditional parametric techniques use historical average, smoothing methods, and autoregressive integrated moving average (ARIMA) to forecast transportation demand.

For the non-parametric techniques, several methods have been used to forecast the transportation demand such as neural networks, non-parametric regression, Kalman filtering models, and Gaussian maximum likelihood.

In this paper, a hybrid of Neural Network and Fuzzy Logic, known as adaptive network-based fuzzy inference system (ANFIS) is proposed to develop a passenger demand forecasting model to be used in operational management of urban rail passenger service within the Belgrade rail node. The proposed model is used to provide one year ahead demand forecast.

The remainder of this paper is organized as follows. Section 2 describes the underlying principle of neuro-fuzzy systems. The applicability of the method is demonstrated by modeling the urban rail passenger demand for Belgrade rail node in Section 3. The concluding remark is provided in Section 4.

2. NEURO-FUZZY MODEL

Neuro-fuzzy modeling refers to the way of applying various learning techniques developed in the neural network literature to fuzzy modeling or to a fuzzy inference system (FIS). The fuzzy inference system (FIS) is a popular computing framework based on the concepts of fuzzy set theory, fuzzy if-then rules, and fuzzy reasoning (Pribyl and Goulias, 2003).

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The basic structure of a FIS is composed of five functional blocks, a rule-base that contains a number of fuzzy if-then rules, a database that defines the membership functions of the fuzzy sets used by the fuzzy rules, a decision-making subsystem that performs the inference operations on the rules, a fuzzification interface that transforms crisp measurement to degrees of membership to different fuzzy sets and finally, a defuzzification interface that transforms the fuzzy results into a crisp output. The block diagram of a fuzzy inference system is shown in Figure 1.

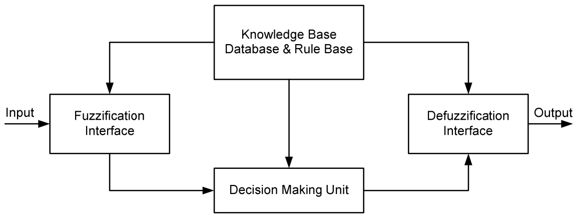

Fig.1. The block diagram of a fuzzy inference system (Vlachos and Tolias, 2003)

FIS implements a non linear mapping from its input space to the output space. This mapping is accomplished by a number of fuzzy if-then rules, each of which describes the local behavior of the mapping. The parameters of the if-then rules (referred to as antecedents or premises in fuzzy modeling) define a fuzzy region of the input space, and the output parameters (also consequents in fuzzy modeling) specify the corresponding output. Hence, the efficiency of the FIS depends on the estimated parameters.

In the present study, the concept of the adaptive network, which is a generalization of the common back propagation neural network, is employed to tackle the parameter identification problem in a FIS.

2.1. ANFIS architecture

ANFIS (Adaptive Neuro-Fuzzy Inference System) represents a class of adaptive multi-layer feedforward networks, applied to nonlinear forecasting where past samples are used to forecast the sample ahead. The ANFIS was created by Jyh-Shing R. Jang (1993) in order to incorporates the self learning ability of neural networks with the linguistic expression of fuzzy inference.

Selection of the FIS is the major concern when designing an ANFIS to model a specific target system. In this paper we use the Sugeno fuzzy model (Takagi and Sugeno, 1985) since the consequent part of this FIS is a linear equation and the parameters can be estimated by a simple least squares error method.

Consider for example, that the FIS has two inputs x and y and one output z: for the first order Sugeno fuzzy model, a typical rule set with two fuzzy if-then rules can be expressed as:

Rule 1: If X is A_1 and Y is B_1, then $f_1 = p_1x + q_1y + r_1$

Rule 2: If X is A_2 and Y is B_2, then $f_2 = p_2x + q_2y + r_2$

A_1, A_2 and B_1, B_2 represent the MFs for inputs x and y, respectively. $\{p_1, q_1, r_1\}$ and $\{p_2, q_2, r_2\}$ are the parameters of the output function.

The ANFIS architecture and the reasoning mechanism are presented in Figure 2. Figure 2a illustrates graphically the fuzzy reasoning mechanism to derive an output f from a given input $[x, y]$. The firing strengths w_1 and w_2 are usually obtained as the product of the membership grades of the premise part, and the output f is the weighted average of each rule's output. As we can see from the Figure 2b, the corresponding equivalent ANFIS network architecture is composed of five layers, fuzzy layer, product layer, normalized layer, de-fuzzy layer and the total output layer.

Layer 1: In this layer, each node generates a membership grade of a linguistic label. The node function of the i-th node is generalized bell membership function:

$$O_i^1 = \mu_{Ai}(x) = \frac{1}{1 + \left(\dfrac{x - c_i}{a_i}\right)^{2b_i}} \qquad (1)$$

Where x is the input to node i, A_i the linguistic label associated with this node and $\{a_i, b_i, c_i\}$ the parameter set that changes the shapes of the membership function. ANFIS uses gradient descent to fine-tune them during the training process. Parameters in this layer are referred to as the premise parameters.

Layer 2: Each node in this layer multiplies the incoming signals, denoted as $\prod$, and the output represents the firing strength of a rule,

$$O_i^2 = w_i = \mu_{A_i}(x)\mu_{B_i}(y),\ i = 1,2 \qquad (2)$$

Layer 3: Node i in this layer calculates the ratio of the i-th rule firing strength to the total of all firing strengths:

$$O_i^3 = \overline{w_i} = \frac{w_i}{(w_1 + w_2)},\ i = 1,2 \qquad (3)$$

Layer 4: Node i in this layer computes the contribution of i-th rule towards the overall output using the node function:

$$O_i^4 = \overline{w_i} f_i = \overline{w_i}(p_i x + q_i y + r_i) \qquad (4)$$

where $\overline{w_i}$ is the output of layer 3 and $\{p_i, q_i, r_i\}$ is the consequent parameter set to be determined during the training process.

Layer 5: The single node in this layer computes the overall output as the summation of contribution from each rule:

$$O_i^5 = \sum_i \overline{w}_i f_i = \frac{\sum_i w_i f_i}{\sum_i w_i} \quad (5)$$

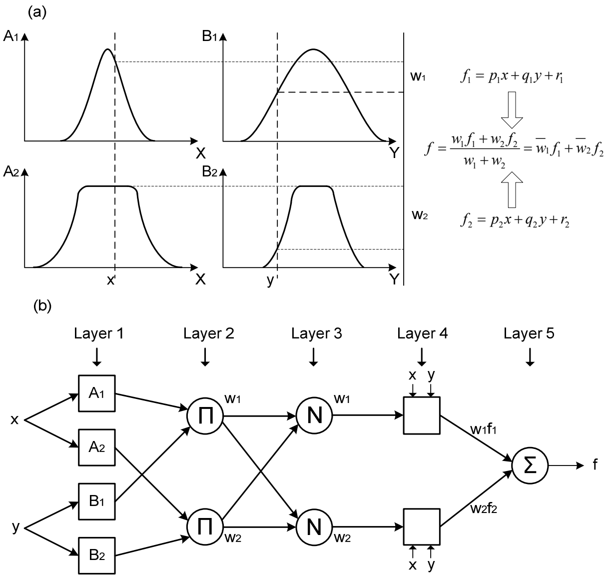

Fig.2. (a) Fuzzy inference system (b) Equivalent ANFIS structure (Jang 1993)

3. ANFIS METHOD FOR URBAN RAIL PASSENGER DEMAND FORECASTING

In this section the applicability of the proposed method is demonstrated. We divided this section in four subsections: in the first we give the main characteristics of Belgrade rail node; in the second subsection historical data are presented and analyzed; in the third subsection input variables are defined and explained; in the fourth subsection, the results obtained by the proposed approach are presented.

3.1. Belgrade rail node

The city of Belgrade has its own commuter rail transit system called Beovoz which is operated by Serbian Railways.

Beovoz provides mass transit service within the Belgrade metropolitan area. Belgrade suburban railway system connects the suburbs and nearby cities to the west, north and south of the city. Beovoz is operated by Serbian Railways.

In this paper we focused our investigation on a line Pancevo Bridge – Batajnica. This line belongs to Bg-Train as urban rail system that serves the city of Belgrade. It is operated by the public transit corporation GSP Belgrade and is a part of the integrated BusPlus system. Bg-Train shares tracks and stations with the commuter rail system Beovoz.

3.2. The data

A passenger flow dataset is collected to investigate the viability of the proposed ANFIS approach for forecasting the passenger flow. The data belong to nineteen consecutive years from 1993. to 2011.

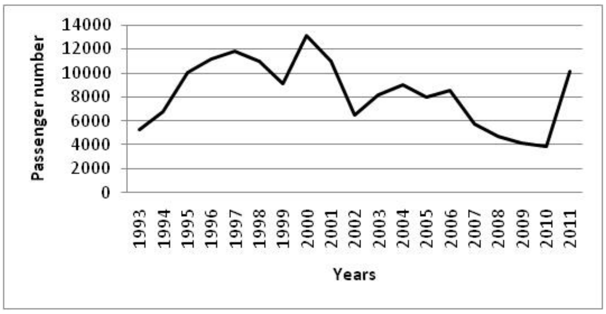

Fig.3. Average daily passenger flow on Bg-Train line

The dataset for average daily passsenger flow on Bg-train line is not available and it is evaluated on the base of an average daily number of passengers in Beovoz system and the share of Bg-train line in total passenger flow within the Beovoz system. This share is evaluated with respect to line-based passenger flow recordings performed by the Transport Institute CIP in time period from 1993. to 1995., 1997. to 2001., and for 2007. year (Milanovic, 2012). Passenger flow recordings for Bg-train have also been performed for 2010. and 2011. but this time by the GSP Belgrade. For the time period from 2008. to 2010. we used a special function in Matlab to fill in missing values.

3.3. Explanatory variables

To obtain accurate forecasts, the most relevant factors should be determined and included in the model (Owen and Phillips, 1987). We hypothesize that the demand for urban rail travel as measured in this study is a function of population, employment, economic activity and car ownership in narrower gravitation area surrounding considered Bg-train line. The source of the data is Statistical Office of the Republic of Serbia.

3.3.1. Population

It is well known and widely recognized that mobility and mode choice is affected by the urban population density. In general, dense cities are associated with a high use of public transport. Dense cities are expected to have large transport systems since supply becomes profitable (or less expensive) by taking advantage of scale and density economies.

3.3.2. Employment

Employment level is a common demographic variable used in causal analysis of rail passenger demand (Liu, 1993).

3.3.3. Economic activity

We also hypothesize that the demand for urban rail travel on Bg-Train line is a function of the level of economic activity. We used the GDP output series as the economic activity variable. The relationship between the demand for urban rail travel and this variable would be the outcome of two opposing tendencies. On the one hand, high income people would tend to do more travelling both in the course of their work and for leisure, but they would also tend to own more cars and therefore be less likely to make a given trip by rail.

3.3.4. Car ownership

Cars undoubtedly represent an important source of competition for city rail passenger service. Rising car ownership increases the competition against the railway, and consequently should have a negative impact on rail demand.

3.4. Estimating results

In this paper, ANFIS is trained and then used to predict the next year average daily passenger flow on Bg-train line. All input and output data were re-scaled to lie in the range 0-1. The number of membership functions (MFs) assigned to each input variable is chosen empirically, that is, by plotting the data set and examining it visually, or simply by trial and error. The model uses a hybrid learning algorithm to identify the parameters for Sugeno-type fuzzy inference systems. The first 60% of data was used for training the model and the 40% for testing the model. The training error goal is set to 0. The model was trained many times using different time of epochs. Finally, the best results obtained at 300 epochs. The Mean Square Error (MSE) was found to be around 0,00027. The output of the model is the next year's average daily passenger demand which is 9206 passengers. The Table 1 summarizes the parameters of the system.

Table 1. ANFIS parameter types and their values used for training

ANFIS parameter type	Value
MF type	Trimf
Number of MFs	3
Output MF	Constant
Number of Nodes	193
Number of linear parameters	81
Number of nonlinear parameters	36
Total number of parameters	117
Number of training data pairs	11
Number of testing data pairs	8
Number of fuzzy rules	81

4. CONCLUSIONS

Short-term passenger flow forecasting can provide useful information for decision makers of urban rail passenger systems. An accurate and stable passenger flow forecasting model can be applied to support transportation system management such as operation planning, revenue planning, and facility improvement.

In this paper we made a forecast of passenger flow volume for Bg-Train line. On the base of available historical data for passenger demand on line belonging to Bg-Train service and the data for the set of explaining variables we made a one-year ahead forecast using the ANFIS method.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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AN OVERVIEW OF THEORETICAL METHODS FOR SWITCHING POINT ANALYSIS FROM THE CAPACITY POINT OF VIEW

Predrag JOVANOVIĆ [1]
Dragomir MANDIĆ [2]

***Abstract** – The need of calculating individual switching point capacities often arises during the construction of technological work processes for individual stations, as well as during the analyses and planning of traffic or capacity technologies. Some of the analytical methods can be utilized for less complicated stations, in lack of appropriate software packages. This paper discusses three analytical methods.*

Keywords – capacity, station area, switching point.

1. INTRODUCTION

Given the necessity of the railroad reform, the capacity of the railroad infrastructure, which remaind state-owned, acquires a new dimension. Various methods assessing railroad capacities have been developed. However, apart from the simulation-based methods, none of them take track situation and railway station capacity into serious account.

The method defined by the announcement of UIC 406 is the newest attempt to formulate a unique method for capacity calculation. However, this method which is based upon the compaction of train routes, fails to be utilized in the assessment of station or junction capacities, i.e. switching points in general.

Recently developed simulation software packages enable capacity assessment of complete rail network segments. Nonetheless, apart from relatively high prices, these require incomparably higher amounts of time for the analyses of simple track situations, and therefore a theoretical method would prove to be less time consuming.

2. THEORETICAL METHODS FOR THE COMPARISON OF SWITCHING POINTS: OVERVIEW

The determination and analysis of a rail network segment represents an important step, not only in the planning of new parts of railroad infrastructure, but also during the consideration of possible modifications to the existing infrastructure, even when determining the most acceptable way of using the existing infrastructure thaking the specified schedule into consideration.

We should consider the fact that the station capacity depends not only on the number of station tracks, but on the switching areas construction.

Station, track situation and switching point analyses start from the possibility of simultaneous rides; therefore we must point out that the observed rides described below are conjoint regular and maneuver rides treated so by the analysis.

2.1. Method based on interlocking table

This is a typical analytic method for determining the station and switching point capacities. It enables the comparison of different variants of switching areas by calculating so-called “route dependence coefficient.” This coefficient represents the ratio between the number of rides which cannot be simultaneously coupled with any other ride, and the total number of combinations of all rides.

The method which starts from the definition of the matrix of all possible rides: each ride represents one element, both in the rows and columns, thus creating a square matrix n×n. The route dependence coefficient is given by:

$$\eta = \frac{\sum z_{ij}}{n^2} \qquad (1)$$

where:

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- η - is the route dependence coefficient,
- z_{ij} - is the status of simultaneous rides i and j,
- n - is the total number of routes.

The state of simultaneous routes is, in fact, a binary value, which means that zij takes on the values of 1 or 0, namely:

- $z_{ij} = 1$ when the simultaneous ride i and j is possible, or
- $z_{ij} = 0$ when the simultaneous ride i and j is not possible.

Simultaneous rides could be rendered impossible due to the following reasons:

- route parts overlap; either when they overlap in the beginning and later diverge, or when they meet at one point and later overlap,
- routes intersect.

Also, taking into consideration the fact that the rides are filled both in columns and rows, they rule themselves out diagonally.

After calculating the route dependence coefficient, which takes on the values between 0 and 1, we choose the track situation with the smallest coefficient, from the viewpoint of the possibility of multiple simultaneous rides.

An example switching point for this and the following methods is shown in the Figure 1.

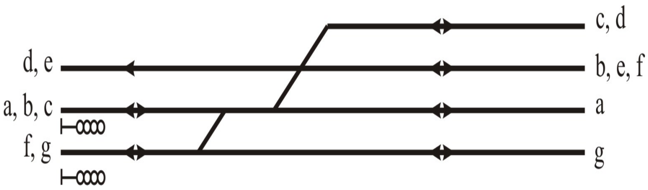

Fig.1. A track situation with assumed routes

As explained previously, a matrix of all routes is formed: each ride is assigned a row and a column. If two rides are impossible to make happen simultaneously, it is shown with the letter X (when the routes intersect) or the letter P (when they overlap, at least partially). The letter S stands for the same ride.

Table 1. Route dependence for the variant 1

	a	b	c	d	e	f	g
a	S	P	P			P	
b	P	S	P	X	P	P	
c	P	P	S	P	X	P	
d		X	P	S	P	X	
e		P	X	P	S	P	
f	P	P	P	X	P	S	P
g						P	S

Now it is easy to calculate the route dependence. For this ride, it is calculated by:

$$\eta_I = \frac{\sum z_{ij}}{n^2} = \frac{35}{49} = 0{,}7143 \qquad (2)$$

Variant 2 (Figure 2 and Table 2) considers an altered track situation, but the intersections are still in one level.

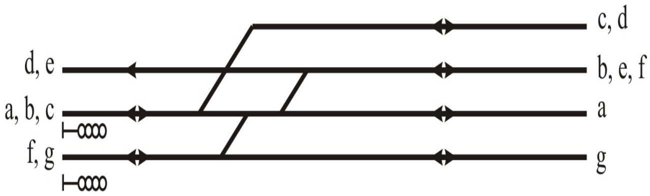

Fig. 2. Variant 2 of a track situation

Table 2. Route dependence for the variant 2

	a	b	c	d	e	f	g
a	S	P	P			P	
b	P	S	P		P	P	
c	P	P	S	P	X		
d			P	S	P		
e		P	X	P	S	P	
f	P	P			P	S	P
g						P	S

Obviously, the number of possible simultaneous rides has increased. The coefficient route dependence is given by:

$$\eta_{II} = \frac{\sum z_{ij}}{n^2} = \frac{29}{49} = 0{,}5918 \qquad (3)$$

Athough the application of this method has been shown clearly, the third variant has been produced to illustrate the effect of track denivelation on the route dependences. Figure 3 shows the third track situation variant, while Table 3 shows its dependence route matrix.

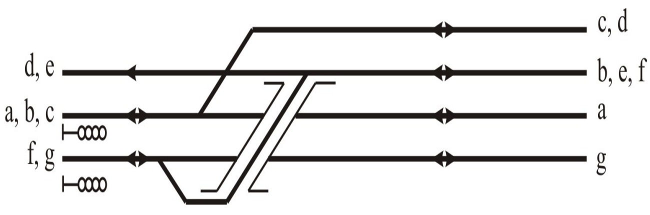

Fig.3. Third variant of a track situation with assumed routes

Table 3. Route dependence for the variant 3

	a	b	c	d	e	f	g
a	S	P	P				
b	P	S	P	X	P	P	
c	P	P	S	P	X		
d		X	P	S	P		
e		P	X	P	S	P	
f		P			P	S	P
g						P	S

It is important to highlight that this simplified way of comparison of *skretničkih lira* and track situations in the station does not take into account the number of rides which are to be realized during the day. That is the reason one has to be extremely careful when we analyze switching points. In other words, if the denivelation of separate tracks has been carried out, which is a costly invesment, it proves to be ineffective, i.e. the coefficient of route dependence remained the same:

$$\eta_{III} = \frac{\sum z_{ij}}{n^2} = \frac{29}{49} = 0{,}5918 \quad (4)$$

However, such invesment can be justified in case the ride f is the switching point's dominant ride during a day.

All hitherto shown analyses practically mean that the relevance of the calculated results will depend on the expencted number of separate rides during the day. In order to acquire more real results, it is necessary that one uses the so-called "weighted route dependence coefficient", which takes into account tre number of realized or planned rides during the period of observation. The weighted route dependence coefficient is given by:

$$\eta_w = \sum z_{ij} \cdot f_{ij} \quad (5)$$

$$f_{ij} = \frac{n_i \cdot n_j}{n^2} \quad (6)$$

where:

- η_w - is the weighted route dependence coefficient,
- z_{ij} - is the state of simultaneous rides i and j,
- f_{ij} - is the relative frequency of the combination of i and j,
- n_i - is the number of rides i,
- n_j - is the number of rides j and
- n - is the total number of routes.

"The improvement" of track situation is achieved by the removal of the conflicts between separate routes. Eventually, we will get an "ideal" track situation, i.e. the one in which further removal of conflicts between routes is impossible without altering or completely losing the track connection with all the connecting tracks. It is important to mention that such track situation do not allow intersecting routes, but only those which overlap. When comparing different *skretničkih lira*, it is useful to compare their dependent routes' coefficients with the corresponding coefficient of "ideal" track situation.

2.2. The Potthoff Method

This method was developed during the sixties at the Technical University of Dresden, and it is still very popular becaose of its simplicity above all.

When comparing *skretničke lire*, or track situations, an unoriented graph is formed for each situation respectively. In the graphs, each possible ride in the observed track situation is represented by a knot. The knots are organized to roughly form a circle, and then the knots are connected by branches, representing the rides which are possible to be realized simultaneously. Thus we create a geometrical figure. The more complex it is, the more simultaneous rides are possible.

We can also calculate the maximum number of simultaneous rides on the observed track situation. The number is defined by the number of sidea within a single closed figure formed inside the graph..

In Figure 4, the graph for the variant 1 is presented, while the figures 5 and 6 show the application of this method to the other two variants..

By observing the created triangle, we notice that the maximum number of simultaneous rides within the observed switching point is three, namely a-g-e and a-g-d.

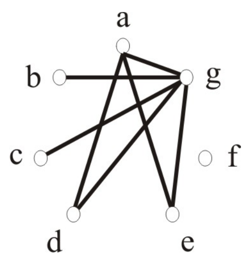

Fig.4. The application of Potthoff method to the variant 1 of the observed track situation

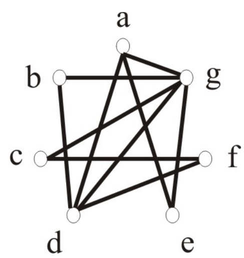

Fig.5. The application of Potthoff method to the variant 2 of the observed track situation

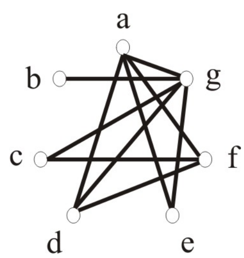

Fig.6. The application of Potthoff method to the variant 3 of the observed track situation

It is clear that none of the variants allow the possibility of forming more than three simultaneous rides, but the number and combinations of "threes" varies from combination to combination..

The main issue Potthoff method lies in the creation of extremely unclear graphs for complex track situations, which can confuse. To prevent this drawback, the branching method has been developed.

2.3. Branching method

This method allows us to represent simultaneous rides in the form of tree branches.

In the initial step, each of the possible rides is represented as a separate banch, allowing them to project from a single mutual point, usually on the left. After that, the diagram expands to the right by forming a tree: each succeeding branch represents the combination of two possible simultaneous rides. Furthermore, by checking if another, third combination can be added to the two observed combinations of simultaneous rides, we expand the graph to the right, until we reach the point beyond which it is impossible to find a single simultaneous ride.

In order to simplify the process, one does not need to repeat che combinations of possible simultaneous rides.

Given the scantiness of space, we will show only the graph for the second variant in the Figure 7.

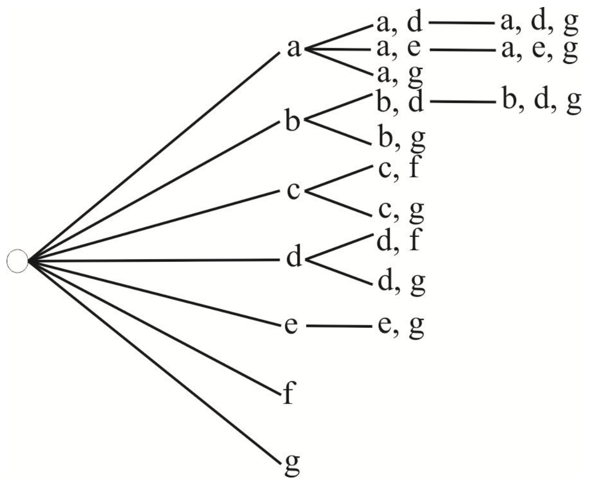

Fig.7. Branching method applied to the variant 2 of the observed track situation

3. CONCLUSIONS

The theoretical methods discussed in this work form the basis of the analyses of capacity and work technologies in stations, i.e. during the rides over switching points. Each of them offers an insight into the capabilities of a single switching point to allow simultaneous rides. The main characteristics of these methods are their simplicity and facility for relatively simple switching areas.

Their application to more complicated track situations becomes progressively more difficult, which appears to be their drawback. also, the very number of possible parallel rides will not represent a valuable piece of information unless real or predicted frequencies of separate rides are available.

The aim of these methods is to allow a fast and simple analysis during the planing of infrastructure or technological working process, without using expensive software.

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Infrastructure

XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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TRACK STIFFNESS AND THE MODELLING OF THE VERTICAL TRACK GEOMETRY DETERIORATION

Leposava MILOSAVLJEVIĆ [1]
Zdenka POPOVIĆ [2]
Luka LAZAREVIĆ [3]

Abstract *– Railway track stiffness is a basic parameter of track design which influences the bearing capacity, the dynamic behaviour of passing vehicles, track geometry quality and the life of track components. In this paper track stiffness is treated from the point of view of vertical track geometry deterioration modelling. In most of the models, vertical geometry deterioration is considered to be a function of the number of loading cycles and/or a function of the magnitude of the loading. Deterioration should also be a function of the properties of track superstructure and substructure, so, the track stiffness should be an indispensable part of those models. The modern approach of stiffness definition includes inelastic and nonlinear behaviour of the superstructure and substructure elements, as well as the existence of the difference between the stiffness under static and under dynamic load. Moreover, there is a problem with unevenness of the stiffness along the track. Also, the relationship between vertical geometry deterioration and stiffness is not unequivocal. The aim of this study was to analyse the vertical track stiffness and its influence on geometry deterioration, and to make a comparative analysis between deterioration models that directly or indirectly include the effect of the vertical track stiffness.*

Keywords - Ballasted track, track stiffness, geometry deterioration, prediction models, track maintenance.

1. INTRODUCTION

Under the influence of dynamic traffic loading, geometry of ballasted railway tracks inevitably deteriorates. Optimizing track maintenance to minimize costs is a complex task and a prediction of the vertical geometry deterioration is the main part of the optimization process. In order to develop a mathematical model for prediction of track geometry deterioration, the phenomena have to be understood and described in an engineering way.

Track stiffness is a significant parameter from the aspect of designing, construction and maintenance of the railway superstructure and substructure. This parameter represents the basis for calculating stresses in the elements of track and track foundation. During the track service life, track stiffness considerably influences the dynamic behaviour of passing vehicles, the life of track components and the track geometry deterioration.

The objective of this paper is to analyse the vertical track stiffness and its influence on geometry deterioration. A comparative analysis is performed between deterioration models that directly or indirectly include the effect of the vertical track stiffness.

2. ANALYSIS OF TRACK STIFFNESS

Track stiffness (D) presents the proportion between vertical load (Q) and track deflection (y) in a given moment (t):

$$D(t) = \frac{Q(t)}{y(t)} \tag{1}$$

Traditionally, analysis of the track behaviour under vertical load is based on the beam on an elastic

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foundation (BOEF) model and the Winkler's Hypothesis. This approach assumes that the behaviour of the superstructure and substructure elements is linear, that there is proportionality between the load and deflection, i.e. the track stiffness has a constant value.

The modern approach of stiffness definition includes inelastic and nonlinear behaviour of the superstructure and substructure elements, the existence of the difference between the stiffness under static and under dynamic load, and the unevenness of the stiffness along the track.

2.1. Nonlinearity of the load-deflection dependence

In reality, elements of the superstructure and substructure behave neither linearly nor completely elastically [1-4]. This can be explained on the example of ballast behaviour under the real conditions. In the majority of cases, leaning sleepers on the ballast is not ideal. There are voids beneath the sleepers which cause great deflections at small load intensity. Moreover, at great load intensities, nonlinearity and track stiffness increases are a consequence of ballast and substructure layers compaction. Load distribution through ballast is done through contact surfaces between ballast stones. As the load value increase, stone deformations lead to an increase of these contact surfaces and thus the ballast stiffness increases.

The absence of linearity of the load-deflection connection actually means that there is no unique value of the track stiffness. Figure 1 shows the procedure for determining linearized stiffness as one of the possible procedures for determining numerical stiffness values in the calculations.

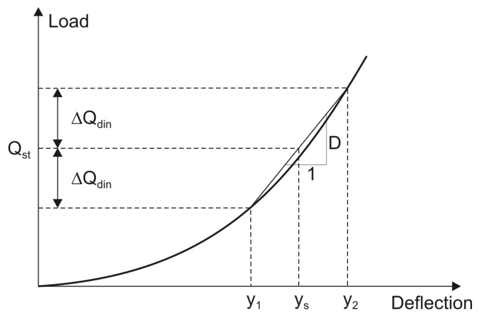

Fig.1. Linearized track stiffness for the corresponding load range [5]

Linearization of the nonlinear load-deflection diagram is performed in the proper load range, which can be the range of dynamic load on the section the stiffness is being determined for. Since there is a difference between the real and linearized stiffness (depending on the load value, the real stiffness can be lower or higher than the linearized one), it is necessary to keep in mind the error, which is the consequence of linearization, at the application of the calculation data in calculation models [5].

2.2. Dynamic track stiffness

The term track stiffness, presented in the previous chapter, is referring to static stiffness, i.e. stiffness under static load. However, it is necessary to consider the stiffness under dynamic load as well.

Except for the load value, track stiffness also depends on the excitation frequency (*f*) and thus a frequency related definition of stiffness is necessary. The term receptance or dynamic flexibility (α) is introduced. It actually presents inverse dynamic stiffness and it is measured on the track under dynamic load:

$$\alpha(f) = \frac{y(f)}{Q(f)} \tag{2}$$

Figure 2 shows dependence of receptance on excitation frequency, according to [6]. Dynamical stiffness increases with the increase in frequency.

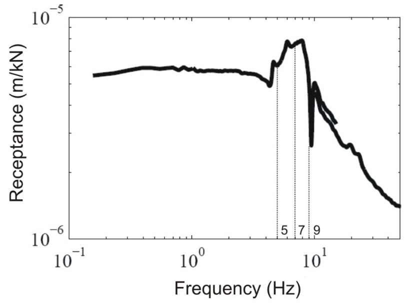

Fig.2. Dependence of receptance on excitation frequency [6]

2.3. Spatially varying track stiffness

Spatially varying track stiffness is one of the basic causes of differential track settlement, which has a primary influence on the track geometry deterioration [5]. The basic causes of the occurrence of spatially varying track stiffness are the change of the superstructure and substructure characteristics along the line, variable ballast thickness, variable blanket layer thickness, characteristics of the material that the embankment was made of, moisture content and geological characteristics of the subsoil.

Uneven track stiffness along the track is the usual problem which has been explored within numerous research projects [7]. Numeric analysis that López Pita and Fonesco performed at the Technical University of Catalonia [8] clearly pointed that if two adjacent sections with considerably different track stiffness are being considered, the stress level on the ballast can be between 30 and 50% higher than the level corresponding to the hypothesis which assumes constant stiffness along the track. This additional stress accelerates the ballast deterioration process. That is why it is necessary to set the new acceptance criteria, which also considers track stiffness homogeneity together with the requirements related to the quality of the track geometry.

3. ANALYSIS OF THE MODELS OF THE VERTICAL TRACK GEOMETRY DETERIORATION

Due to complexity of the degradation mechanism, deterioration of vertical geometry of ballasted track is very difficult to present in a mathematical model. Through the years a lot of research has been carried out and a lot of different models have been formulated. In those models, track geometry deterioration is mostly considered to be a function of the number of loading cycles and/or a function of the magnitude of the loading [5].

Overview of the track geometry deterioration models that are directly or indirectly influenced by track stiffness is given in table 1.

Table 1. Overview of the track geometry deterioration models [5]

Model name and equation	Explanation
Exponential model $\gamma = \frac{N_{ref}}{N_p} = \left[\frac{\sigma_p}{\sigma_{ref}}\right]^w$	γ – factor of relative settlement σ_{ref} – ballast pressure from reference number of loading cycles σ_p – ballast pressure N_{ref} – reference number of loading cycles N_p – number of loading cycles w – exponent*
DSM model $\overline{S}_N = \overline{S}_1\left(1 + K_H \ln \overline{N}\right)$	$\overline{S}_N$ – track settlement after $\overline{N}$ loading cycles $\overline{S}_1$ – initial settlemet (a non-linear function of the sleeper force) K_H – coefficient*
Satoh's model $S = \gamma_{Sh}\cdot\left(1 - e^{-\alpha_{Sh}N}\right) + \beta_{Sh}N$	S – settlement N –number of loading cycles α_{Sh}, γ_{Sh} – coefficients* β_{Sh} – coefficient proportional to sleeper pressure
Hoshino's model $\Delta = L_H \cdot J \cdot Z$	Δ – coefficient of track deterioration L_H – load factor J – structure factor (influenced by sleeper pressure, ballast acceleration, and track stiffness) Z – state factor
Sugiyama's model $\overline{S} = 2.09\cdot10^{-3}\cdot T^{0.31}\cdot V^{0.98}\cdot J^{1.10}\cdot R^{0.21}\cdot K_p^{0.26}$ $P_{ir} = 31.7\log\left(\frac{\overline{S}}{A_T}\right) + 31.6$	$\overline{S}$ – average growth of track irregularities in section T – passed tonnage V – average running speed J – structure factor R – influence factor (jointed rail /CWR) K_p – influence factor for subgrade P_{ir} – percentage of errors exceeding 3 mm A_T – rate of tamping per year
Sato's model $S_1 = \begin{cases} a_s\left(p_b - p_{b,gr}\right)^w, & p_b > p_{b,gr} \\ 0, & p_b \le p_{b,gr} \end{cases}$ $S_2 = \alpha_s p_b^w$	S_1, S_2 – ballast settlement a_s, α_s – coefficients* p_b – sleeper-ballast contact pressure $p_{b,gr}$ – threshold limit value of sleeper-ballast contact pressure w – exponent*
Guérin's model $\frac{dS}{dN} = \alpha_G y^{\beta_G}$	S – settlement N – number of loading cycles y – maximum elastic deflection during the loading cycle α_G, β_G – material parameters*
Fröhling's model $S_{Ni} = \left[\left[\frac{K_{F1} + K_{F2}\cdot}{\left(\frac{D_{2mi}}{K_{F3}}\right)}\right]\frac{Q_{tot}}{Q_{ref}}\right]^w \log N$	S_{Ni} – track settlement D_{2mi} – measured track stiffness at a particular sleeper i K_{F1}, K_{F2} ,K_{F3} – settlement constants* Q_{tot} – prevailing wheel load Q_{ref} – reference wheel load N – number of loading cycles w – exponent*

* - coefficients whose values depend on local conditions and are determined empirically

According to the exponential model, the factor of relative settlement, which is directly proportional to the interval between successive track maintenance, depends on the ballast pressure. Ballast pressure, among other things, is the function of track stiffness. Based on the analysis of this model, conducted in [5], it can be concluded that increasing the track stiffness adversely affect the settlement, and the deterioration of the vertical track geometry.

According to the German DSM model, settlement of the track depends on the sleeper force. As the sleeper forces are lower in the sections with lower track stiffness, according to this model, increased stiffness causes an increase in deterioration of the vertical track geometry.

In the Satoh's model, the settlement depends on the coefficient β_{Sh} that is directly proportional to the sleeper pressure and ballast acceleration. Sleeper pressure and ballast acceleration are both a function of the track stiffness and their values increase with increasing stiffness. Similar to this model, in the Hoshino's and Sugiyama's models a deterioration of vertical track geometry is directly proportional to the structure factor J, which is influenced by sleeper pressure, and ballast acceleration. And in the fourth Japanese model, the Sato's model, ballast settlement is directly proportional to the sleeper-ballast contact pressure.

The French model of vertical track geometry deterioration, Guérin's model, expresses the intensity of the settlement is as a function of the maximum elastic deflection during the loading cycle. The increase in deflection leads to an increase in the intensity of settlement. So according to this model, reduction of stiffness causes an increase in track settlement. It is similar to the South African model, Fröhling's model, where a track settlement is directly proportional to the measured track stiffness.

Thus, according to the exponential, the German and the Japanese vertical track geometry deterioration models, an increase of track stiffness adversely affects the deterioration. On the other hand, according to the French and South African models, an increase in stiffness leads to reduction in track settlement, ie. it has a positive effect on the deterioration.

It is obvious that a unified and consistent view on the impact of track stiffness on the vertical track geometry deterioration does not exist, which leads to the necessity of finding the optimum track stiffness.

4. CONCLUSIONS

Vertical track geometry deterioration is a function of the number of loading cycles, the magnitude of loading and the properties of track superstructure and substructure. Therefore, the track stiffness should be an indispensable part of the track geometry deterioration models.

Taking into account the vertical track stiffness may seem straightforward, but the situation is not so simple. The stiffness definition must include inelastic and nonlinear behaviour of the superstructure and substructure elements, as well as the existence of the difference between the stiffness under static and under dynamic load. Moreover, there is a problem with unevenness of the stiffness along the track. In the end, even if the right value of stiffness is chosen for a deterioration model, the relationship between vertical geometry deterioration and stiffness is not unequivocal.

Too low stiffness value would cause track settlement, with considerable stress increase in the rails. Too high value would increase dynamic load and thus accelerate track deterioration. The necessity to find the optimum track stiffness is obvious.

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RECONSTRUCTION OF TRACKS AND SIGNALLING SYSTEM IN THE OVCA RAILWAY STATION

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Abstract *– The planned construcion of the 2nd track of railway line (Beograd Centar) – Pancevo Glavna – Vrsac – state border, from the junction Pancevacki Most to the station Pancevo Glavna requires a redesign of the track connections in the input and output station sections, construction of additional tracks, platforms and access routes. It is also necessary to adjust works on the substructure and superstructure between the existing and designed state, drainage, reconstruction of the access roads, arrangement of level crossings in the station area, reconstruction of the signalling system, catenary and railway telecommunications. Telecommunication installations inside and outside the station building (along underpasses, eaves, platforms), lighting, traction power plants and transforming stations were also scope of the reconstruction in the Ovca railway station. This paper presents a proposal for the extension of track capacity and new technical solutions for the reconstruction of the existing signalling system SpDrS-64-JŽ (internal and external elements for 2nd track, modernization of power supply unit, substitution of track circuits with axle counters, substitution of signal lamps with LED modules, point heating etc).*

Keywords - reconstruction, substructure, superstructure, SpDrS-64-JŽ.

1. INTRODUCTION

The railway line section between the junction Pancevacki Most and station Pancevo Glavna from km 4+742 to km 19+600 is part of a (Beograd Centar) – Pancevo Glavna – Vrsac – state border (Stamora Moravita) railway line, which in accordance with the AGC Agreement (E 66) and is labelled with E66.

This railway is a link connecting the Pan European transport corridors X and VII on one side and the Pan European corridor IV passing through Timisoara, on the other side. The mentioned section, 14,86 km long, passes the railway-road bridge over the Danube River („Pancevacki Most") and the Tamis River. From the station Beograd Centar to the junction Pancevacki Most is double-track railway line, while from the junction Pancevacki Most to the station Vrsac is a single-track railway, belonging to the D-4 category. From the station Beograd Centar to the station Pancevo Varos, the line is electrified with 25kV/50Hz system. The track is composed of rails, type 49 and provided with both wooden and concrete sleepers and track set, type „K" and „SKL", including a ballast bed made of crushed limestone. On the bridge over the Danube River, the present structure is accommodated for the double-track railway line. The existing bridge structure over the Tamis River is provided with single-track railway line.

All stations from the station Beograd Centar to station Ovca are equipped with a relay interlocking devices Siemens/EI SpDrS-64-JZ. The distance from Beograd Centar - junction Pancevacki Most is equipped with a double-track relay automatic line block(APB) Siemens/EI SpDrS-64-JZ, and other distances to the Ovca station with a single-track relay automatic line block Siemens/EI SpDrS-64-JZ. Distance Ovca - Pancevo Glavna is not equipped with APB devices. The other track to be constructed shall be 14,86 km long. The track shall be designed to support the speed of V = 120 km/h with an axle load of 225 KN and clearance gauge according to UIC-GC.

Works on construction of the other track shall include: superstructure and substructure; stations and stopping places; bridges; station buildings; electrification; signaling and interlocking devices; telecommunications; hydraulic engineering works.

2. THE EXISTING SITUATION OF STATION OVCA

Railway station Ovca is located in km 12+535 of the railway line Beograd Centar – Pancevo Glavna –

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Vrsac – state border (Stamora Moravita). In traffic terms, station Ovca is both intermediate stop and separating station for the railway line Ovca - Padinska Skela. It is used for the reception and dispatch of passengers, luggage, packages and animals concerning both domestic and international transport.

2.1. Rail connections and infrastructure of station Ovca

Station Ovca has four station tracks with center-to-center spacing of 4.75 m, with the following purpose:

- Track nr.1 – handling;
- Track nr.2 – main passing;
- Track nr.3 – reception-dispatching;
- Track nr.4 – reception-dispatching,

as well as two additional tracks: one industrial track for "Butan gas" (detach point nr.2 on the Block I with speed limit of 20km/h on the track and 5km/h on the load/discharge locations) and separating track for Padinska Skela (detach point nr.8 on the Block II).

The final design for the reconstruction of station Ovca (july 1992) predicts a replacement of the bad substructure elements and drainage of the station plateau.

An asphalt access road to the station connects the settlement of Ovca with the main road Beograd-Zrenjanin and objects within the "Butan gas" area. On the exit block of the station there is local road that intersects with the railway line. The station building is located near the track nr.1 (adopted object).

Between tracks nr.1 and 2, as well as between tracks nr.3 and 4, there are low platforms (h=0,20m, w=1,60m). The platforms consist of mounting elements, and access to the platform from the station building is performed with a pedestrian lane over the tracks with wooden sleepers.

There are also two level crossings in the station area:1- LC in km 12+177,03 (km 12+274.69), near Block I: passes over tracks nr.2. and 3., in front of points nr.1 and 3. LC is secured with automatic device; 2- LC in km 13+209,34 (13+305.41) near Block II: passes over tracks Ovca - Pancevo Glavna and Ovca - Padinska Skela, behind point nr.8. LC is also secured with automatic device.

2.2. Signaling/interlocking devices

Station Ovca is equipped with a full centralised relay signalling/interlocking device Siemens/EI SpDrS-64-JZ. All interlocking elements were built using a topological principle ("Spurplan Drucktasten Stellwerke"). Both station level crossings are secured with relay interlocking devices Siemens Fu2H/60, with half-barriers and light signals.

Command and control of the relay interlocking device is done through a signaller's desk in the mosaic version. The power supply of the station interlocking device, APB devices and level crossing devices is performed from a station feeding unit with rotational converters. Sections occupancy detection is done with AC track circuits(83,33Hz). All light signals have standard signal lamps with 2 bulbs. There is no point heating system in the station.

3. CONSTRUCTION OF THE 2ND TRACK IN THE STATION OVCA

With construction of the 2nd track on the section Pancevacki Most – Pancevo Glavna both passenger and freight traffic will be organized.

Planned traffic on this section includes:

- international passenger trains,
- domestic passenger trains (commuter-suburban trains),
- international and domestic freight trains (direct freight trains and loco-trains)

Station Ovca shall perform the following functions according to the user's request: traffic - intermediate stop at the railway line and separating station for railway line Ovca-Padinska Skela; transport-commercial – open for reception and dispatching of passengers, luggage, packages and animals in both domestic and international transport; in station Ovca, work with loco-trains shall also be done, for shunting of cars for/from industrial track for "Butan gas" and railway line Ovca - Padinska Skela.

3.1. Extension of the rail connections - substructure and superstructure, drainage system

In the situation plan of the station, 3 additional tracks with connections were designed. New track nr.5 at distance of 9.50m from existing track nr.4 (due to the new platform). New tracks nr.5, 6 and 7 were designed at mutual distances of 4.75m, which causes changes in the points geometry on the entry and exit block. These rail connections enable direct train routes on both tracks and are achieved with new points on concrete sleepers with radius R=300-6°.

Track elevation in the station is adjusted to line elevation, and the elevation of industrial tracks for "Butan gas" are adjusted with elevation of main passing track (right track) elevation. Zero running distance of the industrial track equals running distance in km 12+233.16 of main passing track (right track

Substructure of new tracks and rail connections consist of regulation of land in the area of construction of new tracks and platforms (stripping of humus, embankment, tamponing)

Uperstrucutre – Existing tracks (nr.1,2,3 and 4) are not included in these works, except on the entry/exit block (min 30m before/after the fitting in the existing tracks), as well as new tracks. The uperstructure is made of rails, type 60E1, quality 260 (new mark according to the EN13674-1), laid over the concrete sleepers and provided with elastic track fastening (SKL14 Vossloh) embedded in a ballast of eruptive origin. Points, type 49E1-300-6° laid on concrete sleepers are also new. (Rail quality 260 matches rail 900A acc. to UIC 860). All tracks and points shall be welded into the long welded track. Before welding, tracks and points must be regulated in both elevation and situation. Below lowest level of concrete sleepers minimal ballast thickness must be 30cm. Uperstructure of the industrial track for "Butan gas" Gornji (324.81m) is designed from new rails type 49E1 laid on wooden sleepers and provided with elastic track fastening SKL12, with purity layer d=20cm. Part of the track for Padinska Skela 43.61m long (up to the level crossing) is designed from new rails type 49E1 laid on concrete sleepers and provided with elastic track fastening SKL14, and the rest of the track (30m long) to the fitting in the existing state is designed from new rails type 49E1 laid on wooden sleepers and provided with elastic track fastening SKL12.

Drainage in the Ovca station in the area of 3 new tracks was designed with transverse inclination of the ballast and with usage of a drainage system. Designed revision shafts are located at distances of 40-50m, with outflows outside the railway trunk. On the locations of the designed underpassages, extensions of the shafts and level crossings, interruption of the existing drainage system was done. There are also open soil canals as well as coating canals in the station, according to the situation and cross-section profile plans.

3.2. Facilities, level crossings, connections between plateau and platforms

The platform in the Ovca station is designed at the +55cm elevation from the top of the rail. Adjoining platform concrete element is located on the 1.7m distance from the designed railway axis on the compacted ballast pad, in order to carry out the filling made of sandy gravel, through which paving with behaton plates is done according to the profile plans. In levelling terms, platforms follow the designed gradient of the main passing track, while the cross-section inclination is designed with an elevation of 2% to the tracks. The pavement of the platform is made from behaton plates.

Platform width is 4.0m and 6.1m and length is 220m. Access to the platform is by a grade-separated pedestrian underpassage, with elevators for disabled persons. Existing skip in the station Ovca was built between 1930 and 1940. Due to the age and damage, it was decided to build a new one, side by side to the old and canal position was adjusted to the position of the new skip. Level crossings in the station Ovca are reconstructed and made from rubber panels in the rail carriageway.

3.3. Signalling/interlocking devices

Reconstruction of the signalling/interlocking devices in the station Ovca means a redesign of the existing signalling/interlocking system as follows:

- dislocation of the existing home signals and mounting of home signals for the 2nd track
- mounting of exit signals for new tracks
- mounting of track circuits for new tracks/points
- replacement of the existing point machines and rail fastening
- laying of cables for new outdoor elements
- mounting and connection of the indoor components for new outdoor elements (relay racks, relay groups, motor relays etc.)
- mounting of outdoor and rewiring of the indoor components for level crossings devices (in accordance with new track situation)

Additionally, on the Investor's request, the following equipment and works for modernization of signalling/interlocking devices were predicted:

1. substitution of the existing station power supply device with modern UPS system with primary source from catenary, auxiliary source from mains and backup source from battery (designed for 3 hrs of full work and additonal 8 hrs of red light on signals)
2. substitution of the existing signaller's desk in the mosaic version with HMI (Human Machine Interface) post with interface to the relay signalling/interlocking device
3. substitution of the track circuits with axle counters (evaulating system "2 out of 2")
4. reparation of existing signals and substitution of the signal lamps with LED modules
5. mounting of new trackside magnets 1000/2000Hz for system Indusi I-60 on all signals
6. mounting of point heating equipment (mast transformers from catenary, distribution racks, connecting racks, heaters) with cabling
7. laying of new, non-PVC cables for new elements
8. substitution of the existing activation/deactivation elements (treadles) of level crossings with axle counters

It is also designed to secure the distance Ovca – Pancevo Glavna with an automatic centralized electronic line block system, with supervision from the prospective electronic interlocking device in station Pancevo Glavna. For communication with Field Element Controler for Centralised Block system in station Pancevo Glavna, in station Ovca additional interfaces shall be mounted.

Interface I is designed for an exchange of indications and commands for direction permission on each track, as well as day/night illumination on signals switchover. Communication is done through existing relay group BsSk1305/117 of the Siemens/EI SpDrS-64-JZ system.

Interface II is designed for receiving information about block signals aspects and forwarding this information to the signal groups BsSk1305/120 of the Siemens/EI SpDrS-64-JZ system. This interface also includes dependencies with level crossing devices, commands for setting block signals directly to the 'Stop' aspect and for reseting the block.

4. SCOPE OF WORKS IN THE STATION OVCA AND PREVIEW OF THE ORGANIZATION OF TRAFFIC DURING THE CONSTRUCTION WORKS

Schedule of works is designed with regulation of traffic with low-speed routes. In certain time intervals it will also be necessary to disconnect catenary or telecommunication/signalling networks in order to perform works. During the works on skips, bridges, underpassages and platforms where necessary traffic shall be interrupted in short time intervals.Works on the construction of pedestrian paths, parking places and asphalt access roads can be executed in earlier phases of the project, because they don't disturb the execution of main works. Works on level crossings are predicted for the end of the 2nd phase, after the reconstruction of the station entry and exit block.

Because of the scope of works on signalling/interlocking devices in the Ovca station, for regulation of traffic during the execution of works design predicts temporary disconnection of the existing station signalling/interlocking device and mounting of the mobile intersignal dependence device (MUMZ), and keylocks for points. The device will be mounted in the train dispatcher's premises, with cables lain down in a separate canal in the floor.

MUMZ is a general purpose relay device for the regulation of traffic without dependence between points position and signal aspects, so the speed in the station area is limited to 50km/h. The device is constructed in such a way that it enables basic front-end protection for up to 4 home signals with distant signals. Commands are sent from a separate signaller's desk.

After the execution of civil and electrical works in the station, the reconstructed device SpDrS-64-JZ shall be put again into service and MUMZ shall be dismantled. During the execution of works it is also necessary to plan adequate traffic of rail vehicles and working trains which shall transport material from/to the construction site. This category of trains should have the lowest priority and should not disturb the regular train schedule.

Railway traffic between stations should be organized according to the phases of work execution.

5. CONCLUSION

Ovca railway station is extended and modernized with this design. During the design, execution an interaction between the investment costs and financial ability of the railway authority was achieved, which resulted in the fact that only minor reconstruction of substructure and uperstructure of the existing tracks was predicted (30m in the both entry and exit station block).

From the aspect of signalling/interlocking devices, the question was whether to reconstruct the existing device or to build a completely new device (electronic interlocking). The basic problem with the existing relay interlocking devices Siemens/EI SpDrS-64-JŽ is a deficiency of spare relay parts, either because they are not produced anymore or their purchase price is too high due to the small number of suppliers. On the other hand, electronic interlocking devices have an advantage in easier maintenance, better diagnostics and availability of spare parts, although they still haven't achieved the same reliability level as relay interlocking devices. And, of course, their high purchase price is still a great minus, but there is a clear tendency which shows falling prices.

This design predicts investment costs for signalling/interlocking devices reconstruction of about 2,2 million €, while estimate for electronic interlocking is about 1 million € more, which shows a significant difference. That is the reason why the investor had choosen a more rational hybrid model (reconstruction+partial modernization), because it predicts the replacement of some of the old relay components with new ones and on the other hand leaves a possibility for the future replacement of the internal relay interlocking device.

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ADJUSTMENT AND RECOMMISSIONING OF ABANDONED INDUSTRIAL TRACK SYSTEMS

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Abstract *– Economical changes at industrial sites often lead to temporary or permanent abandonment of industrial track systems. An extensive review of various aspects and of the complex conditions is required to make a plausible statement about a possible recommissioning of these systems. Among these necessary aspects are economic, space planning, traffic technology and construction observations and analysis. The operability of the plant depends not only on the duration of the closure because during the period in which the industrial tracks are not in use various construction activities could be performed, which may cause problems to the recommissioning of industrial tracks or even prevent it. The surroundings of the line of the industrial track system may cause problems or even prevent the recommissioning of the track system due to changes in space planning. The changes in traffic in the surroundings of the track systems affect the use and exploration of existing tracks. Even if finally all these conditions give permission for a resumption of traffic operations on the existing track systems the new content of use of the industrial site may require significant changes and construction activities in the field of the tracks. This work represents an attempt to record the necessary tests to create a "checklist" of factors influencing the re-commissioning of an abandoned industrial track installation.*

Keywords - Industrial track systems, recommissioning, space planning, traffic operations.

1. INTRODUCTION

The fast pace of economic development during the sixties and seventies led companies to the expansion of sidings and to a bigger focus on rail transportation. In December 2008 according to SBB records 1500 private tracks have connected to the SBB railway system. Although large facilities have been built in the past few years the number of connections to the railway system was reduced by 17% since 1999. That means that a great number of existing track systems remains unused.

According to SBB records (model calculation of the cost of constructing sidings) in case of the construction of a small track system with a length of 300 m the running meter costs approximately CHF 5'000 a medium sized up to a length of 1500 m approx. CHF 3'100 as well as the big industrial track systems with a length up to 6000 m approx. CHF 2'500.

Based on the records by rail track owners CHF 560 Mil. were spent on maintenance (repairs and renewal) during the last 10 years.

If one reckon an average length of approx. 1000 m at an average cost of approx. CHF 3'000 per running meter as well as 300 connecting track systems which are taken out of service over the past 10 years one can reach an estimated value of one billion CHF. As lengths and construction costs are based on assumptions the only assessment given is that the worth of unused track systems not being used or taken out of service ranges from several hundred million to several billion CHF.

These reasons raise the following key questions:

- How can these infrastructural objects of great value again become useful to the owners as well as to the railway company?
- Which steps have to be taken on this path?
- To what extend is it possible to standardise the necessary steps of analysis, testing and procedure?
- How much time may the recommissioning take?

2. INVOLVED AND THEIR INTERESTS

The involved in the procedure of recommissioning existing sidings which have been taken out of service are the track owners and the railway company as well as the local authorities and the residents of the neighboring region.

Figure 1 shows all involved in the procedure and their interests.

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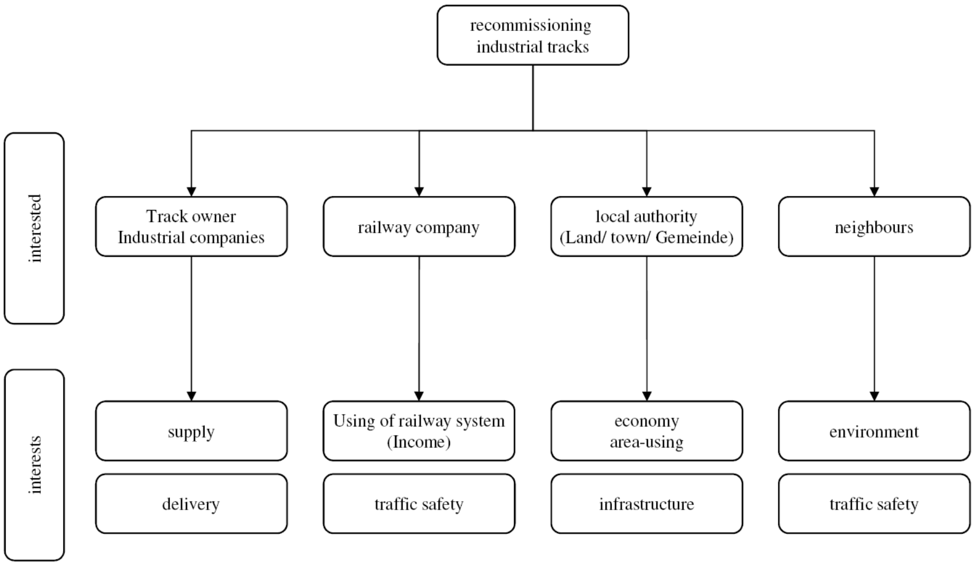

Fig.1. Involved and their interests

To the owner of the sidings the major reason for using them is their profitability. This profitability is bound to the production concerning both the necessary materials for the production and the delivery of the products. The total costs of both transports have a major role to the pricing of the final product.

To the railway company there are two major factors: Use of the railway as major interest of the railway company and the directly related schedules as well as the production related daytimes of the journeys. The second factor of rail operations is the safety of the facilities within the infrastructure and a safe traffic management.

To the local authorities (country, canton, city or township) the usage of the railway and the track systems are a major economic factor to the location. Due to the transport characteristics of railway transport it is to be expected that areas with developed industrial tracks are mostly searched by major companies to use them. These major companies are the guarantor for jobs and the appeal of the entire region. Transport activities of large companies are not only of economic nature. They even are important factors to the environment. In addition to exhaust emissions the noise emission levels are an important environmental factor for transport by road or rail systems.

Residents of the neighbouring region are especially interested in environmental factors. To residents the exhaust and noise emission and the entire road safety in their area are especially important. Both rail and road traffic caused by the industry are dangerous. Various analysis and measures are taken by operating industrial facilities to minimize the resulting hazards.

3. COMMON INTERESTS

By collecting and analyzing of the involved and their interests three groups of the fundamental interests of the involved parties can be defined:

- economic interests,
- traffic-related interests, and
- environmental interests.

These interests of the involved parties can strengthen shared interests through their intersections. Outside of the mentioned intersections the many different individual interests of the involved parties bare a very high potential for conflicts. Accordingly a comprehensive and very precise analysis of interests in such projects is indispensable.

4. POSSIBLE CONFLICTS OF INTEREST AND POSSIBLE SOLUTIONS

Despite of the common interests the emergence of conflicts of interest is quite possible and probable.

Considering the economic interest of the involved parties one can recognize the potential for conflicts. The companies desire and pursue to keep the operating times as long as possible and to organize production in a way so the production material could be transported to the site relatively often and quickly. The final product shall be delivered just as quickly. These measures are saving inventory costs. This can lead to a conflict with the residential interests as permanent industrial transport is likely to cause environmental pollution to the residents. Despite of the benefits for residents by the successful companies of their region the environmental impact of transport-related exhaust and noise emissions negatively affects the quality of living near the company.

The organization of the necessary transport in time slots which would cause an environmental impact that is acceptable for the residents. Then the use of the railway system can eventually lead to time-related conflicts between the interests of the company, the railway company and the residents.

The recommissioning of the closed industrial track systems can also lead to conflicts with the interests of the local authority such as a prolonged shutdown of industrial tracks and a different demand for the use of the area.

5. POSSIBLE SOLUTIONS

To avoid the mentioned conflicts of interest and to recommission an existing industrial track system many important factors have to be considered in advance. Numerous considerations and tests, preliminary inquiries and investigations, detailed analysis and review of various fixed points and variant solutions by every involved party especially industrial company or the owner of the existing tracks.

Following investigations are to be carried out:

5.1. Clarification by the user of the track system

The prospective user or the owner of existing unused industrial tracks has to perform the following tests on the basis of operating activities or internal production:

– review and analysis of the entire operational logistics / all required transportation for the operation procedure,
– analysis of the optimization of the operation procedure by possible use of the existing track systems, and
– comparison of current transport and its possible settlement to the railway (amounts / times / costs).

This leads to the decision if the objective of the recommissioning of the industrial track system should be pursued.

In a further step, the existing industrial track systems is to be technically examined.

Since most industrial tracks remain unused for quite a long time a check for completeness and operability of the track system (the sub and superstructure and all of the available technical equipment) is required.

It is recommended to create a recommissioning catalogue including all structural, electrical, administrative and other necessary repairs and measures.

It is possible to determine the cost of the necessary technical upgrades and an additional assessment of the overall investment needed as well as the efficiency and profitability of such an investment.

The analysis which is to be done by the company as part of the commissioning of the track system could be summarized in a checklist as follows (Fig. 2-3).

	SUPPLY / MATERIAL					DELIVERY / FINISHED PRODUCT					
	RHYTHM (day/week/month)	QUANTITY (t)	TIME	NUMBER VANS	COSTS	RHYTHM (day/week/month)	QUANTITY (t)	TIME	NUMBER WAGONS	COSTS	COSTS YEAR
LOGISTIC OF PRODUCTION											
USING OF TRACKS											
COMPARISON											
1. STREET											
2. RAILWAY											

Fig.2. Checklist of the company – production

	CONDITION			NECESSARY REPAIRS		COSTS
	DEFECTIVE	USABLE		STATION	NOTICE	
		BAD	GOOD			
TRACKS						
SWITCHES						
SUBSTRUCTURE						
PIPE LINES						
CONTROL DRIVE						

Fig.3. Checklist of the company – condition of the track system

After the analysis have demonstrated the economic benefits of the use of an existing track system the next step is the analysis of the time and the definition of different time slots in which the use of the tracks would be operationally feasible and required for the company. The determined time slot should be defined as broadly as possible. This makes the integration into valid schedules or possible adjustments on the side of the railway company easier.

Afterwards both the railway company and the company will check together to find ways of using the existing siding.

5.2. Clarification by the railway company

The railway company should carry out the following analysis and tests:

– Checking the timetables and comparison with the time slots specified and defined by operations of the company. Looking for matches and defining mutually acceptable times.
– Testing of the existing track system, examination of the operability of the track system. Check for any necessary repairs or renovation work and demand the implementation. This should guarantee the necessary traffic safety which is of particular importance for the entire railway operation.

The necessary inquiries by the railway company are summarized in a checklist as follows (Fig. 4-5).

WEEKDAY	FREE TIMEFRAME (TRAIN)		NECESSARY TIMEFRAMES (COMPANY)		INTERSECTIONS	
	START TIME	END TIME	START TIME	END TIME	START TIME	END TIME

Fig.4. Checklist of the railway company – schedules

	CONDITION			NECESSARY REPAIRS		COSTS
	DEFECTIVE	USABLE		STATION	NOTICE	
		BAD	GOOD			
TRACKS						
SWITCHES						
SUBSTRUCTURE						
PIPE LINES						
CONTROL DRIVE						

Fig.5. Checklist of the railway company – schedules

5.3. Clarification by the authority

Before a track system is put back into service the involved local authorities have various inquiries to carry out. Depending on the duration of the closure and associated changes in the area of the existing track system the scope of the necessary clarifications can be very different.

During a relatively short closure of the track system the necessary clarifications are minimal and can be included during the technical inspection of the system and the related traffic safety.

In case of longer closures of the track systems all environmental changes in the area should be assessed and taken into account before restarting. These changes in the environment may be of planed and boiled type both the planed and the constructed are of equal importance. Both are relying on the change of use of the area. If it came to structural changes in the area of the track system during closure it is to be assumed that the land use and the planning have changed, too.

In the approval process for the recommissioning of industrial tracks closed for a long time all the relevant factors of space and town planning and the factors of regional development are taken into account to avoid potential conflicts of interest.

The following example shows a checklist that would be suitable for the testing of various options for the granting of a use permit and recommissioning of a closed track system by a local authority (Fig. 6).

DURATION OF CLOSING SINCE		CHANGES IN LAND–USE PLANNING		CHANGES IN CONSTRUCTION		INFLUENCE ON TRACKS / CONSTRUCTION		APPROVAL	
		YES	NO	YES	NO	YES	NO	YES	NO
	SHORT								
	LONG								

Fig.6. Checklist of the local authority

5.4. Clarification by the residents

The following information is relevant to the residents near the track systems, and especially important for the grant of authorization for their use:

– number of trains and rides,
– daytimes of the rides, and
– securing the tracks and track crossings.

This information about the expected traffic defines the environmental impact of the facilities. They define the noise emission, possible ground vibrations and road safety.

WAYS	TIME	TRACK PROTECTION		PROTECTION OF CROSSING		APPROVAL	
		YES	NO	YES	NO	YES	NO

Fig.7. checklist of the local authority

6. SUMMARY

Even if the path for the recommissioning of the closed industrial track systems is a very long and difficult one it can be said that the difficulties are still manageable. A systematic approach and on time inclusion of all relevant partners and involved parties provide a relatively quick analysis which can recognize quite early if such a measure will ultimately pay off.

The amount of time and effort for the recommissioning is compared to the value of such a facility and its transportation, environmental and cost characteristics negligible.

RECOMMENDATIONS

The aim is to have a regional database containing information on closed industrial track systems that provides recommendations to companies considering investments in infrastructure and facilities.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '12

TECHNICAL SPECIFICATIONS FOR INTEROPERABILITY RELATING TO THE 'INFRASTRUCTURE' SUBSYSTEM OF THE TRANS-EUROPEAN CONVENTIONAL RAIL SYSTEM

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Abstract *– The subject matter of this paper are Technical Specifications for Interoperability (TSIs) relating to the 'infrastructure' subsystem of the trans-European conventional rail system and their application in the Republic of Serbia. The paper presents an analysis showing hierarchy among EU directives, TSIs, EN, and national rules in the Republic of Serbia. The aim of the paper is to define a legal framework for harmonisation of technical regulations related to the railway subsystem 'infrastructure' in the Republic of Serbia with the EU legislation. The paper gives an overview of the TSIs related to the 'infrastructure' subsystem of the trans-European conventional rail system. There are TSI line categories, as well as the minimum capability requirements to be met by the structure of each TSI line category in order to be considered as interoperable. Besides that, the paper specifies the performance parameters of TSI lines and examines the basic parameters of the subsystem 'infrastructure' and interfaces with other structural and functional subsystems. A special accent is put on the obligation to prepare a maintenance plan for the subsystem 'infrastructure' for each conventional line before and after its placing in service. There are also indicated the interoperability constituents of the 'infrastructure' subsystem and their specifications. The paper also examines the procedure for conformity assessment of the interoperability constituents, i.e. conformity assessment modules and conformity documents. It presents the characteristics of the interoperability constituents which are assessed within a certain module at different phases of design, development and production. The paper demonstrates the verification of the subsystem, namely the verification modules and documents. It also includes special procedures for assessment of the subsystem and its characteristics to be assessed in the process of verification and at different stages of design, construction and operation. It describes the elements which have to be entered into the infrastructure register. The paper examines the possibility of application of TSIs infrastructure on the new and the existent railway lines in the Republic of Serbia.*

Keywords - TSIs, railway infrastructure, implementation.

1. RAIL SYSTEM AND SUBSYSTEMS

Trans-European conventional rail system consists of conventional lines of the trans-European transport network and vehicles likely to travel on all or part of the trans-European conventional rail network.

The rail system may be broken down into the following subsystems, either:

(a) structural areas (infrastructure, energy, trackside control-command and signalling, on-board control-command and signalling and rolling stock) or

(b) functional areas (operation and traffic management, maintenance and telematics applications for passenger and freight services.

2. TSI INFRASTRUCTURE

2.1. Scope

This TSI concerns the infrastructure subsystem and

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part of the maintenance subsystem of the trans-European conventional rail system. The geographical scope of this TSI is the trans-European conventional rail system as described in Annex I to Directive 2008/57/EC. It applies to all new, upgraded or renewed infrastructure of the trans-European conventional rail system.

2.2. Content

This TSI:

(a) lays down essential requirements for the infra-structure subsystem;

(b) establishes the functional and technical specifications to be met by the subsystem and its interfaces vis-à- vis other subsystems;

(c) determines the interoperability constituents and interfaces which must be covered by European specifications, including European standards, which are necessary to achieve interoperability within the trans- European conventional rail system;

(d) states, in each case under consideration, which procedures are to be used in order to assess the conformity or the suitability for use of the interoperability constituents, on the one hand, or the EC verification of the subsystems, on the other hand;

(e) indicates the strategy for implementing this TSI;

(f) indicates, for the staff concerned, the professional competences and health and safety conditions at work required for the operation and maintenance of the subsystem, as well as for the implementation of this TSI .

This TSI includes the following aspects of the infrastructure subsystem:

(a) Line layout,

(b) Track parameters,

(c) Switches and crossings,

(d) Track resistance to applied loads,

(e) Structures resistance to traffic loads,

(f) Track geometrical quality and limits on isolated defects,

(g) Platforms,

(h) Health, safety and environment,

(i) Provision for operation,

(j) Fixed installations for servicing trains.

The limiting values set out in the present TSI are not intended to be imposed as usual design values. However the design values must be within the limits set out in this TSI.

2.3. Functional and technical specifications of subsystem

2.3.1. TSI categories of line

The conventional rail network may be subdivided into different categories. In order to deliver interoperability cost-effectively this TSI defines 'TSI categories of line'. The functional and technical specifications of this TSI vary according to the TSI categories of line.

TSI categories of line for the conventional rail infrastructure subsystem:

TSI categories of line		Types of traffic		
		Passenger traffic (P)	Freight traffic (F)	Mixed traffic (M)
Types of line	New core TEN line (IV)	IV-P	IV-F	IV-M
	Upgraded core TEN line (V)	V-P	V-F	V-M
	New other TEN line (VI)	VI-P	VI-F	VI-M
	Upgraded other TEN line (VII)	VII-P	VII-F	VII-M

2.3.2. Performance parameters

The performance levels of the TSI categories of line are characterised by following performance parameters:

		Gauge	Axle load (t)	Line speed (km/h)	Train length (m)
TSI categories of line	IV-P	GC	22,5	200	400
	IV-F	GC	25	140	750
	IV-M	GC	25	200	750
	V-P	GB	22,5	160	300
	V-F	GB	22,5	100	600
	V-M	GB	22,5	160	600
	VI-P	GB	22,5	140	300
	VI-F	GC	25	100	500
	VI-M	GC	25	140	500
	VII-P	GA	20	120	250
	VII-F	GA	20	100	500
	VII-M	GA	20	120	500

2.3.3. List of basic parameters

The basic parameters characterising the infrastructure subsystem are:

A. **Line layout:** structure gauge, distance between track centres, maximum gradients, minimum radius of horizontal curve, minimum radius of vertical curve;

B. **Track parameters:** nominal track gauge, cant, rate of change of cant (as a function of time), cant deficiency, equivalent conicity, railhead profile for plain line, rail inclination, track stiffness;

C. **Switches and crossings:** means of locking, in-service geometry of switches and crossings, maximum unguided length of fixed obtuse crossings;

D. **Track resistance to applied loads:** track resistance to vertical loads, longitudinal track resistance, lateral track resistance;

E. **Structures resistance to traffic loads:** resistance of new bridges to traffic loads, equivalent vertical loading for new earthworks and earth pressure effects, resistance of new structures over or adjacent to tracks, resistance of existing bridges and earthworks to traffic loads;

F. **Track geometrical quality and limits on isolated defects:** determination of immediate action, intervention, and alert limits, the immediate action limit for track twist, the immediate action limit for variation of track gauge, the immediate action limit for cant;

G. **Platforms:** usable length of platforms, width and edge of platforms, end of platforms, height of platforms, offset of platforms;

H. **Health, safety and environment:** maximum pressure variation in tunnels, noise and vibration limits and mitigation measures, protection against electric shock, safety in railway tunnels, effect of crosswinds;

I. **Provision for operation:** distance markers,

J. **Fixed installations for servicing trains:** toilet discharge, train external cleaning facilities, water restocking, refuelling, electric shore supply.

2.3.4. Requirements for basic parameters

Requirements for basic parameters are described in the TSI, together with any particular conditions that may be allowed in each case for the parameters and interfaces with other subsystems concerned (rolling stock, energy, control command and signalling and operation and traffic management.

2.4. Maintenance plan

2.4.1. Before placing a line in service

A maintenance file shall be prepared setting out at least:

(a) a set of values for immediate action limits,

(b) the measures taken (speed restriction, repair time) when prescribed values are exceeded,

related to the following elements:

- requirements for controlling equivalent conicity in service,

- in service geometry of switches and crossings,

- track geometric quality and limits on isolated defects,

- platform edge as required by the 'People with reduced mobility' TSI.

2.4.2. After placing a line in service

The infrastructure manager shall have a maintenance plan containing the items listed in Section 2.4.1 together with at least the following items related to the same elements:

(a) a set of values for intervention limits and alert limits,

(b) a statement about the methods, professional competences of staff and personal protective safety equipment necessary to be used,

(c) the rules to be applied for the protection of people working on or near the track,

(d) the means used to check that in-service values are respected.

2.5. Register of infrastructure

In accordance with Article 35 of Directive 2008/57/EC, the Register of Infrastructure shall indicate the main features of the infrastructure subsystem.

Annex D of this TSI indicates which information concerning the infrastructure subsystem shall be included in the Register of Infrastructure.

2.6. Interoperability constituents

The following elements, whether individual components or subassemblies of the track are declared to be 'interoperability constituents': the rail, the rail fastening systems and track sleepers. This TSI indicates performances and specifications of the constituents.

2.6.1. Assessment of conformity of inter-operability constituents

The conformity assessment procedure of interoperability constituents shall be carried out by application of the relevant modules.

Modules are prescribed in the Commission Decision 2010/713/EU on modules for the procedures for assessment of conformity, suitability for use and EC verification to be used in the TSIs.

The modules for conformity assessment of interoperability constituents shall be chosen from those shown below:

Modules for conformity assessment to be applied for interoperability constituents

Procedures	Rail	Rail fastening system	Track sleepers
Placed on the EU market before entry into force of this TSI	CA or CH	CA or CH	
Placed on the EU market after entry into force of this TSI	CB+CD or CB+CF or CH		

The characteristics of the interoperability constituents to be assessed by the notified body or the manufacturer in accordance with the selected module, in the different phases of design, development and production are indicated in Annex A to this TSI and shall be accompanied by the corresponding certificate.

The applicant shall draw up the EC declaration of conformity for interoperability constituents.

Interoperability constituents which bear the 'EC' declaration of conformity are deemed to meet the essential requirements and comply with the conditions laid down by this TSI and may be placed on the market (Articles 10 and 11 of Directive 2008/57/EC).

2.7. EC verification of the subsystems

The EC verification of the infrastructure subsystem shall be carried out by application of the relevant modules.

For the EC verification procedure of the infrastructure subsystem, the applicant may choose either:

- Module SG: EC verification based on unit verification, or

- Module SH1: EC verification based on full quality management system plus design examination.

Modules are prescribed in the Commission Decision 2010/713/EU on modules for the procedures for assessment of conformity, suitability for use and EC verification to be used in the TSIs.

The characteristics of the subsystem to be assessed in the different phases of design, construction and operation are indicated in Annex B to this TSI and shall be accompanied by the corresponding certificate.

Particular assessment procedures for subsystem are prescribed in this TSI with the reference to various ENs which have to be applied during the assessment.

The applicant shall draw up the EC declaration of verification for the infrastructure subsystem.

Subsystem 'infrastructure' is subject to the authorisation for placing in service by national safety authority (NSA), in accordance with the Article 15(1) of Directive 2008/57/EC.

2.7.1. Assessment of maintenance plan

The notified body shall confirm that the maintenance file exists and contains the required items.

2.7.2. Assessment of Register of Infrastructure

The notified body is responsible for assessing that all the necessary information have been prepared for the Register of Infrastructure.

3. IMPLEMENTATION OF TSI INF IN REPUBLIC OF SERBIA

In the Republic of Serbia, TSI INF (as well as all the other TSIs) cannot be directly applied like in the EU member states. In order to be applied, TSIs shall be provided for by a law, in form of bylaws. The same law shall define the authority to pass those bylaws. However, this has not been provided for by the Draft Railway Safety and Interoperability Law because of the entry into force of the amended Convention Concerning International Carriage by Rail (COTIF) ratified by the Republic of Serbia in 2007. According to the Appendix G to COTIF (APTU), OTIF shall draft and adopt the so-called Uniform Technical Prescriptions - UTPs for all subsystems. Functional and technical specifications included in the TSIs are the same as those given in the UTPs. UTPs, as an integral part of the Convention, are directly applied according to the Constitution. The future UTP Infrastructure shall apply to new, renewed and upgraded lines intended for international traffic.

4. CONCLUSIONS

The commercial operation of trains throughout the rail network requires in particular excellent compatibility between the characteristics of the infrastructure and those of the vehicles.

There are major differences between the national regulations and between internal rules and technical specifications which the railways apply, since they incorporate techniques that are specific to the national industries and prescribe specific dimensions and devices and special characteristics. This situation prevents trains from being able to run without hindrance throughout Europe.

It is therefore necessary to define basic essential requirements for the whole of Europe which will apply to its rail system. These requirements are laid down in various TSIs, including TSI Infrastructure, with the aim to achive interoperability of European rail system - the ability of a rail system to allow the safe and uninterrupted movement of trains which accomplish the required levels of performance. This will help to promote the competitiveness of rail transport.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '12

ROLLING CONTACT FATIGUE ON SERBIAN RAILWAYS – PHENOMENON AND CONSEQUENCES

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Abstract – *Rail rolling contact fatigue (RCF) is an increasing problem in high speed, mixed and heavy haul railways around the globe. Fatigue occurs in rail steels when the stress is above a certain level and when the number of cyclic traffic loading is high enough. The load needed to trigger fatigue damage is lower than that for static failure. The crack nucleations can occur at the rail head surface or at subsurface. The subsurface-initiated cracks occurred more frequently in the past because of non-metallic oxide inclusions in rail steel. The development of steel making technology has reduced RCF defects associated with non-metallic oxide inclusions. RCF defects represent severe threat for railway traffic worldwide. This threat is particularly expressed on modern rail lines without appropriate maintenance strategy. This paper presents the example of non-appropriate maintenance strategy, whose consequence was the occurrence of RCF rail defects. The realization of interoperability of European railway system demands for every infrastructure manager to have a maintenance plan for the infrastructure. This plan includes maintenance strategy against RCF defects. This paper figures out the importance of rail grinding strategy during the rail service life.*

Keywords - Rolling contact fatigue, rail defects, rail maintenance.

1. INTRODUCTION

The rail rolling contact fatigue (RCF) phenomenon threatens the traffic safety and increases the cost of rails maintenance. It may lead to expensive rail grinding, premature removal of rails and complete rail failure. The standard life cycle of rails can be reduced to only 2-3 years, if the adequate maintenance measures against RCF rail defects are not taken at the time [1, 2].

The major occurrence of the RCF rail defects are: "head checkings" (HC) and "squats", as well as "belgrospi". The study [3] proposed unique names for defects in order to avoid the current confusion in terminology. For this reason, the terms "head checking", "squat" and "belgrospi" are officially used in all of the languages of the world in scientific and technical literature without translation.

Unfortunately, all three types of RCF defects can be observed on the Serbian Railways. Despite this, the Serbian technical regulations for the infrastructure maintenance do not include the aforementioned rail defects. Also, the Serbian Railways does not have a management strategy against RCF rail defects.

This study is of great importance and actuality for increase of railway transport safety and reduction of rails maintenance cost in the Republic of Serbia.

2. RCF PHENOMENON

Rolling contact fatigue is a process of gradual destruction due to the creation and development of an initial crack, until the rail breaks under the influence of variable traffic load, which is transferred to the rail via a small wheel/rail contact patch (Fig. 1).

The study [5] describes and explains the rail defects due to RCF. Generally, a fracture surface due to rolling contact fatigue has a characteristic figure.

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Two visually different surfaces can be distinguished: fatigue area and rail break area (Fig. 2).

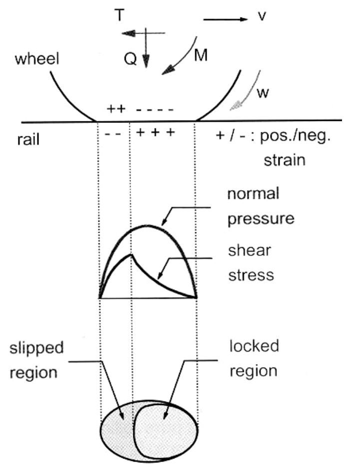


Fig.1. The structure of the contact patch [4]

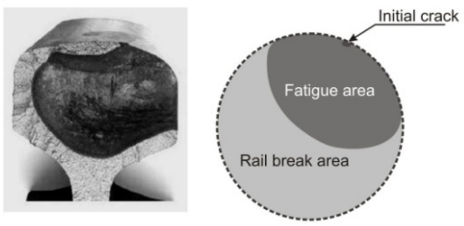


Fig.2. Characteristic look of a steel surface after break caused by RCF [5]

Fatigue occurs in rail steel when the stress is above a certain level and when the number of traffic loading cycles is high enough. The load needed to trigger fatigue damage is lower than that for static failure. The crack nucleation (the origin or starting point of a defect) can occur at the rail head surface or at subsurface. The subsurface-initiated cracks occurred more frequently in the past due to non-metallic oxide inclusions in rail steel. When inclusions exist in the material they can become a centre of stress concentration and nucleate cracks. The development of steel making technology has reduced rolling contact fatigue defects associated with non-metallic oxide inclusions.

Figure 3 shows the influences of various factors on RCF crack growth rate [6]. A crack will have a certain detectable size (P- potential of crack development before detection). This depends on the detection technique used. From this size the propagation of the crack can be followed until it reaches the critical size where a rail break can be expected (F – failure due to breakage). The time or traffic load (expressed in million gross tons) between crack detection and rail break can be used to define the P-F interval.

For all type of defects, crack growth rates can vary considerably. However simple and reliable crack growth mathematical models cannot be produced.

Experimental research of the influence of rail steel grade on wear and RCF shows that it is possible to reduce RCF and wear by using higher steel grades [7, 8, 9]. On the other hand, studies have shown the importance of wear for producing large thin metallic flakes and removing surface micro-cracks [10]. Anyway, studies have shown that none of the laboratory techniques for determining the rolling contact fatigue resistance of rail steel could reproduce all of the necessary service loading conditions [3].

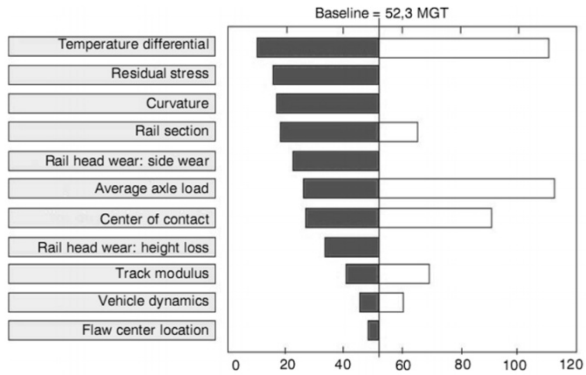
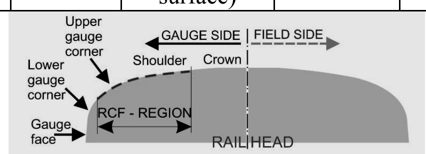


Fig. 3. Influence of various factors on crack growth rate (variation of the P-F interval) [6]

Therefore, appropriate methods for rail inspection and monitoring under conditions of undisturbed traffic flow have a great significance. An optimal detection method should provide reliable data on measured length, depth, position and spatial orientation of rail defect. Unfortunately, this kind of method for non-destructive testing of rail in service does not exist so far. This paper presents the real limits of non-destructive methods for detecting rail defects in track.

The Handbook of rail defects (UIC CODE 712 - Rail Defects) includes head checking and squat type of defects, according to the UIC issue from 2002 [11]. Table 1 shows the principle of coding of defects head checking and squat, according to [11].

Table 1. Coding of HC and Squat defects

1st digit	2nd digit	3rd digit	4th digit	Rail defect type and code
2 (defect away from rail ends)	2 (head)	2 (fissuring)	3 (scaling at the gauge corner)	Head checking 2223
		7 (cracking and local depression of the running surface)	-	Squat 227
				

3. VISUAL AND EC INSPECTION OF HC DEFECTS ON THE SERBIAN RAILWAYS

During autumn of 2011, visual inspection for needs of this paper is conducted on lines: Belgrade Center – New Belgrade (from km 0+700 to km 2+854) and Belgrade – Šid – state border (from km 4+446 to km 13+400). According to UIC CODE 700, category of line is D4 with following characteristics: mass per axle P=22,5t and mass per unit length p=8,0t/m. Both are double track line for mixed traffic. In last decades, Serbian railway operator did not plan enough resources for maintenance. The result is especially bad conditions of railway infrastructure.

Visual inspection of HC defect was quite difficult due to lubricant that was covering rail gauge corner. Besides that, inspection was also difficult in tunnels. HC defects were found on expected places: outer rail in curves with radius from 600 to 800 m (Fig. 4).

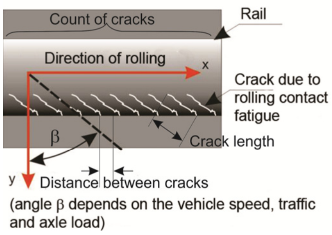
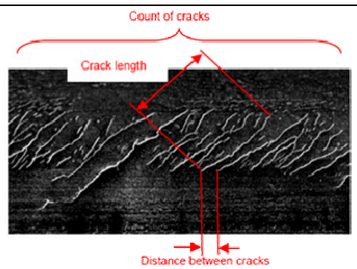


Fig. 4. Orientation of HC fissures on rail gauge

The defect was more severe on head-hardened rail (grade 900) comparing to other rails (grade 700). On a certain sections HC was registered only two years after the laying of new rails. Defect intensity is more significant on sections with high traffic load. Classification of HC defects was conducted according to Table 2.

Table 2. The severity classification of HC defect



Crack length < 10 mm	Light defect (L)
Crack length 10 – 20 mm	Medium defect (M)
Crack length 20 – 30 mm	Heavy defect (H)
Crack length 30 mm or more	Severe defect (S)

However, HC defect also appeared on unusual places: straight track sections (Fig. 5), inner rail in curves, parts of the main track in rail switches and rail welds.

HC defect was registered on straight track sections only on rails that are manufactured in 1969 with quality grade 700. These rails are currently in use over 40 years with high traffic load accumulation. Besides it, causes of HC defect are worn out elements of track super structure and irregularities of track geometry.

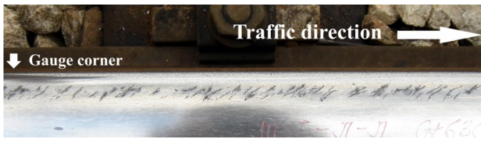


Fig. 5. Light HC defect on the straight track section (1-4 cracks / 1 cm, crack length of 5-10 mm, railway line New Belgrade - Zemun, the left track, km 6 +630)

Until spring of 2011, on section of the left track of rail Zemun – Zemunsko Polje, due to inadequate ratio between speed and cant of the outer rail (cant deficiency in long period with reduced speed), all curves with radius R=700 m moved laterally towards curve center, in some cases over 20 cm. It led to high stresses of inner rail and to appearance of nontypical HC defect on the inner rail.

Severe combination of HC and belgrospi defects can be observed on the ridges of the corrugation surface (Fig. 6).

Fig. 6. Railway Zemun - Zemunsko Polje the right track, the left outer rail in a curve, km 10+850

An example of unprofessional maintenance is shown in Fig. 7.

Fig. 7. Railway Zemun - Zemunsko Polje, the left track, the left inner rail in a curve (the former right outer rail)

HC defect was also noted in some switches in stations New Belgrade and Zemun. Reason for this can be found in irregular track geometry and worn out elements of switches.

Lubrication of the outer rail in curves on the one hand reduces lateral wear of rail, but on the other hand it leads to HC development. The visual inspection on Serbian railways shows progressive development of HC defects due to the penetration of lubricant mixed with impurities and water in the fissures on gauge corner. The visual inspection of HC defect was quite difficult due to lubricant that was covering rail gauge corner. Besides that, the inspection was also difficult in tunnels. Lubricant also influences negatively visual inspection and it disables the use of penetrants.

Information about HC defects, which were observed during the visual inspection, is entered in the special form and saved in a data base. The form was created for this research, according to [11].

After the visual inspection, the rail sample (rail type 60 E1, steel grade 900) was tested by eddy current (EC) testing in the Laboratory JAT in Belgrade (Fig. 8). The rail sample 60E1 was treated by sandblasting prior to the laboratory testing.

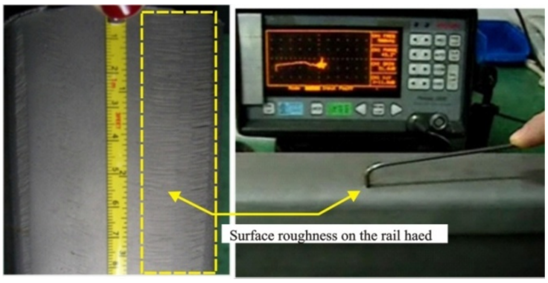


Fig. 8. The surface roughness detection using the the EC device Phasec 2200 (NDT laboratory JAT in Belgrade, 2012)

EC signal amplitude depends only on the depth of the crack. It can determine depth of the defect only approximately since the calibration and rail material can not have the same mechanical and electrical quality, homogeneity, roughness etc. However, the amplitude is dependent of the crack spatial position on rail gauge but independent of the crack spatial orientation.

The device for EC testing detects roughness, surface and subsurface defects that cannot be detected by visual inspection. This proves the importance of grinding of new rails and cyclic grinding

4. CONCLUSIONS

Rolling Contact Fatigue is a serious hazard to rail traffic across the world and a major problem for railway infrastructure managers. That hazard is more distinct on railways without adequate maintenance strategy. Increased traffic density, axle loads and speed as well as lubrication of rails are contributors to this problem. In contrast to this, correct track geometry, correct wheel/rail contact patch geometry, improved maintenance (appropriate inspection, rail grinding) can reduce problems due to RCF.

This paper presents an example of sporadically conducted maintenance and its negative consequence. Realization of interoperability of European railway network demands from every infrastructure manager to have for each conventional line a maintenance plan for the infrastructure subsystem. Besides that, this plan should include inspection and strategy against RCF defects. Maintenance strategy should provide extra rail service life and should reduce overall rail maintenance costs.

The authors recommend the use of grinding strategies against RCF rail defects. It also points on the importance of preventive activities ("rail care"), removal of more or less severe defects (corrective activities) and cyclical (controlled) activities during the whole rail service life.

Every infrastructure manager needs to adjust maintenance strategy to local conditions in order to improve traffic safety.

Anyway, the authors recommend combining several non-destructive testing methods for efficient rail testing: visual inspection, ultrasound testing, optical inspection by camera, and eddy current testing.

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SIGNALLING DEVICES AXLE COUNTER BO23 AND TRAIN DETECTION SYSTEM TDR14 - SAFETY INTEGRITY LEVEL SIL4

Zvonimir VIDUKA [1]
Darko BARIŠIĆ [2]

Abstract *– At the beginning of the last decade, in European Union were established railway standards EN 50126, EN 50128 and EN 50129, which classify the safety of signaling equipment and regulate the procedure for safety assessment and verification. Many manufacturers and users of signaling equipment are still uncertain in which way to develop, test, analyze, certify, and even use and maintain the equipment so that it could be integrated into the larger signaling systems without lowering the safety integrity level and to provide the transparent safety assessment and verification. The effect of this situation is that many railways whose modernization began 10 or more years ago, are still not commissioned for regular traffic. This article describes the procedure of development, certification and application of devices Axle counter BO23 and Train detection system TDR14, in order to maintain the assessed level of safety SIL4 obtained by independent certification firm.*

Keywords - signaling, SIL4, axle counter, train detection system.

1. INTRODUCTION

With traffic and railway infrastructure development in West Europe, it was reasonable to believe that safety level of electronic signaling devices that were being rapidly put on the market could fall because of their express implementation on the railways or because safety level could not be verified, especially in the case of bigger amount of different electronic devices which work together in the same system on the rail.

Regarding previously mentioned facts different norms/standards are being used for safety estimation, certification but also for regulating whole life cycle of signaling (SS) devices. Different principles are determined according to which a device can be developed and its safety can be verified in order to determine whether it fulfils certain appliance on the railway or not. Highest safety level estimated by mentioned facts has SIL4 label (safety integrity level 4). Axle counter BO23 and Train detection system TDR14 are completely designed according to CENELEC norms EN50126, EN 50128, EN 50129 so the highest safety level SIL4 could be achieved.

To achieve this goal it was necessary to develop Safety Case documentation, including all analyses and testing reports necessary for device safety assessment by the independent third party and for obtaining the certificate for required safety level according to European norms and associated Safety Assessment Report. Testing reports were preceded by numerous tests, including tests for proving the functional regularity of device under various conditions (temperature, humidity, vibrations, shocks, sea level / lowered air pressure, electromagnetic disturbances / EMC).

2. AXLE COUNTER BO23

Axle counter BO23 (figure 1) consists of the outdoor equipment - rail wheel sensor ZK24-2 on rail and trackside box VUR (figure 2), and indoor device – axle counter BO23 (figure 3) in level crossing's housing (cabinet) or on railway station. One 19" × 3U rack controls up to 8 counting points configured on 1 to 6 sections, plus fail safe long automatic block section control according to EN 50159-1 using all existing communication mediums, transmission systems and networks.

Indoor device contains microprocessor module with configuration 2-out-of-3 with safety program structure. The device counts axles at train speeds up to 350 km/h.

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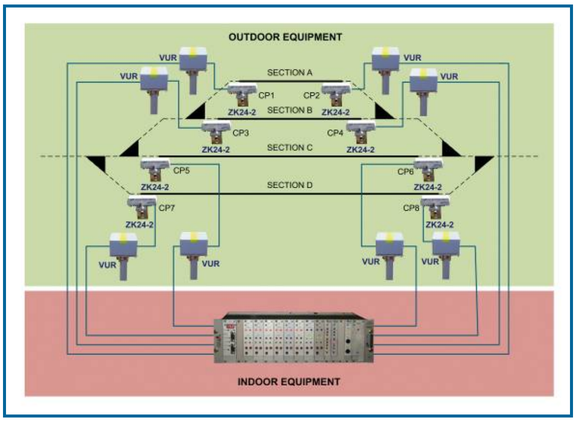

Fig.1. Indoor and outdoor equipment of BO23

Distance between outdoor and indoor device can be up to 49km. The device has options of local or remote (modem) control and diagnostics on PC.

Fig.2. Outdoor devices of BO23 (wheel sensor and trackside box) for train detection on level crossing

Basic application of the modular axle counter system BO23 is the station section occupancy control (switch points, crossings and other sections on railway stations), level crossing occupancy control as well as block section occupancy and single block between stations dependency control.

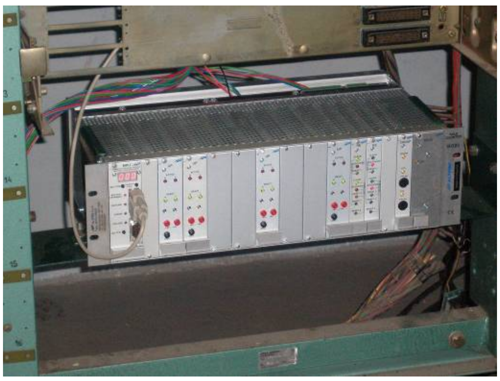

Fig.3. BO23 indoor unit

BO23 is developed and certified according to the CENELEC standards and norms (EN 50126, EN 50128, EN 50129, EN 50159-1) for the safety integrity level SIL4. The system is certified by the TÜV Rheinland InterTraffic (figure 4).

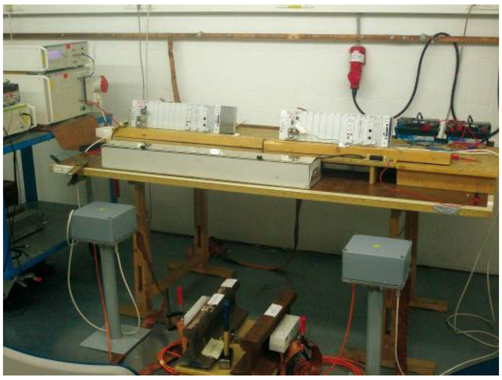

Fig.4. BO23 on EMC testing in the TÜV Rheinland InterTraffic laboratory

Multi-section digital axle counters can be used as replacement for existing track circuits on busy station areas. During resignalling projects, axle counters can first be an overlay over track circuits so the traffic can continue without interruptions, and during the final stage of project, track circuits can be shut off, and axle counters can be activated. They have improved reliability and reduced life cycle costs, and therefore they are cost effective and reliable solution. Axle counter applications which are particularly useful are those on steel structures (e.g. bridges) where track circuits cannot operate. They are also used for long block sections (e.g. single section between stations) where track circuits are not an economic solution**.**

In a last few years, axle counters are particularly often used for section occupancy control, i.e. control of train position on level crossing area, for the purpose of switching on or off the level crossing (figure 2). In a few projects, axle counter BO23 has already been introduced as replacement for legacy solutions for train detection on level crossing (e.g. two or three track circuits on LC area) or as train detection unit for new microprocessor systems of level crossing protection. Figure 5 shows two examples of axle counter BO23 applications in purpose of LC switching on and off control and block section control.

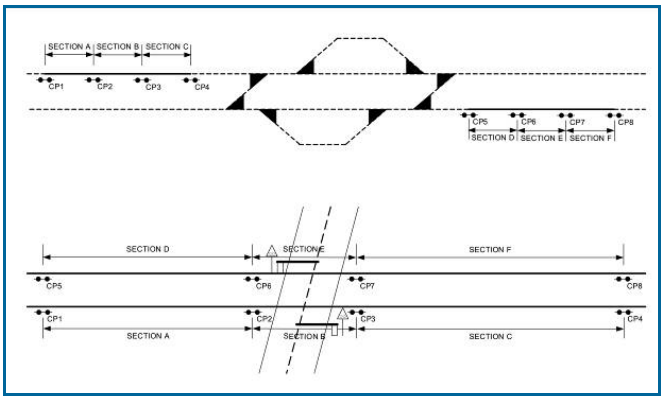

Fig.5. Examples of axle counter BO23 in purpose of switching on/off of the level crossing and for block section control

3. TRAIN DETECTION SYSTEM TDR14

Train detection system TDR14 (figures 6, 7) consists of rail wheel sensor ZK24-2 (figures 7, 9) on the rail and indoor device TDR14-UNUR (figures 7, 8) in the LC housing/cabinet with safety relays or optocoupler outputs. TDR14 with its safety relay contact outputs provides possibility of connection with both new and older types of level crossing systems and other signaling systems.

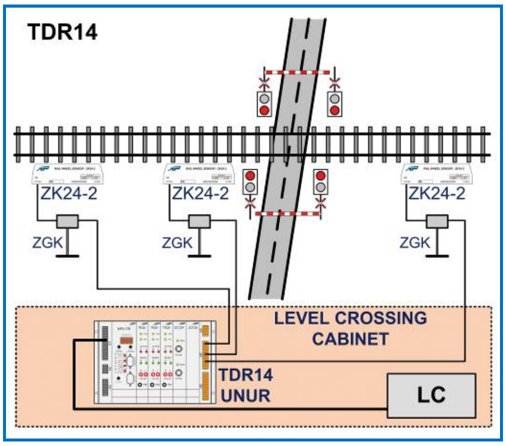

Fig.6. Configuration of train detection system TDR14 for application on level crossing

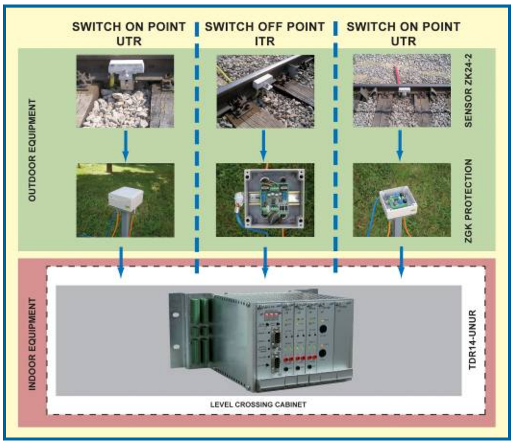

Fig.7. Train detection system TDR14

Indoor unit TDR14-UNUR (figure 8) is suitable for wall or rack mounting.

Fig.8. Indoor unit TDR14

It is possible to configure unidirectional (activation in only direction of train movement) and bidirectional (activation in both directions of train movement) operation mode; both operation modes are fail safe. It is ideal replacement for old mechanical or magnetic treadles, track circuits or inductive loops; one sensor ZK24-2, because of its double wheel detection structure, can replace two single treadle devices (figure 9).

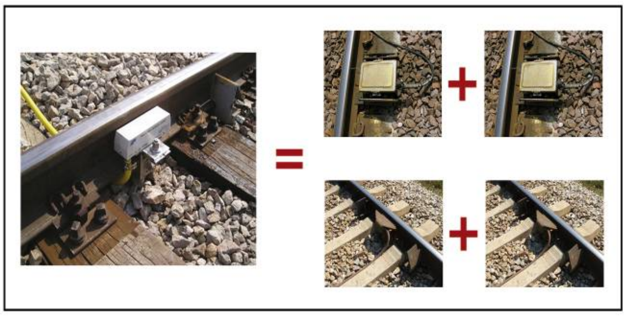

Fig.9. Sensor ZK24-2 as replacement for mechanical and magnetic treadles

Train detection system TDR14 is developed for the safety integrity level SIL4 and according to EN 50126, EN 50128 and EN 50129. It has high level of EMC immunity according to EN 50121-4. System is tested for EMC immunity and is certified by the TÜV Rheinland LGA (figure 10).

System TDR14 detects all types of rail wheel flange according to 510-2, UIC 512, for speeds up to 350 km/h. Device also has detection on both sensor channels if the sensor drops away from rail. It has function which enables remote monitoring of device's operating with failure self-detection and failure indication.

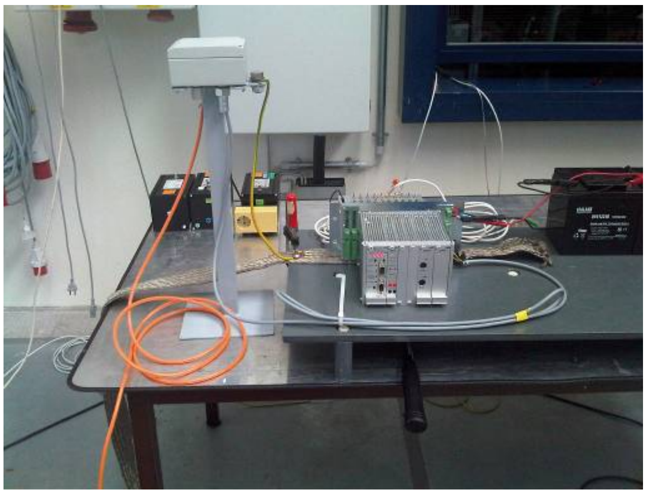

Fig.10. TDR14 on EMC testing in TÜV Rheinland LGA laboratory

TDR14 system's intelligence is achieved by introducing computing power to process and analyze all the signals, events and cross-dependencies where maximum integrity of level crossing operation is required. All signals from all wheel sensors are constantly tested for integrity of sensors and cables. Date, timing, speed, direction, number of axles and other parameters of each train passage are recorded in event log and van be later delivered to any required location through any demanded communication protocol. This data can be used in case of any event reconstruction on that level crossing.

Special versions of TDR14 system also exist, e.g. with relay outputs which activate only above or below limited train speed. Special algorithms are implemented in the software in order to prevent dangerous events, such as too early switch off of the level crossing due to vandalism (so-called “anti-tamper protection”).

Except of application of TDR14 for switching on/ switching off the level crossings (figure 6), it can be also used for announcement of incoming train to the station (figure 11).

Thanks to unidirectional mode of operation of TDR14, the light and/or sound signalization in the operator’s room in the station will activate only when the train is moving in direction towards the station.

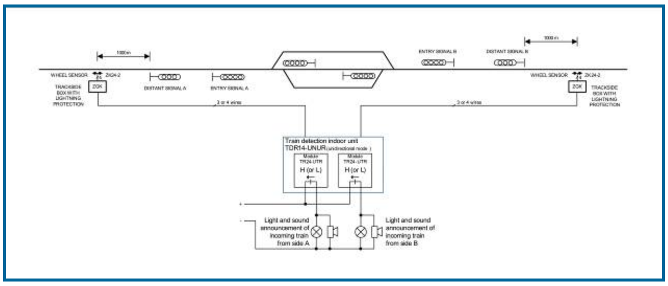

Fig.11. Application of train detection system TDR14 for announcement of incoming train on the station

4. CONCLUSIONS

With electronic signaling devices such as Train detection system TDR14 or Axle counter BO23, it is emphasized the importance of implementation of Safety Case documentation during the whole project, because application of detection device with double wheel sensor structure (of level SIL4 or less) can be numerous: from wheel detection for announcement of incoming train to the station, wheel detection in systems for automation of marshalling yards, in systems of automatic diagnostics in train (e.g. detection of overheated axle), in systems of automatic positioning of metro trains on stations, up to high-safety applications such as wheel detection for purpose of level crossings switching on and off. Lately, in Europe, just like in the rest of the world, it is common that, during the projects of railway infrastructure modernization, all interested parties follow relevant documents and certificates of particular SIL level of all signaling devices and complete signaling system. Interested parties are project companies, railway infrastructure operators, producers of railway signaling equipment and certification firms. Concerning applications which require high safety integrity level (SIL3 or SIL4), signaling devices without certificates of safety assessment nowadays cannot be used any more.

Fig.12. SIL4 and EMC certificates for Axle counter BO23

Fig.13. SIL4 and EMC certificates for Train detection system TDR14

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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PLANNING NOISE ABATEMENT MEASURES FOR VALJEVO-LIPNICA RAILWAY LINE

Aleksandar GAJICKI [1]

Abstract *– To respond to growing transport demand, PE "Serbian Railways" is planning to build a new railway line from Valjevo to Lipnica. The line is planned as electrified single track with maximum speed of 120 km/h and length of 67.4 kilometers. Opening of the new railway line will result in increased noise levels and disruption of the population living along the tracks. In order to minimize negative effects on the population, it is necessary to calculate the future noise levels through noise mapping. Also, it is necessary to do annoyance analysis and propose abatement measures in accordance with obtained results. This paper presents a procedure for developing a simulation model of railway traffic, noise mapping, annoyance analysis, design procedure for optimizing of noise barriers and a proposal of noise abatement measures. The calculation of noise propagation, annoyance analysis and optimization of noise barriers were made using simulation modeling software package "Predictor-LimA Software Suite - Type 7810".*

Keywords - railway, noise, simulation, noise abatement, noise barriers.

1. INTRODUCTION

Nowadays, the traffic noise become an increasing problem as a form of environmental pollution causing degradation and compromising the quality of life. Often long-term human exposure to noise can cause temporary or permanent physiological and psychological disorders [1].

In the future Valjevo-Lipnica railway corridor, which is 500 m wide, there are 3.077 buildings, out of them 1.791 are residential. In the current state, residential buildings are exposed to traffic noise transmitted from national and local road network. Small number of the buildings are also exposed to the rail noise from Ruma-Šabac-Donja Borina-State borders railway line.

Valjevo-Lipnica railway line is emerging as a new source of noise which will increase noise levels and disruption of the population living along the tracks. In order to minimize negative effects on the population it is necessary to calculate the future noise levels through noise mapping. Also, it is necessary to do annoyance analysis and propose abatement measures in accordance with obtained results.

The calculation of noise propagation, annoyance analysis and optimization of noise barriers were made using simulation modeling software package "Predictor-LimA Software Suite - Type 7810".

2. CALCULATION AND NOISE MAPPING

For noise calculation and noise mapping it is necessary to use a structural approach in a problem solving. To ensure the reliable output data, it is very important to well-observe the problem, define the model and all necessary input data. During data collection, it is necessary to carry out their analysis in terms of completeness, accuracy, consistency and compliance with the requirements of the computational model.

The process of noise calculating and noise mapping produced by rail traffic can be divided into the four main phases:

1. Input data collection and preparation,
2. Calculation of noise indicators produced by rail traffic,
3. Presentation and analysis of results, and
4. Planning of noise abatement measures which will reduce negative impacts on the environment.

2.1. Collection and preparation of input data

The input data, as well as the calculation, must be done on the basis of the chosen method`s technical instructions. Regardless of the method, it is necessary to ensure that the input data are describing the situation for the calendar year prior to the calculation. In each case the data should not be older than three

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years.

It is essential to provide following data: about the terrain topography, soil types in terms of sound absorption, about influence of obstacles to the propagation of sound, about the track alignment including formation width, technical characteristics of railway line, railway transport data, acoustic zones through which a new railway line passes and meteorology data.

All necessary data are obtained from Conceptual design of the Valjevo-Loznica railway line and accompanying environmental impact assessment study [2].

2.2. Calculation of noise indicators

Traffic noise computation is done using German methods. "Schall 03 - Richtlinie zur Berechnung Schallimmissionen von der Schienenwegen" is used for railway, while „RLS90 - Richtlinien fuer den Laermschutz an Strassen” is used for the road.

Both methods are in accordance with Directive 2002/49/EC and Regulation of noise indicators, limits, methods for assessing noise indicators, disturbance and adverse effects of environmental noise (Official Gazette RS, No. 75/2010) because they give results comparable with the recommended methods of calculation.

2.3. Presentation and analysis of results

The impact of new railway line on noise levels on the environment can be divided into two segments. The first one includes a noise during the construction of new track, a second one noise from railway traffic. The impacts of individual segments on the environment will not overlap.

The obtained results are presented in the form of noise maps.

a) Noise during construction works

Noise levels during construction of the railway line depend primarily on the number and types of construction machinery involved, their position and distance from residential buildings in the zone of influence. At this level of design, technology of construction site is not yet defined, so we have not done the modeling and analysis of potential noise impacts on the environment.

b) Noise during operation of railway

Calculation of noise levels is done based on the perspective volume railway traffic data, the characteristics of new line and 3D terrain models.

Analyses on the basis of the obtained results showed that the levels of traffic noise on the most exposed facades of 94 residential and other sensitive buildings in the respective area of influence are beyond legally permissible value for the period of day or night. Noise map’s details for night period, with group of exposed buildings before implementing noise barrier, are shown on Fig 1.

2.4. Noise abatement measures

The noise on the most exposed facades of residential and the other sensitive buildings exceed the legally permitted levels, therefore it is necessary to plan and implement abatement measures. Primary abatement measure is planning of noise barriers. During their calculation and optimization, economic effects are taken into account. Also, during feasibility calculation, besides existing facilities, planned land use and possible development plans will be included.

In the corridor of future Valjevo-Lipnica railway line, national road No. 23 has a significant impact on noise levels. During the planning of noise abatement measures, impact of this road has been taken into consideration. Depending on the level of the impact of road and/or rail traffic noise to the overall noise levels and differences between them, appropriate abatement measures are planned.

For residential and the other sensitive buildings where rail transport is not significantly contributing to the overall noise level and is not the dominant source of noise, abatement measures are not planned within the project of railway construction. The levels of noise produced by road traffic are higher by more than 7 dB comparing to rail traffic on these objects’ facades. There are 5 objects in this group.

For residential and the other sensitive buildings where rail traffic contributes to the overall noise levels, but dominant source is still road traffic noise, abatement measures are planned. The levels of noise produced by road traffic are higher by 3 to 7 dB comparing to rail traffic on facades of these objects. There are 24 objects in this group. As the objects of this group are mostly located between the existing road and newly planned railway line, noise barriers are not an appropriate noise abatement measure. Noise barriers along the railway tracks left the objects exposed to the road traffic noise, and vice versa. For these objects other abatement measures are planned, such as replacing existing joinery with new one with better sound insulation. It is also necessary to provide both an appropriate sound insulation of facades and closed air intake system.

For residential and other sensitive objects where rail transport is the dominant source of noise, and contributes significantly to the total noise level, abatement measures are planned. The levels of noise produced by road traffic are not higher than 3 dB comparing to rail traffic on facades of these objects. In this group there are 65 objects.

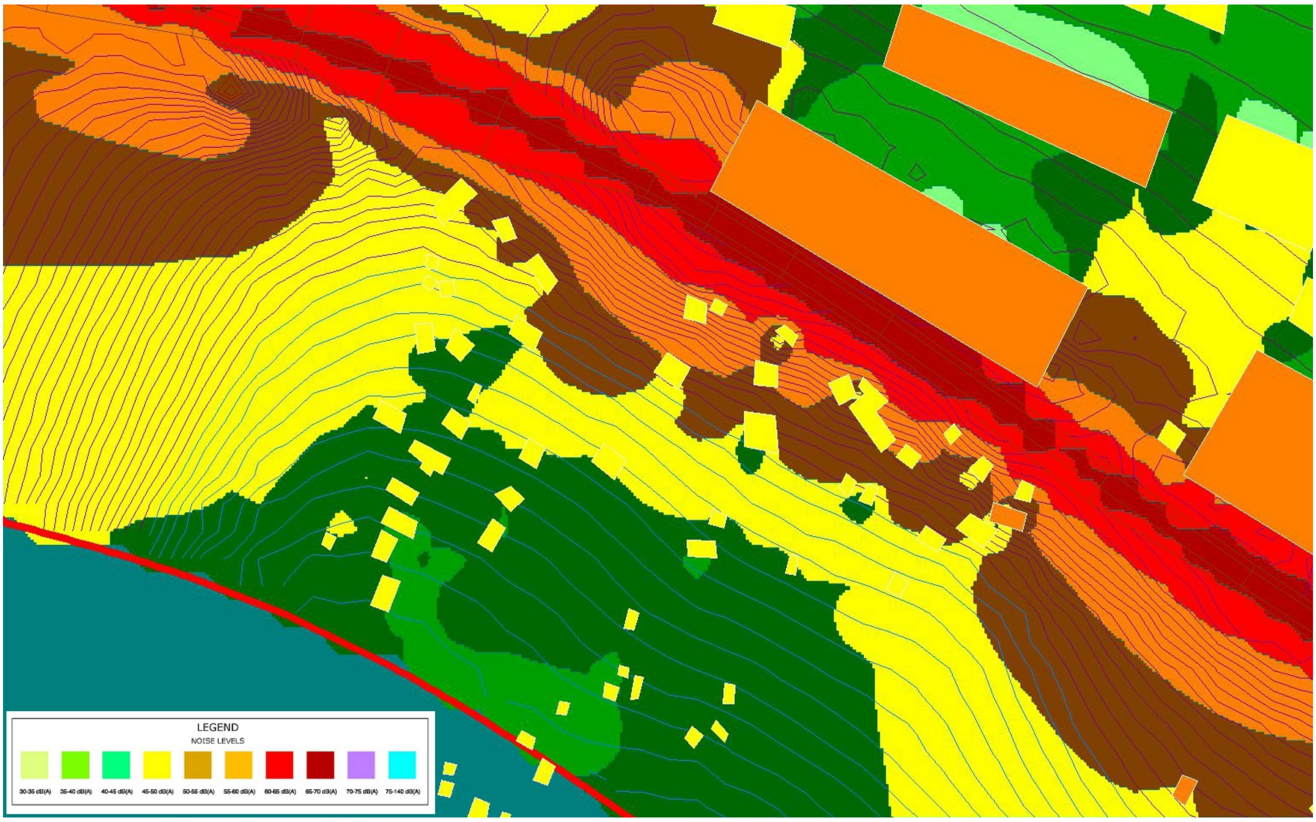

Fig 1. Noise map for night period before implementing noise abatement measures (detail)

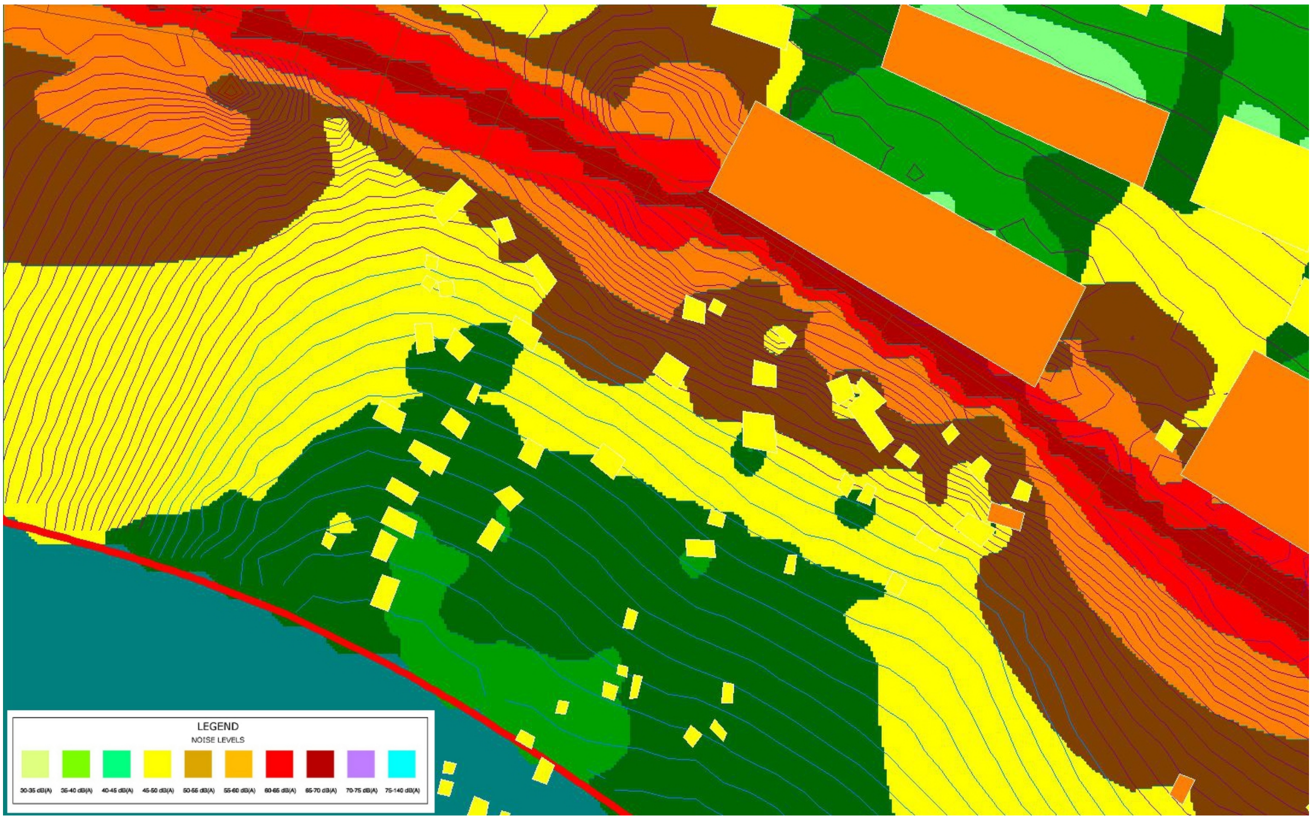

Fig 2. Noise map for night period after implementing noise abatement measures (detail)

Table 1. Basic information about the noise barriers

Number of the noise barrier	Position along track		The position in relation to track	Height	Length	Surface
	start	end				
	[km]	[km]		[m]	[m]	[m^2]
1	30+908	31+092	left	2.0 - 4.0	184	639
2	31+649	31+793	right	2.0	144	288
3	32+823	32+923	left	2.0	100	200

It is necessary to build three noise barriers with overall length of 428.0 m and the area of 1127.0 m^2 to protect part of this group of objects which is obtained by calculation and optimization. Detail of noise map for night period with group of exposed building after implementing noise barrier is shown on Fig 2.

Noise barriers are planned for protection of at least three objects in one group. Planned noise barriers protect three groups of facilities with seven, six and three buildings. For all 16 protected object noise levels on facade after implementing noise barriers are within the legal limits for day, evening and night. Except for the first group where on one object facade, there are still exceeding of noise levels.

The other abatement measures, such as implementing joinery with better sound insolation, facade insulation and closed air intake system, are planned for all other objects that are not protected with noise barriers, as well as objects where despite of noise barrier the significant exceeding of noise levels occurs.

Details of the planned noise barriers with their beginning and endings, heights, length and surface area are given in Table 1.

The efficiency of noise barriers varies on many factors such as wall height, distance from objects, height difference between the barrier and building, etc. The maximum efficiency for each of the planned noise barriers are provided in Table 2.

Table 2. The efficiency of noise barriers

Number of the noise barrier	The maximum efficiency
	night
	[dB]
1	7.6
2	11.5
3	10.5

For objects where the overdraft does not exceed the legal allowable levels for more than 1 dB, abatement measures will be implemented only after the completion of noise monitoring and determining the actual state of the noise level.

3. CONCLUSION

Traffic noise from the new railway line will significantly contribute in increasing existing noise levels in areas along the railway. Noise from new source will threatened 94 residential buildings which represents 5.3% of total number.

Abatement measures are planned as follows:

- Noise walls for protection of 16 object;
- New joinery with better sound insulation for protection of 62 objects;
- Noise monitoring for 11 objects;

The project investor is obliged to provide funds for noise abatement's measures of objects where the dominant source of noise is the railway. This will include three new noise barriers, new joinery for 41 object and noise monitoring for 9 objects. For the remaining objects, where the road is dominant source of noise but railway significantly increases the existing noise levels, the project investor and the manager of the national road network should share the costs of noise abatement's measures on an equal basis, as well as their responsibilities.

Noise abatement measures are not planned for 5 objects where the road is dominant source of noise. Their protection is the obligation of the manager of the national road network, which must also bear the entire costs.

The values of noise levels are given on the basis of calculation. After the railway will be put into operation it is necessary to carry out the noise monitoring. If the measured values of noise levels will exceed permitted levels, appropriate noise abatement measures will be applied.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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PLACE AND IMPORTANCE OF RAILWAY CORRIDOR VC THROUGH BOSNIA AND HERZEGOVINA IN TER NETWORK

Igor MARKOVIĆ [1]

Abstract *– The railway Corridor Vc passes through Bosnia and Herzegovina at direction of north-south, it has a total length of 405 +741 km and it is a branch of a Pan-European Corridor V. Because of its significant origin Corridor Vc needs to be bound and compatible to others traffic corridors, harbours and inland ports and economic segments. Economic segments make baseline development of the country which results in GDP increase and it is directly reflected on Corridor development through increase of good transportation extent and growth of its capacities. Corridor Vc plays an important role in the international railway network because it is functionaly and well-connected to other corridors. Geographical location of the Corridor makes it strategically important to international European transport of goods because many of the southeasterly and central European countries are gravitationally oriented to the Corridor. Besides that it is well-connected to sea and river ports. Trends in economic development and increase trends of goods transporting via Corridor Vc are represented in this paper through three scenarios: Low, Medium and High scenario.*

Keywords - Corridor Vc, comaptible, economic segment, transportation extent.

1. INTRODUCTION

In the last two decades, political and social segments created a requirements to the free european market which enables undisturbed flow of goods among diferent geographical and political sphere. This is how transport became actuator of social development, because transport connects and opens new markets. During those times traffic policy of Europe was directed at forming of Transeuropean and Pan-European Corridors. In the beginins of forming a multimodal transport corridors, road traffic was primal in transport of goods. Whith the increase of transporting of goods, railway captivated competitive position in transporting of goods and got a strategic key position in market of transport thanks to its solid and inexpensive transport and environmentally-friendly vehicle. Bosnia and Herzegovina is a country that is seeking to became member of EU and this country needs to educe its transport policy in the direction of EU transport policy and became a part of unique european market that provides new accomodations and opportunities.

This paper is presented whith problematics and evaluation of compatibility of railway Corridor Vc. Guidelines to transport flow development at Corridor are also presented which shows that Corridor Vc has a place in TER network of corridorsthat have strategic position and importance. Trends of goods transporting via Corridor Vc are represented in this paper through three scenarios: Low, Medium and High scenario whith results and evaluation analyses.

2. RAILWAY CORRIDOR VC THROUGH BOSNIA AND HERCEGOVINIA

Railway in Bosnia and Herzegovina has the length of 1 041 km:

- 948 + 732 km one-track railroad
- 93 + 053 km two-track railroad

Corridor Vc is a branch of Pan-European Corridor V. This branch is spred from Budapest (Republic of Hungary) by the Ploče (Republic of Croatia). It passes through Bosnia and Herzegovina (405 + 741 km) with its greatest part and therefore Bosnia and Herzegovina needs to invest a lot of material and technical recourses in reconstruction and modernization of Corridor Vc. Corridor Vc enter Bosnia and Herzegovina at Bosanski Šamac where it is add to rout line Bosanski Šamac – Sarajevo and retrace it all along Sarajevo. From Sarajevo it traces road line Sarajevo – Čapljina – state board. Line of Corridor Vc

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through Bosnia and Herzegovina is shown at Fig. 1.

Railroads at Corridor Vc are framework of railway traffic in Bosnia and Herzegovina.

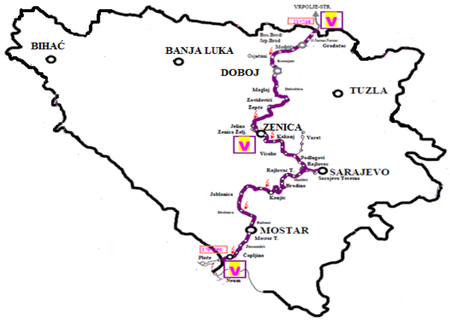

Fig.1. Rout of the Corridor Vc through B&H

3. TRENDS OF ECONOMIC DEVELOPMENT THAT ARE RELEVANT FOR TRANSPORTING OF GOOD IN THE FUTURE

Exploitation of coal, iron ore and bauxite ore, coal-based energetics, processing of iron ore and bauxite, coke production based on imported coal coke, construction materials, chemicals (salt, soda) and wood processing are the key driver of industry in Bosnia and Herzegovina and of importance to the railway transport [10].

3.1. Scenarios and forecasts period

Forecast was made for two periods:

Forecast period:	Horizon period:
Mid-term	2015.
Long term	2030.

Table 1. Economic development scenario defining

LOW	MEDIUM	HIGH
Slow pace of economic revitalization	Continued revitalization of the economy, key drivers are mining and heavy industry	Rapid recovery and the dynamic development of economy
Opportunities for export under the influence of disorder on the global market	Positive opportunities for export in the global market that is developing normally, with no major disturbances	A very positive opportunities for global market export

3.2. Freight traffic forecast on the Corridor Vc, depending on the gravitating port

Ploče harbor is the closet harbor to the B&H that gravitates to the Corridor Vc and has the highest participant percentage at imports and exports of goods by rail in the Corridor Vc. Trends of expanding the capacity and facilities at the harbor, such as the construction of container terminals, and growing Foreign Trade will lead to increased volume of traffic and transport by rail between the Ploče harbor and the interior of Bosnia and Herzegovina (*Table 2*).

Cargo traffic in the period of forecast is characterized by the following:

- Increase in domestic sales in the forecast period will be absolute,
- Exports will increase more than the average

Risks for the cargo transport development:

- Economic revitalization will not be continued.
- Political instability in the Western Balkans and especially in Bosnia and Herzegovina will have a negative impact on economic development
- Price of iron ore wil significantly increase in global market
- Railways will not change their policy towards greater market orientation

Table 2. Scenarios of capacity growth at the Ploče harbor forecast

Total growth 2006. = 100%	2015.			2030.		
	LOW	MEDIUM	HIGH	LOW	MEDIUM	HIGH
	205%	284%	308%	247%	301%	343%

In the aim of positive prospects for the development of B&H's economy the demand for rail-related traffic based on the results of investments and development of mining, industry, forestry and agriculture in Bosnia and Herzegovina will grow dynamically in all the scenarios shown in *Table 3.*

Table 3. The demand for railway transport according to the scenarios [10]

Type of traffic	LOW 2015	LOW 2030	MEDIUM 2015	MEDIUM 2030	HIGH 2015	HIGH 2030
TOTAL:	12.850	16.125	17.819	23.433	21.954	30.754
Therefrom:						
Domestic:	5.416	6.121	6.966	8.095	7.728	9.570
Export	2.973	4.341	4.893	8.241	6.921	12.319
Import	3.482	4.223	4.882	5.344	6.146	6.832
Transit	200	350	250	500	300	700
Others transportation	779	1090	173	1.253	857	1.333
Volume of traffic along the Corridor that is included in the paper						
Corridor Vc	8.959	11.836	12.884	12.884	15.856	23.324
Parallel Corridor X	7.780	9.366	11.499	15.009	14.565	21.178

3.3. Proposed infrastructure measures

Research resulted with important projects that are essential for the Medium and High scenarios for year 2030. namely:

1. The leg appearance (Medium scenario)

- Double tracked line between Sarajevo and Zenica, parallel to the existing leg
- Maximum speed of 120-160 km/h whenever feasible during the reconstruction of railroad phase
- Extension of leg of the tour up till 750 m

2. The leg of the tour appearance (High scenario in appendix to the Medium scenario)

- Beside to the medium scenario a double track line between Konjic and Šamac

- Adaptation and extension of the leg of the tour between Konjic and Mostar
- The new block signals between stations in order to boost the capacity
- Part of the double track section at Doboj - Banja Luka leg of the tour that is parallel to the Corridor X

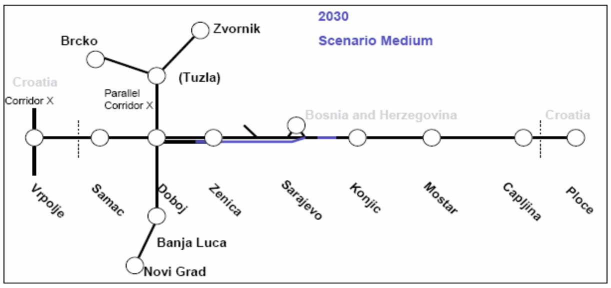

Fig.2. The leg of the tour appearance - Medium scenario for year of 2030 [9]

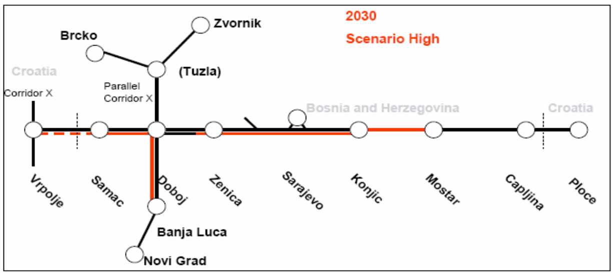

Fig.3. The leg of the tour appearance - High scenario for year of 2030 [9]

4. PLACE OF CORRIDOR VC IN SOUTHEAST TRANSPORT NETWORK

The main railway network in SE Europe is consisted with 4807 km of railways, of which 2 911 km belongs to the corridors that are strategically important remaining 1 896 km belongs to other rail services. Components of the rail network are shown in Fig. 4.

Fig.4. Railroad components of southeast network of railroads [5]

As for the financing and constructing of southeast corridors Fig. 5. shows the level of investment and financing sources at railway corridors.

Line corridors and routes are well connected with the sea and river ports, whose existence is justified in role and importance of the corridor. In the case of Bosnia and Herzegovina emphasis is put on the Ploče harbor, which is connected to the Corridor Vc and the port of Brčko, which is linked to the parallel Corridor X and the railway rout Doboj - Tuzla - Brčko. Besides to these harbors, the Split harbor, Šibenik and Zadar harbors (Croatia) and Bar harbor (Montenegro) are of importance to the Western Balkans. These harbors are connected to the railway lines with countries interior. associated with the interior.

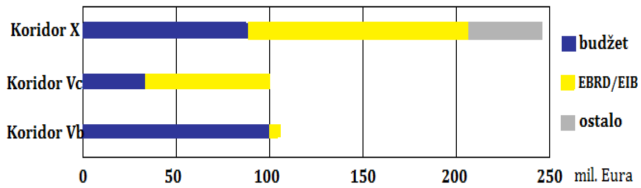

Fig.5. The amount and method of financing of investments in SE railway corridors [8]

In comparison to sea and river ports, traffic from B&H for most industrial centers in B&H is the cheapest option for rail and road traffic. Only for the industrial centers in northern B&H (Lukavac, Zvornik) Vukovar river posrt could be competitive with the Ploče harbor to the costs of rail transportation. Fig. 6. shows results of comparison of the costs of railway transportation of dry bulk cargoes between various ports and locations in B&H.

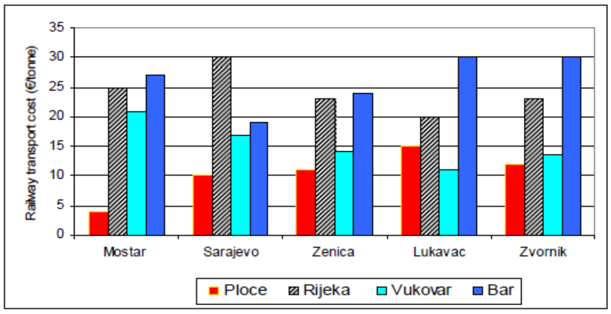

Fig.6. Costs of rail transport for the selected route from the ports to locations in B&H

5. FORECASTS FOR CARGO TRAFFIC AT CORRIDOR VC

The forecast is based on three scenarios of LOW-MEDIUM-HIGH forecasts for two periods: the midterm to 2015th and longterm 2030th. Forecast was developed based on market research from which they obtained the perspective of development for large companies, that could be relevant as clients for rail transport in the mid-term and long-term future. Demand for transportation related to railways that is based on the input and taking because of mining, industry, forestry and agriculture development in Bosnia and Herzegovina, will grow very dynamically in all scenarios [4]:

- LOW by 16,1 million of tons at year of 2030. that is 181% in comparison to the year of 2006

- MEDIUM by 23,4 millions of tons at year 2030. that is 263% in comparison to the year of 2006
- HIGH by 30,8 millions of tons at year of 2030. that is 345% in comparison to a year of 2006.

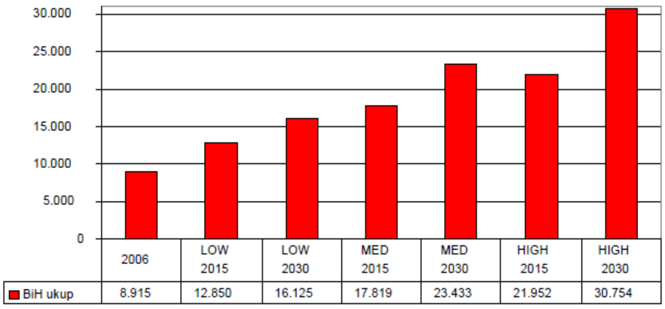

Fig.7. Demand for B&H's railways related transport in years of 2015 and 2030 by scenarios (1000 tons)

Table 5. Forecast of rail traffic on the regional aspects

Type of traffic	LOW 2015.	LOW 2030.	MED 2015.	MED 2030.	HIGH 2015.	HIGH 2030.
Domestic	5 416	6 121	6 996	8 095	7 728	9 570
Export	2 973	4 341	4 893	8 241	6 921	12 319
Import	3 482	4 223	4 882	5 344	6 146	6 832
Transit	200	350	250	500	300	700
Other types of traffic	779	1 090	173	1 253	857	1 333

6. COMMENTS ON PLANNED NETWORK OF LINES THROUGH B&H WITHIN SEETO PROGRAM

The planned railway network in B&H of international importance, as shown in *Figure No. 4* is defined in the SEETO strategy (*South-East Europe Transport Observatory*). This network includes only those lines that have emphasis at international significance, such as railroads the Corridor Vc and railroads Doboj - Tuzla, Doboj - Banja Luka and Tuzla - Brčko. This kind of a scenario of the rail network is determined by railroad lines to the Ploče harbor and Brčko port connection. According to the extent and distribution of traffic flows in B&H railway network, beside SEETO track network, railroads Tuzla - Zvornik, Doboj - Banja Luka - Dobrljin and Banja Luka - Bihać – link to Knin have a large role in the transport of goods. These lines should be included in SEETO network (*Fig. 8.*) because they are of huge importance to the national economy that has indirect impact on the regional level provides better links between lines in the neighborhood and other strategically important European railway routes.

7. CONCLUSIONS

Transport and transport corridors are of vital importance in developing of economies. Developing economy to affect the development of the region and the entire society within a community such as the European Union, regions and transportation corridors must be both physically and functionally linked.

Fig.8. Existing SEETO network (green network) and tracks that have the potential to join SEETO network (red network)

In scenarios that have been descussed in this paper is shown that the Corridor Vc is fully compatible with other European corridors and it will have an important geo-strategic importance for the European railway network. In guidelines of Corridor Vc development, opportunities for development of Corridor and scope of of transport is defined by the following:

- Ploče harbor could attract significantly greate amount of traffic from the countries in its regional service area of which reaches up to Central and Eastern Europe
- Transit traffic through B&H and Corridor Vc could grow faster than predicted by the High scenario
- Some effects of synergy in terms of market orientation and efficiency could attract more traffic than predicted.

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BALLAST BED CLEANING MACHINE OF THE TYPE RM900VB

Werner AFFELD [1]

***Abstract** – The design of the rail roadway is made for a period of use of ca. 25 – 50 years. The consequences of negligence in the repair works are not directly provable in their whole range. Still experience shows that a careful treating of the rail roadway pays out in a longer economical affective service period. The classic rail roadway consists of the ballast bed, the sleeper and rails. Active traffic loads have static and dynamic influence on the ballast bed. The pressure resulting from that has to be taken over by the ballast and the formation. Due to the working forces there appear stress peaks between the sleeper and the ballast, respectively within the ballast, which causes spalling of the ballast stones. This ballast compression is the one mainly responsible for the settlements of the tracks. By temping in the ballast bed the track quality can be corrected or improved up to a certain degree. Here we want to present the RM900VB, a high performance ballast cleaning machine.*

Keywords - Ballast cleaning machine, Ballast recycling, Ballast cleaning, Total excavation.

1. INTRODUCTION

The classic rail roadway, consisting of the ballast bed, the sleeper and rails, is mostly found on the sections of the DB – Netz AG and in other European countries. This is a result of its important values. So this structure is – compared with its alternatives (e.g. slab track) – competitive and ease to execute from the technological point of view. Moreover it offers good possibilities for the correction of the track position with a relative wide correction spectrum. [5]

The task of track maintenance means is to keep the initial quality over a longer period by special means and to extend this way the service life of the tracks.

For the bearing capacity of the ballast bed the shearing strength is of importance. This is characterized by the inner friction angle, which depends on several ballast characteristics (non-uniformity, grain size, grain form, grain roughness). Due to wetness and contamination in the ballast the inner friction angle is decreased and the tension shear strength goes down. As a dimension: a strongly contaminated ballast has a tension- shear strength of gravel. [1]

2. PRESENTATION OF RM900VB

In case of RM900VB (Fig. 1) we have a high performance ballast cleaning machine for the cleaning of tracks. The machine has a preseparator and a crasher for ballast recycling, still it enables the adding of fresh ballast. The special device within the equipment is the integrated device for dynamic stabilization of tracks. Moreover it provides the option of the integration of a ballast washing device. In the basic configuration, i.e. without ballast washing device, the RM900VB contains four main elements:

- Part A, screen (Fig. 1, Part A);
- Part B, preseparator and crasher (Fig. 1, Part B);
- Part C, excavator (Fig. 1, Part C);
- Part D, power train with sweeper and tank end measuring train with integrated dynamic track stabilizer (Fig.. 1, Part D).

As well to the front part (Part A) as also to the back part (Part D) of the RM900VB material silos units can be connected.

General information about RM900VB:

- The maximal excavation output goes up to 900 m³ per hour.
- The operation speed is without steps adjustable from 0 to 450m/h.
- The smallest working radius of RM900VB is 200m.

The RM900VB provides an automatic operation computer (ALC) and a SPS-control.

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2.1. Part A, screening machine

The screen is equipped with a UIC-frame in hinge structure. In the front and back part of the screening machine there are snubbers and draw gears installed. Their six axles (three double axle trucks) are executed as driving axles each. A routable track for loading of spoil, makes a maximal distance from the rail outer edge to the middle of the ballast pile of 5,25m possible, in case the spoil material cannot be disposed by MFS-units on the same track. The track height is 3,25 m and makes therefore loading from the flat or MFS wagons with the same clearance possible (G2). Assembled are two water cooled diesel engines with an integrated monitoring of the engine temperature: one of the type Caterpillar C27 with 700 kW output and one of the type Deutz TCD 2013 L6 with an output of app. 200 kW. A 4500 Liter- fuel tank provides a good reach. The dust removal device has a 1170 l water tank made of niro steel on the screening machine. A water pass pipeline supplies the water ducts on the clearing beam, the tumbler of the clearing chain, on the ballast leveling device and on the ballast transfer belts on the screens and the transfer places of the fresh ballast delivery belts. The center of the screening machine are two high power eccentric screens, which have three levels with machine screens for upper and middle deck and finger grate elements on the lower deck each. Moreover the eccentric screens are equipped with a oversized grain eliminator.

The chassis frame is adjustable automatically hydraulic and can therefore compensate superelevations in the bends on a value of up to 160 mm. The machine part A stays therefore leveled all the time during the working modus. With a video device the screens are monitored from the carrel. Several conveyors transport the excavation material, the cleaned ballast and the spoil material. Directly at the hydraulic pump or over the flow volume control an adjustment of the conveyor speed is possible. The closed and soundproof carrel has windows made of 14mm safety glass. Thanks to one seat for the operator and another for the pilot and the equipment in heating and ventilation, the transfer trips are performable with possibly lowest exposure to the personnel.

2.2. Part B, the preseparator – and crashing machine

The UIC-frame of the preseparator – and crashing machine is executed as a welded structure and is equipped, similar to Part A snubbers and draw hooks in the front and in the back. Over a draw bar Part A and B are connected. The Part B rolls on four axles, which are placed in two double axles bogies. Also this part of the machine provides a leveling of the superelevations by an automatic hydraulically adjustable inclination gear at the chassis frame. The crashing aggregate for scarfing of the ballast is a parallel crashing machine with a hydraulic drive system. In order to keep away all metal parts from the crashing machine, a magnetic separator is integrated. The built in preseparator is equipped with grid elements. By several conveyors the excavated material, crashed ballast and the spoil are transported to Part B. Over a conveyor shiftable in length direction a bypass function of the preseparator and the crasher can be implemented.

2.3. Part C, Excavator

Between the Parts B and D an excavator is assembled. Its UIC-frame is also in the front and in the back equipped with snubbers and draw- hooks. Over a draw bar the excavator is connected to the Parts B and D. Its two bogies have two axles each. The center element of Part C of RM900VB is the 3-fingers-excavation-chain. It has a chain height of 350 mm. Cleaning depths of min. 150mm under the bottom edge of the sleeper up to max. 1000 mm under top edge of the sleeper can be adjusted. With a sleeper length of 2600 mm the normal clearing width is 4000 mm. This can be extended by using two feeder shields with a width of 300 mm each. By two extension elements a maximal beam width of 4920 mm plus feeder shields is being reached. The channel width on the transport side is 620 mm, the one on the empty side 550 mm. The tumbler-power output is given as 350 kW. In order to be able to work under possibly best conditions, the chain speed is adjustable stepless between 1,8 m/s and 3,4 m/s. With a laser system the cleaning chain can be controlled. A hydraulic crane makes an easy manipulation of the chain cross pieces possible. The chain cross beams are equipped with a hydraulic quick action lock. In order to make the cleaning of the ballast lying on the site of the upper edge of the sleeper also possible, there is a wiper in front of the cleaning chain, which cleans the upper edge of the sleeper from ballast. The closed soundproof. In order to provide a better working space, it is equipped with air condition (heating, ventilator, cooler. With a rail lifter and shifting device consisting of four rolls pincers, a maximal rail lifting of 250 mm and a maximal rail shifting of +/- 300 mm (on a straight section) can be reached. In case fresh ballast has to be added, it is made by the conveyors, which are connected to an interim silos with a volume of app. 5 m^3. The fresh ballast respectively the cleaned ballast may be added directly before the ballast drag. Therefore there are two movable ballast conveyors with an also movable control desk built in. Diverse conveyors are used fort he transport of excavation material and cleaned ballast. The excavation conveyor for the supply of the machine part B is executed in such a way, that a direct loading from the MFS-wagon with a decoupled machine part A and B is possible. In order to be able to influence the rail height, also the ballast drag is equipped with rail position pincers. Directly behind the ballast drag the ballast shoulder temping aggregate is placed. In order to enable the proof of a working quality acc. to the DB – provisions, electric multichannelwriter. They are used for recording the cleaning depth and the formation inclination and also superelevation, deformation, settlement and rise of the cleaned track.

2.4. Part D, prime mover with a sweeping device and a tank – and monitoring wagon with integrated dynamic rail stabilizer

The machine part D consists of two parts. The prime mover and the tank – and monitoring wagon. Both wagons are equipped with an UIC-frame with snubbers and draw gears in the front and in the back. The prime mover is connected to the machine part C with a drawbar. Its two bogies have two axles each. In there there are also two diesel engines. They is a 700 kW Caterpillar-engine of the type C27 and a Deutz-engine of the type TCD 2013 L6 with ca. 200 kW output. Both engines have a water cooling system with an integrated engine temperature monitoring and are supplied from the tank of 1500 l capacity. A generator with a maximal output of 50 kVA provides the power for RM900VB in 230 respectively 380 V. It provides the supply for the lightning, the air condition, the heating, the hydraulic emergency pumps and the connection of electric tools. The rail sweeper also assembled on the prime mover is equipped, opposite to the most cleaning machines, not with a cross conveyor but a steep belt conveyor. It can take over the ballast surplus and transport it back to the ballast adding conveyors. The tank-/ monitoring wagon rolls on two double axle bogies. Its UIC-frame is also in the front and in the back equipped with snubbers and draw- hooks. the two main fuel tanks with a capacity of 5000 l each are built in into the tank-/monitoring wagon. Two aggregates for a dynamic rail stabilization are also installed there. Moreover there is a closed workshop carrel with a work bench. The loading is executed over the sliding doors on the side with a trolley and a loading crane. At the monitoring wagon there are also measuring axles for the multichannelwriter installed. For the transfers there is a closed sound proof carrel with heating and ventilation, at the back end of the prime mover, so opposite to the working direction. The front window of this carrel is made of 14mm safety glass.

3. WORK MODES OF RM900VB

3.1. Ballast recycling with optional addition of fresh ballast

In this work mode the ballast, which has to be cleaned, is taken out by the machine part C (pict. 3). From there the excavated material is transported to the preseparator (in the machine part B) by the conveyors. After the way through the preseparator the usable ballast parts are sent to the crusher for scarfing and the spoil is brought on the spoil conveyor to machine part A. The scarfed ballast is transferred to the screening device (machine part A). In the screening machine the usable ballast is again separated from the spoil. The spoil comes over a movable conveyor belt to the connected MFS – wagons or to the wagons on the adjacent track. The scarfed and now screened ballast goes again over conveyor belts through the machine part B to the movable ballast adding conveyors in machine part C. If fresh ballast is required, it can be transported from the MFS – wagon, which are then connected to machine part D, over conveyor belts on the prime mover and the sweeper directly up to the ballast adding conveyor. From the sweeper taken ballast surplus is also transported by the steep belt conveyor to the ballast adding conveyor.

3.2. Ballast cleaning with optional adding of fresh ballast

On principle the modes 1 and 2 differ from each other by the fact, that the mode 2 will activate the proper bypass function of the preseparator and of the crasher. So the excavation material goes directly from machine part C to the screening machine. The cleaned ballast is here also being transported to the movable ballast adding conveyors. The addition of fresh ballast is realized as in mode 1.

3.3. Total excavation with optional addition of fresh ballast

If the ballast bed is to contaminate it has to be taken out completely and disposed. The excavation material is transported directly from the machine part C over the spoil conveyor belt to the connected MFS - wagons. The preseparator, the crasher and the screening machine remain in this mode without any function. In case of adding fresh ballast, it is made similar to the work modes 1 and 2.

4. CONCLUSIONS

The initial quality of the rail roadway may be influenced among others by the used technology of works and the used initial materials. Several tests show, that the gained initial quality forces the quality limit fort he whole operation period of the track system. Moreover the quality of the roadway gained during the use may by the repair works only be brought closer to this quality limit.

By temping in the ballast bed the track quality can be corrected or improved up to a certain degree.

These kinds of corrections and improvements can be conducted precisely and efficiently by high performance ballast cleaning machine such as the RM900VB.

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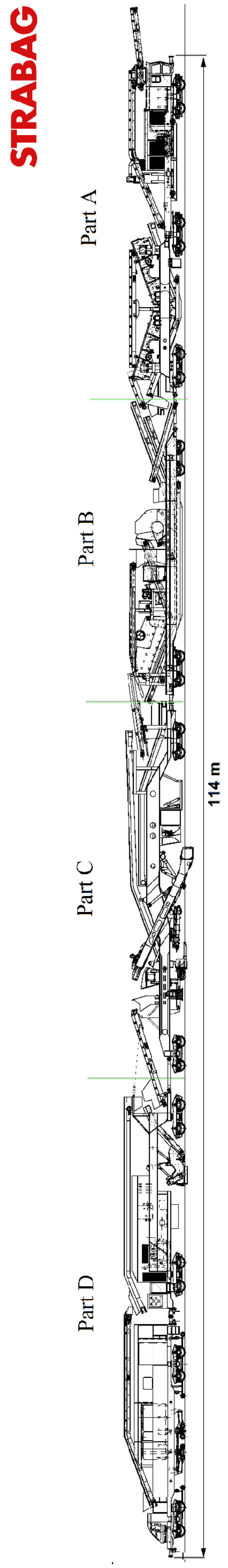

Fig.1. Ballast bed cleaning machine RM900VB

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MODERNIZATION OF THE RAILROAD INFRASTRUCTURE IN BULGARIA – MAIN PROJECTS OF THE NATIONAL RAILWAY INFRASTRUCTURE COMPANY (NRIC) 2007-2013

Nikolay ARNAUDOV [1]
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Abstract *– Main infrastructure projects in progress have been overviewed. Technical data of the current condition and after the reconstruction have been presented. A comparison with the situation with the railroad infrastructure and upcoming projects in other EU countries has been made.*

Keywords - reconstruction, railroad, infrastructure, high speed railways.

1. INTRODUCTION

After the joining of Bulgaria to the European union the main priority of the railway transport becomes its integration to the railway transport systems of the other EU member countries. This priority is grounded also in the politic for planning and development of the European commission, which trough different funds has foreseen mechanisms for financing of such infrastructural projects for the EU member countries. The main point for these programs are the main trans European corridors, with accent of the decrease the time of traveling using these corridors, in other words the increase of the project speed. In the countries from the west side of Europe long time ago the standard for high speed railways has been reached, where the project speeds are about 250 km/h. In Bulgaria this project speed is impossible to be reached because of lot of reasons, for example – there are geographical, economical, demographical and other reasons. Therefore real reachable are only project speeds between 160-200km/h.

And railways with project speeds between 160-200km/h are real reachable and are classified in Bulgaria as high speed.

As owner of the whole railway infrastructure in Bulgaria The State Company NRIC /National Railway Infrastructure Company/ is the main beneficiary of the resources from the funds of European union and it assigns/delegates / projects for reconstructions and rehabilitations of railways and equipments.

Since the joining of Bulgaria to the EU in 2007 NRIC has provided successfully resources from the funds of EU for some of its projects, which have an international importance, according to the European priorities. One of this project is already finished and now it is at the stage of testing.

2. MODERNIZATION AND ELECTRIFICATION OF THE RAILWAY IN THE SECTIONS KRUMOVO – PARVOMAJ AND PARVOMAJ – DIMITROVGRAD

The two sections are part of the railway „Plovdiv-Svilengrad – Turkish border" and are also a part of the trance European transport corridors IV and IX. At the moment this two sections are being tested and after their modernization and electrification they allow now speeds up to 160km/h.

In 2011 were concluded agreements /which included working design and building works/ for the next railroads.

3. RECONSTRUCTION AND ELECTRIFICATION OF THE RAILWAY DIMITROVGRAD - SVILENGRAD FROM KM 231+560 TO KM 297+750

The railway „Plovdiv-Svilengrad – Turkish border" is a part of the trance European transport corridors IV and IX. Recently were signed the contracts for reconstruction of the railway

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Dimitrovgrad - Svilengrad and the funds are provided by operational programmes.

Fig.1.Railway net of Bulgaria

"Transport" and ISPA. The project was sep3rated in tree lots: position 1 - Reconstruction and electrification of the railway section Dimitrovgrad - Harmanli (from km 231+560 between Yabalkovo and Dimitrovgrad to km 266+000 between Simeonovgrad and Harmanli), including stations Dimitrovgrad and Simenovograd and all stations and stops between them with approximate section length 36 km; position 2 - Reconstruction and electrification of the railway section Harmanli - Svilengrad (from km 266+000 between Simenovograd and Harmanli to km 297+750 between Svilengrad and Turkish border), including stations Harmanli and Svilengrad and all stations and stops between them with approximate section length 34 km and rehabilitation and electrification of the railway Svilengrad - Greek border with approximate section length 4 km; position 3 - building of new railroad power-plants in Simenovograd and Svilengrad and extending of the existing power-plant in Dimitrovgrad. The order of each lot includes design and realize of the building works as follows: designing of working project which includes all activities for renovation/rehabilitation of railway infrastructure and execution of all building works by positions/or building of power-plants by lots. All building works are written in details in tender documentation. The total cost of the project is 272 847 970 BGN excl. VAT.

"Reconstruction and electrification of the railway Svilengrad - Turkish border from km 298+800 to km 315+600" /blue on map/

The funds are provided by cohesion fund by operational programme "Transport 2007-2013" priority axis 1. Main goal is development of the NRIC's railway net by electrification and renovation of the infrastructure of the section Plovdiv - Svilengrad - Turkish border for speed up to 160 km/h with high operational indicators and according to EU requirements for safety, operational compatibility, power efficiency and ecology. The order consists of: 1. Design and build of the infrastructure facilities and earthworks for them for single track for the whole length Svilengrad - Turkish border; 2. Design and build of earthworks for single track for the whole length of the section and superstructure with concrete sleepers and rails type 1UIC60, design parameters that allow speed 160 km/h for conventional rolling stock and 200 km/h for rolling stock with tilting wagons, minimal radius for circle curves 1500m (in the border area with Turkey - 800m), maximal longitudinal gradient 10‰, bearing capacity - 22.5t/axis, gauge GC standard, minimal radius of vertical curve - 15 000m; 3. Design and build of a bridge over Maritza river with approximate length 415m, two level cross with other roads/communications, securing the railroad in urban locations; 4. Design and build of the electrification of the new infrastructure and connection in the border area with TCDD systems and related works; 5. realization of measures according to "Natura 2000" program. The total cost of the project is 69 999 666 BGN excl. VAT.

4. REHABILITATION OF THE RAILWAY INFRASTRUCTURE IN SECTIONS OF THE RAIL TRACK PLOVDIV - BURGAS

This project is separated in tree lots: position 1 - rehabilitation of the railroad section Mihailovo - Kaloyanovetz, incl. main lines of the stations, with approximate length 21 km; position 2 - rehabilitation of the railroad sections Stara Zagora - Zavoy (to km 190+590 between Yambol and Zavoy) and Zavoy - Zimnitza (from km 192+706 to entrance switch of Zimnitza station), incl. main lines of the stations and all stations and stops between them, with approximate length 120 km; position 3 - rehabilitation of the railway section Cerkovski - Karnobat, incl. main lines of the stations, with approximate length 28 km and renovation of the section Karnobat - Burgas, incl. main lines of the stations and all stations and stops between them. The order of each lot includes design and realize of the building works as follows: designing of working project which includes all activities for renovation/rehabilitation of railway infrastructure and execution of all building works by positions, which are written in details in tender documentation.

5. MODERNIZATION OF THE RAILWAY SECTION SEPTEMVRI - PLOVDIV

On 05.07.2011 were signed 3 contracts for design and building of the following tree lots of this project: position 1 - modernization of the railway section Septemvri - Pazardzik with design period 10 months and building period 16 months; position 2 - modernization of the railway section Pazardzik - Stambolijski with design period 12 months and building period 17 months; position 3 - modernization of the railway section Stambolijski - Plovdiv with design period 12 months and building period 18 months. The main works for each lot are as follows: 1. geological, hydro geological, hydrological, geodesy and more researches and surveys in working sections; 2. developing and acceptance of technical and working projects for substructure and superstructure between stations, main lines in stations and switches, projects for railroad facilities - bridges, over- and underpasses, culverts and others, projects for electricity systems of the railway, all this for speed 160-200km/h; 3. material supply for the building works and realize of these building works according to the projects in point 2; 4. build/recovery of all drainages in stations and between stations; 5. executing of activities for environment protection. The total cost of the project is 57 083 580 BGN excl. VAT.

6. CONCLUSIONS

In conclusion it must be mentioned, that in this moment Bulgaria is active in modernization of its railway infrastructure. The described projects are in advanced level of progress, but there are more 5 - 6 other huge projects, that are on early stage and are not considered in this article. The main goal of all this infrastructure renovation must be Bulgaria as a member of EU to get closer to the standards of the union. As effect of this the traveling time must be decreased, respectively the higher speed must be reached. This policy was accepted in 2004, when the new Regulation №55 for design and building of railways, stations, crossings and other elements of the rail road infrastructure was published. But in the practical realization of this standards the country is in the beginning.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '12

SURVEY OF EXISTING SIGNALING SYSTEMS AND MODEL ANALYSIS OF EUROPEAN TRAIN CONTROL SYSTEM (ETCS)

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Andreas SCHÖBEL [3]
Simo MIRKOVIĆ [4]

Abstract *–Several different signaling systems and railway signalization are in use today. In relation to the development of specific methods, some systems are more or less accepted among different railway authorities. Interoperability between states leads to necessity of an unified data reading system development for various types of signals and signalization systems. This paper deals with signaling systems in use today. Special emphasis is additionally given onto European Train Control System (ETCS) through a model solution and a review of operation characteristics which are obtained by application of this system solution.*

Keywords - signaling systems, railway signalization, European Train Control System (ETCS)

1. INTRODUCTION

Railway signals serves for giving signs in communication among railway personnel in various types of train service.

Conventional systems for railway signalization are based on visual signs given by light signals positioned along the line. Signal positioning, types of signs and meanings are defined by Signal regulations. Each railway authority has its own signal rules and and differences between signal rules can be significant among some of them. However, the differences are not significant for conditions of signs use. The differences among signal systems are the major obstacle in international train service, particularly in service of traction vehicles across national borders, on railway networks of other railway authorities. In order to achieve interoperability in service over corridors trough foreign countries with variety in signal systems, it was recognized as indispensable to create one unique way of data collection together with unambiguous display for driver inside the cabin. Such system is called European Train Control System (ETCS) and its main characteristics are given in this paper. Further, the model analysis of a train run on line with conventional signaling and ETCS 2 made in Open Track software for railway simulations, will follow.

2. SIGNALING AND TRAIN PROTECTION SYSTEM

Control and information transmission (orders or instructions) by signal signs is done by Signaling system in order to provide safe train service.

Before allowing a train to enter a block, a signalman must be certain that it is not already occupied. When a train leaves a block, he must inform the signalman controlling entry to the block. This is the reason for extreme caution which is permanently given to following of the exact train position.

Operating rules, policies and procedures are used by railroads to enhance safety. Particular operating rules may differ from country to country and even from railroad to railroad within the same country.

General concept of the right to enter a track section is issued by the operator who is in charge of controlling train movements on the track section. Hence, a train is always under external guidance of an operator.

In a signal-controlled territory, the order for train movements is given by:

- a proceed indication of an interlocking or block signal
- a proceed indication of a cab signal
- a call-on signal permitting a train to pass a signal displaying a stop aspect under special conditions

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- a written or verbal instruction permitting a train to pass a signal displaying a stop aspect under special conditions.

In non signal-controlled territory, the order for train movements is given by:

- timetable and train order
- verbal or written order.

Generally speaking, interlockings can be categorized as mechanical, electrical (relay-based), or electronic/computer-based. The newest systems use cab signaling, where the trains constantly receive information regarding their relative positions to other trains.

There are many different types of signaling systems in Europe today (Fig. 1): ALSN, ASFA, ATB, ATC, ATP, AWS, BACC, CAWS, CBTC, CONVEL, Crocodile/Memor, EBICAB, EVM 120, HKT, Integra-Signum, KVB, LZB, LS, PZB, Indusi, SHP, SCMT, TASC, TBL , TPWS , TVM, ZUB 123, ZUB 262 .

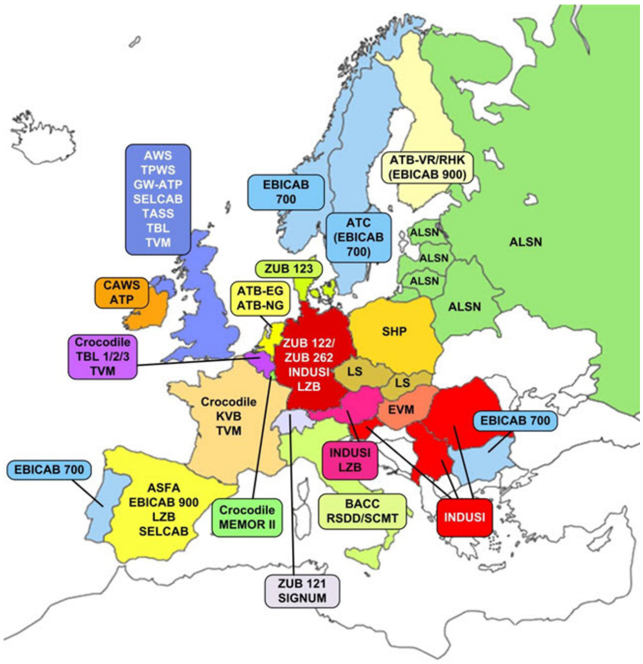

Fig.1. Signaling systems in Europe

3. ETCS - DESCRIPTION OF THE LEVELS

There is currently a large variety of train protection systems in Europe. This is one of the main obstacles for interoperability on the European continent. To eliminate this disadvantage, the European Train Control System (ETCS) has been developed since the early 1990s as a future unified system for the continent and is still in redevelopment process.

Beginning in the early 1990s, the specifications for ETCS are being continuously redeveloped, resulting in updated versions being introduced every few years Therefore, an important point is compatibility between the versions.

ETCS is currently being introduced on several railways in Europe.

3.1. Technical Components and Application

ETCS specifications distinguish five application levels regarding the equipment of the lines: the levels 0,1,2,3 **and STM.**

The term 'ETCS **Level 0'** describes the situation where a vehicle which is equipped with ETCS moves in an unequipped area. The supervision functions are limited to supervision of a constant speed, which is the minimum of the maximum train speed and a general nationally defined speed limit for Level 0.

Level 1 (fig. 2) The main transmission medium are transponder balises called 'Eurobalise' which transmit, among others, movement authorities and profile data to the train (which is not individually known) when passing above the balise.

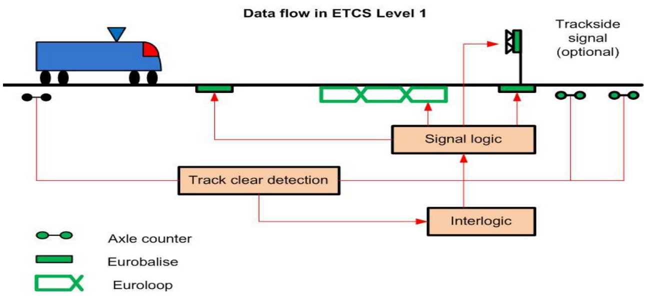

Fig.2. Data flow in ETCS Level 1

Beside balises, linear infill devices can be used locally to transmit changes of signal aspects beyond. Based on the information received from the trackside and upon train data which include braking characteristics, the train computer calculates the dynamic speed limit which can be signalized to the driver by cab signaling equipment and supervised.

At **Level 2** (fig. 3) **and Level** 3 (fig. 4) information can be continuously and bidirectionally transmitted by Euroradio, a radio standard based on GSM-R.

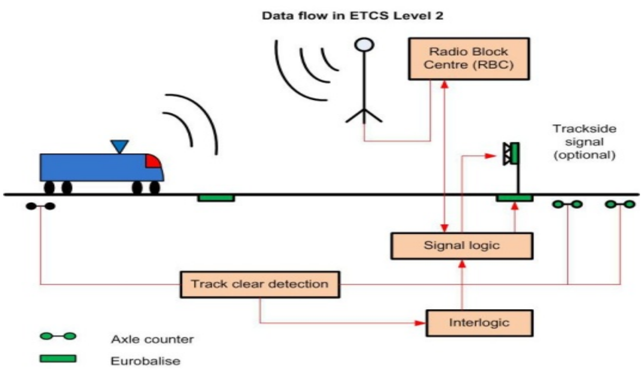

Fig.3. Data flow in ETCS Level 2

The central trackside unit is the Radio Block Centre (RBC). It is responsible for a longer section of line, stores the static data and obtains dynamic data like signal and point positions from the interlocking stations in the area.

The difference between Levels 2 and 3 is that in Level 2 ETCS only takes the responsibility for signal and train protection functions, whereas Level 3 also replaces the interlocking-based track clear detection by continuously checking train completeness on the train and transmitting this information to the RBC.

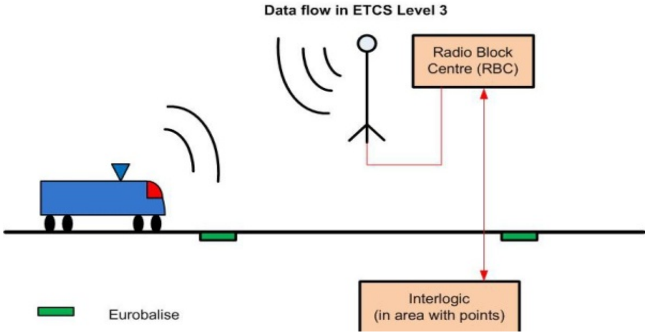

Fig.4. Data flow in ETCS Level 3

STM level (Specific Transmission Module) is designed for situations when train which is equipped with ETCS moves on a line without ETCS, but with a national train protection system. This level allows collecting information from various national and local systems and has been developed for the migration period.

In the following, the main technical components of ETCS are summarized, beginning with the train equipment (Fig. 5):

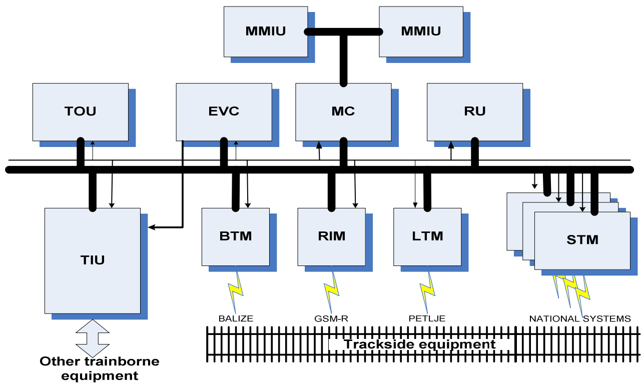

Fig.5. ETCS trainborne equipment

EVC	European Vital Computer
MC	Management Computer
RU	Recording Unit
TOU	Time and Odometer Unit
MMIU	Man Machine Interface Unit
TIU	Train Interface Unit
BTM	Balise Transmission Module
RIM	Radio Interface Module
LTM	Loop Transmission Module
STM	Specific Transmission Module

The main trackside components of ETCS are:

- Eurobalises
- Radio Block Centre (RBC)
- Euroloops and Radio infill Units.

4. EXAMPLES OF OPERATION

4.1. Opentrack model

Open Track software for simulation of railway operation is used for crating the infrastructure test model upon its methodology and general phases of simulation. (Fig. 6)

Simulation is done for conventional signaling and ETCS 2. General approach of modeling consists of creating data for infrastructure, trains and timetable (train number, traction, length, weight, priority, departure and arrival time, station retention time etc.). Output data for model are speed - distance diagram, timetable chart, track occupation and statistics.

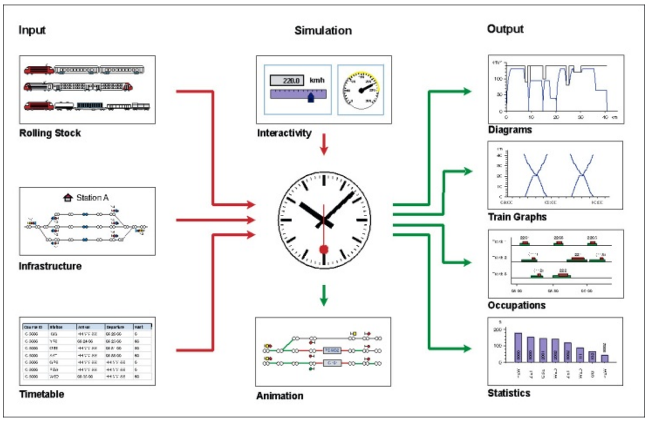

Fig.6. Opentrack working scheme

Electro motor train unit with tractive effort of 260 kN and with V_{max}=200 km/h is used for simulation on this model.

Infrastructure model is built as a combination of conventional signaling and ETCS 2. Conventional signals are set for braking distance of 2500 m. Infrastructure model consists of 5 stations and 4 line sections. All stations are at the same distance of 11 km and total length is 44 km. The first and the end (fourth) section are with conventional signaling and middle two sections are controlled by ETCS 2. (Fig. 7)

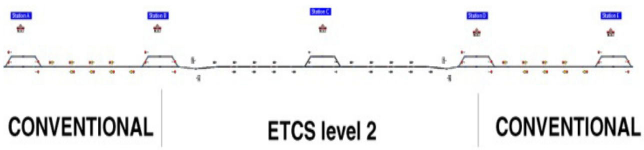

Fig.7. Infrastructure model

4.2. Data from operational performance

Conventional signaling has to fulfill many parameters such as: visibility distance and minimal distance between signals. In order to respect all restrictions there are limited number of locations over one line section.

Contrary to conventional signaling, all parameters in ETCS 2 are related to cabin signalization (virtual signals which can be placed anywhere). This way of sector control between stations eliminates undesirable influence of block section in comparison to conventional signaling. Further, the traction vehicle performance is better because there is no necessity for speed limitation like when running over line with conventional signalization on block sections.

Three diagrams were chosen for representation of train run on this infrastructure model:

- Speed - Distance, Fig 8,
- Acceleration - Distance, Fig 9,
- Energy consumption – Distance, Fig 10.

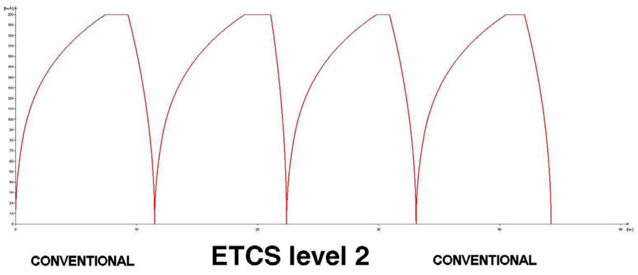

Fig.8. Diagram of train speed and distance

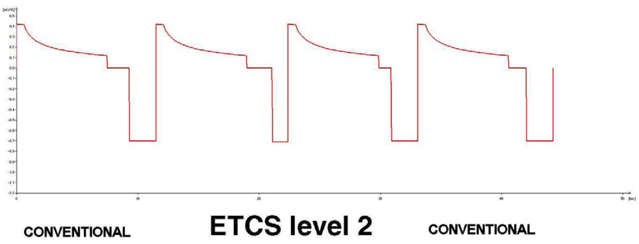

Figure 9 Diagram of acceleration and distance

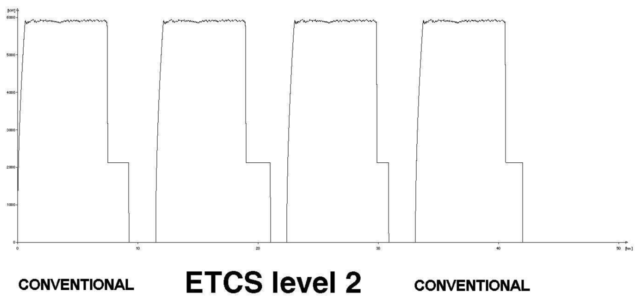

Fig.10. Energy consumption and distance

All three diagrams show no significant differences in running performance for line sections equipped with ETCS 2 and others with conventional signaling equipment.

5. CONCLUSION

Railway operators and networks are more and more attracted to interoperability and consequently ETCS signalization has been spreading over many railway corridors.

Permanent speed control which provides defining of train braking effort is the great advantage of ETCS. The speed control by the majority of other signaling systems, including autostop device on ŽS, is done in signal zone. This is particularly an issue in the entry section of station area where today's systems are the limiting factor. It is possible to shorten the headway times of trains entering stations by application of ETCS due to the opportunity of a continuous data transmission of allowed signal aspect. Another advantage in comparison to national signaling systems is cabin signalization which guarantees clear recognition of "signal signs" regardless to track weather condition.

Finally, the major advantage of ETCS as common European choice is the unique, unequivocal cabin sign representation of all variety of signaling systems.

Software simulation of a train run through the infrastructure model with ETCS 2 and conventional signaling created for the purpose of train performance and track capacity investigation does not show possibilities for track capacity increase on sections with ETCS 2. It is not possible to make other conclusion since the differences shown on figures 8, 9 and 10 are hardly noticeable.

Taking into consideration the fact of organization of train service on tracks with ETCS 2 based upon fixed blocks, like on tracks with conventional signaling and APB (Absolute Permissive Block), the results obtained absolutely are expected.

The track capacity increase is also not possible on tracks with ETCS 1 because of the same reason, as a result of a fixed section block control.

Implementation of ETCS level 3 can lead to track capacity increase because of introduction of movable block sections which are created upon exact positions of trains moving on the same track.

This analyzes leads to a simple conclusion that ŽS should not hurry to invest in ETCS equipment since it is not possible to gain any track capacity increase. The speeds on ŽS network are quite low and the density of trains is not so high. Consequently it is hard to justify the investments in new ETCS train control systems. Present conditions of train service on ŽS network can only slightly benefit from all advantages offered by ETCS. There are many other urgent problems on ŽS network which are waiting to be solved.

The interoperability of Serbian railway corridors can be improved by upgrading to level STM instead to ETCS. Existing track devices can provide infrastructure interoperability by simple technical upgrading at acceptable price. It is considered that traction vehicles equipped wit ETCS also have STM unit for INDUSI I 60 autostop device used on tracks of ŽS network. STM unit is vehicle mounted and it has to be an investment done by the railway operators. Simultaneously, ŽS traction vehicles do not need any upgrading for ŽS network equipped with INDUSI I 60 system.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '12

DETECTION OF OVERHEATING IN AXLE-BOXES OF RAILWAY VEHICLES

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Abstract *– The consequence of axle-bearing failure in railway vehicles is regularly derailment with huge material damage and often with human casualties. Because of the very serious consequences, railway aims to introduce appropriate techniques for early detection of overheating of axle-bearings or more precisely axle-boxes. The commonly used technique is based on application of stationary measurement stations or so called checkpoints. There is also an innovative technique based on the use of systems for on-line monitoring of axle-boxes temperature. The task of this paper was to explore these techniques in order to provide a critical analysis and guidelines for further development in this area. The main conclusions are that the technique of checkpoints has limited effectiveness in case when temperature increases rapidly, and that technique of on-line monitoring is far more efficient because it allows an immediate response in order to prevent derailment and accident.*

Keywords - Detection, overheating, axle-boxes, railway, wagons.

1. INTRODUCTION

The basic requirement that is seeking from the railway is to be reliable, efficient, and cost-effective compared to the other modes of transport. The main prerequisite for meeting these requirements is continuous and quality maintenance of railway vehicles and railway infrastructure [1]. The failures on railway does not happen often, but when it happens, the consequence is usually derailment accompanied with enormous material damage and loss of human life. In addition, there are a huge material losses caused by the interruption of the traffic and reparation of the infrastructure.

One of the most common causes of derailments is the failure of the axle-bearing [2–4]. It leads to the failure of the wheelset, which may cause derailment not only the one wagon but also the whole train. The consequences are regularly with huge material damage and often with human casualties. From that reason the railway pays special attention to this problem. It aims to introduce the appropriate techniques for early detection of overheating of axle-boxes. The main task is timely detection of defects in bearings and prevention of derailment and accident. The commonly used technique is based on application of stationary measurement stations or so called checkpoints, placed at certain points along the rail [5–10]. The checkpoints are usually equipped with the special sensors whose role is to detect an overheating in axle-boxes during the train passing above them. There is also an innovative technique based on the use of systems for continuous (on-line) monitoring of axle-boxes temperature. The task of this paper was to explore these techniques in order to provide a critical analysis and guidelines for further development in this area.

2. CAUSES AND CONSEQUENCES OF AXLE-BEARING FAILURE

The most responsible parts of any running gear of

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railway vehicles are not only the wheelsets, but also the elements for their connection on the bogie framework, called axle-bearings. In the process of exploitation of vehicles they are among the most loaded parts and their reliability directly influences on the reliability of the entire train. In practice there are many types of design of axle-bearing, but all they are based on the similar concept. All different types of axle-bearing must meet the requirements of international regulations and recommendations UIC, EN, ERRI, etc. Functionality of the assembly of axle-bearing depends of the correctness of the every its part. In practice this assembly is sealed and can be opened only with the presence of the authorized person. Its inspection and maintenance are also defined by the international regulations UIC, railway regulations, and instructions of individual manufacturer.

Causes of axle-bearings failures are very various. Some of them are: defects in material, errors in manufacturing (during the minting, pressure, hardening, cracks formed during grinding, errors in tolerances), incorrect assembly or installation of the bearing, incorrectly lubrication (lack of lubricant, too much lubricant, or inadequately lubricant), passage of current, the effect of moisture, mechanical impurities, etc [2]. The main characteristic of any defect is that it causes changes in performance and an increase in axle-bearing temperature. In many cases the final consequence is derailment, not only that wagon, but also entire train. This occurrence is very common, especially characteristic for the freight wagons used in extreme operating conditions such is for example transport of coal in thermal power plants. Figures 1 and 2 show the consequences of axle-bearing failure of one wheelset of wagon for coal transportation from Kolubara to the thermal power plant "Nikola Tesla" Obrenovac, Serbia.

Fig.1. Derailment caused by the axle-bearing failure

Fig.2. Typical damage of the axle and track

The accident occurred in 1995. in station Stubline. The direct consequence of this derailment was a huge material damage on wagons and infrastructure. However, much more serious were the indirect effects such as delay of rail transport of coal and threat of supplying of thermal power plant, and thus its normal functioning.

There are many such examples in technical practice. From the previous it can be seen how important is the proper functioning the axle-bearings and what consequences may result after its breakdown.

3. DETECTION OF OVERHEATING

Because of very serious consequences, railway is introduced a certain techniques for early detection of overheating of axle-bearings or more precisely axle-boxes. The main task is timely detection of defects in bearings and prevention of derailment. The most commonly used techniques are based on the application of stationary measurement stations or so called checkpoints. There are also a modern techniques that are based on the use of systems for on-line monitoring of axle-boxes temperatures.

3.1. The checkpoints for detection of axle-boxes overheating

The wide use of stationary measuring stations or checkpoints is started in the last twenty years on many world railways. In addition to axle-boxes overheating detection, the modern checkpoints simultaneously detect the overheating of the wheels, brake discs, dimensions of the vehicle, lateral movements, axle loads, flat seats on the wheels, noise, impacts, etc. This technique is based on the installation of a certain number of checkpoints at the certain mutual distances along the railway line. The main problem in design of contemporary checkpoints when it comes to detection of axle-boxes overheating is how to provide a high-speed measurement. Overheating of axle-boxes has to be detected even at the highest speeds of the train that goes up to *200 km/h*. For example, if train is moving at a speed of *200 km/h*, axle-box which is about *220 mm* width will pass a fixed point on the track for approximately *0.004 sec* or *4.0 msec*. Therefore, in this case the duration of measurement must be maximal *4 msec*, and obtaining the temperature state of axle-box is very complex problem. In contemporary solutions of checkpoints for detection of overheating of axle-boxes the infrared temperature detectors are used. They allow obtaining the adequate temperature profile of axle-boxes on each wagon in moment of train passing. Some of modern solutions allow detecting overheating even when the train speed is up to *500 km/h*. One of the most important problems in use the technique with the checkpoints is how to determine the distance between two checkpoints. That calculation is based on the risk-analysis where the speed of increase of the temperature is takes into account. In most axle-bearings normal operating temperature is *55-60°C*, and alarms from checkpoints will be started if temperature of axle-boxes is about *80-90°C*. The question is how fast the temperature increases if there is some defect in axle-bearing. Overheating may be to the certain temperature which is not dangerous for the normal function of the bearing, but it creates disorder of bearing performance and after a certain period of time may leads to the failure. On the other side, the overheating can be very rapid, while the temperature increases to the critical value for only *30-60 sec*, and the failure is coming very soon. If overheating occurs per second scenario, on the section of the track between two checkpoint, it is very debatable whether in this case the checkpoints will be able to detect overheating, or derailment may occur even on the so-equipped track. Accordingly, the question is, will the temperature rise be detected before bearing failure and occurrence of derailment.

In accordance with the previous observations a simple model of system of checkpoints along the one railway line is analyzed. Checkpoints are located at the mutual distances of 3 to 15 kilometers as shown in Fig. 3. The similar system of trains observation is used on the Austrian railways OBB [5].

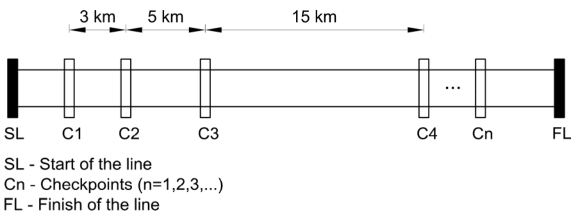

Fig.3. The system of checkpoints along the one railway line

The motion of one wagon or more precisely one wheelset between two checkpoints at a distance *L* was analyzed, where the train speed is *V*.

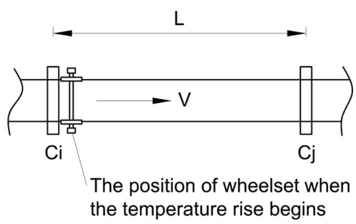

Fig.4. The analysis of overheating on one wheelset between two checkpoints

Also, it was assumed that an increase in temperature occurs immediately after the passage of observed wagon (wheelset) through the first checkpoint *Ci* (Fig. 4). This critical case means a maximum time for axle-box temperature increasing, until passing through the next checkpoint *Cj*, when this increase can be detected. The time that elapses from the moment of passing through the first checkpoint *Ci* until the moment of passing through the second checkpoint *Cj* is $t=L/V$. Table 2 gives the comparative review of time *t* for different combination of distance between checkpoints *L* and train speed *V*.

Table 2. The comparative review of time t for different combination of L and V

CASE	*L* [km]	*V* [km/h]	*t* [sec]
A1	3	160	67.5
A2	3	200	54
B1	5	160	112.5
B2	5	200	90
B3	10	160	225
B4	10	200	180
C5	15	160	337.5
C6	15	200	270

From Table 2 it can be seen that the observed wagon the distance between two checkpoints, at best case A2, passing for *54 sec*, while the train speed is *200 km/h* and distance between checkpoints is *3 km*. Based on data from Table 2 it can be noted that scenario of temperature increasing for *60 sec* to the critical value, can be eventually detected in case A2, where the time to reach the following checkpoint is less and equal to *54 sec*. In addition, when take into account the speed of reaction and stopping the train, it is very debatable whether in this case accident may be avoided. If, for example an increase in temperature occurs in the middle of the distance between two checkpoints *Ci* and *Cj*, and reach the critical value for *60 sec*, in that case the overheating can be detected at the $V=200$ *km/h* and $L=3$ *km*. For the same situation, if the distance between checkpoints is $L=10$ *km*, the overheating can not be detected before the failure.

Thus, the checkpoints can give some results and can detect overheating in some cases. However, all is based on randomness and a combination of particular circumstances. Despite the large investment of funds in the installation of checkpoints, quite a high risk of their inefficiency is always there. This is confirmed by the technical practice which shows that despite the implementation of a modern checkpoints, some derailments did not avoided.

3.2. On-line monitoring of axle-boxes temperature

Because of limited efficiency of checkpoints, in recent years there is a need to develop techniques that enable continuous (on-line) monitoring of axle-boxes temperature. This technique involves continuous monitoring of temperature of each axle-box of each wagon in the train. This means that every axle-box of every wagon in the train must be equipped with the special sensor unit for temperature monitoring. For example, one four-axled wagon must be equipped with the eight sensor units, as shown in Fig. 5. If the train is composed, for example, of 100 wagons, the number of sensor units would be 800.

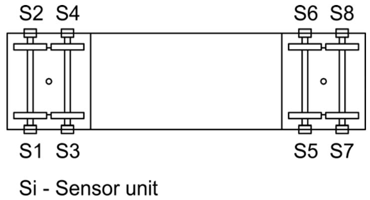

Fig.5. The sensor units for on-line monitoring of axle-boxes temperature of one four-axled wagon

The main problems of this technique are transmission of data and power supplying of sensor units. Usually the problem of data transmission can be solved by using the wireless network connection. This is the most suitable solution because of large number of sensor units. In that case, the one sensor unit must be equipped with the box, sensor, antenna, radio transceiver, central processing unit, and power supply. The data from all sensor units must be collected in one receiving unit and must be processed in real time. This receiving unit should be placed into the locomotive. Its task is to collects data on the temperatures of all axle-boxes, processes them in accordance with the appropriate algorithm, and displays an alarm in case of exceeding the normal values. In the case of temperature increase in any axle-box, engine driver is immediately alerted and can react to stop the train. Therefore, this technique allows a timely response in order to prevent derailment and accident. Its importance is especially pronounced when takes into account the continuous trends for increasing of trains operating speed and increasing the safety and security on the railway.

4. CONCLUSION

The failures of axle-bearings are among the most dominant causes of derailment, especially in railway vehicles that are used in extreme working conditions. The commonly used prevention technique is based on application of stationary measurement stations – checkpoints placed at certain points along the rail. They are equipped with special infrared sensors whose role is to detect an overheating in axle-boxes during the train passing. Checkpoints can give some results and can detect overheating in some cases, especially when the temperature rise is slower. However, all is based on randomness and a combination of particular circumstances. Despite the large investment of funds in the installation of checkpoints, quite a high risk of their inefficiency is always there. This is confirmed by the technical practice which shows that despite the implementation of a modern checkpoints, some derailments did not avoided. There is also an innovative technique based on the use of systems for on-line monitoring. It involves continuous monitoring of temperature of each axle-box of each wagon in the train. In the case of temperature increase in any axle-box, engine driver is immediately alerted and can react to stop the train. This technique allows a timely response in order to prevent derailment and accident. Therefore, its efficiency is far greater than the effectiveness of technique with checkpoints. By proper engineering solutions of data transmissions and power supplying of sensor units, this technique can be customized for the specific mass use in industrial and commercial rail lines. Of course, before the widespread use a detailed testing of the system in exploitation conditions should be done. When it comes to techno-economic feasibility of introducing a systems for on-line monitoring, it should be taken into account that detection of every overheating prevents derailment with huge material damage and human casualties.

ACKNOWLEDGEMENT

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '12

APPLICATION OF FBG SENSORS IN SMART RAILWAY

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Abstract *– Fiber Bragg grating (FBG) sensor technology has become one of the most rapidly progressing sensing topics of this decade in the field of optical fiber sensors. FBG sensors are currently emerging from the laboratory to find practical applications. Rapid progress has been made in both sensor system developments and applications in recent years. The need for improved safety, reliability and efficiency is one of the most important aspects of the railway industry worldwide. FBG sensors could be used in smart condition monitoring system that can allow real-time and continuous monitoring of the structural and operational conditions of trains as well as monitoring of the structural health of rail tracks and the location, speed and weight of passing trains of the entire rail systems. This information is very important for ensuring a safer railway industry with reduced maintenance costs, optimized performance and capacity; therefore FBG sensors could play a major role in the realization of "Smart Railway". In this paper basic working principle of FBG sensors and its application in railway systems will be described.*

Keywords – FBG sensors, monitoring system, railway industry, "Smart Railway".

1. INTRODUCTION

The need for improved safety, reliability and efficiency is one of the most important aspects of the railway industry worldwide. A smart condition monitoring system would allow real-time and continuous monitoring of the structural and operational conditions of trains as well as monitoring of the structural health of rail tracks and the location, speed and weight of passing trains of the entire rail systems. Ultimately, the inclusion of train location, speed restrictions, and train and track conditions to an 'intelligent system' will herald a safer railway industry with reduced maintenance costs, optimized performance and capacity. Integration of smart condition monitoring system and railway in one big system makes 'intelligent system' known as "Smart Railway". Smart condition monitoring system for railway application requires extensive sensor networks (thousands of sensors) for measuring strain, vibration, temperature, velocity, etc. The use of conventional sensors would be very difficult and expensive. Instead of this, fiber Bragg grating sensors (FBG) could be used because they offer many advantages over classical electrical sensors: immunity to electromagnetic interference (EMI), long life-time (more than 20 years), high precision, durability, no calibration needed, and massive multiplexing capability - hundreds of sensing points along a single strand of optical fiber.

The first report of photosensitivity in optical fiber was attributed to Hill [1]. However, the first practical grating technique was regarded to be UV grating fabrication [2]. In 1989, Morey disclosed the potential sensing abilities of FBG [3]. Exposure of optical fiber to ultraviolet light induces a permanent change of the refractive index. This effect is used to write Bragg gratings into fibers which then can reflect very small wavelength peaks. The wavelengths of these peaks change with temperature or when such fibers are strained. This effect can be used for measuring strain, vibration, temperature, velocity, etc. In recent years, FBG sensors have attracted a lot of interests and are being used in numerous applications. One of these applications is in "Smart Railway". In [4] FBG sensors are used for health monitoring of railway. Paper [5] describes exploitation of FBG sensors for axle counter in railway engineering, and in [6] FBGs are used for monitoring of a steel railway bridge.

There is great potential for application of FBG sensors in railway systems. This paper has intended to provide systematic review of recent progress in

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applications of FBG sensors in railway, which will promote classical railway to “Smart Railway”.

2. FIBER BRAGG GRATING SENSORS

The FBG is a short section in the core of an optical fiber with periodic variations in the index of reflection (Fig.1). FBG sensors based on the principle that the FBG is sensitive to the variation of the temperature and the stress [3].

2.1. Fabricating Fiber Bragg Grating

Bragg gratings are written into so called single-mode fibers. These fibers consist of a very small inner core of 4 to 9 μm diameter and an outer part (cladding) of pure glass (SiO_2) of 125 μm diameter. The core has a higher refraction index caused by high Germanium doping. The difference of refraction indexes between inner core and cladding causes the light to propagate only inside the small core.

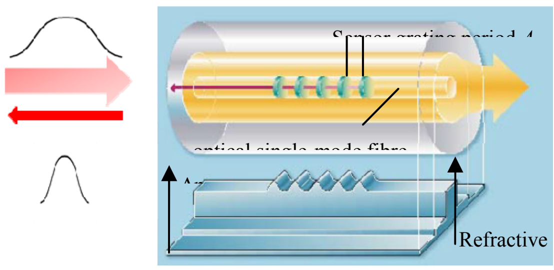

Fig.1. Structure of fiber Bragg gratings

Currently, there are two major methods for fabricating Fiber Bragg Grating: holographic method [2] and phase mask method [7]. Easier method for fabricating FBG is by phase mask (Fig.2) because holographic method requires more stable setup, and a good coherence light source.

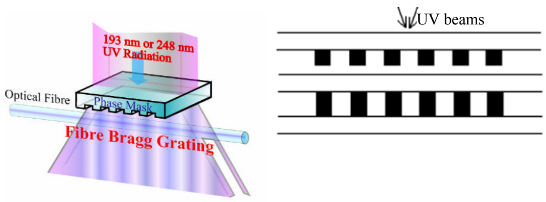

Fig.2. FBG fabrication using phase mask

Phase mask is a piece of diffractive grating with depth modulation on fused silica. The phase mask were designed to suppress 0^{th} order diffraction efficiency (<5%) and increase +/-1^{st} order efficiency (>35%). When a UV beam incident on phase mask, the +/-1^{st} order beam will credit an interference pattern, this pattern will write the FBG on the fiber. Basically, when a germanium-doped silica core fiber is exposed to this ultraviolet (UV) radiation (with wavelength around 240 nm), it produces a permanent change in the refractive index of the germanium-doped region, due to the photosensitivity nature of the fiber and, using such an exposure, it is possible to obtain realize changes in the refractive index by factors as large as 10^{-3} in germanium-doped silica fiber. If the fiber is exposed to a pair of interfering UV beams (Fig.2), then in regions of constructive interference which correspond to high UV intensity, the local refractive index will increase. At the same time, in regions of destructive interference, where the intensity of UV light is negligible, there is no index change. Therefore, an exposure to an interference pattern will result in a periodic refractive index modulation along the length of the fiber, the period of modulation being exactly equal to the spacing between the interference fringes.

2.2. Operating principle of the FBG sensors

Operating principle of the FBG sensor system is shown in Fig.3.

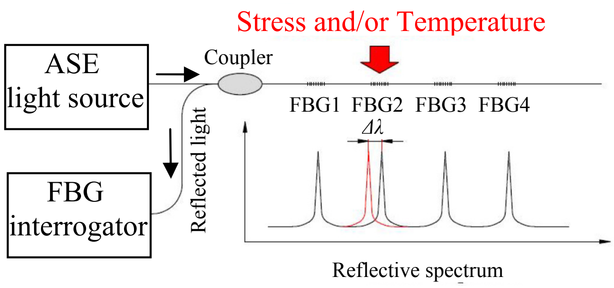

Fig.3. Operating principle of FBG Sensor

An amplified spontaneous emission (ASE) light source illuminates sensor chain through a coupler. Different FBG has different reflective wavelength which will be demodulated by the interrogator (system that detects the wavelength shift in relation to the external perturbation). When an FBG is expanded or compressed due to temperature change or stress, it will induce wavelength shift $\Delta\lambda_B$ in the reflective spectrum. FBGs couple the forward propagating core modes to the backward modes at the wavelength, λ_B, that satisfy the resonance condition:

$$\lambda_B = 2 \cdot \Lambda \cdot n_{eff} \quad (1)$$

where n_{eff} is the effective index of the core mode and Λ is the period. Equation 1 indicates that the Bragg wavelength (λ_B) depends on the effective refractive index of the core mode (n_{eff}), besides of the grating periodicity (Λ). External parameters can affect both n_{eff} and Λ resulting in changes on the λ_B. This dependency allows the FBG to be applied as a various types of sensors (temperature, strain, etc.) [8]. The strain response occurs because of both the physical elongation of the optical fiber (and the corresponding change in Λ), and the change in refractive index of the optical fiber due to elasto-optic effect (that consequently modifies n_{eff}) [9]. The inherent thermal expansion of the optical fiber material (that changes

Λ) and the dependence of the refractive index of the optical fiber with the temperature due to thermo-optic effect (that modifies n_{eff}) justify the FBG temperature response [10]. Mathematically, the shift in the Bragg wavelength ($\Delta\lambda_B$) due to an applied strain and temperature change is given by [11]:

$$\Delta\lambda_B = 2\left(\Lambda\frac{\partial n_{eff}}{\partial l} + n_{eff}\frac{\partial \Lambda}{\partial l}\right)\Delta l + 2\left(\Lambda\frac{\partial n_{eff}}{\partial T} + n_{eff}\frac{\partial \Lambda}{\partial T}\right)\Delta T \quad (2)$$

where, l is the FBG length, and T is the temperature.

The Equation 2 shows that any change in wavelength, associated with the action of an external perturbation to the grating, is the sum of both strain and temperature terms. Therefore, in sensing applications where only one perturbation is of interest, the decoupling of either temperature effect or strain effect becomes necessary. The simplest approach for elimination of cross-sensitivity problems is to use two FBG, with one of them isolated from the unwanted perturbation. Typical values for FBG sensitivities with Bragg wavelength close to 1.5 μm are 1 pm/με and 10 pm/°C [12]. Hence, when the temperature effects are compensated and/or controlled, the FBG response can be associated only with strain changes.

3. APPLICATION OF FBG SENSORS IN RAILWAY

The FBG sensors can be used to monitor many important railway sub-systems such as axle counters [5], anti-derailment monitors [13], and train load detectors. They can serve as continuous rail crack detectors, to monitor the instantaneous vibration signatures of passing trains at selected locations, for on-line measurement of train speed, train weight estimation, detection of untoward activities [14], etc.

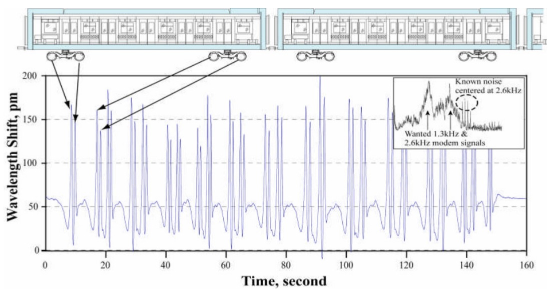

Fig.4. FBG sensors for counting train axles

FBG sensor system is best suited for railway monitoring due to its many unique features that are not found in electrical monitoring systems: EMI (electromagnetic interference) immunity, capability to multiplex large number of sensors along a single fiber, remote sensing, inherent self-referencing capability, no calibration needed etc. By measuring the strain induced on the tracks when a train passes over them FBG sensors can serve as axle counters. As show in Fig.4 [4], each peak represents the presence of each axle, by counting the number of peaks generated from each sensor it is possible to calculate the number of axles [5]. This is important to ensure the same number of cars entering and leaving tunnels.

The same approach can be used to detect the speed and weight of a passing train (Fig.5). Since the distances between the wheels are known, train speed can be easily computed by using just one FBG sensor.

Fig.5. FBG sensor installed on the track

FBG sensors can be installed on each side of a rail to detect imbalances on the two sides of rail wheels. It is well known that if there are large difference between the left and right hand side loading of an axle, there is the danger of train derailment.

FBGs can be also used for the measurement of strain and temperature of train body shells.

The axial stress distribution and variation of continuous welded rail tracks under the action of environmental temperature will be related to the deformation of the track and the safety of the rolling stock. FBG sensors could be also used in track deformation monitoring system. Fig. 6 shows three FBG sensors that are installed at each cross section of a track. These three axial strains can be used to back calculate the axial force, bending moments and deformation curvatures at their section as well as to calculate the axial stresses [15].

Fig.6. FBGs for measuring deformation of rail track

FBG sensors could be installed on a number of equipment in the underframe of trains for monitoring the vibrations in critical locations which include the welding joints, cross beams and sole bars as shown in Fig. 7 [4].

The FBG sensors can be used for structural health monitoring of railway bridge. As shown on Fig. 8, one fiber Bragg grating sensor can be placed in the middle of a secondary beam section, exactly below the rail track on the one edge of the bridge. This sensor can precisely determine loading conditions and exact structural behavior of the bridge [6].

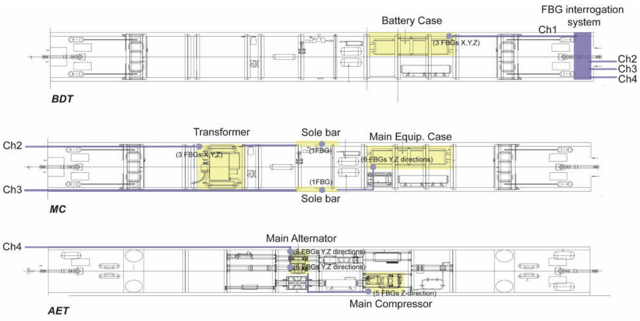

Fig.7. Locations of weld joints where FBG sensors are installed for monitoring dynamic strains of critical parts: BDT = Battery Trailer, MC = Motor Car, AET = Auxiliary Equipment Trailer

Fig.8. FBG sensor installed on the beam section of the bridge

4. CONCLUSIONS

In this paper basic operating principles of fiber Bragg grating (FBG) sensors, and its application in railway systems are shown. In essence, a small piece of FBG sensor can generate lots of train running information with good data integrity. Due to many advantages over classical electrical sensors: small size and weight, electrical isolation, environmental robustness, and ability to be multiplexed, the FBG sensors can be used to monitor many important railway sub-systems such as axle counters, anti-derailment monitors, train load detectors, speed detectors, etc. This permits real-time monitoring of the entire rail network, allowing maximization of network capacity, optimization of electricity utilization and effective detection of potential operational hazards to enhance overall service safety and quality. Nowadays FBG sensors and sensor systems are available in production scale; they are gaining more popularity and an increasing market – and they have their potential by far not yet realized. In conclusion we can say that the application of FBG sensors along the rail tracks have the potential to revolutionize the railway industry and to update conventional systems into *'Smart Railways'*, thereby providing safe, reliable and vital information to rail operators.

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Vehicle and infrastructure maintenance

XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '12

EFFECTS OF INFORMATION SYSTEM TO EXPLOITATION AND MAINTENANCE OF RAILWAY WAGONS

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Vojkan LUČANIN [2]
Snežana GOLUBOVIĆ [3]

Abstract *– The "TEKOD" information subsystem of maintenance of railway wagons has been used for the past 11 years on one part of the Bar railway line, at the organization unit for TKP Pozega. This paper presents the conveniences in application of this kind of data recording and processing in the malfunctioning of railway wagons. Over 64000 malfunctions in railway wagons have been recorded in the indicated period. Necessary information about the state of the malfunctioning rolling stock is observed by the processing of the collected data. Daily updates of these data and permanent teamwork with Section for transport and "ZOVS" maintenance offices, lead to the primary goal of this subsystem - reduction of period of wagon immobilization. Further use of this information can be used to obtain new knowledge of better use and maintenance of railway wagons. The use of such knowledge among responsible workers and managers at Serbian Railways would lead to higher quality maintenance of railway wagons. It would result in greater profits and lower costs of maintenance.*

Keywords - railway, railway wagons, maintenance, information system.

1. INTRODUCTION

The process of maintenance of railway wagons is a complex and responsible one. The number of wagons available for use and traffic depends on many factors. Maintenance as a term may be defined as a set of diverse procedures employed in order to postpone, or completely prevent the occurence of malfunctions (failures) of wagons.Technical efficiency of wagons in AD "Železnice Serbije" is very poor because of relatively old rolling stock. In 2007, after a long pause, this company has bought about 700 new freight wagons of Eanos series. It is troubling that a quite large number of the new Eanos wagons are undergoing repairs. Nobody pays adequate amount of attention to the defects in wagons during exploitation and the very current repairs. Numerous factors affect the efficiency of the rolling stock. The very organizational division in the company has in part contributed to the fact that the process of exploitation and maintenance is not viewed as a whole. A comprehensive view of the process of exploitation and maintenance, together with all the factors affecting the efficiency of the rolling stock is the only way to increase the current number of the available rolling stock.

Constant monitoring and analysis of reasons for removal of malfunctioning wagons from traffic may provide the necessary information on the causes for the occurence of malfuctions. The application of information system for monitoring malfunctions on every wagon would quickly and more precisely provide us with the information on system malfunctions and defects. Based on the observed system malfunctions and defects occurring during the use of wagons, it is necessary to undertake appropriate preemptive measures in order to reduce and eliminate those defects and malfunctions. The task of the information system is to monitor malfunctions of every individual wagon in its time of operation between two investment repairs. All the data collected in this period would be invaluable to the person performing the overhaul during the large-scale periodical investment repair. An information system that would encompass all the malfunctioning wagons removed from exploitation because of current repairs with unhinging, on the level of the entire railway network, does not exist. The need for this comprehensive information system of use and maintenance is evident from the experiences of use of a similar system in the inspection department in Pozega. The analysis of the collected data may yield different information that would help the responsible people in the company when making decisions on better use and maintenance of the rolling stock of Serbian Railways.

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2. FROM DATA VIA INFORMATION TOWARDS KNOWLEDGE

This poetic title leads us to the inevitable information system that allows us to collect, process and analyze data, turn them into information that we can later use in order to increase knowledge with wisdom as the ultimate goal (figure 1).This is a general principle that is applicable to all technical systems. Before we can start processing the data we must perform an estimate of accuracy and importance of data. We need to reject the unnecessary data, and process only that which is necessary and the accuracy of which has been confirmed. After the verification, we can start with a more detailed processing and purposeful direction of data to obtain the necessary information. In this part, the database plays one of the key roles as an information subsystem. Updating of data is inevitable, and the database must be constantly, daily updated with precise, reliable and timely data. Only in this manner can the real effects of this type of data management be achieved.

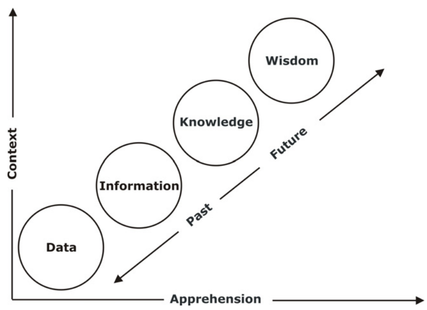

Fig.1. From data towards knowledge and wisdom

Investments in the maintenance of railway wagons have lately been scarce. In working with wagons, from exploitation, to maintenance and further on, old monitoring systems are still being used, with various manually operated procedures within already set patterns. These procedures have not changed for a long number of years. More precisely, it can be said that they are almost the same as 20 or more years ago. The data are still difficult to process because, simply put, everything is still being done by hand. In the system as a whole, there is little and insufficient progress in improvement of the use and maintenance. The little progress that has been made does not apply to the whole, and is done individually, everybody in their area of work. Only a comprehensive consideration of the system of use and maintenance of railway wagons as a whole, together with all the factors affecting it, can lead to better results. Until then, we can only point out advantages of this kind of reasoning through examples of local solutions and their application and results in practice.

3. INTRODUCTION AND APPLICATION OF INFORMATION SUBSYSTEM ''TEKOD'' AT OU FOR TKP POZEGA

In order to have more efficient records of operation of the inspection department at the organization unit for TKP Pozega there was a need for a system like this one even in the last century. The application of subsystem for regular maintenance (TEKOD) at OU for TK Pozega has started in 2001. In first years of application the new mode of operation with computerized management of data has seen many modifications and improvements. As the computer science developed, it was easier to process and manipulate the database of removed cars. The program was simultaneously installed in the maintenance office of their colleagues in ZOVS Pozega and the Section for transport of goods Uzice. TK dispatcher is responsible for daily updates of data on the status of malfunctioning rolling stock on the whole length of Bar railway line in Serbia. The updated databases are daily delivered to responsible colleagues, primarily to ZOVS maintenance offices, who need these data to further work on repairs of malfunctioning wagons.

The application of this type of data management can provide the following, most often used information:

- Overview of currently malfunctioning wagons according to their individual numbers;
- Overview of malfunctioning wagons waiting for current repair in maintenance offices;
- Overview of malfunctioning wagons according to their type and series;
- Monitoring of wagon malfunctioning history and monitoring of repeated malfunctions;
- Average time the wagons spend removed from traffic, individually per maintenance office, or in total;
- Monitoring of foreign wagons removed from traffic;
- Statistics of repaired cars per individual maintenance office;
- Control of accuracy of every individual car number;
- Monitoring of work of maintenance staff;
- Overview of work on international transfer of wagons (preparation of different reports);
- Faster and higher quality inventory of cars (monthly, yearly).

Timely analysis of these data and daily updating may result in the following effects:

- Reduction of the length of time the cars stay in repairs;
- Daily consideration of removed wagons and deciding to start the work on those with priority (freight, foreign, passenger cars);
- Analysis of malfunctions according to various criteria (place of removal from traffic, train number, type of malfunction), with the goal to establish the cause for the occurence of the defect and to preemptively act in order to avoid those defects in future;
- Reduction of unnecessary time the car needs to wait for a current repair if the time for another type of

repair (checkup, regular repair) is approaching;
- Analysis of available information from the system may easily show the economic indicators on savings made due to reduced amount of time the cars are removed from traffic;
- More precise acquisition of spare parts, both according to type and quantity.

The information subsystem "TEKOD" has been in operation constantly for the past eleven years and it has reached its eighteenth revision, successfully processing over 64.000 of malfunctions in railway wagons.

4. ANALYSIS OF MALFUNCTIONS IN THE RAILWAY ROLLING STOCK IN THE PERIOD BETWEEN 2001-2011

This analysis encompasses 64.200 malfunctions in the rolling stock recorded during more than 11 years of application. The figure 2 shows the recorded categories of the rolling stock. As the diagram shows, the largest part of the recorded rolling stock are freight wagons.

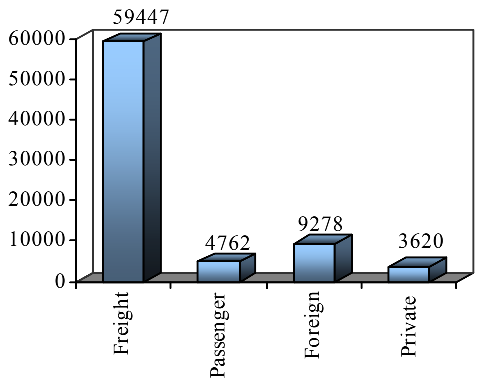

Fig.2. Malfunctioning rolling stock according to categories

4.1. Analysis of malfunctions in the freight rolling stock

The analysis of the most frequent series of malfunctioning rolling stock brings us to the conclusion that the largest number of malfunctions occurs on open cars of the series Eas and E. More detailed data on the number of cars removed from traffic according to the series may be found in fig. 3.

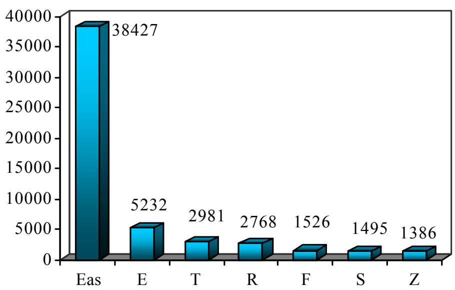

Fig.3. Malfunctioning freight rolling stock according to series

The largest percentage of malfunctions is recorded on the wagons from the series Eas and E. This type of wagons is most frequently used, but it is also most likely to be removed from traffic, because these wagons are used to carry bulk materials.

Most frequent malfunctions the freight wagons were removed for and sent for current repairs with unhinging are presented on figure 4. Front and side doors of the vehicle car-body and damage to the wooden floor of the wagon are the most frequent reasons for removal of open freight wagons from the sereis Eas/E. Malfunctions and defects occur due to improper use and their worn-out condition.

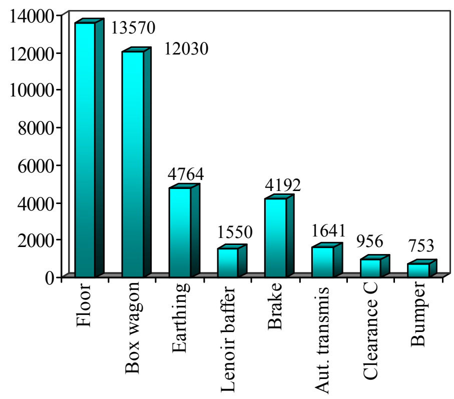

Fig.4. Most frequent malfunctions in freight wagons

The cause for these malfunctions is incorrect loading and unloading of wagons by the users of transport, poorly performed investment repair and the age of the wagons from this series. It is necessary to increase supervision over the party who uses the wagon and charge any damage caused to the wagon to this party. It is further necessary to increase supervision during the investment repair and replace heavily damaged doors with new ones. For lack of new doors one can use the doors from decomissioned wagons that are long overdue for investment repairs. During installation and overhauling of the wagon floor one must use the floorboards of appropriate quality. The built-in floorboards must comply with the prescribed levels of humidity and their installation must conform to all the standards prescribed for installation.Proper working order of air brake is also an important, if not the most important factor for safety in traffic. Lately, the number of wagons with malfunctioning air brake is on the increase.

4.2. Analysis of malfunctions in passenger rolling stock

On the part of Bar railway line in the indicated period a total of 4762 malfunctions have been recorded in passenger cars. The most frequent malfunctions are shown in figure 5.

Out of the total number of wagons removed from traffic, more than 40% have been removed because of malfunctions in heating and lighting. A large number of recorded passenger wagons repeatedly experiences the same malfunctions in heating and lighting.

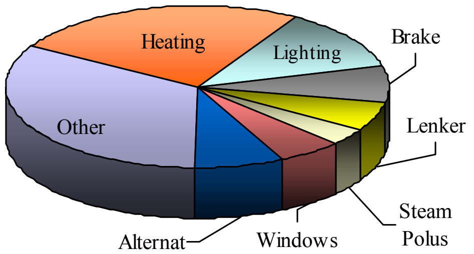

Fig.5. Malfunctions in passenger cars

Malfunctions in devices for heating and lighting are the perennial problem that is yet to be successfully resolved. It is necessary to pay much more attention to these malfunctions in the course of repairs. In addition, these systems incur high expenses for the acquisition of spare parts, which is one of the limiting factors. More attention should be paid to repairing of wagon heating systems during the whole year, and not only in the heating season. Furthermore, it is necessary to pay more attention to the malfunctioning of the brake, as the vital part of a wagon, directly responsible for the safety in traffic.

4.3. Average time the wagons are removed from traffic

During the period of application of the information subsystem in this unit, the average immobilization of malfunctioning wagons has been reduced from 16,2 days/car in 2001 to 4,9 days in 2006 (figure 6). In the last few years it is within acceptable 6-8 days per car.

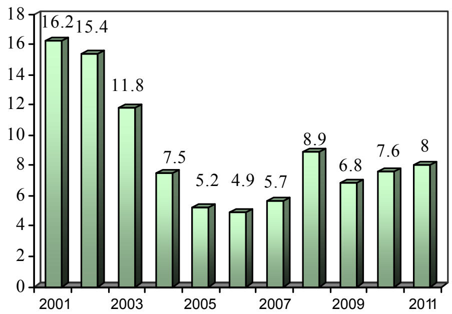

Fig.6. Average time the cars are removed from traffic

Average time the wagons are removed from traffic is clearly different in maintenance offices Pozega and Lajkovac. A comparative analysis of these two maintenance offices in the past 5 years is presented on figure 7. The cause for the large amount of time the wagons stay in the maintenance office Lajkovac is the long time needed to set up malfunctioning wagons and send them from station Vreoci to the maintenance office Lajkovac. The set up and delivery of malfunctioning wagons from station Vreoci to maintenance office Lajkovac should be much faster. Additionally, a certain amount of time is spent in waiting before the wagons can return from maintenance office Lajkovac back to traffic. This is not the case with the maintenance office Pozega, where the maneuvering and sending of the wagons is much faster.

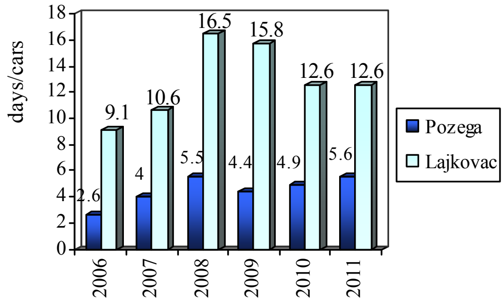

Fig.7. Comparative analysis of the time the wagons stay in maintentenance offices Pozega and Lajkovac

5. CONCLUSION

The application of this information system in the past 11 years has lead to significant results in increasing the quality of current repairs with unhinging on the part of the Bar railway line. Daily analysis of wagons removed for current repairs, in cooperation with ZOVS maintenance offices lead to reduction of removal of wagons from traffic, which is one of primary goals of this information system.

Daily update of these data provides us with daily status of current repairs in overview reports that facilitate analysis of malfunctioning wagons waiting for repair. We can also notice systematic malfunctions and repetition of the same malfunctions in certain wagons.

By analyzing the application of this type of management of records of the malfunctioning rolling stock, we can perceive the complexity of the maintenance system that cannot be viewed separately from the exploitation part and the traffic of wagons. Based on the results, we can conclude that the involvement of all of the participants in traffic is necessary for the readiness of the rolling stock, and only with proper use of the wagons can the damage be avoided. Preemptive actions in case of perceived malfunctions and damage in the wagons would significantly reduce the number of wagons removed from traffic. By far the greatest damage of the freight wagons is on the boxcars. This damage could be avoided with a better supervision during loading and unloading of wagons when the boxcars are most often damaged.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '12

MODERN CONCEPT OF FREIGHT CARS MAINTENANCE

Dušan STAMENKOVIĆ [1]
Života ĐORĐEVIĆ [2]

Abstract: *Service life and availability of freight cars greatly depend on the maintenance. The permanent monitoring is the basic maintenance of railway cars and it is essential for the safety of service if it is done continuously during the operation. From the point of rolling stock reliability and safety of rail service, the most important assemblies, in addition to the brake system, are wheel sets, particularly the wheels. Due to the damage of the wheels derailment of the train can apear, and the early detection of wheel defects is essential for the transport safety. In this paper are described some of the modern diagnostic systems that are in function on the lines of the developed railways. The modern concept of freight cars maintenance is based on the diagnostics and processing of systematized diagnostic data.*

Key terms: maintenance, freight car, diagnostic systems, operation of rolling stock.

1. INTRODUCTION

Railway service was constantly improved and developed over its long period of existence. The requirements for higher speeds, more powerful locomotives, the increased capacity of rail cars and similar have been set. This caused an increase in axle load, resulting in the increased load on the rails and all elements on the railway track. The maintenance of rolling stock and infrastructure has also been changed, substantially. Today with the increased demands of availability and reliability of the technical systems, it is developed the preventive condition-based maintenance.

The quality of service life of rolling stock depends primarily on the quality of production, and components that are built into it. However, an important role have the conditions of exploitation and maintenance of the vehicles. If the vehicles during operation are not exposed to the overload and extreme conditions, and if the maintenance is well-timed and efficient, the vehicle service life will be longer. The activities implemented in the operation and maintenance have in the aim to increase availability of vehicles to perform the transport efficiently.

The basic maintenance of railway vehicles comprises the interventions implemented on daily basis before, during and after the performed transport and it is called the permanent monitoring. The control inspections of vehicles are performed with the scope that is determined by the running distance. With the new types of railway vehicles, which are equipped with modern diagnostic systems, maintenance interventions are planned on the basis of processing of the signal from the sensor. After the long period of exploitation, the regular repairs are carried out on the vehicles and they have the aim to improve the condition of the equipment and operation of vehicles in the next service period until the next regular repair.

In this paper, the continuous monitoring of freight vehicles as the most important part of the maintenance is analyzed.

2. DEFECTS IN FREIGHT VEHICLES ENDANGERING SAFETY

Based on the studies and analysis, the highest percentage of extraordinary events in railway service, affecting directly the safety, is the consequence of the failure of the running gear and brakes.

The role of the running gear and particularly, wheel sets is the safe movement of vehicles on the track, and for the brake, it is prompt and safe stopping of the vehicle. Both for the movement and stopping of the vehicle is very important the wheel-rail contact, or the condition of wheel flange. Because of thier excessive or irregular wear, there is a risk of derailment of the rail vehicles.

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The wear of wheels and turning costs, of course, can not be completely avoided, but they can be significantly reduced, if the failures are detected in the phase of their formation, when it is still possible to take measures to slow their development or removal in a cheaper way. In addition to these costs, there are also special expenses caused by switching off the vehicles from the service (lost wagon days, the reloading if the wagon is loaded, the costs of transporting the vehicle to the workshop for the repairs, the costs of dismounting and mounting, etc.).

Table 1 provides an overview of rejected-detached vehicles from service in the shift stations by types of failures from 2009 to 2011.

Table 1. Review of the rejected – cancelled vehicles in shift stations

	FAILURE TYPE	2009	2010	2011
PAIR OF WHEELS	DEFECTS ON SURFACE OF WHEEL ROTATION	188	148	171
	CIRCULAR GROOVE	5	7	3
	LOOSE WHEEL BAND	3	3	8
	OTHER	13	46	10
BRAKE	BRAKE PADS	17	11	19
	BRAKE LEVERAGE	8	8	8
	OTHER	24	24	30
R. G.	MANGANESE DISC	17	35	24
	OTHER	90	70	33
	COUPLING HOOK –BUFFER	11	27	106
	VEHICLE FRAMEWORK	23	34	33
	SUPERSTRUCTURE	137	134	120
	CONTAINER	44	38	21
	LOAD ADJUSTING	260	403	285
	COMMISSION	231	218	139
	OTHER	56	90	74
	TOTAL	**1127**	**1296**	**1084**

Fig.1. Damage of the wheel flange

There are many defects that can occur, but as the basic ones, can be specified:

- damage of the wheel flange (Figure 1),
- overheating of wheels due to normal braking or due to faults of the brakes (usually due to blocking),
- overheating of the brake discs on vehicles with disc brakes due to the reasons above,
- overheating of the axle bearings,
- other damages on wheel sets (wheel damages, excessive wear and changes of geometric measures, cracking of axles and wheels, etc.).

In addition to these mentioned defects, the service safety may be compromised by exceeding of the admissible axle load and load per wheel and by fouling the gauge.

3. FREIGHT CARS MAINTENANCE

The national railway administrations establish the regulations and standards for the maintenance of their vehicles in the fleet. If the vehicles operate in international service, their maintenance has to be aligned with international regulations and standards for the exploitation of these types of vehicles. The plan and program of maintenance interventions are made by the vehicle manufacturer, and the most often the railway companies' regulations rely on them. In the aim of consolidatation and mutual harmonization of national railway regulations, a new system of standardization in the field of railway has been established in the EU: Technical Specification on Interoperability - TSI. For the implementation of activities on harmonization of existing national regulations in the railway system within TSI, as well as for the adoption of new regulations, the European Railway Agency - ERA is in charge.

Regular maintenance of freight vehicles include the constant monitoring, control inspections and emergency and regular repairs. Permanent monitoring is the basic maintenance of railway vehicles and it is the most important for the safety of service as it is done continuously during operation and represents the continuous monitoring system of the vehicles. Activities of permanent monitoring of freight cars are carried by many of the participants in the railway transport organization, such as train drivers, train crew, the traction and station staff, as well as technical wagon unit.

Permanent monitoring includes the visual inspection of the technical condition of vehicles and their supply and it is done during the preparation of the vehicle for service, during operation and after it. During the preparation of freight vehicles for service, the wagon examiners perform the inspection of vehicle condition such as the visual control of condition of parts, components, devices and equipment of the vehicles, checking the proper condition of the devices by putting them in service (what can be done), validation of regularity of the loading, both in terms of loading gauge and regularity of loading i.e. the arrengement of the load in the wagons, i.e. permissible weight per axle and linear meter etc. (Figure 2). During the operation, the continuous monitoring of freight wagons are performed mainly by wagon examiners in the stations where the train passes. Upon the completion of operation, the constant monitoring of railway vehicles include their safe housing, storage and security.

Fig.2. Pipes transport from TCDD to ÖBB [2]

The highest number of damages in vehicles occurs during movement, and it can be determined exactly in dynamic conditions and not when they stay in a station. Therefore, it is expedient to perform the monitoring of the condition of individual parts and assemblies and wheel sets during the operation. Using the development of electronics, sensor and computer technology, on-board diagnostics and stationary diagnostics were introduced. On-board systems are installed in the vehicle and they are used for continuous monitoring of devices in operation. Stationary diagnostic systems are used for casual-periodic safety inspections of railway vehicles and thay are installed along the line. The modern diagnostic systems have significantly improved the constant supervision of railway vehicles and increased the effectiveness of condition-based maintenance. In addition, it is essential that the registered measured data are recorded and systematized in order that, according to them, the decision could be made on the implementation of certain maintenance activity. The essence of the modern approach to the maintenance of railway vehicles is in the reliable diagnostics and treatment of systematized measurement data [1].

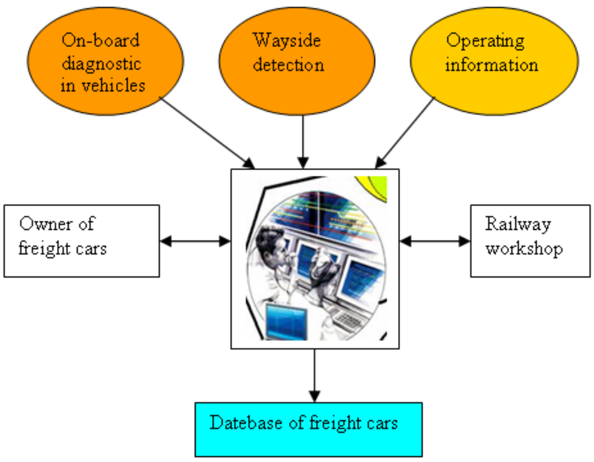

Fig.3. Modern concept of freight cars maintenance

4. EXAMPLES OF MODERN TECHNOLOGY FOR FREIGHT CARS MONITORING

Stationary diagnostic systems, installed on the line represent the measuring stations for railway vehicle dynamic control, in other words, the inspection of vehicles, within the regular operation, is performed without stopping. The first stationary diagnostic systems on the line were developed in the Sixties of the 20th century, but the widespread use came in the last 20 years. The Canadian National Railways by 2002, installed 452 diagnostic systems 452 with detectors for the shaft bearings heating and detectors for the detection of the gauge. In the U.S., various types of detectors were installed, including detectors bearings noise, lateral movement detectors, detectors of bogies performance and wheel profile detectors. In the European countries, also occurs the intensive development of devices for monitoring, leading to extremely favorable results in the reduction of vehicle failures.

Measuring stations, installed along the line usually have the aim in the following:

- discovering the parts of the car coming out of the loading gauge;
- establishing overheating axle bearings and heating of the wheel;
- establishing the slipping of the wheel;
- acoustic detection of bearing– failures;
- monitoring the vehicle performance;
- wheel condition monitoring;
- vehicle video monitoring.

The control – the measurement of the profile of the train is performed via the measurement system, based on a laser distance measurement, combined with high frequency scanning (Figure 4). This diagnostic system measures the profile of the train in the movement and it can determine the loading gauge in the freight train.

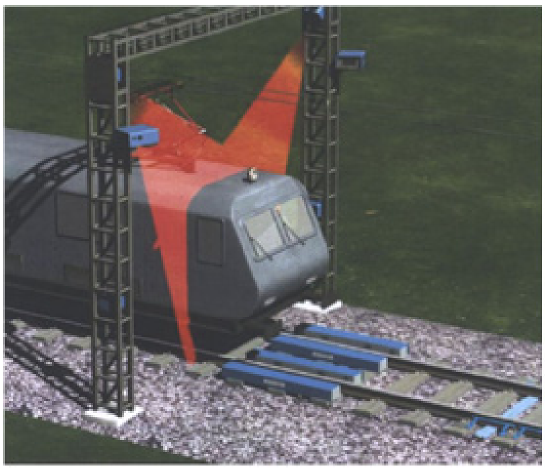

Fig.4. System for train gauge diagnostic

Acoustic measurement method application is increasing rapidly. This technology uses the microphones for recording the sound of vehicles passing. Monitoring systems used are mainly related to the shaft bearings, because it is well known that the failures of the bearings make vibrations in frequences that can be linked to the characteristics of defects. Acoustic detection system "TADS" is a preventive system for axle bearing maintenance developed in the U.S. to identify bearings with internal defects in the early stages of failure, prior to catastrophic failure due to increased temperature during operation. System "TADS" consists of a series of microphones placed in the casing on both sides of tracks that record data about the sound track of each bearing (Figure 5).

Fig.5. System for acoustic detection of defected bearings on measuring coaches

The heat radiation from the objects may be detected by infrared cameras. This technology allows to mark accurately the areas with high or low temperatures. The system uses thermal imager technlogy and digital image processing. FUS II - Detection of overheated wheels, bearings and blocked brakes has one linear infrared detector with 4 pixels (Figure 6). This system (perpendicular to the direction of the run) can scan at speeds up to 600 km/h. In the standard configuration, the overall system consists of three to four modular scanners covering axle bearings and brake discs.

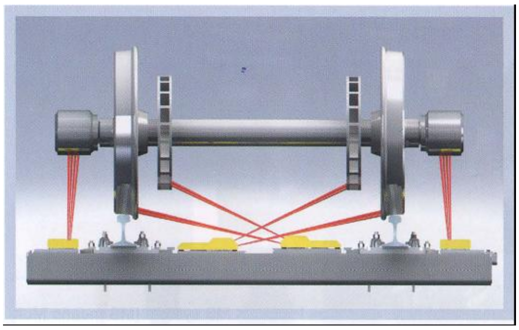

Fig.6. FUS II system for detection of preheated wheels, bearings and blocked discs

For the assessment of the wheels condition and their service is important to control the wheel rolling surface, wheel flange profile as well as the wheel stress and fractures. Tensometrical measurement is applied to the point of attack detector. This type of detector is intended to detect defects at the surface point of the wheel by measuring the dynamic vertical force on the rail throughout the complete round of the rolling wheel. If there is a damage on the wheel, such as flat surfaces, during the rolling of the wheel over the rail, the high impact forces in the contact with the wheel / rail can happen, which can cause the damage to infrastructure. Wheel profile measurement technologies by laser and camera are non-contact methods for measuring of the state of wheels. This method is based on the optical triangle between the laser beams and high-resolution digital cameras recording.

5. CONCLUSIONS

Statistic data on immobilization of freight cars on the Serbian Railways, as well as the reasons for reject in the shift traffic stations, indicate that the defects have to be detected even during the train running. Particularly, this is applied to the failures of axle and brake assemblies. The Serbian Railways must establish the system of measuring stations on main lines and thus reduce the costs of transport delays. It will provide the conditions for the modern freight cars maintenance. In the selection of the system for detecting and monitoring, all the specificities of the railway transportation management system must be taken into account. The experiences of developed railways can be valuable.

With the help of a monitoring system, the data on rolling stock and rail infrastructure can be systematized, which is a significant to increase the efficiency of maintenance. With the ability to monitor the entire system, the railways can develop the concept of condition-based maintenance.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '12

THE CHANGE OF THE CRITERIA FOR REGULAR REPAIRS OF SERIES 441 TRACTION VEHICLES

Dragan B. RAJKOVIĆ [1]

***Abstract** – Criteria for the regular repairs for traction vehicles are defined by the Regulation book 241. During a long-term follow up, it was found that both criteria - time criterion (expressed in years) and kilometer criterion- stipulate exclusion of a vehicle from the traffic, even if the vehicle is in excellent technical condition, after the expiration of stipulated years or kilometers crossed. A change of criteria during the vehicle exploitation was given. In the paper time criterion and criterion of crossed kilometers were considered with purpose of finding optimal criteria for exclusion of vehicles from the traffic based on the number of defects on 100,000 km and other criteria.*

Keywords - Regular repairs, Regulation book 241, series 441

1. INTRODUCTION

Maintenance of the railroad vehicles is defined by the Regulation book 241, titled “REGULATION BOOK ON RAILROAD VEHICLES MAINTENANCE”. This Regulation book article 2 states: This Regulation book’ stipulations refer to normal-gage railroad vehicles included into Serbian Railroads, namely:

A - Traction vehicles

1. Locomotives,
2. Motor trains,

B - Pulled vehicles

1. Passenger cars,
2. Freight cars,

C - Vehicles for railroad purposes

1. Inspection cars,
2. Cars for specific railroad purposes,
3. Vehicles on rails,
4. Special vehicles for railroad purposes.

This paper will examine vehicles listed under A in the Regulation book, namely: series 441 locomotives. For other railroad vehicles principle given in this paper with every series’ peculiarities may be applied. Maintenance of the railroad vehicles may be:

a) regular, periodically repeated and planned in advance,

b) extraordinary, performed to repair malfunctions, defect or wear-out.

Regular maintenance includes:

a) constant supervision,
b) washing and cleaning,
c) control examinations,
d) regular repairs.

Constant supervision, washing and cleaning, control examinations and extraordinary repairs are part of so-called current maintenance, and regular repairs are part of so-called investment maintenance. By investments, regular repairs bring vehicles into proper technical state, capable of regular exploitation without major interventions until the next regular maintenance. In regular railroad vehicle maintenance there are regular maintenance cycles and intervals.

Regular maintenance cycle, according to the regulation book in effect, include sequence of control examinations [monthly P1, quarterly P3, semi-annual P6 and annual P12] or regular repairs [medium repair SO, main repair GO].

Regular repair interval refers to elapsed time (calendar), kilometers the vehicle crossed or other adequate criteria, between two examinations or two repairs. The interval between those two repairs of the vehicle in every series of train resources is defined in such way that most vehicles in that series can withstand exploitation until the next repair without any major extraordinary works upon the vehicle. Cycles and intervals are defined specifically for every sort and series of railroad vehicles.

1.1. Former regulation book modifications

The book of regulation 241 “REGULATION BOOK ON RAILROAD VEHICLES MAINTENANCE” according to the information [in possession of the author] published in 1968, 1978, 1983 and 1995. In these books of regulations intervals for regular’s maintenance vary. Creation and modifications of this book of regulation was done by the Association of the Yugoslav railroads. According to the regulation book 241 from 1968 the cycle of the repairs for an electric locomotive was as follows:

PO1 – PO2 – GO – PO3 – PO4 – GR and intervals between planned repairs (PO) totaled 350000 km or two years maximum. The modification of the book of regulation in 1978 the following cycle of regular repairs was stipulated:

SO – GO – SO – GO - ---- SO – RO and intervals between medium repairs (SO) and major repairs (GO) were 600 000 km ± 15% based on km or 5 years maximum. Based on the 2003 decision of the ŽTP "Beograd" (Belgrade Rail Transport Company), the cycle and the intervals in km remained the same, except that the calendar 5 years limitation was cancelled. In 2012 the decision was made on trial extension of the intervals of regular repairs for traction means and motor trains, where the crossed km criteria for the running interval limitation for series 441 is extended probationary for another 200 000 km.

Based on the "Regulation book on railroad vehicles maintenance article 5, "ŽTP "Beograd" also modified intervals of the regular maintenance control examinations. Based on series 441 locomotive behavior follow-up, semimonthly control examination was cancelled (P0) in 1999.

1.2. Former experiences

Series 441 locomotives were released into the traffic according to the following dynamics:

Year ofLocomotives numbers:
release :

1969: 008,009,010,011,029,310,311,412,413,416, 418,419,420,421,422,423,424
1970: 031,038,039,040,041,042,043,313,314,415, 417
1971: 060,062,064,066,068,312,314,315,316,317, 318, 319,320,321,322,323,324,325,326
1972: 074,075,076,077,078,086,087,088
1975: 507,508,509
1976: 510,511,512,513,514,515,516,517,518,519, 522, 523,525,527,530,532,601,602 ,603
1977: 604 (78 pieces)
1980: 701,702,703,704,705,706,707
1981: 708,709,710.
1986: 746,747,748,749
1988: 750,751,752,753 (18 pieces)

All the regular repairs were performed according to the Book of regulation 241 in effect. As an example, two locomotives were taken, in which repairs were performed based on years and on km crossed and dates of repairs made, as given in Table 1.

Table 1 shows that in locomotive (441-312) regular repairs were made according to, at that time Regulation book 241 in effect (350,000 km and two years); then later it went on according to, at that time regulation book in effect (600,000 km and four years), and then they changed to 800,000 km and five years. The table also shows the total of the km crossed by the locomotive, which is almost the same for both locomotives, which is the outcome of the locomotive standing due to an accident or larger daily use of a locomotive or for both reasons.

Table 1. All regular repairs performed

Loc.No	Year	km	Year	km
441-312 4.145.641 km	1973	397 922	1976	419 780
	1979	392 345	1985	700 687
	1991	532 940	2004	714 189
441-701 4.228.280km	1985	666 914	1992	783 140
	1998	808 652	2007	818 305

As a measure of the locomotive reliability, the number of the defects on 100,000 km crossed by the locomotive and the availability are taken. The availability is connected to the malfunctions, which may be large due to shortage of the parts, which is why it is better to take the number of defects on 100,000 km crossed for comparison. From the data for series 441 recorded throughout past 10 years presented in Table 2.

Table 2 The number of defects on 100 000 km and the number of performed repairs by years

Year	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Def.No. per 100 000km	12.41	16.88	14.39	13.37	11.70	11.70	12.54	12.73	11.48	10.06
No. of reg. Rep.	0	4	7	3	2	5	6	6	2	13

Based on table 2, it is possible to make a conclusion that a number of performed regular repairs does not affect the number of defects on 100,000 km. The table shows that the number of defects on 100,000 km does not have a regular patern, which can be justified by the very large number of influences upon the number of defects (the quality and the quantity of the spare parts, the maintenance quality, the load of the locomotives, staff, the quality of the tracks, the speed of trains and many other causes emerging from these influences).

2. CONSIDERATION OF REGULAR REPAIRS INTERVALS

Time (calendar) interval as a criterion for regular repairs proved to be very distensible and that regular maintenance started with two years, then was extended to four, then five years and then excluded as a criterion. Even though locomotives 24 to 42 years old proved to be reliable, their age does not show large influence upon reliability. This can be explained by the extent of works performed during regular repairs. The extent of works and measure lists prescribed for regular repair conduction foresee complete dismantling of the devices, systems and parts of the locomotive. Dismantled devices, systems and parts of the locomotive are exposed to dismantling, washing and control based on prescribed measure lists, so that the flaws are removed by repair or installation of new devices, systems and parts of locomotive. The extent of works also foresees obligatorily changeable parts, which refers to rubber-metal elements, rolling bearings, contractors, amortisseurs and a large number of electric elements. Final examination of the locomotive, also performed according to prescribed measure lists, the locomotive basically resumes down to a new locomotive.

Kilometre interval as the criterion for regular repair determination also had the trend of increasing the number of km the locomotive should cross before it is directed to regular repair. It started with 350,000 km, was increased to 600,000 km and then to 800,000 km, which did not reflect onto the decrease in reliability. The extension of intervals, particularly in km, was influenced by the locomotive manufacturer, who foresaw for the last series of delivered locomotives (subseries 700) 800,000 km ±15%. Naturally, with these modifications, calendar and kilometer based, the foreseen extent of works was modified as well.

For the newest locomotives from the series 444, which are actually modernized locomotives series 441, the manufacturer gave kilometer interval of 1,000,000 ±15% km between two regular repairs. Spare parts manufacturers, such as amortisseurs and rubber elements give a million km warranty for their products. Between regular repairs, control examinations are performed every month with various extent of works every three, six and twelve months. In these exams, the locomotive is checked according to prescribed lists of examination (written extent of works and prescribed measure lists for performing measuring), so that the condition of devices, systems and parts of locomotive are under constant supervision of the experts in workshops as well as of the locomotive drivers during the drive.

According to current regulations on maintenance, these are conceived as planed maintenance, both maintenance by control examinations and by regular repairs. This paper considers introducing the combination of concepts of planed maintenance and maintenance based on condition. Planned maintenance would be the part conducted monthly, as until now, with all the characteristics that define it. Nothing changes in that part of maintenance and everything is performed in accordance with former rules and methods. The changes would occur in the part of planned maintenance with refers to regular repairs. According to the new concept, regular repairs are not planed long term as until now, instead the criterion for regular repair is modified, and that criterion is defined through probationary extension of kilometer interval. The interval can be extended by 200,000 km at first with regular monitoring of devices, systems and parts of locomotive condition during control examinations. In addition to locomotive condition monitoring in workshops, the locomotive monitoring is conducted by monitoring locomotive exploitation parameters, namely the number of defects on 100,000 km crossed by the locomotive. Besides monitoring numerical changes, in order for the number not to increase drastically above the average, it is important to analyze every defect in the sense of determining whether the defect shows extensive deterioration of the device, system or a part. Defects are now monitored and analyzed, and there are departments and persons that are up-to-date with the defect analyses; it is necessary to say that this tracking is performed by the employees from the department of maintenance and traction.

3. CONCLUSIONS

During the exploitation of the series 441 locomotives since their release into the traffic, the criteria for directing locomotives to regular repair changed. The change from 350,000 km to 600,000 km was made in the early 1980's, and the change from 600,000 km to 800,000 in the early 1990's. The extensions in running did not reflect onto the number of defects on 100,000 km as measures of the locomotive reliability. For the change of the locomotive running interval from 800,000 km to 1,000,000 km, based on the previous experience and based on the recommendation of the series 441 locomotive manufacturer that the running interval for the series 444 is 1,000,000, it is possible to foresee there will not be problems. The extension of the running interval should be performed as it was done in 1990's, as a probation on locomotives, so that the parameters of reliability can be monitored; if a steep parameter increase occurs and the change analyses (increase) shows that the change occurred due to running interval extension, the extension interval should be decreased or the idea of the interval increase deserted, which is unlikely to occur.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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THE FIRST YEAR OF USING PROTOTYPE OF LOW-FLOOR EMU 6 112 001 IN PUBLIC TRANSPORTATION

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***Abstract** – The prototype of the low-floor electric multiple unit (EMU) with asynchronous electric drive for regional transportation was developed and manufactured in the factory KONČAR KEV from Zagreb according to the needs of railway company HŽ Putnički prijevoz. After few months of testing this prototype of EMU was released into the public transport at 2nd July 2011. During one year EMU regularly drove each day on the long distance line Zagreb-Vinkovci and regional line from Zagreb to Sunja and Sisak. After a year of using EMU the most important indicators of exploitation are analysed from the users point of view which are briefly presented in this paper. In addition, this paper provides a review and other experiences of using this EMU and changes and improvements made to EMU during a first year of exploitation.*

Key words: prototype, low-floor EMU, regional transportation, exploitation.

1. INTRODUCTION

According to actual plans for modernization vehicles fleet of HŽ Putnički prijevoz (Croatian railways Passenger Division) in near future conventonal trains will be replaced step by step with train sets (EMUs and DMUs). The first step has been made in November 2009 through contracts with Croatian companies KONČAR-KEV and TŽV GREDELJ about development and production of 2 prototypes of low-floor electric trains (EMU) for regional and suburban transportation and one prototype of low-floor diesel-electric train (DMU) for regional transportation. The first produced prototype is EMU for regional transportation numbered 6 112 001 (Fig 1). This EMU was produced in February 2011.

During the tests EMU has driven a total of 5914 km. Regular exploitation in passenger transportation of EMU started at 2nd July 2011.

2. THE THE CONCEPT OF THE EMU

The prototype of EMU is a four modules train designed for use in regional traffic, consisting of two powered units and two middle segments. Passenger areas of the modules are interconnected by bellows, forming a unique space without any partition walls. Floor height within the bellows area is max. 850 mm, and passages from one side to another are realized as smoothlysloped ramps (inclination 1:8). Transparent partly partitioning walls are built in the passenger compartments; they are not closing the space visually, but protect the passengers from cold air when the doors are opened.

Fig.1. EMU 6 112 001 at test drive in Moravice (line Zagreb – Rijeka)

Seats are mainly realized as double seats, except for a part of the space intended for accommodation of invalid persons in wheelchairs and parents with children in strollers, where single seats and foldable seats are built in. Part of the space is equipped with bicycle hangers. The passenger interior is adequately heated and cooled, depending on the use of the train.

2.1. EMU main drive

EMU main drive consists of two identical traction units, each of them located at one powered module (Fig. 2). Each traction unit consists of one transformer, two traction converters and two asynchronous traction motors, mounted on powered bogies.

Each powered module has its own independent operating microprocessor system for traction/braking force regulation, speed regulation and sliding protection.

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Table 1. Fundamental technical data of EMU

Gauge	1435 mm
Axis arrangement	Bo'2'2'2'Bo'
Overall lenght	75 m
Vehicle width	2885 mm
Floor height	550 / 600 / 850 mm
Seating capacity	1. class 20 2. class 192
Number of entering doors	8
Vehicle weight	141 t
Max. axle load	180 kN
Max. acceleration (at gross weight)	>1,0 m/s^2
Max. retardation	>1,0 m/s^2
Maximal traction force	200 kN
Maximal EMU speed	160 km/h
Number and type of traction engines	4 asynchronous motors
Continuous power at wheels	2000 kW
Main brake	Direct pneumatic and electric
Supplemental brake	Magnetic on 2 of 3 non powered boogies
Parking brake	Spring action
Nominal catenary supply	25 kV 50 Hz

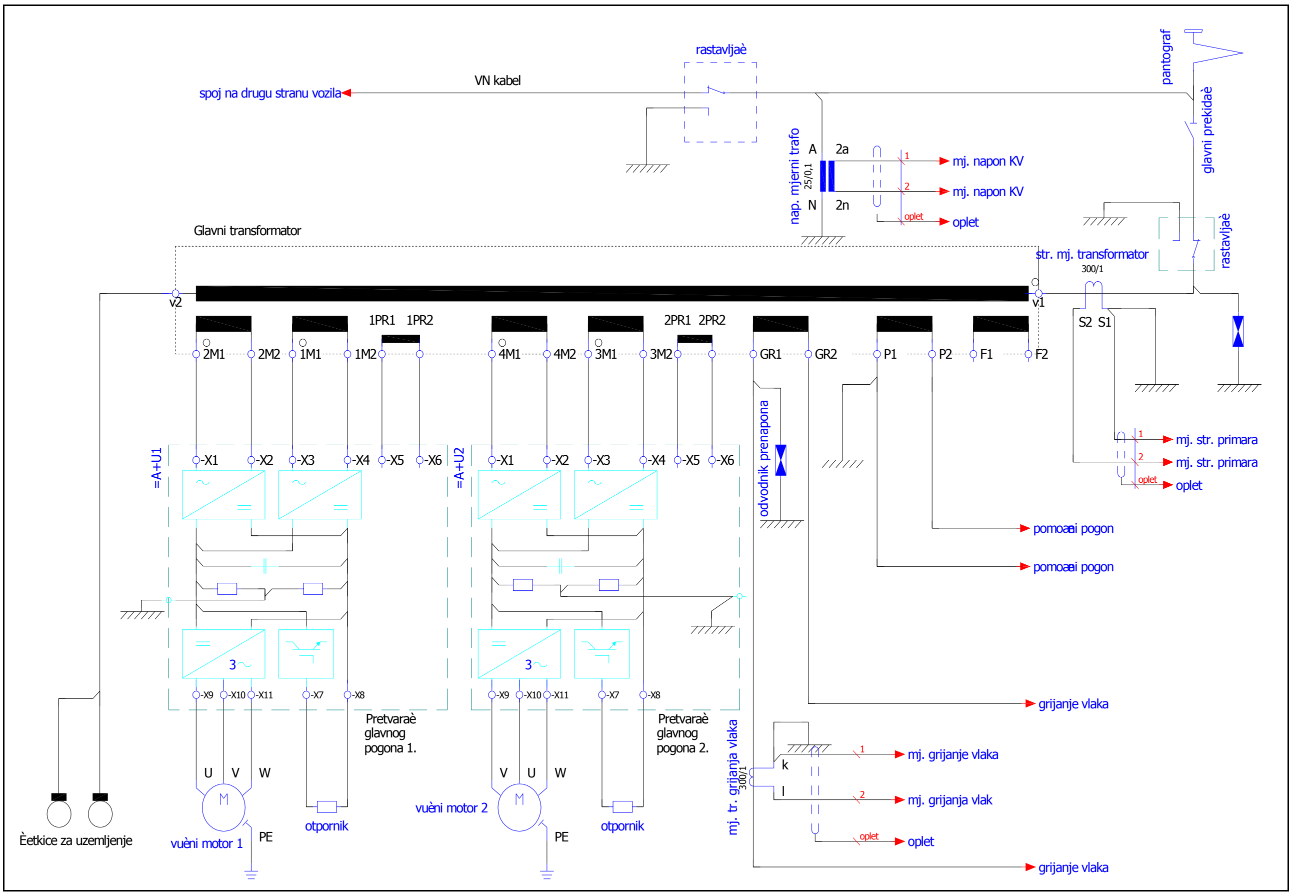

Fig.2. Main drive of EMU

Operating system is programmed to obtain the Input converters are designed as 4-quadrant single-phase bridge junctions, supplying approximately sinusoidal catenary supply current at cos φ near to 1. Three-phase asynchronous squirrel cage motor is connected to the converter. The converters are designed in IGBT technology. The converters are running in both traction and recuperative braking mode of operation. Optimal conditions of traction and electric braking. The microprocessor system includes functions of measuring, protection, diagnostics and logging malfunctions of main drive, and communication functions to train master computers.

2.2. EMU auxiliary drives

The auxiliary train drives includes static converters and energy-using devices (Fig.3). There are two identical converters on the train, each of them located at one motorhead. Each converter consists of input converter, DC circuit, two output converters and battery charger. Two converters for conversion of DC voltage to three-phase alternating voltage are connected to the DC circuit. One converter operates at constant voltage 3x400 V, 50 Hz. The second converter operates at adjustable voltage level 0-400 V, and frequency 0-50 Hz.

Three-phase asynchronous squirrel cage motors of auxiliary drives and air conditioners are connected to the converters. To the DC circuit connected are also battery charger and powering 24 V= installation. All converters are designed in IGBT technology and feature its own microprocessor control.

3. EXPLOITATION OF EMU

Exploitation of EMV prototype took place in the long distance and local passenger traffic. EMU was driving each day a couple of long distance trains between Zagreb and Vinkovci and two pairs of local trains between Zagreb and Sunja (Sisak). Usual daily mileage to the timetable was 766 kilometers a day. During exploatation deviations from the plan of exploitation were conditioned for a longer period of immobilization of 33 days due to failure of the transmission of one of the powered axles which is why the whole axle set set in Germany and two-week test ride tandem with prototype of EMU for suburban transportation. Maintenance is performed in the TZV Gredelj once a week (service or control exam). Distance of railwyj line from main station in Zagreb to workshop in TŽV Gredelj is about 10 km.

3.1. Indicators of exploitation

During the year use following indicators were achieved:

Kilometers .... 191.731 km
Defects on journey 4
Immobilization total....................................... 15 %
Immobilization without waiting on repair..... 7,5 %
Average energy consumption .... 4,61 kWh/km
Days in regular service 302
Days of testing drives 10
Days in workshop 20
Waiting on repair (out of service) .... 33 days

According to previous data is it possible to make conclusion that the prototype of EMU achieved a relatively high mileage in regular traffic, corresponding to the target annual mileage of a modern traction vehicle of approximately 200.000 km. Taking in acount that EMU is prototype the number of service of 4 defect can be considered satisfactory. Defects were created for the following reasons:

- Low battery
- Failure of the contactor of auxiliary convertor
- Failure of the auxiliary convertor itself (2 defects)

Availability on an annual basis would be greater than that obtained 85% of the EMU was immobilized for 33 days waiting for replacement bearing of gear in 2nd transmission that is carried out at VOITH company in Germany.

3.2. Handling and education of staff

Before putting in regular service it was necessary to provide educated staff for driving. That's why first group of 12 engine drivers were trained by producer during one week course. After 3 days of theoretical practice they have practical education on the vehicle 2 days. Each engine driver had to practice for 8 days driving under the supervision of producers engineers.

3.3. Rating exploitation

When drafting the technical specifications of the prototype application EMU was taken into account on how to build a modern train to regional transport, which means to be fit for travel at distances up to 150 km or a travel for up to 2h. During the exploitation EMU is used on a long distance relation to the journey time of 4 h and local travel time of less than 2 h. EMU has been well received by passengers at long distances, especially in the local transport due to the significantly higher level of comfort that provides the EMU with respect to existing EMU series 6111 produced late seventies of 20th century. During the month of use EMV and observed a number of advantages over conventional passenger trains or existing EMU Series 6111, of which we can point out the following:

- *High level of safety*
- *Easy handling*
- *Small consumption of spare parts*
- *High plant availability*
- *Low-energy consumption*

- *Adequate comfort for travel on these routes up to 150 km or 2 hours of travel*
- *Possibility of easy implementation of software*
- *Simply way to modification and implementation of new applications*
- *Simple technological processes in the preparation phase to run or laid up*

As the vehicle defects observed in the one-year period of exploitation of vital statistics indicate the following:

- The complexity of the technological process of repair external damage (replacement windows, parts of the shell)
- Unreliable operation of the lubrication of the wheel rim
- Unreliable operation contactor to turn the drive power take-offs
- Loosening of joints on the cooling of the main converter
- Unfavorable distribution of air conditioning the cabin air
- Difficulty in cleaning the windshield
- Delays in the work of vacuum toilets

3.4. Maintenance

According to basic agreement about development and delivery of prototype EMU with producer KONČAR-KEV the regular maintenance is free of charge for first two years of exploitation. Company KONČAR does not deal with regular maintenance of traction vehicles and in this case regular maintenance of EMU were arranged with TŽV Gredelj which is registrated for such kind of job. HŽ Putnički prijevoz had to pay costs of unplanned maintenance. That was also arranged with TŽV Gredelj as maintenance approved company. The price of irregular maintenace was fixed at 0,2 €/km for works and extra payment for spent materials according to market prices.

According to law of railway safety in Republic of Croatia it was necessary to prepare official rules for maintenance of EMU before starting with regular service. That was duty of HŽ Putnički prijevoz as end user or owner of vehicle. Respecting existing laws, railway rules and recommendation of vehicle producer and producers of particular parts of equipment basic principle of maintenance was established as follows:

- week inspection after 5.000 km or one week lately
- month inspection (control exam) after each 15.000 km or after 35 days lately

Month inspection were made cyclic each 15.000 km (with tolerance of +15%).

P1	15.000 km
P3	45.000 km
P6	90.000 km
P12	180.000 km

Besides regular inspections maintenance includes repairs also. For this vehicle first middle repair is planned after 2,1 milion of km. During future exploitation some changes in maintenance could be expected according to further experience.

Unplanned maintenance mainly consists of eliminating some failures or change of some components.

During one year exploitation of EMU total about 233 corrective actions on the EMU have been made. Mainly they were warranty obligations. But some were consequence of behavior of passengers or damaging from outside .

Typical actions of unplanned maintenance were:

- *Repair of windscreen cleaner*
- *Repair snow plow*
- *Reseting PC panels*
- *Covering losses of cooling water in cooling system of traction convertors*
- *Repair of video recorder of video monitoring system*
- *Cleaning of fire protection sensors*
- *Repair of pump of transformer*
- *Deblocking of vacuum toilets*

It was characteristic that needs of material and spare parts for unplanned maintenance were very small.

4. CONCLUSIONS

During the one year of use EMU prototype for regional transport this vehicle meets the requirements set by end user, and it is characterized by a satisfactory level of availability and reliability in operation. Experiences about maintenance of EMU are positive also and show that EMUs from future series production, based on this prototype, could be exploited with very high level of availability and reliability and low operational costs.

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TESTING METHOD FOR RAILWAY VEHICLES TRACTION CHARACTERISTICS DETERMINATION BASED ON SPEED AND ACCELERATION MEASUREMENT

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Abstract *– When purchasing or reconstructing the traction vehicles, it is rare to have the complete information about output operating parameters of power pack. Since the traction characteristics directly depends on these parameters, it is necessary to check them. Power pack operating parameters could be checked either on test-bench or in service tests. Since, in our conditions, it is almost impossible to perform the test-bench checking, we have to collect the output operating parameters, as well as traction characteristics, in service run tests. These tests are most competent for establishing the real traction characteristics, and its possible deviation from the estimated one.*

Keywords - railway, traction vehicles, traction characteristics.

1. INTRODUCTION

Traction sharacteristic is the most important indicator of operating parameters for traction vehicles, which is representing the functional dependence of traction effort on wheel rim drive shaft assembly F_v and velocity v.

Traction characteristic, with known vehicle moving resistance, represent the basics for determining the vehicles working regime in service. With defined traction characteristic and moving resistance we can very precisely predict the vehicle behavior for all real in service conditions.

For diesel motor trains, traction characteristic should be such that it can provide enough engin power for moving on straight and flat tracks with maximum speed, and also to overcome the road rise with speeds which does not endanger the cooler performance and capacity.

The output working sharacteristics for diesel motor train powertrain, which consist of diesel engine and hydrodynamic transmitter, directly affect on traction characteristic and these should be in such manner to provide the maximum efficiency of hydrodynamic transmitter when engine works in maximum power regime.

The specific of diesel engine and hydrodynamic transmitter interface is that only in certain working regimes of engine and transmitter common operation, power can be transmitted with high efficiency.

In order to gain the required traction characteristic on the drivig axle wheels rim, it must be provided the adequate connection between two powertrain engines and shaft gear, as well as the connection between diesel engine and hydrodynamic transmitter.

For diesel motor trains, the optimal output characteristics should be reached with relatively higher speeds. In our domestic terms, the train speeds are mostly determined with rail track condition, so the working regimes depend mostly of railroad state, rather than powertrain working characteristics.

With traction characteristics testings it can be achieved (if track condition allows) the adjustments of diesel engine working regimes in exploitation with real (the actual, measured) traction characteristic.

2. EXPERIMENTAL TRACTION CHARACTERISTIC DETERMINING

The traction characteristic of diesel motor vehicles recording in order to analyse and compare it with the calculations can be done on test-bench and by riding in service. The best, if possible, will be to do the both recordings.

In our domestic conditions it is very hard to organize the test-bench testings. This fact is

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aggravating factor, especially if the reconstruction of powertrain is done. In that case it is very useful to have test-bench, since the possible defect during coupling can be detected.

Traction characteristics tests in service can be done in two ways: directly and indirectly. The direct tests are done using measuring car with dynamometer, and indirect tests are done with appropriate measuring sensors.

Tests with dynamometer equiped car are more compehensive because along with traction characteristic can be recorded some other values important for car exploitation such as: engine fuel consumption, track profile, speed and wind direction. Wind conditions are especially important when determining the basic vehicle movement resistance. All these values are recorded directly without any calculations, which is the great advantage of using the measuring car.

Doing tests with appropriate sensors is much simpler but the traction characteristic is not taken directly. It has to be calculated using speed and acceleration records cosidering the train mass.

It is possible to do the tests by measuring only one of theese values and later, using appropriate math, to calculate other values and draw a diagram of traction characteristic.

3. EXAMPLE OF EXPERIMENTAL TRACTION CHARACTERISTIC DETERMINING

In this paper will be described the checking of the traction characteristic for diesel motor train serie 711, manufactured by „Metrovagonmash“. Figure 1 displays the train and its basic dimensions.

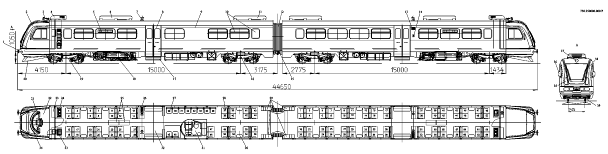

Fig.1. Drawing of the diesel motor train serie 711

Powertrain for modern diesel motor trains is usually designed as unique power modul so-called POWERPACK, and by that is achieved the compactness of the structure. The Powerpack consist of diesel engine with its following systems and the hydrodynamic transmitter.

Powertrain of the DMT consist of diesel engine MTU 6H 1800 R83, with nominal power P=360 kW, and hydrodynamic transmitter VOITH T 211 re.4 with retarder KB 190. Both DMT units have one one power modul installed. The train maximum speed is limited to 100 km/h due to domestic track conditions.

Figure 2 shows the look of the power module installed in DMT serie 711.

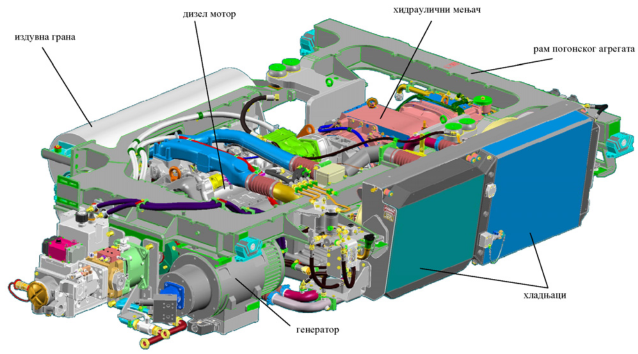

Fig.2. Power modul – THE POWERPACK

Traction characteristic provided by the hydrodynamic transmitter manufacturer VOITH, is shown in Figure 3.

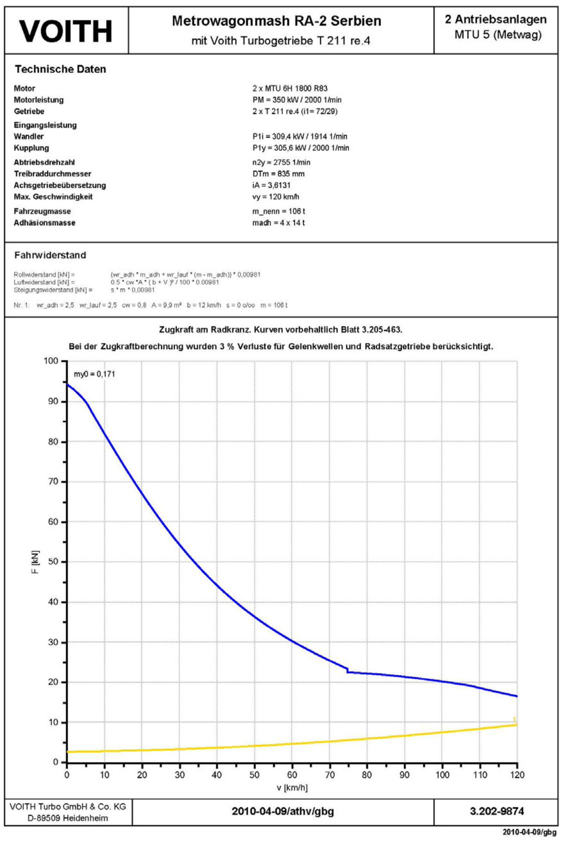

Fig.3. DMT traction characteristic by VOITH

This traction characteristic is given for DMT mass of m=106t and shaft gear transmission ratio of i=3.613. From the diagram can be seen the speed value when hydrodynamic converter working regime changes to hydrodynamic coupling working regime and that value is v ≈ 74 km/h.

The DMT manufacturer, „Metrovagonmash“ gave the calculated traction characteristic as in Figure 4.

This traction characteristic has been calculated for train mass m=108.43 t and and transmission ratio i=3.32. From the diagram can be seen the speed value when hydrodynamic converter working regime changes to hydrodynamic coupling working regime and that value is v ≈ 78 km/h.

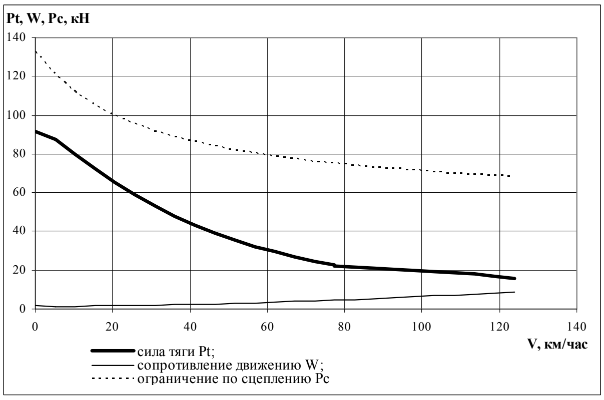

Fig.4. DMT calculated traction characteristic

In order to determine the real traction characteristic and to find its deviation from the calculated, the tests must be conducted. For the reasons previously mentioned, only riding tests in service has been done.

Test and recording of traction characteristic were performed using the following measuring equipment:

– Acceleration sensors HBM B12/200;
– Impulse frequency and counter sensor FYCAP 88059;
– Data aquisition system HBM QuantumX MX840;
– Notebook Dell Inspiron 1545 and related software.

Traction characteristic testing was performed on straight and flat track, riding the train in both direction, under dry and windless weather conditions, by measurement of longitudinal (the railroad direction) accelerations inside the car body.

Fig.5. Acceleration sensors

The measured values during the tests were the speed of train and car body accelerations. The empty train mass was previously determined by weighing m=87662.5 kg. The mass of maximum loaded train during the tests was m=107660 kg. The train was riding at full engine charge level from start (v=0km/h) until reaching the maximum speed of 100km/h.

The acceleration sensors were mounted on car floor level and is shown in figure 5.

Figure 6 shows the real traction characteristic obtained by conducted tests. The traction force is obtained by multiplying the acceleration value with train mass. The same diagram contains the basic movement resistance curve.

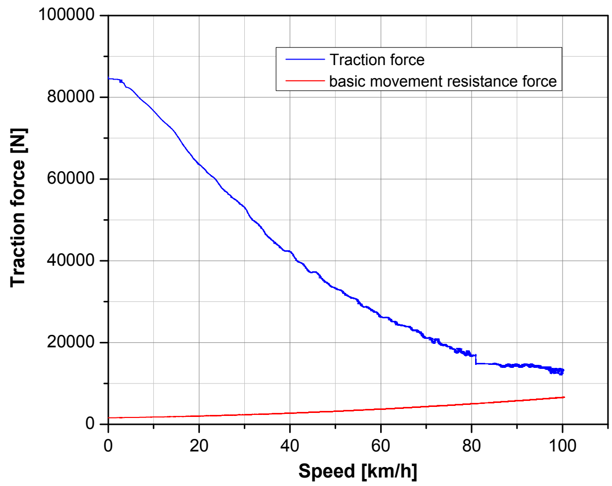

Fig.6. Recorded DMT traction characteristic

The real traction characteristic is in principle the same as the calculated one but it is evident the difference in speed value when hydrodynamic converter working regime changes to hydrodynamic coupling working regime. For real traction characteristic this value is v ≈ 80.5 km/h

This difference in speed when hydrodynamic converter working regime changes to hydrodynamic coupling working regime appears because of different values for real and calculated shaft gear transmission ratio, as well as different train masses.

During the traction characteristic calculation the transmission ratio is i=3.6131 (as stated before, value is given by VOITH).

The real tranmission ratio value is i=3.32, and therefore the speed when hydrodynamic converter working regime changes to hydrodynamic coupling working regime is v ≈ 80.5 km/h.

This speed difference is not insignificant if it is known that the system eficiency is about 10÷12% higher when hydrodynamic transmitter is in hydrodynamic coupling working regime.

From all the above it can be concluded that it is more efficient if these transition speeds could be lower because the vehicle would be longer in hydrodynamic component working regime where the efficiency is higher.

This is especially apparent on domestic railway where, due to track condition, DMT in some sections can not reach the speed when the hydrodynamic coupling turns on.

4. CONCLUSIONS

In order to determine the working regimes for some diesel motor train in exploitation it is necessary, during the design proces, to find its traction characteristic as precise as possible. Precise determination of traction characteristic as well as the movement resistance determination can help us later with reduced exploitation costs and DMT maintenance.

Considering that during the process of procurement of vehicles from manufacturer cannot always be acquired complete data about output working characteristic of powertrain before putting the vehicles in operation, these working characteristic must be checked either on test-bench or in service.

The traction characteristic tests in service is most authoritative for determining the real traction characteristic. The simplest and cheapest way to find traction characteristic in service is using appropriate sensors.

In this paper has been described the process of recording of traction characteristic for diesel motor train serie 711, manufactured by „Metrovagonmash“, which is from this year in operation on domestic non-electrified lines.

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THE INFLUENCE OF STRESS STATE IN MONOBLOCK WHEELS WITH TREAD BRAKE

Zoran SAVELJIĆ [1]

Abstract *– The paper analyzes the thermal load impact on railway vehicle monoblock wheel with tread brake and its influence on monoblock wheel stress state in exploitation. Technical conditions for manufacturing and delivery of railway vehicles monoblock wheels are given, as well as the limits of residual stresses of monoblock wheels with tread brake and wheels monitoring procedures during exploitation. The operating principle for measuring devices for measuring of monoblock wheels residual stresses has been analyzed, as well as their strengths and weaknesses manifested during the comparative measuring of the same axle sets. The paper proposes measures for overcoming of stress state influence on monoblock wheels with tread brake.*

Keywords - railway, railway vehicles, monoblock wheel, thermal loading.

1. INTRODUCTION

The rail vehicle monoblock wheel with tread brake suffers a significant thermal load in exploitation. In contact area between tread brake and wheel running surface kinetic energy is transformed into heat and in a very high percentage is transmitted onto the wheel. As a consequence, the wheel temperature rises during long breaking periods, so that constant speed of train movement at slopes can be maintained, while influencing the changes of stress state of the monoblock wheel.

As the wheel temperature is highest on running surface during breaking, the significant plastic deformations appear. Accumulation of plastic deformations influence the enhancing of residual stresses in stretching, which causes appearance of crack and its spreading, eventually leading to the wheel fracture.

Conditions for monoblock wheel manufacturing and delivery are defined according to the UIC leaflet 812-3. Monoblock wheel manufacturer shall fulfill the conformation by which he proves that provisions of manufacture are complied with the technical requirements of monoblock wheels.

2. THE THERMAL LOAD INFLUENCE ON THE STRESS STATE OF MONOBLOCK WHEELS

The contact between the tread brake and the running surface during breaking causes the temperature rise up to 720˚ C, in short-term period, and, at the same time it is followed by rapid cooling on the residual surface.

Due to the low depth of penetration of induced heating, the surface is exposed to the thermal shock, which causes fractures;

The phenomenon of thermal fractures is connected to influence factors:

- Metallurgical factor is caused by the transformation of austenite structure, leading to the change of crystal lattice volume. These changes induce additional loads in metal, which can cause the appearance of micro-cracks.
- The physical factor - in the heated area on the running surface acts as special ring which spread independently of the metallurgical crystal structure transformation, what corresponds to the thermal shocks incurred cracks.

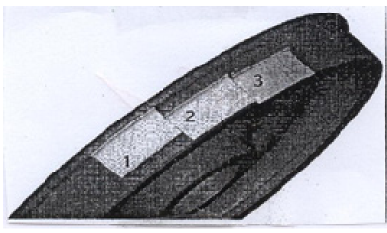

Fig.1. The load cases with different positions of tread brake on the running surface

To determine the thermal load influence on the stress state of monoblock wheel during breaking with tread brake, the examinations are performed on Yugoslavian rails during the period of 1975-1982.

In thermal load of monoblock wheel with tread

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brake examinations, one could consider the different wheel position compared to the running surface as shown on Figure 1.

As the wheel temperature is highest on the running surface during breaking, limit of elasticity of material is lowest in that area (yield strength), so many plastic deformations appear.

3. TEMPERATURE AND STRESS STATES DEPENDENCE

In order to determine temperature and stress state dependance of monoblock wheel at the long term breaking laboratory tests were performed for third load case (Figure 1), for which the simulation of long breaking in duration of 12000 s was made. During that period, the monitoring of wheel temperature distribution is enabled in a number of time intervals. Thus, the temperature and corresponding stress distribution were obtained on every 120 s from the beginning of breaking.

The temperature distribution is shown in the Figure 2 and the stress state of monoblock wheel in MPa is shown in Figure 3.

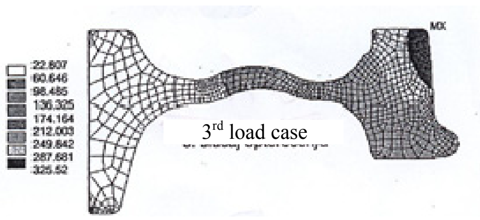

Fig.2. The temperature distribution in °C

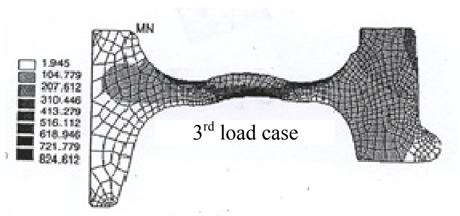

Fig.3. Stress state of wheels in MPa

Given image of stress distribution shows the area of relatively high stresses is on central wheel curve and on the outside edge where shoe crosses the outside edge.

On monoblock wheels with tread brake, made of steel of classes R2, R6, R7, R8 and R9, boundary values of residual stresses are defined according to the UIC 510-2:

- 250 MPa, rim of monoblock wheels must not be exposed to any higher compression.
- 300 MPa, for monoblock wheels with high hardness.
- 400 MPa, for monoblock wheels on where the fracture toughness /KQ/ is:
  - the mean value of residual stresses of new monoblock wheel from /6/ measurements ≥ 80 MPa.

4. CONTROL AND DETERMINATION OF RESSIDUAL STRESSES

The procedure of wheel sets control with monoblock wheels with tread brake is shown by diagram which represents the treatment of wheel sets with monoblock wheels after heat induced fractures (Figure 4).

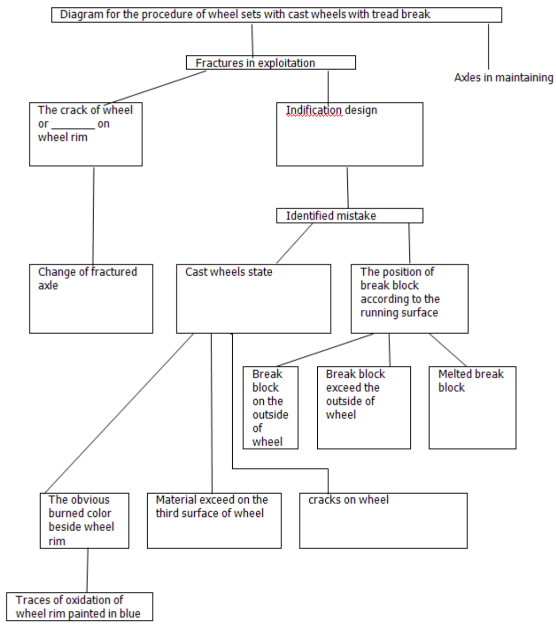

Fig.4. Diagram for the control procedure for monoblock wheels with tread brake

1. MEASURING OF RESIDUAL STRESSES IN MONOBLOCK WHEELS

The procedure for monoblock wheel treatment after their thermal loading is shown in Figure 5.

European railway research institute (ERRI) based in Utreht, Federal German Republic deals with wheel set standardization.

Monitoring of residual stress of monoblock wheels issues in exploitation began in 1984.

Fractures of monoblock wheels are subject of many studies, so that their cause can be identified. Those examinations showed some variables which identify vulnerability of wheels with twin shoes, as follows:

- Fracture toughness of materials
- Direction and distribution of wheel stresses
- Dimension of thermal fractures
- Defects that occurs due to the grooves of collet lathe.

In order to avoid the wheels fractures, an ERRI work group was formed to suggest a method of measuring of residual stress caused by thermal load in monoblock wheels.

Acoustic-elastic effects describe the speed change by spreading ultrasonic waves as the function of stresses or loaded state of solids. A solid body is placed in testing machine and the stress tensioning is applied. The effect will vary depending on direction of spreading of ultrasonic waves compared to the stress.

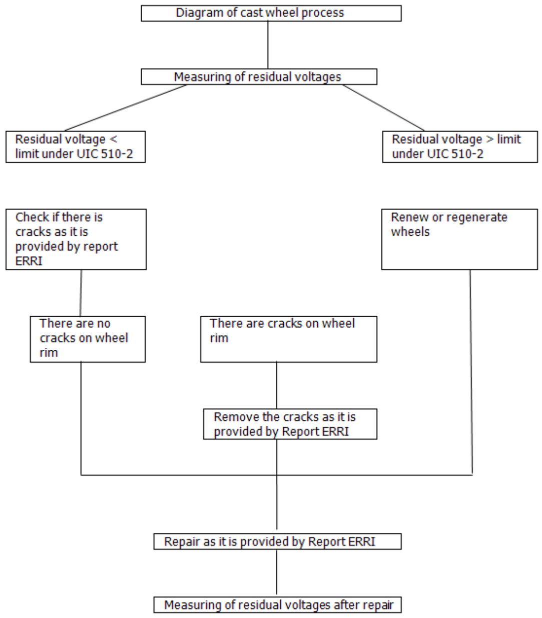

Fig.5. Diagram of monoblock wheels treatment

The change of residual sresses of new wheels is shown in Figure 6.

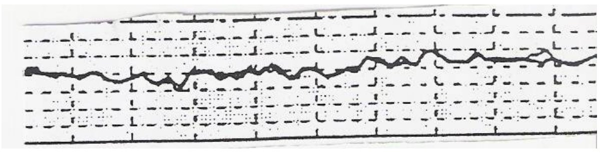

Fig.6. The change of residual stresses of new wheels

The change of residual stresses in monoblock wheel with plastic deformations due to the effect of breaking on running surface is shown in Figure 7.

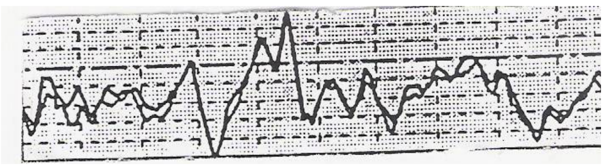

Fig.7. Change of residual stresses on wheels which have plastic deformations

Parameters which affect the measuring results are:
- The influence of wheel temperature;
- The influence of wheel rim width and height;
- The wheel fracture during rotation.

There are several devices for measuring of ressidual stresses of monoblock wheels, namely:
- Measuring device DEBRO-30 of state owned Railways of Poland (PKD), developed by Institute for basic technological problems of Academy of Science in Varšava,
- Measuring device UER of Federal German Railway (DB), developed by Institute for nondestructive testing in Zabrubninu, Germany,
- Measuring device SNCF was developed by National Association of French Railways.

Noted measuring devices have a set of common features:
- Devices are mobile
- It is possible to perform the measuring of residual stresses on wheel sets which are dismantled from vehicles, and those which are not.

The measurement process is defined by a following procedure:
- fixation of the the mesured wheel sets
- preparement of measuring devices,
- definition of at least three measuring places on the inside surface of the wheel; the measuring surface have to be cleaned and lubricated by machine oil or epoxy resin,
- set the measuring probe with the pattern,
- adjusting of the basic unit, measuring and memorising of impulse,
- performing of measurement in the duration of 1 min.

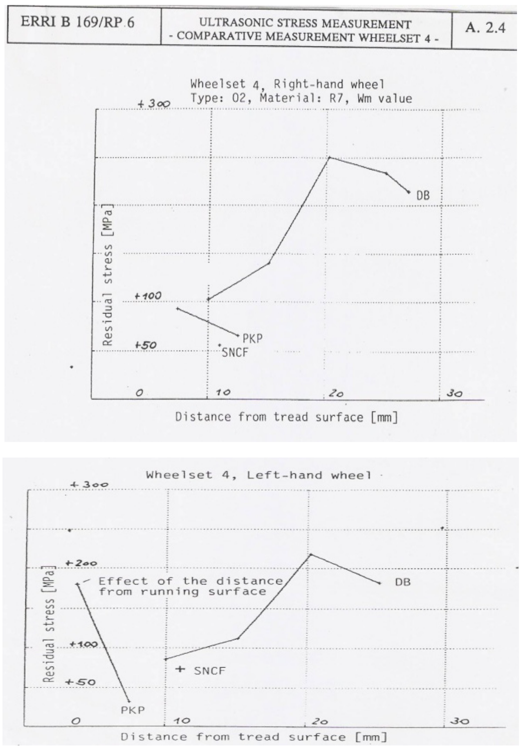

Fig.8. Comparative measurements of residual stresses in monoblock wheels

The values of measured residual stresses have to be shown, monitored and then printed.

The measuring accuracy in the range of above descibed devices is:
- On measuring device DEBRO – 30 ± 10 MPa
- On measuring device SNCF ± 20 MPa
- On measuring device UER ± 0 MPa.

The aim of comparative measurement was definition of the measurement range of devices UER, DEBRO – 30 and SNCF, i.e. is it possible to obtain equivalent results. For comparative measurement only five wheel sets were used.

Diagram A2.4 (Figure 8), shows the measurement results of residual stresses in wheel sets, which are out of exploitation due to the thermal load of wheel material R7. In can be noted from the figure that there is a difference in residual stresses measurement.

The results reproduction is the most convenient with device UER due to the system for automatic data recording; while there is slight difference between measurements with devices DEBRO-30 and SNCF.

2. NEW DESIGN OF MONOBLOCK WHEELS WITH TREAD BREAK

Subcommittee UIC 46B stated that, starting with 1st January 2002, monoblock wheel material R2, R8 and R9 would no longer be acceptable for monoblock wheels with twin shoe breaking in international transport.

To enable the usage of wheel sets withouth the risk of fracture after the designated date it was necessary to guarantee that ressidual stresses are below ≤ 250 MPa. The residual stresses grater than > 300 MPa were found in 624 wheel sets.

Based on performed measurements the railway administrations started the activities for new design of monoblock wheels.

By analyzing the current research and development efforts to reduce the possibility for fractures of monoblock wheels, several sets of activities aimed at solution of noted problem can be indentified:

- The first set refers to development of new standardized construction of wheel „less vulnerable" to thermal loading.
- The second set of activities represents a measures taken in exploitation, wheel control and introduction of residual stresses measurements in order to prevent fractures.

Based on obtained results of ERRI examinations, the following procedures of control are defined:

- definition of the wheel color change;
- performing of measurement in order to define the increased distance of inside wheels;
- determination of the position of break block on the surface of wheel rotation;
- noting of the processing of the additional slots, introduced by clamping of wheel during its profile correction on lathe

The railway administrations adopted new designs of monoblock wheels as follows:

- Swiss Federal Railways (CFF), monoblock wheel type nine,
- Austrian Federal Railways (OBB), monoblock wheel type three,
- National Association of French Railways (SNCF), monoblock wheel type three
- German Federal Railways (DB), monoblock wheel type three.

The results of testing of monoblock wheels are shown in Table 1.

Table 1. The results of testing of monoblock wheel new design

Description	Railways	
	DB	CFF
Testing period	1992-1994	1994
Type	02,80,88	0677, 0647, 0697
Material of wheels	R1, R7	R7
The number of tested monoblock wheels	15470	4096
Wheel Material	Color changing	Color changing
Residual tension > 300 MPa	624	204
Exceeded limit value %	8.3	12.25

Based on the testing results, German Federal Railways (DB) and Swiss Federal Railways (CFF) identified boundary values for residual tension and their application;

- Monoblock wheels made from material R7 with cracks - > 300 MPa
- Monoblock wheel made from material R7 without cracks - 400 MPa.

3. CONCLUSION

Analyzing the previous work to reduce the possibility for fractures of monoblock wheels, some basic activities can be noted:

- The first set of activities refers to the development of new monoblock wheel construction;
- The second set of activities is aimed at implementation of control: identifying of burned color, identifying of increased distance of inside surface of wheels, the position of tread brake, noting of additional grooves construction on the lathe.

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THE MEASUREMENT OF QUALITY PARAMETERS OF ELECTRICAL ENERGY IN THE SERBIAN RAILWAYS ELECTRO-TRACTION SUBSTATIONS

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Abstract *– The measurement of electrical energy quality in the Serbian Railways 25kV 50Hz electro-traction system is nowadays exclusively done by collecting the values of currents, voltage, frequency, active and reactive forces and the basic accordion power factor in electro-traction substations. However, according to the regulations of the EN 50160 international standard, such measurements are not only insufficient but without any proper program procession of the measured values as well. The paper suggests one of the possible modern solutions to the measurement and supervision of electrical energy quality on the "Serbian Railways" electrified tracks in accordance with the regulations of the EN 50160 standard.*

Keywords - electrified tracks, quality, electrical energy.

1. INTRODUCTION

During the last ten years, many different standards have been used in the field of the quality of electric energy, but the actual breakthrough occurred in the mid-nineties. The problem was approached globally. Members of the CENELEC (European Committee for Electro-technical Standardization headquartered in Brussels) are the national electro-technical committees (there were 18 members during that time) consisting of: Belgium, Denmark, Germany, Finland, France, Greece, Ireland, Iceland, Italy, Luxembourg , the Netherlands, Norway, Austria, Portugal, Sweden, Switzerland, Spain, and the United Kingdom. In 1993, the International Organization CENELEC BTTF 68-6 adopted a new standard called EN 50160, used to measure the voltage at the location where electricity was transmitted to the consumers of low voltage (LV) and medium voltage (MV) networks under normal operating conditions. CENELEC accepted this standard on June 5th, 1994, and instructed its permanent members to announce the implementation of the new standard, and to terminate the utilization of the old standards. For other countries, mainly European ones, the deadline for implementing the new standard was advised to be in 2003.

Despite the fact that the provisions of EN 50160 standard were accepted in the Republic of Serbia in 2003 under the name of SR - EN 50160, it has not been fully implemented on the single-phase 25 kV/50 Hz electrified tracks of Serbian Railways.

The purpose of this paper is to introduce the provisions of this European standard, which will enable Serbian Railways as a large consumer of electric energy to recognize its responsibility (rights and obligations) in terms of providing the required quality of electric energy from the three-phase electric network.

2. BASIC PARAMETERS OF POWER QUALITY

There are eight basic parameters used for determining the quality of electric energy on electrified tracks with the mono-phase 25 kV/50 Hz system based on the EN 50160 standard: 1. Voltage fluctuation, 2. Flickers: Short-term (Pst) and Long-term (Plt), 3. Harmonics: from 2 to 40, 4. Signalization voltage (Ripple Control – signaling controlling voltage), inter-harmonics, MTU, 5. Frequency voltage, 6. Asymmetry (skewness) of the voltage, 7. Voltage dips and / or surge transients, excessive voltage, 8.Power outage.

According to the EN 50160 standard, it is important to monitor the values of the eight parameters, and determine whether they are within the

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recommended limits, as shown in Table 1. Values of individual higher harmonics (*h*) at the location of transmission to the 25th higher harmonic with a percentage of the nominal voltage *Un* = 25 kV showed in Table 2.

Table 1. The limits of the eight parameters according to the EN 50160 standard

Parameters	Time	Limits during 95% of the week (160 hours)	Limits during the entire week (100%= 168 hours)
Voltage Fluctuations	10 min	$\pm 10\% \cdot U_n$	U_n +10% −15% during the remaining 5% of the week
Flicker	P_{st} – 10 min. P_{lt} – 120 min.	$P_{lt} < 1$	
Harmonics	10 min	Please refer to Table2	
THD	10 min	< 8%	
Signalization Voltage	3 s	< 5% from U_n (1…10 kHz) in 99% of 24 h (1 day)	
Frequency (50 Hz)	10 s	±1% (during 99.5% of one year)	+4%/-6% during the remaining 0.5% of the same year
Asymmetry	10 min.	*< 2%*	
Voltage Dips	10 ms	No exact limit	
Power Outage	10 ms	No exact limit	

Table 2. Values of individual higher harmonics (h) at the location of transmission to the 25th higher harmonic with % of the nominal voltage Un = 25 kV

Odd-numbered higher harmonics not divisible by 3		Odd-numbered higher harmonics divisible by 3		Even-numbered higher harmonics	
Number of a Harmonic	*Uh* in % of *Un*	Number of a Harmonic	*Uh* in % of *Un*	Number of a Harmonic	*Uh* in % of *Un*
5	6.0	3	5.0	2	2.0
7	5.0	9	1.5	4	1.0
11	3.5	15	0.5	6 to 24	0.5
13	3.0	21	0.5		
17	2.0				
19	1.5				
23	1.5				
25	1.5				

2.1. Voltage Fluctuations

Even though it is possible to distinguish between gradual and sudden changes in voltage due to the changes in the towing force, we can generally say that voltage fluctuations are acceptable if 95% of all the median ten minute effective values are within the +/-10% of the standardized nominal voltage (*Un*). For the other 5%, voltage can fluctuate between -15% and +10%. That means that out of 1008 median effective ten minute voltage values measured within a week, 958 should have the value between 22500V and 27500V for the standardized nominal voltage of 25kV, according to the EN50160 standard (Fig. 1).

2.2. Flickers

It is important to define this parameter because a change in the towing resistance causes changes in the intensity of electric energy, not only for electro-traction vehicles but also for electro-traction substations and overhead line.

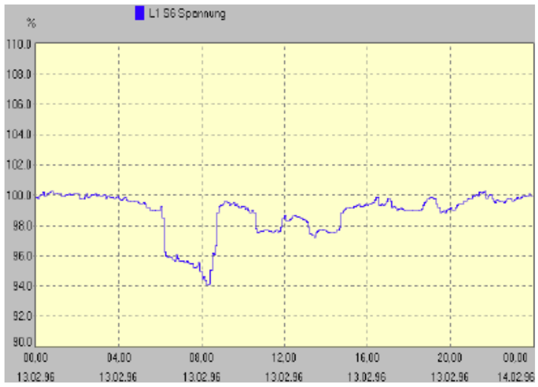

Fig.1. Ten minute median effective voltage values Un = 25kV.

In the single-phase electro-traction system, short-term flicker intensity (P_{st}) is only measured during a ten minute time interval, while the long-term flicker intensity (P_{lt}) can be calculated by using a sequence of the twelve consecutive P_{st} values using the following formula:

$$P_{lt} = \sqrt[3]{\sum_{i=1}^{12} P_{sti}^3 / 12} \quad (1)$$

The long-term flicker values (P_{lt} = 120 min) cannot exceed 1 during the 95% of the week (168 hours) as shown in Fig. 2.

2.1. Harmonics and Inter-harmonics

The permitted values of higher harmonics (h from 2 to 40) can be displayed in tables:

-individually using their amplitudes (U_h) simplified to the amplitude of the basic harmonic (U_h)

- together using the total of higher harmonics.

Total Harmonic Distortion (THD) that can be calculated using the formula:

$$THD = \sqrt{\sum_{h=2}^{40} (U_h)^2} \qquad (2)$$

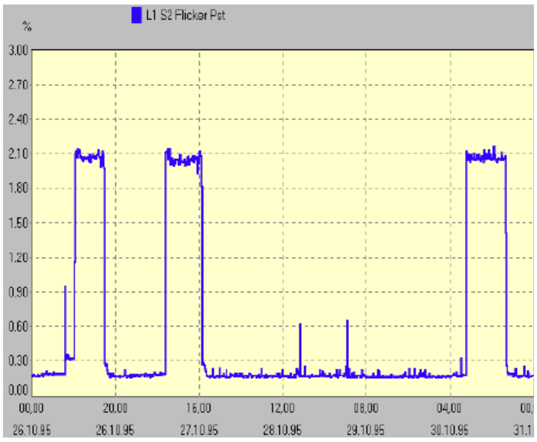

Fig.2. The long-term flicker values cannot exceed 1 during the 95% of the week

During the each ten minute interval, the value of THD has to be less than 8% of the first harmonic value. On the other hand, the values of individual harmonics can have values (shown in Table 2) between 0.5% and 6% of the first harmonic value (Fig. 3). Higher harmonics are most commonly produced by higher harmonics of nonlinearly loaded electro-traction vehicles, which are connected at difference distances from the electro-traction substation. These higher harmonics produce other higher harmonics inside the overhead line at the location of pantograph. On the other hand, an increasing use of frequency converters and similar devices on electro-traction vehicles causes an increase in the value of inter-harmonics, whose permitted values are still not defined within the EN 50160 standard. However, lower intensity inter-harmonics can also cause flickers and interference in signaling-safety devices with the three-phase control.

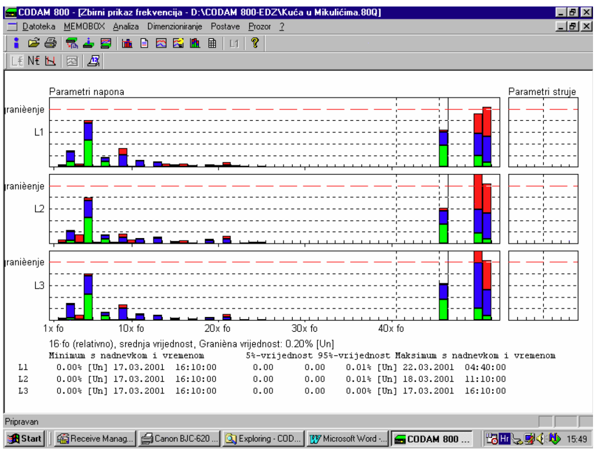

Fig.3. Application of CODAM 800 program support: up to 120 harmonics (3x40) in accordance with restrictions

2.2. Voltage Dips

Voltage dips most frequently occur due to the failures in the electro-traction system. A dip (partial loss of voltage) is a sudden and short-term (10 ms to 1 min) decrease in voltage to the level between 90% and 1% of the nominal voltage. The number of dips within one year can be in the range between 1 and 1000. The majority of dips have to have duration of less than 1s and amplitude of less than 60% of the nominal voltage.

2.3. Power Outage

Power outage occurs when the voltage falls under 1% of the nominal voltage. There are planned and non-planed, as well as short-term and long-term power outages. The duration of 70% of short-term power outages (<3 min) has to be less than 1 s. Long-term power outages (>3 min) has to occur less than 50 times within a year.

2.4. Signalization Voltage

Since railway tracks are also used for the transmission of safety signals, these signals have to satisfy certain conditions. For example, 99% of all the three-second median effective signalization voltage values cannot exceed 5% of the nominal voltage for frequencies between 1 and 10kHz. (Fig. 4).

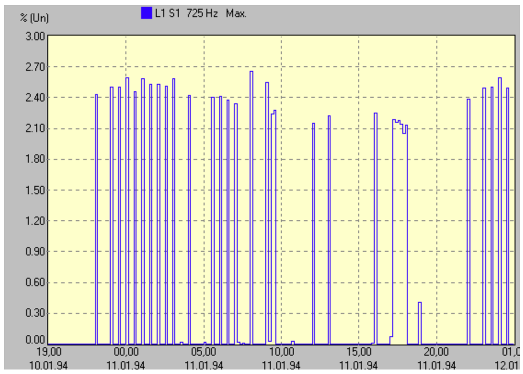

Fig.4. Signalization voltage cannot exceed the frequency limit based on a % of the nominal voltage.

2.5. Frequency

Nominal voltage frequency in the single-phase electric system of 25kV is 50Hz. During normal operational conditions, ten-second median value of the basic frequency in the catenary has to be between 50Hz +/- 1% during 99.5% of every week (year), and 50Hz +/- 6% during the remaining 0.5% of the week (year).

2.6. Asymmetry

Since the electro-traction substations in the single-phase 25kV 50Hz system are connected to the three-phase system, the connection of the two different phases leads to voltage asymmetry in this system. During normal operational conditions, all the ten-minute median effective values of the inverse component cannot exceed 2% of the corresponding direct component for 95% of the median weekly values (Fig. 5).

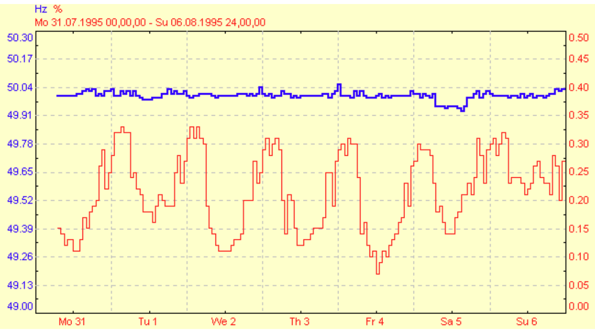

Fig.5. Asymmetry and frequency outside the limits

3. MODERN QUALITY MEASURES OF ELECTRIC ENERGY

In the electro-traction 25kV/50Hz system of Serbian Railways, measuring the quality of electric energy is done by collecting the values of currents, voltages, frequencies, and active and reactive power in the electro-traction substations, which are used as the locations for connecting the three-phase electric system with the electrified tracks. Also, the measured values from the electro-traction substations are sent to the centers for remote control (Fig. 6). However, the measured values are not processed according to the EN 50160 standard. In order to determine whether the quality of electric energy satisfies the provisions of the EN 50160 standard, we need to use computer software for processing the measured values.

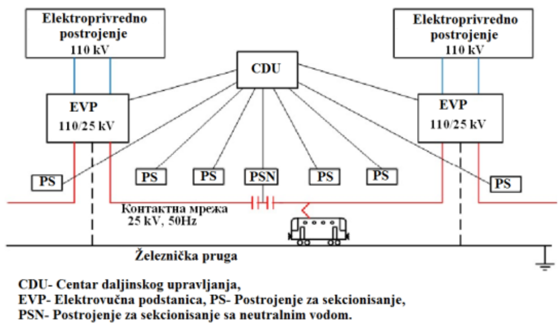

Fig.6. Electro -traction 25kV/50Hz system of Serbian Railways

During the past few years, many different devices for measuring the quality of electric energy have been available in the world and also in Serbia. All these devices work in accordance with the EN 50160 standard. Because more than 2000 users in over 20 different countries have good experience with using the equipment of an Austrian firm called LEM-FLUKE, we want to present the characteristics of this high quality equipment. In Fig. 7, we present ful set of the LEM MEMBOX series 800/800A device for monitoring the quality of electric energy in the electro-traction system.

Fig.7. The full set of the LEM MEMOBOX device

This system consists of three elements:

1) Measuring devices which are permanently connected to a 25kV electric transformer in the electro-traction substation 110/25kV,

2) Communicational link which is used to remotely collect information,

3) The mainframe computer in the center for remote control that is used to process collected information.

The red line represents the permitted limit for the parameters. According to the EN 50160 standard, this limit has to be met in 95% of the observed measured period (7 days). The red bars represent the values that have been achieved during 95% of the observed times relative to the recommended values. The blue bars represent the values that have been achieved during the other 5% of the observed time, which is 7 days according to the EN 50160 standard.

4. CONCLUSIONS

Based on the current measurements, we cannot conclude whether the quality of electric energy on Serbian Railways satisfies the provisions of the EN 50160 standard. As a result, we need to use computer software and modern equipment to determine the exact quality of electric energy. Based on the good experience among more than 2000 users in over 20 countries, the implementation of the LEM MEMBOX series 800/800A device would enable Serbian Railways to continuously monitor the quality of electric energy according to the EN 50160 standard.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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CORROSION PROBLEM IN RAILWAY

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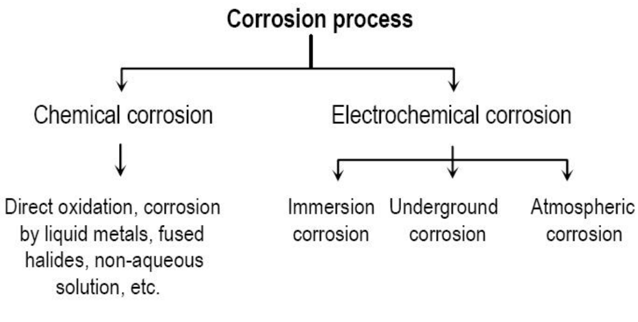
Abstract *– Corrosion is a general problem degradation of engineering materials and defined as the deterioration of a material due to its interaction with environment. Corrosion is affected by several factors, including electrochemical, metallurgical, physical-chemical and thermodynamics. As the most structural parts in railway made from metals, corrosion appearance is inevitably. Rails are expected to function reliably and continuously over several decades. Rail corrosion, particularly at the base of the rail, is a serious problem in transit systems. Atmospheric and crevice corrosion are dominant kinds of rail corrosion. In most cases, it is difficult to detect rail corrosion in the base because it is usually hidden between the tie plate and rail base. The corrosion rate along the rail base is affected by humidity, deposited salts and stray DC currents that generate electrolytic reactions. The best way to prevent the corrosion of the rails is by properly insulating the rails, avoiding any DC leaks from the rail to the ground, forcing the current to return properly and closing the circuit. The best way to detect corrosion is visual inspection.*

Keywords - Corrosion, atmospheric corrosion, rail, rail base.

1. INTRODUCTION TO CORROSION

The most common types of damage that occur to structural steels during their lifetime are fatigue and corrosion. Except for stainless steels, which are more costly, almost no uncoated ferrous products can resist the influences of various corrosion factors coming from the atmosphere, e.g. sulfide, chloride, dust, and moisture [1]. Corrosion is defined as the destruction of materials caused by chemical or electrochemical action of the surrounding environment and it is affected by several factors, including electrochemical, metallurgical, physicochemical, and thermodynamics [2]. Corrosion process can be conveniently classified as follows [3]:



Reaction of metals with dry air or oxygen is considered as a chemical corrosion. High temperature oxidation of metals and metals tarnish, like copper, silver etc. fall in this category. Of late this is also considered to be an electrochemical process with the diffusion of oxygen (inwards) and metal ions (outwards) through the oxide layer, the electromotive force at metal-oxide interface being the driving force. Electrochemical corrosion occurs in the presence of electrolyte. The reaction is considered to take place at the metal-solution interface with the creation of local cathodic and anodic sides on the metal surface [4].

Rust is the corrosion product formed, when iron compounds corrode in the presence of oxygen and water. It is a mixture of iron oxides and hydroxides and is a common form of corrosion on steel. This corrosion is the result of the oxidation reaction when iron metal returns to a more stable state. The rust forming process is summarized in three stages: (1) formation of Fe_2^+, (2) formation of hydroxide ions, and (3) the chemical reaction with oxygen to create rust. Hence, rust is Fe_3^+ oxide that is formed by the dehydration of Fe_2^+ and hydroxide. The concentration of chlorine ions accelerates corrosion by making the solution (water + salts) more conductive. A magnetic hydrous ferrite, $Fe_3O_4xH_2O$, often forms a black

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intermediate layer between hydrous Fe_2O_3 and FeO. Hence, rust films normally consist of three layers of iron oxides in different states of oxidation

2. RAIL STEEL

High carbon eutectoid steel (about 0.70–0.80 wt % C and about 1.2 wt % Mn) is used as rail steel due to its superior mechanical properties (ultimate tensile strength 880 - 1600 MPa). This steel possesses a fully pearlitic microstructure, which provides a good combination of strength, hardness and ductility. However, the presence of a high amount of cementite in pearlite makes the structure susceptible to corrosion [5, 6].

The load conditions for rails are quite severe. The pressure at that contact point exceeds 1000 MPa, which is more than the yield stress, and sometimes causes partial plastic deformation of rails. The coefficient of linear expansion of rail is around 10^{-5}/°C, if a 1000 m rail freely expands, it would expand by more than 10 cm as temperature rises by 10 °C [7].

The corrosion resistance of eutectoid carbon steels has not been studied much in detail. However, it is known that pearlite reduces the corrosion resistance of steels in chloride saturated environment [8]. Chen et al. [1] reported that steels with complete ferrite microstructure showed lowest weight loss during the early stages of wet–dry test in a chloride environment, compared to steels with pearlite/ferrite microstructures. The corrosion resistance was related to the carbon content in steel [1].

Corrosion of carbon steel in water is controlled by the availability of oxygen to the metal surface. In rail structures, the water or humidity deposited on the rail usually has high amounts of dissolved oxygen, and the water layer is thin enough to permit an easy flow of oxygen. Under static conditions, carbon steel corrodes at rates between 100 and 200 μm/year, depending upon the oxygen level and temperature variations at different locations. As velocity causes a mass flow of oxygen to the surface, corrosion is very dependent on flow rate and can increase by a factor of 100 [9]. This factor of 100 does not consider the presence of stray currents, a major concern for transit systems. Additionally, when the deposited salts on top of the rails become dry, very aggressive corrosion conditions are formed. This is due to the relatively good conductivity and the ability to dissolve oxygen, resulting in an increase of the rate at which corrosion erodes the rail.

According to the Indian Permanent Way specification, the normal C–Mn rail is expected to have a life of 800 gross million tons (GMT), which works to approximately 12–13 years under normal traffic conditions in India. However, the life of the rails is reduced to nearly half the expected life due to corrosion. An analysis of rail renewal in India for 2006–2007 indicates that only 32% of the replacement of rails took place after completion of normal expected life of the rails. Data show that 37% of the rails undergo replacement due to corrosion before their estimated service life, whereas only 16% of the rail replacement is due to wear and 15% due to rail-weld failure [5]. Based on these estimations, it can be seen the corroded rails have to be replaced frequently, disturbing traffic, as well as, resulting in economic loss. Moreover, sudden failure of rails is a major safety concern.

3. RAIL CORROSION

Corrosion of rails has been recognized as one of the serious cause of damage railway track. The corrosion of rail along with cyclic loading may lead to corrosion fatigue failure of the railway track. Cases of failure of rails have come to light at load much below the safe load mainly due to deterioration of rail as a result of corrosion. It is therefore, essential that all railway engineers should have a broad knowledge of composition of rail and environmental effect on it. Railway track comes closely to different environment during its service life like seacoast environment, various humidity of the atmosphere, different temperature of the atmosphere and tunnel area which is acidic in nature. Strength of the rail material changes with the change in atmosphere [10].

Rail base corrosion is a combination of corrosion environments; for example, humidity (seawater and highly polluted water) and soil. The corrosion problems of systems with the presence of water have been well studied over many years, but despite published information on material behavior, corrosion is in some cases unpredictable. Most of the elements that can be found on earth are present in seawater, at least in trace amounts, with chloride ions being by far the largest constituent. On the other hand, soils are formed by the combined weathering action of wind and water, and also organic decay.

Corrosion in soils is a major concern, especially because of much the buried infrastructure is aging. Rails are expected to function reliably and continuously over several decades. However, corrosion in soils is very complex due to the presence of several elements as well as variations in properties or characteristics across three dimensions resulting in a major impact on corrosion. Chemical reactions involving almost all of the existing elements are known to take place in soils, and many of these have not yet fully understood [11].

In addition, corrosion is generally hidden under the base and flanges of the rail, growing internally and forming intricate shapes within the flange impeding visual or ultrasonic inspection

When the salt and humidity combine with the return DC current that strays to ground, galvanic

corrosion between the rail and tie plate is initiated, resulting in an aggressive environment that increases corrosion rates which are further enhanced by the high returning voltage and current [12]. Rails in transit systems are used to carry two types of currents: return current (usually DC) and signal current (AC).
AC current does not present a major concern for corrosion. In fact, most publications focusing on AC current discuss the effects of the conductance and resistance of the rail and the ground and their effects on signal system. One of the works published on rail base corrosion [13] proposes a method to control stray currents and was implemented with good results. The stray DC current control system lowers the density of stray current (thus corrosion) along the rail considerably and the stray current control system works as a sacrificial anode, second return current system on insulated rails to further reduce the effects of corrosion.

Also, railway officials and corrosion engineers believe that the corrosion is caused by microbes present in human wastes. Intense corrosion takes place at certain locations (i.e. under the liner) due to accumulation of moisture from the atmosphere and discharge from the open toilets of the railway coaches. Human urine contains 0.4– 0.5 M urea which results in an annual release of 10 kg of urea per adult. It is also well known that many ureolytic microorganisms are present in human wastes which hydrolyse urea into carbonic acid and ammonia [14].

3.1. Atmospheric corrosion

The term "atmospheric corrosion" comprises the attack on metal exposed to the air as opposed to metal immersed in a liquid [4]. It is the most prevalent type of corrosion for common metals. Atmospheric corrosion is a subject of global concern because of its importance to the service life of equipment and durability of the structural materials.

The most common form of corrosion of rails is atmospheric corrosion, resulting from the wetting and drying process. The atmospheric corrosion of rails results in uniform corrosion. Corrosion will be more severe for longer moisture residence time and frequent wetting and drying. Uniform corrosion will be aggravated in the presence of chloride ions, because they destabilize the protective rusts on the surface [15]

Conventional atmospheric parameters that may lead to metal corrosion comprise of weathering factors such as temperature, moisture, rainfall, solar radiation, wind velocity, etc. Air pollutants such as sulphur dioxide, hydrogen sulphide, oxides of nitrogen, chlorides have also been found to contribute to atmospheric corrosion.
The appearance of a corroded rail, elastic rail clip, rail insert and under the liner is shown in figure 1.

Fig.1. Atmospheric corrosion of rail base [14]

Predictability of atmospheric corrosion, in principle, should be based upon the complete understanding of the corrosion process and interdependence of the contributing parameters. Extensive data have been collected all over the world on atmospheric corrosion of metals exposed at different locations. Empirical and semi-empirical relationships have been developed to generalize these observations. Most prominent of these relationships have been the linear and exponential dependence of corrosion rate with relative humidity, pollutant levels and temperature.

Atmospheric corrosion can further be conveniently classified into dry, damp and wet categories [4]. Dry oxidation takes place in the atmosphere with all metals that have a negative free energy of oxide formation. The damp moisture films are created at a certain critical humidity level (largely by the adsorption of water molecules), while the wet films are associated with dew, ocean spray, rainwater, and other forms of water splashing. By its very nature, atmospheric corrosion has been reported to account for more failures in terms of cost and tonnage than any other form of corrosion.

3.2. Localized corrosion

There are two origins for the occurrence of localized corrosion in rails. The first cause is due to leakage of current in electrified railway systems [17]. Intense corrosion attack takes place at the location where the electrons leave (or positive current enters) the track. This is known as stray current corrosion. This can be usually solved by proper design of the railway electrification system. Therefore, this problem is related more to design than material aspects.

The second problem is localized corrosion under the liners, leading to thinning of the rail foot under the liners. The end result is premature failure of the rails, which is a great safety problem. Intense corrosion takes place at these locations (i.e. under the liner) due to collection of moisture from the atmosphere and discharge from the open lavatories of the coaches. The form of corrosion that is noted below the metal liner is commonly referred to as crevice corrosion. The region where oxygen is depleted (i.e. inside the crevice) becomes anodic with respect to the rest of the exposed material. This leads to an intense attack at the crevice location. The process is autocatalytic and more importantly, the attack is not easily visible to the naked eye. Crevice corrosion is accelerated in the presence of chloride ions, which are present in environments near the sea coast as well as in discharge from the toilets of passenger trains.

3.3. Combating corrosion

Corrosion prevention methods are required for both forms of corrosion (described above) that affect rails. One of the most effective ways of them is by insulating the contact between materials or components with different chemistries that have a tendency to form galvanic pairs. However, this is close to impossible because perfect insulators do not exist. The simple corrosion control philosophy, for prevention of crevice corrosion, will be to apply a protective coating on the surface so that the environment will not flow into the crevice. With this aim, many researches were conducted to check the efficiency of different coatings. Polymeric coatings were not effective due to their degradation in the atmospheric environment [18].

It were revealed, in the researches, the best performance was noted in the case of rails coated with zinc. Protection is offered by the zinc coating which acts as a barrier and also as a sacrificial anode (cathodic protection). Cold-sprayed zinc can be coated quite easily with minimum heavy-duty equipment. However, it may not be possible to actually implement the process in field due to practical problems. Moreover, the process is expensive [5].

A different way of approaching this problem is by developing corrosion-resistant rails of new chemistry that will resist corrosion better than the rail steel currently in use.

4. CONCLUSION

The best way to detect corrosion is by visual inspection. Expert track walkers can detect corrosion on exposed rail easier than on rail that is embedded. For instance, locations where there is homogeneous erosion, visual detection is easy. Locations where corrosion is hidden between the tie plate and the base of the rail make its detection more difficult until erosion forms on the rail flanges. However, these locations can be visually detected where salts are deposited on the track, particularly at the rails section seated above the tie plate and where iron like oxide powder is observed at the tie plate locations.

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Strategy and Policy

BUSINESS DEMANDS FOR AN MSC PROGRAMME IN RAIL FREIGHT AND LOGISTICS

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Abstract *– The paper presents the results of the survey on demands of business for staff training in rail freight and logistics. It was implemented within the Erasmus project RiFLE aimed at developing an MSc programme in Rail Freight and Logistics that will be offered in English as separate but shared programme at the participating institutions: the University of Newcastle upon Tyne, UK (coordinator), University of Rome "Sapienza", Italy, Todor Kableshkov University of Transport, Bulgaria and University of Applied Science in Ingolstadt, Germany. The survey showed the significant interest of business in recruiting staff with an MSc degree in Rail Freight and Logistics: 40% of companies are planning to employ graduates trained for these sectors in a period of one year and 75% in a 5-year period. The expectations to the programme are to be interactive, intensive, enjoyable and preferably part-time. Universities should also offer short courses of specific topics to enhance personnel knowledge and skills through the LLP (life-long learning programme). Based on the results of the survey, the RiFLE partners have developed the curriculum framework, which consists of mandatory and optional subjects. The latter will provide students with knowledge and skills necessary for career in 5 business areas: Rail Transport and Logistics Management; Transport and Logistics Project Management; Rail Operation Management; Railway Infrastructure Management; Railway Policy and Regulations.*

Keywords - Rail freight and logistics, business, MSc programme, RiFLE project.

1. INTRODUCTION

RiFLE (Rail Freight and Logistics Curriculum Development) is a Curriculum Development project with duration of three years (01.10.2010-30.09-2013) funded under the Erasmus Programme of the EC. The project objective is to develop Master courses in Rail Freight and Logistics to be delivered in English at the participating institutions as separate but shared programmes. The approach is multidisciplinary, equipped with IT curriculum modelling tools that will help to analyze, enhance and adapt existing courses at partners' universities.

The innovative idea is that the MSc courses in Rail Freight and Logistics will be compatible to allow students to do some modules at another partner's university.

The first two years of the RiFLE project have been planned as a development phase that should lay a reliable basis to implement the new MSc courses.

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2. AIMS AND STRUCTURE OF THE SURVEY ON BUSINESS DEMANDS FOR A MASTER COURSE IN RAIL FREIGHT AND LOGISTICS

2.1. The necessity of the survey

Among the main reasons for developing an MSc programme in Rail Freight and Logistics, the RiFLE project considered the statement of the Freight Transport Logistics Action Plan of The European Commission (COM(2007) 607 final) that "efforts are required to focus and enhance the qualifications of logistics personnel, notably by strengthening competence in transport, and to support lifelong learning".

To achieve its goal, the RiFLE team needed a feedback from both sides influencing on transport staff training: universities and companies where students are supposed to work after graduating their studies. It is known that knowledge and skills acquired in academic institutions are not equally assessed by teaching staff and labour market players. The discrepancy in visions on theory-practice proportion in overall training could result in difficulties both for graduates and enterprises. The students often face lack of competence or inability to find a job. On the other hand, business is not satisfied with newly-recruited employees or even is not able to employ relevantly educated young people. Because of that the project included two surveys on the interested parties, academic institutions and rail freight and logistics companies.

The latter was of great significant for the RiFLE project team aiming to create MSc courses, which will contribute as much as possible to overcoming the gaps in visions between academic staff and business. The task to design the questionnaire, conduct the survey and analyse the results obtained was assigned to the partners from the Higher School of Transport (VTU) in Sofia. The coordinator and other three partners were responsible to disseminate the survey among interested stakeholders and send the filled in questionnaires to the WP leader (VTU).

2.2. Questionnaire design

The questionnaire developed is enough comprehensive to collect data on the current demands for Rail and Logistics training as seen from significant players on the labour market in the transport sector. The goal was to conduct a survey that will:

- find out demands for experts in rail freight and logistics;
- explore the expectations for staff training;
- study on the requirements to modern rail and logistics higher education from the viewpoint of practice.

The questionnaire was divided into seven parts according to information expected to acquire. The first three sections related to the company's profile: its type, staff educational level and strategy for increasing the staff qualification. A special accent was put on the place and role of transport and logistics functions in company's strategic management. The data was used as a reference with evaluating the expectations to the MSc course to be developed within the project.

The next four sections comprise the essential contents of the questionnaire. The respondents from the business sector (potential employees of graduates in future) had to share their opinions on:

- the type of training;
- the company's requirements;
- the staff promotion in organisational structures;
- the forms and duration of education (regular, part-time, evening, etc.).

It was of certain importance to investigate how and to what degree University – Industry Partnership works as well if there are demands to improve it.

2.3. Methodology and data acquisition

While compiling the set of questions, the VTU's team considered different types of respondents (rail companies, logistics companies, forwarding companies, public bodies). The questionnaire was intended to investigate staff demands within the whole range of players in the transport sector.

The invitation and the link to the questionnaire (http://surveys.supersurvey.com/survey-bin/surveys /s35448.pl) were published on the website of RiFLE project. They were also circulated by e-mails to all potential respondents suggested by the partners. The message sent explained the survey purpose as part of the whole project.

The questionnaire was filled in by 38 institutions from 17 countries in Europe, most of them being from the UK (7), Bulgaria (5), Spain (4) and the Netherlands (4). Concerning the status of respondents, 41% of them represent top management positions in their organizations, 23 % are managers on intermediate level and 13 % work on operational level.

3. OUTCOMES OF THE SURVEY ON BUSNESS DEMANDS

3.1. Company profiles

The institutions that took part in the survey are quite different by functions (transport, forwarding, consultancy, training, etc.) and size (most of consultancy and forwarding companies are SMEs while the companies dealing with transportation are manly large enterprises). However, 85% of all companies operate in the European Union.

The variety of respondents determined by their company profiles influenced on the answers. Moreover, the share of staff whose jobs are related to rail transport varies according to the company type:

- 75%- 90% for railway carriers;
- 10%-30% for forwarders and logistics providers;
- 2%-5% to 50% for port and industrial operators;
- 50%-80% - for training institutions.

The company profile also predetermines the educational level, which is required for new recruitments. Despite the differences existing, a university degree (minimum BSc) is determined as mandatory. The prevailing degree of current employees is MSc (Dipl. Engineer) but the number of people with special training in rail freight and logistics is insufficient (average 9%). The high percentage of PhD holders (in some companies to 25-30%) shows the growing need of more educated and qualified staff in the sector. In addition, it should be underlined that smaller companies employ staff of higher educational levels to be able to perform specific tasks with high responsibility. On the other side, "Associate degree" or secondary education is considered enough for executive positions.

As for field of training, companies in the rail freight and logistics sector usually employ engineers. Among managers, there are holders of economic and MBA degrees as well.

It is important to mention that more than two thirds of respondents not only have pointed out lifelong learning as necessary (68%), but also conduct a regular training for staff. The reason is that only 1/5 of the people interviewed think that the current educational level of the staff is adequate to the company's needs. Concerning the competences, the following areas of training have been pointed out as most significant:

- Information systems in railways and logistics;
- Technology and management of rail freight;
- Supply chain management;
- Finance and commercial operations;
- Management of internal logistic processes.

Finally, it is hopeful for students to know that 40% of the companies that participated in this survey are planning to employ graduates trained in rail freight and logistics in a year-period while 75% of establishments expect to do that in the next 5 years.

3.2. Evaluation of current university courses and expectation for new curricula

The main aim of the survey on industry demands for MSc courses in rail freight and logistics was to summarize the opinions on the existing state of university training for the needs of this economic sector. It has been established that 51% of respondents think that the current courses at the universities are inadequate to meet the requirements of business. More specifically, respondents have evaluated the training in the following fields as necessary to meet the demands of their companies:

- Freight Flows Forecasting and Planning (82,86%)
- Railway Operation (80%);
- International Transport (80%).

Over 70% of the participants in the survey have identified as equally important the skills in Marketing and Management (77,14%), Business (74,29%); Technology and Organization in Freight Rail Transport (74,29%). Transport Infrastructure (71,43%) and Information Systems and Customers Services (71,43%.

To summarize, the results of the survey have shown that except for Civil Engineering all other areas of study included in the questionnaire have been assessed as significant. The expectations for the new courses are to cover the whole spectrum of rail and logistics activities including management, finance, training, personnel, IT. However, the emphasis should be put on commercial, operational, managerial and technical areas.

The opinions shared by respondents from both industry and academia revealed also a number of potential risks with developing such an MSc curriculum, one of them being the necessity to balance with combining subjects related to rail freight and logistics.

3.3. Visions on course organisation and methods of teaching

The part related to how to organize and implement an MSc course in the questionnaire contributed much to acquiring significant information related to both assessments of the state-of-the-art and interesting suggestions for future.

First, all respondents expect that the new Master curricula should be inter-active, intensive, demanding and enjoyable. A quarter of the interviewed people have pointed out that modular training, which is a combination of linear and block learning, is the most suitable for such a programme.

The number of those who are in favour of part-time taught MSc courses (17%) is almost equal to the supporters of full-time training. That has made necessity to discuss how to mach these two types of learning and find out appropriate forms, so that students could perform their jobs during the period of MSc study. In this aspect, there are good practices in many European countries that can be examined and further applied. In addition, business representatives recommend as appropriate for universities to offer short courses on specific topics to enhance personnel knowledge and skills through LLP (Life long learning) programme.

Almost all of those who participated in the survey (97%) stated that it would be of their interest to involve rail freight practitioners and logisticians in higher education training staff for the needs of companies operating in this business sector. Most have evaluated the cooperation with academic institution as beneficial to a great extent, so it is logical that they keep close connections with different institutions of higher education. The most effective activities of collaboration pointed out by the respondents are:

- Providing guest lectures (80%);
- Working with Carrier Centers (58%);
- Offering scholarships (57%).

The least supported activity is "Funding research" (4,35% "yes", 52,17% "no"). Related to education, only a few companies have been sponsors of MSc courses by now. The reasons for that as well as for the lack of more active collaboration are different but eventually can be summarized as "lack of time and money".

4. CONCLUSIONS

The survey results have given a possibility to outline the expectations of business and wider public from the MSc courses in Rail Freight and Logistics and the project as a whoele. They have proved that the aim of RiFLE is reasonable and relevant to the needs of transport sector.

The information collected from the questionnaires served as a basis to determine the mandatory courses and groups of optional ones in order to flexibly meet the demand of professionals in rail freight and logistics sectors, which has been done within the WP5.2 (Curriculum Framework) and WP6 (Curriculum Development).

The outcomes from the survey on "Staff Demands in Rail Freight and Logistics" were widely discussed by representatives of universities and transport companies during the first RiFLE workshop in Sofia on 3 November 2011. The problem of supply/demand for rail and logistics higher education has been included as a main topic also in the agenda of the second workshop at the Faculty of Engineering of the University "La Sapienza" in Rome on 28 September 2012. The purpose of the latter event is to validate the developed MSc curricula by participation of major players in the European Rail Freight and Logistics sectors.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '12

A MALMQUIST INDEX APPROACH FOR CROSS-COUNTRY PRODUCTIVITY ANALYSIS: THE CASE OF EUROPEAN RAILWAYS

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***Abstract** – This paper demonstrates the potentials of DEA (Data Envelopment Analysis) Malmquist Index to measure productivity of the rail sector across selected European countries. An empirical example covers the period 2005-2009 and includes 14 countries. The results indicate that 2008 was the year of the productivity regress. Decomposition of the obtained Malmquist Index scores shows that both technological change and changes in technical efficiency can be seen as the causes of total factor productivity (TFP) variations.*

Keywords - Malmquist Index, Data Envelopment Analysis, productivity, European countries, railway.

1. INTRODUCTION

Productivity is often seen as one of the main economic concepts used to evaluate how successful a firm, sector, region or even a country is. It is used to track changes in performance in relation to transformation in regulation, management, organization or overall market conditions. The very important question in productivity measuring is to find the appropriate method, technique or tool to make meaningful assessments – the one that can give substantial information to the decision makers.

European railway sector experienced an intensive change during last decades of 20th century concerning: separation of infrastructure and transport management, interoperability of national railway systems, assurance of third-party access to the infrastructure, and introduction of independent railway regulatory systems [1]. This was enforced with European Commission regulatory pressures starting with Directive 91/440/ECC in 1991, continued with so called railway packages (first in 2001, second in 2004 and third implemented in 2007) and with the latest Regulation EC 913/2010 - concerning the *European Rail Network for Competitive Freight* that entered in force in November 2010. The principal aim was to make the rail transport more competitive and more attractive by opening the market and improving the efficiency and productivity of the railway sector in EU. This created the need for deploying different methods and techniques to monitor and evaluate the productivity of rail sector across European countries. The aim was to see how European rails are affected with deregulation, economic crisis, and other market conditions.

One of the tools that is often used for cross-country rail sector productivity evaluations is Malmquist index approach based on linear programming technique called Data Envelopment Analysis (DEA). Wetzel [1] relied on this approach to analyze the productivity change in of the European railway sector in the period of deregulation (1990-2005). Sanches et al. [2] also used DEA and Malmquist index to evaluate productivity in 16 national railway systems in Europe over the period 1985-2004. They discussed

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results depending on the effects of vertical and horizontal separation processes.

In this paper we demonstrate the potentials of DEA based Malmquist index to measure productivity of the rail sector across selected European countries. An empirical example covers the period 2005-2009 and includes 14 countries. This study is the continuation of our previous research on cross-country efficiency and super-efficiency rail sector estimations based on DEA models (for details see [3]).

The paper is organized as follows. Section 2 describes the concept of productivity and associated measuring dilemmas. Special part of this section is devoted to DEA-based Malmquist productivity index. Empirical example is presented within section 3 with the discussion of the obtained results. The paper ends with concluding remarks and future research directions.

2. METHODOLOGY

2.1. The concept of productivity and measuring dilemmas

Productivity is an economic concept closely related to the ability to convert inputs into outputs. It can be calculated both at micro (company units, departments, firms, organizations…) and macro level (municipalities, regions, countries…). It is a relative concept - comparisons are made across time or between different production units. The other important element of productivity estimation is the selection of inputs and outputs, since different types of input measure give rise to different productivity measures. Mawson [4] points to the differences between labour and capital productivity measures. The first one reflects the amount of labour used in production while the second shows the amount of physical capital used in the production process. The kind of overall productivity measure is total factor productivity (TFP) which can be measured by dividing total output by total inputs. Since it is hard to assure that all inputs and their contribution to the output are accounted it is more appropriate to evaluate TFP growth rather than the TFP level. This allows researchers to, beside the input-output conversion (i.e. efficiency change), account the so called technological change as the factor of the rise in outputs. However, there are some authors (like Lipsey and Carlaw [5]) that do not agree with the fact that TFP estimation results can be clearly associated with the technological change. In fact it can be argued that sources of changes in production frontier are hard to catch i.e. one can experience lack of arguments for TFP growth caused by more experienced and trained work force or R&D investments.

Nevertheless, efficiency and productivity measures retain its popularity especially in terms of total (or multi-) factor productivity.

When it comes to measuring TFP there are different approaches such as: the growth accounting approach, the index number approach, a distance function approach, the econometric approach [4]. Growth accounting approach and econometric approach require the specification of a production function. This function determines what level of output can be produced at some particular time given the availability of a certain level of different inputs and Total Factor Productivity.

However, there is a method that does not require this kind of estimation and still can point to the sources of TFP growth. It is a distance function approach based on linear programming method Data Envelopment Analysis (DEA). This approach uses DEA technique to calculate the so called Malmquist index (MI) that can indicate TFP growth along with sources of this growth.

Description of DEA based Malmquist productivity index (with the emphasis on output oriented MI used in this study) is described in the following section.

2.2. DEA-based output oriented Malmquist productivity index

The idea of Malmquist index was proposed by Malmquist himself [6] and was grounded in comparing the input of firm at two different points of time in terms of the maximum factor by which the input in one period could be decreased such that the firm could still produce the same output level of the other time period. Since it was oriented on changes in input values it was called Malmquist input index. DEA based Malmquist productivity index was proposed by Färe, Grosskopf and Lovell [7]. DEA helps calculating Malmquist index by allowing computing distance functions the researcher needs to know i.e. the production frontier at all time periods under consideration. For example, in their later study Färe et al. [8] analyzed productivity growth in 17 OECD countries, and used DEA to evaluate a world production frontier and then they compared their 17 countries to this "world" production frontier.

DEA MI can be calculated in output or input orientation. If the input orientation is used than the frontier is the minimum set of inputs required for a given level of output.

The Malmquist output orientation index requires four DEA models to be estimated, which respectively specify efficiency in the current time period $\theta_0^t(x_0^t, y_0^t)$; efficiency in the next time period $\theta_0^{t+1}(x_0^{t+1}, y_0^{t+1})$; efficiency of the decision making units (DMU- represented by European countries in this study) operating in this time period relative to

DMUs operating in the next time period $\theta_0^{t+1}(x_0^t, y_0^t)$; and the efficiency of DMU operating in the next time period relative to the frontier in this time period $\theta_0^t(x_0^{t+1}, y_0^{t+1})$. The Malmquist productivity index is then calculated as in (1). M_0 measures the productivity change between the *t* and *t+1 period*. The above Malmquist productivity index can be written in an equivalent way as in (2), which allows the decomposition of productivity change into changes in efficiency and shifting of the frontier [7].

$$M_0 = \left[\frac{\theta_0^t(x_0^{t+1}, y_0^{t+1})}{\theta_0^t(x_0^t, y_0^t)} \frac{\theta_0^{t+1}(x_0^{t+1}, y_0^{t+1})}{\theta_0^{t+1}(x_0^t, y_0^t)}\right]^{1/2} \quad (1)$$

$$M_0 = \frac{\theta_0^{t+1}(x_0^{t+1}, y_0^{t+1})}{\theta_0^t(x_0^t, y_0^t)}\left[\frac{\theta_0^t(x_0^{t+1}, y_0^{t+1})}{\theta_0^{t+1}(x_0^{t+1}, y_0^{t+1})} \frac{\theta_0^t(x_0^t, y_0^t)}{\theta_0^{t+1}(x_0^t, y_0^t)}\right]^{1/2} \quad (2)$$

The first term outside the bracket, measures the change of efficiency between periods t and t+1 (catching up to the frontier), whereas the bracketed term provides a measure of technological change (innovation or technical change). The change in productivity, i.e. M_0, and its decomposition into technological change and efficiency change can have values of unity, greater than unity and less than unity, which are interpreted as no change, progress and regress, respectively.

3. EMPIRICAL EXAMPLE

In this section we present the empirical example of our study and discuss the Malmquist index results obtained for rail freight sector across 14 European countries for the period 2005-2009.

3.1. Data sample

The selection of inputs and outputs for MI calculations is very important but it can be limited by many circumstances: the question of comparability when using revenue or investments indicators, the accountability of transit tone kilometres (tkm) and the very availability of adequate indicators (like energy consumption). Generally it is difficult to decide on indicators for productivity estimation when we are analysing the sector still burdened with strong regulatory pressures especially in countries where separation of infrastructure management from transport operations is on the run [1].

In order to make a meaningful selection in ongoing trade between "breadth and depth" in input/output indicators, we decided to follow some previous respectful studies from the field (like [9]; [1]). We considered one labour (number of employees) and two capital inputs (lengths of lines in use -total route in km and rolling stock - number of wagons for the transportation of goods). For output we used transport activity measured by freight tone – kilometres (tkm).

Data for selected indicators were obtained from *EUROSTAT*, *International Transport Forum - ITF*, *International Union of Railways - UIC*, and for Serbia from National Statistics Office.

For MI calculations we used Excel implementations of output oriented DEA models introduced in [10]. Depending on the envelopment surface DEA models can be applied with the assumption of CRS (constant returns to scale) or with VRS (variable returns to scale). In this study we decided on CRS specification, since some efficiency scores may return as "infeasible" when Malmquist is calculated under non-CRS conditions.

3.2. Results and discussion

Table 1 presents the Malmquist index i.e. TFP scores for rail freight in 14 European countries from 2005 to 2009.

Table 1. Malmquist Index for rail freight in 14 European countries from 2005 to 2009.

	2005-06	2006- 07	2007-08	2008-09	mean
Belgium	1.058	1.077	0.979	0.701	0.941
Czech Republic	1.062	1.043	0.954	0.978	1.008
Estonia	0.895	0.780	0.740	1.565	0.948
Finland	1.154	0.956	0.966	0.949	1.003
Croatia	1.254	1.086	0.948	0.796	1.007
Latvia	0.859	1.109	1.608	1.009	1.115
Lithuania	1.063	1.133	1.004	0.813	0.996
Poland	1.078	1.016	0.965	0.857	0.976
Slovak Republic	1.053	0.970	0.966	0.839	0.954
Slovenia	1.030	1.070	0.982	0.819	0.970
Serbia	1.424	1.160	0.978	0.620	1.001
Spain	0.856	0.930	0.983	0.720	0.867
Sweden	1.012	1.033	0.986	0.888	0.978
Turkey	1.070	0.965	1.077	1.069	1.044
mean	1.053	1.019	0.997	0.880	

None of the analysed countries showed TFP growth in each observed point of time. Latvia can be seen as the most successful since it showed the highest TFP growth within analysed period (11.5%). Spain was the one with the lowest TFP scores. Here we want to emphasize that TFP estimates based on DEA require the assumption that all the units being compared, (here seen as countries), have identical production functions. Lipsey and Carlaw [5] see this as "a heroic assumption". The European countries analyzed here can be seen as the part of the same development policy framework – strategies and action plans for European railway sector. This justifies selecting them as decision making units (DMUs) in MI evaluation. However regional differences and disparities are evident and must be taken into account and this is why one of the primary goals of common transport policy is to achieve harmonization and interoperability within European rail network and system. If we look at the results "as a whole" we can see that TFP is declining with evidence of regress around 2008. This can be seen as a consequence of recession. As reported by Railway Business Magazine (Railway Pro) after a period of sustained growth, EU rail transport performance started to be affected by the economic crisis at the beginning of 2008. Nevertheless, rail passenger transport remained less affected than rail freight transport (Figure 1). This is also visible from MI results and somehow logical taking into account the methodological assumptions (output oriented index) and to some extent the "invariable" nature of considered inputs.

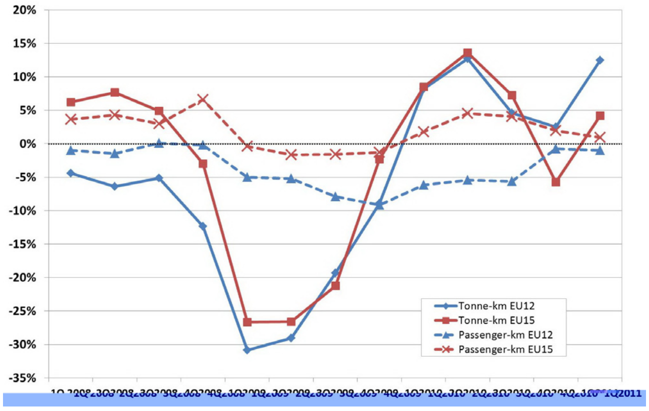

Fig.1. Quarterly rail freight and passenger growth compared to the same period in the previous year (based on pkm and tkm)

The obtained MI results can be decomposed in order to examine the sources of TFP growth/regress i.e. to analyse the changes in efficiency and technological change. However, decomposition results from our study our not straightforward – MI scores are slightly more correlated with efficiency change results than they are correlated with the results on frontier shift (technological change or innovation). Pearson product moment correlation coefficient is 0.54 for efficiency compared to 0.44 in case of technological change. This can be the consequence of rather small country sample and analysed period. Unlike our results [1] found clear indication that technological progress was the main driver of productivity growth within the European railway sector. Nevertheless, his sample covered incumbent operators from 21 EU countries with panel set of data for 16 years (1990-2005). This allowed Wetzel [1] to make more reliable conclusions about sources of TFP growth of European railways.

4. CONCLUSIONS

This paper demonstrates the potentials of DEA based Malmquist index for productivity assessment across European countries. The study explains the concept of productivity, measuring dilemmas and the usefulness of Data Envelopment Analysis and Malmquist index in cross-country productivity estimations. Obtained DEA-based MI scores for railways in 14 European countries revealed that productivity was affected by the economic crisis at the beginning of 2008. On the other hand the obtained results were not clear about the sources of TFP growth. This imposes several questions regarding methodology – the decision on inputs and outputs, the assumption on the same production function as well as the size of the sample needed in order to obtain reliable results. All these methodological challenges can be the subject of future research.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '12

METHODOLOGY FOR REVITALIZATION OF REGIONAL AND LOCAL RAILROADS

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Abstract *– The paper presents the methodology of the feasibility research of regional and local railroads revitalization. There has been the need for such research particularly in order to define the best possible solution in volume and quality, in compliance with the socio-economic conditions. It is necessary to conduct the research based on real-life potential of each railroad. The assessment of feasibility of investment in regional suburban transit should be based on socio-economic assessment of income, cost and investment plan in the period of about 20 years. The criterion in dynamic approach is internal rate of returns. The output results and suggestions for models of regional passenger and freight traffic organization should be used as means for strategic decision making in Serbian Railways and the Ministry for Infrastructure and Local Government.*

Keywords –regional traffic, railroad revitalization, methodology, public transit models.

1. INTRODUCTION

In last two decades, there has been the drastic decrease of passenger and freight railway traffic work volume. In the passenger traffic, train number is hugely reduced, the number and length of train sets is reduced as well and there is lots of train cancelations. Primarily reliable transport company, the railway has become irresponsible and unreliable.

In many Serbian regions passenger transport was focused on railways, traditionally for all citizen categories. Many years back, there have been the requests from many local communities for introduction of reliable railway traffic that can satisfy the requested volume and quality of transport services.

Every closing of a railroad of local importance can create problems to citizens, passengers and economy of the region. Generally, the decision to close the railroad down after initiated economic effects, inevitably comes to worsening of total socio-economic parameters. Apart from that, the connection between accessibility of the region and its economical power and dynamic functionality and development is equally important as railway profitability.

Therefore, there has been the huge need for researching the possibilities and defining the model for railroad and railway traffic revitalization on regional and local railroads in Serbia in order to offer the best possible solution regarding volume and quality in contemporary socio-economic conditions.

Financial load that local and regional railroads can't be reduced in short or mid- term by closing them down for traffic because of its transport value and because of the personnel costs that decrease only in mid- and long-term period.

After their cancellation there is no possibility, even in theory, to transfer the traffic in that region from road to railroad systems. Therefore, for those regions and their regional railroads, political decisions based on economy parameters are necessary. It is important to emphasize that there has not been a competent methodology for railway traffic profitability in regions and that all so far assessments of railway system efficiency have been without competent base.

2. CARENT STATE IN REGIONAL TRAFFIC

Current traffic situation mirrors in the following. Shortage of busses in regional traffic, high transport prices (up to 60% more than in railways) and lack of reliability (especially in winter) are everyday state. High passenger flows in zones of regional railroads

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with huge jams in peak hours. Lack of trains with small numbers of wagons, often failures and cancellations, low quality (small train frequency, lot of late arrivals, dirt). Schedule not adapted to needs and requests of dominant passenger categories in regional and suburban trains (employees, pupils and students, users of medical services, etc.) [1].

Lot of local governments showed interest for solving the problem of passenger transport by railway because the contemporary situation with regressing the public transport based on many complaints that the bus is expensive motivates them to look for solution to the problem of transport in reliable railway passenger transport with much lower prices.

Many regions have networks of railroads, especially in Vojvodina, East and Central Serbia. Regional and local railroads are in different statuses: railroads in function, railroads out of function and liquidated railroads.

The state of railroads that are in function is changeable- from good to very bad, which depends on the railroad itself. Example: railroads Bogojevo-Sombor-Subotica, Pancevo-Vrsac and Pozega-Kraljevo are in very good state. It is often the case that the state of railroads differs a lot in its sections. So, on Sombor-Vrbas railroad there are two sections whose main characteristics of technical state are presented as illustrative example in Table 1.

Table 1. Sombor – Vrbas railroad

Technical state of sections
1. Repaired section Crvenka – Vrbas - V_{max} = 90 km/h - Rail type S-49 - Superstructure and subgrade in good condition - axel load 20 t
2. Unrepaired section Sombor – Crvenka - V_{max} = 40 km/h, in some parts even V_{max} = 30 km/h - Heterogeneous types of rails (VIII b, S-35) - Unclean superstructure (dirt, weeds, trees, etc.) - axel load 16 t

Negligible means that Serbian railways can allocate for these railroad maintenances result in their slow decadence: Kraljevo-Stalac, Petrovaradin-Beocin and Sombor-Apatin. Huge number of railroads is endangered (Sombor-Vrbas, N.sad-Becej, N.Sad-Zrenjanin, and Kucevo-Zajecar) with real possibility that traffic is cancelled if the future decadence is allowed.

Passenger traffic is mostly carried on diesel motor units (DMU) of 812 and 712 series (40-50 years old), electric motor units (EMU) of 412/416 (around 40 years old) and classic train sets with locomotive traction (very often with only one passenger car). Freight transport on these railroads is almost paralyzed due to small axel load and irregularity caused by unsatisfied requests of economy due to lack of locomotives and adequate types of freight cars.

The reasons for bad state of many regional and local railroads mainly lie in huge distance of stations from central zones of inhabited areas, in irrational and inflexible company management, and in politics of spatial planning that cares little about railways. However, all these problems can be solved easily with relatively small costs, apart from the problem of railroads that are distant from inhabited areas. Even that problem can be solved by intermodality in passenger transport (public bus transport, Park and Ride systems...) [5].

3. METHODOLOGY OF REGIONAL AND LOCAL RAILROADS' REVIALIZATION

The main objective of the revitalization of regional and local railways is to achieve a better, more reliable and economical transportation link especially with the economic, educational, administrative and cultural centers to which that gravitate such as Belgrade, Nis, Novi Sad, Subotica , Kragujevac, Novi Sad, Subotica, Kragujevac, Zenjanin and Uzice.

Fast, comfortable and reliable transportation for all categories of passengers in the estimated, sufficient volume, and also good links with domestic and international passenger traffic are desired. The strategic plan of the region, based on the revitalization project of railways, is certainly the connection to Corridor X, IV and V, and the Danube Corridor VII.

Greater railways participation in the passenger and freight transport aims to achieve great economic savings to the population, economy and local governments. It aims to increase safety, achieve significant environmental effects and reduce the total external costs of transport which is all very important not only for the regions but also for the Republic [2]. In this way, great contribution is given to the essential requirements of smaller cities - to keep cohesion and improve the social status of residents.

In the freight transport, main goal is the transfer to railway transport as the main means of transport, especially when transit goods is in question, but the goods receiving and dispatch in and from the region, as well. In this way transport costs would be reduced, road traffic would be relived and facilitated and their longer life enabled.

The methodology for revitalization of regional and local lines encompasses the analysis of development and the basic characteristics of the current state of railroad and road network in the region, as well as passenger and freight traffic. Analysis of the infrastructure condition shows the utilization of railway and road lines. In the analysis of traffic in the region special attention is given to geographical, socio-economic and demographic characteristics. This part presents the following: the existing network of regional rail and bus lines; flow of passengers at stations and railway lines, transport units flow in rail and bus transport. The comprehensive analysis is done with the purpose of forecasting flows and appreciation of the possibilities of redistribution of passengers from road to rail. The forecast of traffic flows should be based on surveys, interviews and reviewing the potential of each railroad.

The forecast of railway flows is the basis for defining the concept of regional passenger railway transport and selecting the lines and volume for the regional trains. The central part of the methodology proposes the revitalization of railways and bringing them to a level that enables the organization of reliable and regional railway transport of high quality. This proposal is based on the previous feasibility study, i.e. Cost-Benefit analysis in terms of the needs of the community [4]. Under such a plan contains the proposal of variants of infrastructure management and organization of traffic and exploitation of regional railways.

4. THE REVITALIZATION VALIDITY OF REGIONAL RAILROADS

Assessing the feasibility of investment of the regional suburban traffic needs to be done by socio-economic assessment, based on plan of income, costs and investments in the period of 20 years. The criterion for dynamic assessment approach is the internal rate of returns. The goal is to determine whether the income as derived from the regional passenger traffic on the railway can develop a positive contribution for covering the total fixed costs and investments in diesel motor units (DMU) and railroad overhaul, after deduction of variable costs (costs that depend on the scope of work).

Only the income that would be achieved by selling tickets to passengers who use regional passenger trains and possible subsidies would be taken into the assessment.

All costs are divided into two groups: fixed costs that do not depend on the volume of traffic and variable costs that depend on traffic volume. Fixed costs are: capital maintenance of train units, their insurance, railroad maintenance, salaries of personnel necessary to execute scheduled regional traffic. Variable costs include: DMU maintenance and energy costs of passenger train.

For this project, the investments for the overhaul of railroads and rolling stock are the necessary. Overhaul would receive the following savings: it would keep the transit freight transport, reducing the required number of locomotives i.e. reducing the investment in locomotives and reducing the required number of wagons.

Figure 1 shows the internal rate of return for the three railroads in Zapadnobački County, and in Figure 2 internal rate of return is a function of changes in prices of DMU [3].

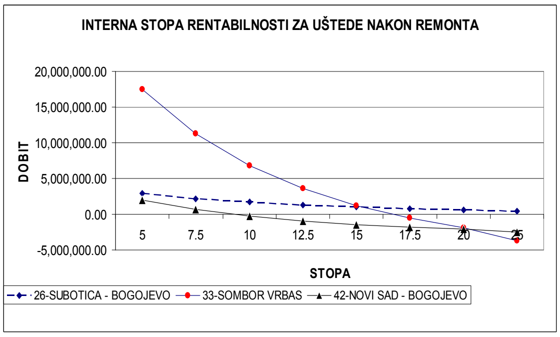

Fig.1. Internal rate of returns for investment in railroad overhaul in Zapadnobački County

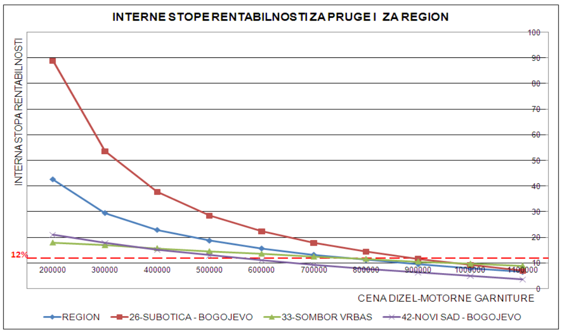

Fig.2. Internal rate of return according to DMU prices

5. MODELS FOR REGIONAL AND LOCAL PUBLIC TRANSIT

5.1. Models on railroads of Serbian Railways interest

Based on their interest Serbian Railways decide whether regional or local lines are of economic interest for the Railways, or of the general public interest, and based on it, passenger traffic is organized. As the regional - suburban passenger transit is not profitable for the railways, local government or the State determines compensation model for differences between costs and revenues. In the practice of European railway enterprises and the Euro region there is a whole range of different approaches and solutions of local government participation in the organization of regional traffic and exploitation of regional and local railways [6]. Such a possibility exists in the Serbian Railways as well. The aim is that local government and Serbian Railways find common interests and solutions.

a) The local government or the State introduces the obligation of public transport

Based on the by-law which determines the amount of subsidies for regional transport the contract is signed between local government and Serbian Railways defining schedules, quality of transport (rolling stock quality, timeliness, commercial speed, services stations, etc...). Based on the agreement and its implementation the subsidies should be paid.

b) The local government co-finances the rolling stock for regional passenger transport

The local government signs an agreement with the Railways on the method of financing the procurement of rolling stock for passenger transport. The contract defines the obligations of local governments, and the amount and quality of transport to ensure Railways. Here, a number of sub models concerning methods for maintaining the rolling stock, taking its depreciation costs and subsidies on the price of the ticket is possible.

c) Creation of the Company to carry passengers within the local government

Local governments establish their own enterprises to transport passengers, which may be engaged in public passenger transport by road and rail transport (joint or separate companies). It is preferable to form a single enterprise (single tariff policy, coordination of schedules, better utilization of other resources, etc...). Regionally the company for public transport passengers is licensed only for transportation at the regional and local railways. It buys the railway routes from the infrastructure manager (here Serbian Railways).

d) Selection of a private company that offers service within the local government

Local government has no interest in forming their own company to transport passengers. On the basis of the tender, it selects interested companies to sign an agreement with them on commercial and technical conditions for the organization of regional and commuter traffic. Of course, leasing or exploitation of local and regional railroad would be performed under the same conditions as if performed by the regional company for the railway exploitation.

5.2. Models on railroads of local government interest

If the Railways do not have the interest to manage some regional or local railroads, local government with the Government and the Railways can agree which on the lines there is an interest to take over management of infrastructure. Based on the obtained licenses and safety certificates it controls the part of railways that it was given the responsibility for. Management includes maintenance of the railway in accordance with the applicable technical parameters and collection of fees for usage of railway infrastructure which is the responsibility of local government. Passenger transport is done by an enterprise for the passenger transport within the local government or a private company does it.

5.3. Models on railroads of private company interest

In the case that both Serbian Railways and local government have no interest in managing some regional or local routes with a private company, it can agree with the state or local government on which lines there is an interest to take over management of infrastructure. Based on the obtained licenses and safety certificates it controls the part of railways that it was given the responsibility for. Such agreements shall be concluded in the form of concessions on certain pre-determined number of years.

6. CONCLUSIONS

The methodology of the feasibility research of regional and local railroads revitalization, the output results and proposals for the organization of regional passenger and freight traffic should serve as means for making strategic decisions to be taken by Serbian Railways, Ministry of Infrastructure of the Republic of Serbia, Executive Council of AP Vojvodina and local governments in their strategic development plans.

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DEVELOPMENT INDICATORS FOR SUSTAINABLE TRANSPORT POLICY AND PLANNING IN EU

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Abstract *– A sustainable transport system is one that is accessible, safe, environmentally and affordable. This paper presents the vision, mission and goals of a competitive and resource efficient EU transport system with emphasis on rail transport. The European Commission plans to increase the sustainable mobility and transport with 60% reduction in emissions by 2050. year. Presented the transport, economic, social and environmental indicators and how they can be applied in the assessment and transport planning. It also provides a description of the factors in the selection of sustainable transport indicators.*

Keywords - indicators, sustainability, rail transport.

1. INTRODUCTION

Sustainability is sometimes defined narrowly, focusing on a few specific problems such as resource depletion and pollution, but is increasingly defined broadly to include other economic, social and environmental issues. Narrowly defined sustainability can overlook connections between issues and opportunities for integrated solutions. For example, comprehensive analysis allows planners to identify the congestion reduction strategies that also help achieve equity and environmental objectives, or at least avoid those that are socially and environmentally harmful. These integrated solutions can be considered the most sustainable.

Sustainable development has become an overarching objective of the European Union and other countries around the world. Many definitions of sustainable development have been put forward during the last two decades. Most formulations are very similar, there is however one fundamental aspect of the definition that is of great importance. Experts (including the Transportation Research Board's Sustainable Transportation Indicators Subcommittee, the European Council of Ministers of Transport and the Centre for Sustainable Transportation) for sustainable transportation system prefer the next definition:

A sustainable transportation system is one that:

- Allows the basic access needs of individuals and societies to be met safely and in a manner consistent with human and ecosystem health, and with equity within and between generations.
- Is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy.
- Limits emissions and waste within the planet's ability to absorb them, minimizes consumption of non-renewable resources, limits consumption of renewable resources to the sustainable yield level, reuses and recycles its components, and minimizes the use of land and the production of noise.

There is no one single measurement of sustainable development that allows us to evaluate the progress and current state of transport and sustainable development. Sustainability is linked to many aspects and it is therefore necessary to establish a set of indicators to determine the current situation and trend.

Indicators of sustainable development are used to quantify the multiple dimensional impact of traffic at environment and represent „strategic management tool" to operationalize the concept of sustainable transport [4]. They need to be carefully selected to provide good quality information base for decision making.

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Every two years, the European Commission issues a special progress report on the implementation of the EU sustainable development strategy (Mainstreaming sustainable development …, 2009), complemented by Eurostat's monitoring report (Sustainable development in the European Union …, 2009), which covers more than 100 sustainable development indicators [5]. Individual European countries are also reviewing their experiences and tracking progress on sustainability goals. However, the messages are mixed due to the usually high number of indicators included, some of them showing favourable trends, others quite the opposite.

The same applies to the majority of contemporary sustainability research, projects, which use numerous quantitative and sometimes also qualitative indicators with the ambition of encompassing "all" relevant sustainability issues.

In some cases, the transportation indicators that have been developed or proposed are part of a larger project on sustainable development. When this is the case, only the transportation indicators and the ones that could be relevant to the monitoring of transportation trends are presented.

2. RAIL TRANSPORT IN EU

Transport industry in itself is an important part of the economy in the EU directly employs around 10 million people and accounts for about 5% of GDP.

Intensified international trade, transportation experiencing rapid development, but according to it is the sector with the fastest growth of environmental degradation. Therefore in the European Union (EU) for many years, make a special effort to assess future traffic scenarios and develop strategies to reduce negative impacts on the environment.

The transport sector is a major consumer of energy (responsible for 19% of global final energy consumption in 2007), will be responsible for the increase in world primary oil use by 97% between the 2007th and 2030.

For Europe the 2050th achieve the targeted reduction in CO_2 emissions by 80% compared to 1990th, oil consumption in the transport sector has to decline by about 70% compared to today, which implies the necessity of revolution in terms of transport fuels and the way on which we travel [2].

Transport is responsible for about a quarter of emissions of greenhouse gases in the EU. 12.8% of the total emissions caused by air, sea transport 13.5%, 0.7% railways, waterways 1.8% and 71.3% of road transport (2008).

No other major transport mode can boast energy efficiency similar to that of rail transport. Moreover, rail is the only mode that has decreased its share of CO_2 emissions since 1990. All other motorised transport modes have increased their share [3].

About 80% of the European rail fleet runs on electric power, meaning most trains can switch to clean electricity when it becomes available. Furthermore, modern trains are equipped with „regenerative systems" that recover energy for power generation when braking.

Rail transport generates the lowest specific CO_2 emissions compared with road, air, and even waterborne transport.

According to the White Paper from 2011., it is necessary to optimize the performance of multimodal logistic chains, including by making greater use of more energy-efficient modes.

30% of road freight over 300 km should shift to other modes such as rail or waterborne transport by 2030, and more than 50% by 2050, facilitated by efficient and green freight corridors [2]. To meet this goal will also require appropriate infrastructure to be developed.

By 2050, complete a European high-speed rail network [2]. Triple the length of the existing high-speed rail network by 2030 and maintain a dense railway network in all Member States. By 2050 the majority of medium-distance passenger transport should go by rail [2].

By 2050, connect all core network airports to the rail network, preferably high-speed; ensure that all core seaports are sufficiently connected to the rail freight and, where possible, inland waterway system [2].

The area where they are still the most obvious bottleneck is the internal market of railway services, which must be completed as a priority in order to achieve the Single European Railway Area [2]. This includes the elimination of technical, administrative and legal obstacles that still impede entry to national railway markets.

3. SUSTAINABLE TRANSPORTATION INDICATORS

Transport for sustainable development should include social, economic and environmental sustainability. Working towards sustainable transport systems requires that all aspects of sustainable development are considered. With policies targeting only one aspect there is a risk, that other dimensions of sustainable development may be neglected or even negatively affected. Environmental concerns, for example, are important and have to be addressed, but by focusing only on the environmental impacts of transport, certain policies may have converse and even negative reduce impact on social and economic sustainability. It is therefore imperative to understand that sustainable transport is important for all dimensions of sustainability.

At the beginning of the sustainability planning proces is necessary to define *goals* (what we ultimately want to achieve), *objectives* (way or methodology to achieve goals), *targets* (specific, reasonable, measurable objective that we want to achieve), *outcomes* (ultimate changes in activities and impacts, such as travel activity, consumer costs, accidents, pollution emissions, etc.) and *performance indicators* (specific factors that are measured to indicate progress toward goals) [1]. In Table 1 are given Sustainable transport goals, objectives and performance indicators [1].

Indicators can reflect various levels of analysis, for example, indicators may reflect the decision-making process (planning process, pricing policies, stakeholder involvement, etc.), responses (changes in mobility, mode choice, pollution emissions, crashes, land development patterns, etc.), physical impacts (emission and crash rates), human and environmental effects (changes in pollution exposure, health, traffic injuries and fatalities, ecological productivity, etc.) and their economic impacts (property damages and productivity losses due to crashes and environmental degradation; increased travel costs due to reduced accessibility).

Performance indicators can be categorized in the following way [1]:

- Process – the types of policies and planning activities, such as whether the organization has a process for collecting and publishing performance data, and public involvement.
- Inputs – the resources that are invested in particular activities, such as the level of funding spent on various activities or modes.
- Outputs – direct results, such as the miles of sidewalks, paths and roads, and the amount of public transit service provided.
- Outcomes – ultimate results, such as the number of miles traveled and mode share, average travel speeds, congestion and crowding, number of accidents and casualties, energy consumption, pollution emissions, and user satisfaction.

In most situations, no single indicator is adequate, so an index (a set of indicators) that reflects various objectives and impacts should be used.

The distinction between general transportation indicators and sustainable transportation indicators my best be illustrated by a few examples, each of which features once or more often in the above review.

The indicator „total passenger-kilometres per unit of GDP" has value as an expression of the economic efficiency. An increasing trend could suggest that transportation is being provided more efficiently; a decreasing trend could suggest that GDP growth is becoming less dependent on transport. These are useful things to know. However, such an indicator has no clear relevance to the sustainability of transportation, which is largely-although not entirely-a matter of intergenerational equity, i.e., whether present practices are reducing opportunities for future generations. Indeed, a declining trend could provide false comfort in that it could present the appearance of greater intergenerational equity while obscuring an absolute increase in transport activity and consequent environmental impacts.

The indicator „total passenger-kilometres by public transport" is again a useful presentation of data about transport activity, for some purposes. An increasing trend suggests growing viability of transit operations,

Sustainability Goals	Objectives	Performance Indicators
I. Economic		
Economic productivity	Transport system efficiency. Transport system integration. Maximize accessibility. Efficient pricing and incentives.	• Per capita GDP • Portion of budgets devoted to transport. • Per capita congestion delay. • Efficient pricing (road, parking, insurance, fuel, etc). • Efficient prioritization of facilities
Economic development	Economic and business development	• Access to education and employment opportunities. • Support for local industries.
Energy efficiency	Minimize energy costs, particularly petroleum imports.	• Per capita transport energy consumption • Per capita use of imported fuels.
Affordability	All residents can afford access to basic (essential) services and activities.	• Availability and quality of affordable modes (walking, cycling, ridesharing and public transport). • Portion of low-income households that spend more than 20% of budgets on transport.
Efficient transport operations	Efficient operations and asset management maximizes cost efficiency.	• Performance audit results. • Service delivery unit costs compared with peers. • Service quality.
II. Social		
Equity / fairness	Transport system accommodates all users, including those with disabilities, low incomes, and other constraints.	• Transport system diversity. • Portion of destinations accessible by people with disabilities and low incomes.
Safety, security and health	Minimize risk of crashes and assaults, and support physical fitness.	• Per capita traffic casualty (injury and death) rates. • Traveler assault (crime) rates. • Human exposure to harmful pollutants. • Portion of travel by walking and cycling.
Community development	Help create inclusive and attractive communities. Support community cohesion.	• Land use mix. • Walkability and bikability • Quality of road and street environments.
Cultural heritage preservation	Respect and protect cultural heritage. Support cultural activities.	• Preservation of cultural resources and traditions. • Responsiveness to traditional communities.
III. Environmental		
Climate stability	Reduce global warming emissions Mitigate climate change impacts	• Per capita emissions of greenhouse gases (CO_2, CFCs, CH_4, etc.).
Prevent air pollution	Reduce air pollution emissions Reduce exposure to harmful pollutants.	• Per capita emissions (PM, VOCs, NOx, CO, etc.). • Air quality standards and management plans.
Prevent noise pollution	Minimize traffic noise exposure	• Traffic noise levels
Protect water quality and minimize hydrological damages.	Minimize water pollution. Minimize impervious surface area.	• Per capita fuel consumption. • Management of used oil, leaks and stormwater. • Per capita impervious surface area.
Openspace and biodiversity protection	Minimize transport facility land use. Encourage more compact development. Preserve high quality habitat.	• Per capita land devoted to transport facilities. • Support for smart growth development. • Policies to protect high value farmlands and habitat.
IV. Good Governance and Planning		
Integrated, comprehensive and inclusive planning	Clearly defined planning process. Integrated and comprehensive analysis. Strong citizen engagement. Lease-cost planning (most beneficial solutions are selected and funded).	• Clearly defined goals, objectives and indicators. • Availability of planning information and documents. • Portion of population engaged in planning decisions. • Range of objectives, impacts and options considered. • Transport funds can be spent on alternative modes and demand management if most beneficial overall.

Fig.1. Sustainable transport goals, objectives and performance indicators [1]

and vice versa. However, if the energy intensity of public transport is higher than that of alternative modes, as it is for example in the United States, then an increasing trend in the indicator does not necessarily represent progress towards sustainability.

Some organizations, such as the *OECD* (The Organisation for Economic Co-operation and Development) and the European Union provide international transportation-related data, and a few countries, particularly the United Kingdom and Australia collect and make available data sets, but they are often unsuited to comparisons between different jurisdictions and countries [1].

Currently, many economic analysts and academics use the information about the input and output units of the railways for two key sources: the International Railway Statistics within the UIC railways and The individual sources, and the fact that UIC statistics depends on the data quality of individual railroads [7]. Other sources of information include national statistics, such as the Transport Statistics Great Britain, Eurostat and the World Wide Web that continuously collect data from official and unofficial sources. Some authors used data from sites that are designed and restored by enthusiasts (Norway railway).

The United Nations Economic Commission for Europe (UNECE) is one of the five United Nations regional commissions administered by the Economic and Social Council (ECOSOC) [6]. UNECE is working to help acheive various sustainability objectives including basic mobility, cost efficiency, traffic safety, environmental sustainability, and sustainable development. Consequently UNECE works in five inter-related transport areas (Environmental, Security, Safety, Affordability, Accessibility) covering the three pillars of sustainable development (Social, Economic, Environmental). To evaluate the current situation UNECE consider a set of 17 indicators (see [6]).

4. CONCLUSIONS

Greening the transport sector is vital for the EU to meet the ambitious environmental targets it has set itself to reach by 2050.

„Rail transport still lacks a level playing field with regard to other modes of transport. It is an important task for EU policy makers to tackle these distortions in order to promote Sustainable transport in Europe.“ (Hartmut Mehdorn - Chairman and CEO of DB, member of the CER Management Committee (until 30 April 2009)).

It is widely accepted that a modal shift towards railways can contribute to meeting EU targets on climate protection and reducing greenhouse gas emissions. A stronger role for rail will help to achieve real progress towards the 2020 target of a 20% cut in EU greenhouse gas emissions.

While the rail transport has higher environmental and safety benefits compared to road transport, it lacks in flexibility, quality of service and reliability.

The substantive reason for developing the Sustainable Transportation Performance Indicators lies in the embrace of sustainable development as a global mission by almost all national governments. The term sustainable development had been popularized by the World Commission on Environment and Development, and defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

Indicators have many purposes: can help identify trends, predict problems, assess options, set performance targets, and evaluate a particular jurisdiction or organization. Indicators are equivalent to senses (sight, hearing, touch, smell, taste) – they can help determine how problems are defined and which impacts receive attention [1]. An activity or option may seem good and desirable when evaluated using one set of indicators, but harmful when evaluated using another. It is therefore important to carefully select indicators that reflect overall goals. It is also important to be realistic when selecting indicators, taking into account data availability, understandability and usefulness in decision-making.

There are currently no standardized indicator sets for comprehensive and sustainable transport planning. Each jurisdiction or organization must develop its own set based on needs and abilities.

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EFFICIENCY MEASUREMENT OF RAILWAY ENTERPRISES USING DATA ENVELOPMENT ANALYSIS

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Abstract *– This paper discusses method that evaluates the relative performance of a group of public railway enterprises considering multiple input and output measures. The proposed method is intended to answer the question of how efficient is each of enterprises analysed, relative to the other enterprises considered in the analysis. The most efficient enterprises within the group are identified. The procedure is based on data envelopment analysis.*

Keywords - data envelopment analysis, efficiency, railway enterprises.

1. INTRODUCTION

Over the past three decades Data Envelopment Analysis (DEA) has emerged as a useful tool for business entities and organizations to evaluate their activities. DEA evaluates the efficiencies of a set of homogenous decision making units (DMUs) with multiple performance criteria. Data used in evaluating the efficiency usually consists of multiple inputs and multiple outputs which represent possibly conflicting criteria. DEA evaluates the relative efficiency of DMUs by using a ratio of the weighted sum of outputs to the weighted sum of inputs with the weights being variable. DEA identifies the source and the amount of inefficiency in each input relative to each output for a target decision making unit based on peer-group comparisons.

In this paper we measure efficiency of eight public railway enterprises considering three inputs (number of employees, track length and number of freight cars) and two outputs (ntkm and total number of carried tons). We defined DEA model (linear programming model) and solved by LINDO (software tool for solving linear, integer and quadratic optimization models).

2. THE LITERATURE REVIEW ON DEA

Many applications of DEA can be found in the literature. The method has been used to evaluate the efficiency of DMUs including banking systems, educational institutions and post offices. DEA has also been applied in various modes of transportation.

Chu et al. (1992) use DEA to measure efficiency of selected bus transit systems in the United States. Boile (2001) extends previous work by considering variable returns to scale and using both a CCR and BCC based approach. She uses DEA to measure efficiency of 23 bus transit systems. Cullinane and Wang (2006) use DEA for measuring the efficiency of 69 container terminals in Europe. Deprins et al. (1995) present a study that evaluates performance of services of 972 Belgian post offices. Doble in (1995) measures efficiency in UK post office counters. The study includes 1281 UK post offices. Tongzon (2001) uses DEA to measure efficiency of four Australian and twelve international ports.

Drenovac and Nedeljkovic (2011) applied DEA method on estimating delivery post office efficiency. Knežević and Lekić in (2008) use DEA to measure efficiency of 28 post offices in Prokuplje area and consider functioning of post office counters and delivery services. Pjevcevic and Vukadinovic (2010) measured efficiency of bulk cargo handling at river port.

3. CONVENTIONAL DEA MODEL

Data Envelopment Analysis (DEA) is a non-parametric methodology for measuring efficiency within a group of decision-making units (DMUs) that utilize several inputs to produce a set of outputs. DEA models provide efficiency scores that assess the performance of different DMUs in terms of either the use of several inputs or the production of certain

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outputs. The input-oriented DEA scores vary in (0, 1], the unity value indicating the technically efficient units.

Suppose that there are n decision making units (DMUs), each of which has m inputs and r outputs of the same type. All inputs and outputs are assumed to be nonnegative, but at least one input and one output are positive. The following notation will be used throughout the paper:

- DMU_i is the i[th] DMU,
- DMU_0 is the target DMU,
- $x_i \in R^{m\times1}$ is the column vector of inputs consumed by DMU_i,
- $x_0 \in R^{m\times1}$ is the column vector of inputs consumed by the target DMU,
- $X \in R^{m\times n}$ is the matrix of inputs of all DMUs,
- $y_i \in R^{r\times1}$ is the column vector of outputs produced by DMU_i,
- $y_0 \in R^{r\times1}$ is the column vector of outputs produced by the target DMU,
- $Y \in R^{r\times n}$ is the matrix of outputs of all DMUs,
- $u \in R^{m\times1}$ is the column vector of input weights, and
- $v \in R^{r\times1}$ is the column vector of output weights.

In the most frequently used DEA model, CCR model, the multiple inputs and multiple outputs of each DMU are aggregated into a single virtual input and single virtual output, respectively.

For the CCR model, a DMU is inefficient if it is possible to reduce any input without increasing any other inputs and achieve the same levels of output (Cooper, 2006). If the efficiency of a DMU is equal to 1, the DMU is weakly efficient (technically efficient).

The CCR model is formulated as the following linear programming model:

$$(CCR) \quad \max_{u,v} v^T y_0$$

$$\text{s.t.} \quad u^T x_0 = 1$$
$$-u^T X + v^T Y \leq 0$$
$$u \geq 0, \quad v \geq 0$$

4. NUMERICAL EXAMPLE

Eight public railway enterprises of former Yugoslavia were selected for this analysis. The selected group will be analyzed to determine the relative efficiency of railway enterprises and determine inefficiencies associated directly with the selected inputs and outputs.

Tables 1. and 2. show the name of enterprises considered in the analysis and relevant input and output information obtained through Statistica of Yugoslav railway for year 1989.

The enterprises use three inputs (number of employees, track length and number of freight cars) to produce two outputs (ntkm and total number of carried tons).

Table 1. Case study data - inputs

DMUs	Inputs		
	Number of employees	Track length (km)	Number of freight cars
PRE BG	32848	1893	9224
PRE NS	13603	1561	6200
PRE PR	2947	333	1482
PRE LJU	21872	1361	8715
PRE SA	25356	1038	9405
PRE SK	9270	696	2436
PRE TG	3133	251	1089
PRE ZG	40910	2436	13739

Table 2. Case study data - outputs

DMUs	Outputs	
	ntkm	Total number of carried tons
PRE BG	5219959616	23028692
PRE NS	2532586304	23591863
PRE PR	274933986	2649672
PRE LJU	4271017830	22677702
PRE SA	5281515279	29193427
PRE SK	1036562037	7502875
PRE TG	663275009	4451991
PRE ZG	7133259358	39720171

The CCR model described earlier is used to determine the relative efficiency of the selected railway enterprises.

Table 3. Efficiency scores

DMUs	Efficiency scores
PRE BG	1
PRE NS	0.999
PRE PR	0.605
PRE LJU	1
PRE SA	0.999
PRE SK	0.861
PRE TG	0.962
PRE ZG	1

The efficiencies of DMUs were illustrated in Table 3.

Based on the scores reported in Table 3. the following conclusions may be derived regarding the efficiency of the selected DMUs. DMUs PRE BG, PRE ZG and PRE LJU are efficient units in the group. Efficiences of units PRE NS and PRE SA are 0.999 wich may be regared as efficient. The remaining three units are inefficient since their efficiency scores are less than 1.

5. CONCLUSIONS

This paper has utilized data envelopment analysis as a way to evaluate relative performance of a group of decision making units. A numerical example is given to illustrate the implementation of the approach. Efficiencies of eight railway enterprises in former Yugoslavia are measured, considering three inputs and two outputs.

DEA model has the form of a linear programming model. The model is solved by LINDO solver. A possible topic for further research would be to apply sensitivity analysis on inefficient units due to determine ways of potential improvement.

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TRENDS IN LIBERALISATION OF THE EUROPEAN RAILWAY MARKET ACCORDING TO THE LIBERALISATION INDEX

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Abstract *– The European Union (EU) has decided to create a unique European transport market which implies restructuring of the railway sector and opening of the national railway markets. Creation of the European railway market is being realized relying on a unique basis defined by the EU's primary and secondary legislation. The initial stage of the opening of national railway markets has already revealed the need to harmonize their development. Therefore, there has been defined a liberalization index. The manner of defining of the liberalization index has been changing through different stages of legislative and institutional development, both in the EU and EU member states themselves. The paper shows various types and railway market according to which there has been made a comparative analysis and an assessment of the restructuring process of the Serbian railway sector.*

Keywords - railway market, liberalization index, trends.

1. INTRODUCTION

Creation of a unique European railway market is a process which is being realized according to the unique rules defined in the EU primary and secondary legislation, by opening and harmonization of national railway markets. It is a long and difficult process since it includes implementation of the EU legislation into national laws and regulations. At the same time, this process opens many unsolved issues regarding railway sector which represent an obstacle to the opening of the market, such as monopoly of national railway undertakings on the national markets and non-competitiveness in relation to other modes of transport (road, air). Therefore, solving of these problems requires complete restructuring of the railway sector.

The first and the most important directive promoting a common EU railway market was the Directive 91/440EC, and then, in 1996, the European Commission issued the White Paper [COM (96) 421 final] and thus made the first step in the revitalization of the European railways. The Directives of the 1st railway package, drafted in 2001, have influenced the opening of the market, especially the Directive 2001/14/EC which has introduced a new manner of levying of charges.

Thanks to the transposition of these directives into the legal system of the EU member states, the EU railway marked has started to open and caused the need for a serious analysis of methods and trends related to the opening of national markets, as well as for definition of a quantity measure showing the degree of the market opening allowing a comparative analysis in order to achieve the highest possible degree of opening and harmonization.

Thereby, in 2002, there was made a study named „Liberalization Index of the Railway Market" (LIB Index 2002), and then, following the changes in the EU legislation, there were made several new versions: LIB Index 2004, LIB Index 2007 and the latest version - LIB Index 2011. Each of these versions differs in the manner of calculation of the LIB Index since the coefficient values and structure of index in the formula used to calculate LIB change according to the achieved degree of the development of the market. The study includes nine chapters explaining objectives, retrospective and conception of the study which are followed by final results and analysis of LIB Index for all examined countries, as well as individual results for each country.

2. LIBERALISATION INDEX OF THE RAILWAY MARKET (LIB INDEX)

"Liberalization Index of the Railway Market" is the name of the empirical study calculating and comparing the degree of opening of railway markets for freight and passenger transport in the EU member

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states, including the markets of Norway and Switzerland. The quantity measure showing the market opening in this study – LIB INDEX is obtained by a detailed analysis and scoring of obstacles to be overcome by a potential railway undertaking in order to get access to a national railway market.

2.1. Formula for calculation of the LIB INDEX [3] and its structure

LIB INDEX represents a quantity measure of the market opening and it is calculated by the following formula:

$$\begin{aligned} LIB &= K1 \times \text{LEX Index} + \\ &K2 \times \text{ACCESS Index} + 0 \times \text{COM Index} \end{aligned} \quad (1)$$

LEX Index (law in books) is a measure showing the suitability of national laws and regulations for the liberalization of the railway market of a country. Its numerical value is obtained by scoring of answers to questions from the Questionnaire Lex index related to national regulations.

The elements of the Lex Index and, at the same time, of the different chapters of the Questionnaire Lex index are the following:

1. Organization structure of the railway undertaking having a dominant position on the market
2. Regulation of market access
3. Competencies of the Regulatory Body

K1 – represents the share of legal obstacles covered by Lex Index in the total number of obstacles to market access and depends on the current situation on the market.

ACCESS Index (law in action) is an efficiency measure of the legislation in relation to specific obstacles to access to a certain national market. Its numerical value is obtained by scoring of answers to questions from the Questionnaire ACCESS Index.

The elements of the ACCESS Index and, at the same time, of the different chapters of the Questionnaire ACCESS Index are the following:

1. Information barriers
2. Administrative barriers
3. Operational barriers
4. Accessibility of the different segments of the market
5. Selling services in passenger transport

   K2 – represents the share of de facto barriers covered by the ACCESS Index in the total number of barriers to the market access and depends on the current situation on the market.

COM Index represents effects of the market liberalization in form of number of railway undertakings, their market share and degree of modification of their market share. This index is not directly included in LIB, but its values correlate well with the values of LIB.

The coefficient values for LIB 2011 are: K1=0,2 and K2=0,8 and therefore we have:

$$\begin{aligned} LIB\ 2011 &= 0,2 \times \text{LEX Index} + \\ &0,8 \times \text{ACCESS Index} + 0 \times \text{COM Index} \end{aligned} \quad (2)$$

2.2. Analysis of the LIB Index and trends in the liberalization of the European railway market

According to the results of the calculation of LIB index, given in points, the examined countries can be sorted in categories showing the opening of their markets in order to compare them.

From the Table 1 we can see that LIB index 2007/2011 includes and Advanced group which did not exist in the previous versions of LIB and which, according to the number of points, offers the best conditions to the new entrants on the market. Figure 1 shows that Sweden (872) is at the top of that group, followed by Great Britain (865), Germany (842), Denmark (825), the Netherlands (817) and Austria (806).

The progress in opening of the market is also attested by the fact that LIB index 2007/2011 does not include the group with less than 300, that is, less than 467 points, any more.

Table 1. Comparison of market opening categories for LIB index 2002/2004 and LIB index 2007/2011

LIB index groups	Number of points per group	Number of countries in the group for LIB index			
		LIB 2002	LIB 2004	LIB 2007	LIB 2011
Advanced	800-1000	0	0	4	6
on Schedule	600-799	6	8	19	15
Delayed	300-599	7	12	4	6
Pending Departure	100-299	4	5	0	0

[3] IBM Deutschland GmbH in cooperation with Prof.dr.Christian Kirchner,Humbolt-University,Berlin:Rail Liberalisation Index 2011,Brusseles, 2011

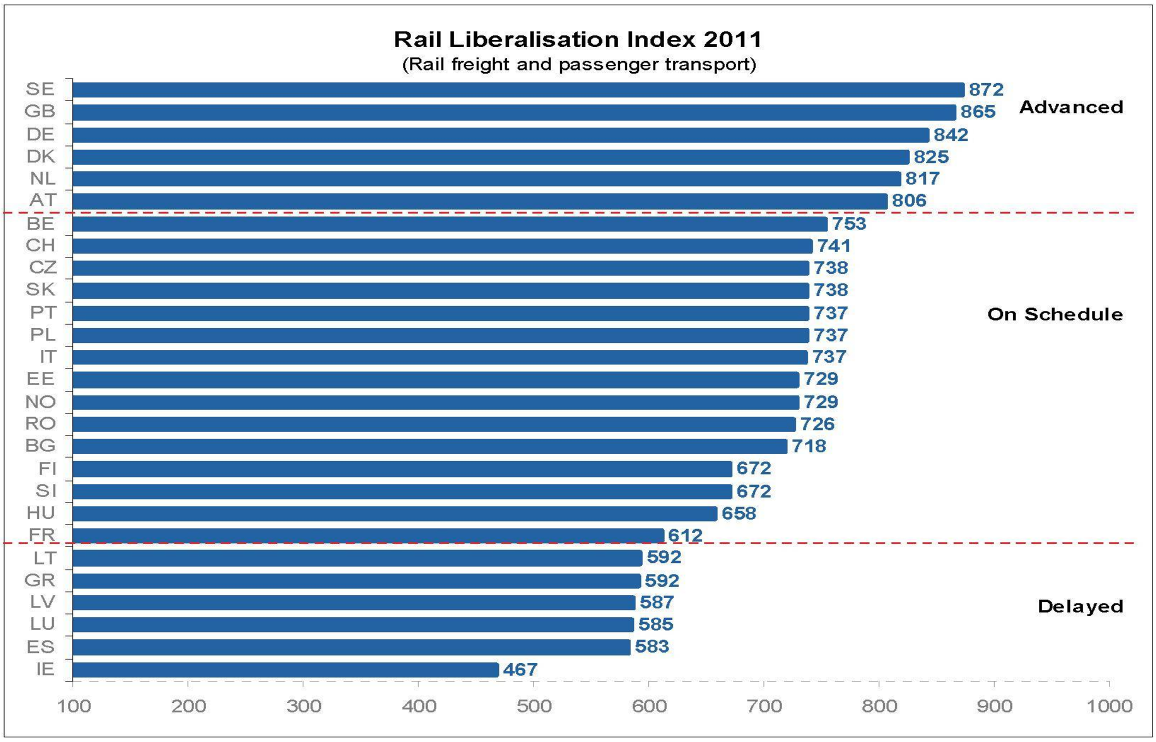

Fig.1. Values of LIB index 2011 given in points [4]

Therefore, we can conclude that there is a positive trend regarding the opening of the railway market in the EU member states, as well as that all the examined states have taken part in restructuring of the railway sector:

1. All countries have established a Regulatory body, and those belonging to the group with the highest level of liberalization (Advanced) already have a strong and independent Regulatory body, with important influence and competencies, as well as great experience with complaints of railway undertakings.
2. All national railway undertakings have an independent status and assets and their accounts and finances are separated from the state.
3. The law guarantees an open access to the network for all freight railway undertakings.
4. The law guarantees access to essential facilities
5. Comparing the coefficient values for LIB 2011 with the previous versions of the LIB index, the study shows that, actually, the legislation represents a much smaller barrier to the market access and that de facto barriers are becoming more and more important, taking into account that K1 is constantly decreasing and that K2 is constantly increasing.

3. VALUE OF LIB INDEX FOR SERBIA

Calculation of LIB index for the Republic of Serbia has not been covered by the study „Liberalization Index of the Railway Market" and it is the subject matter of this paper. It has been done in the same manner as in the above mentioned study.

LIB 2011 for the Republic of Serbia is:

$$\text{LIB } 2011 = 0,2 \times \text{LEX Index} + 0,8 \times \text{ACCESS Index} + 0 \times \text{COM Index} \quad (3)$$

$$\text{LIB } 2011 = 0,2 \times 278 + 0,8 \times 422 \quad (4)$$

$$\text{LIB } 2011 = 393 \quad (5)$$

The calculation shows that the value of LIB Index for the Republic of Serbia is 393 points which is below the lowest value amounting to 467 points in LIB 2011 and it belongs to the Delayed group which includes 6 of the EU member states.

The analysis of the results of LEX and ACCESS Index shows that a low degree of market opening is first of all due to the legislation which does not enable opening of the market and which is not harmonized with the EU legislation. The influence of the low ''access index'' is even more important, that is, there are all sorts of barriers to the opening of the market imposed by the Serbian Railways which is the only infrastructure manager on the national market. These

[4] IBM Deutschland GmbH in cooperation with Prof.dr.Christian Kirchner,Humbolt-University,Berlin:Rail Liberalisation

barriers are due to the fact that the railway undertaking, as well as other parts of the railway sector, has not been restructured. The result is the absolute monopoly of the national undertaking and impossibility for the other potential undertakings to enter the market.

4. CONCLUSIONS

The aim of this paper is to define the level of compatibility of Serbia with the European environment and to indicate the measures to be taken within the further process of restructuring of the Serbian railway sector by using the experiences from the EU and its methods designed to measure the harmonization process concerning the opening of the railway market.

Therefore, it is necessary to adopt the existing Draft Railway Act and Draft Railway Safety and Interoperability Law, as well as to reinforce the existing institutions related to the railway market and establish the new ones according to the EU directives. Consequently, the most important issue is to establish a strong Regulatory body in order to ensure the development of the railway market. The restructuring of the incumbent railway undertaking is also an important factor in establishing and opening of a market, especially concerning the management of infrastructure, as well as the other elements and procedures provided for by the Network Statement.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '12

DEVELOPMENT SCENARIO FOR RAILWAY MARKET INSTITUTIONS IN SERBIA

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Abstract *– Opening of the railway market requires establishment of new institutions in the railway sector. Among them we distinguish those institutions that directly regulate relations between the market participants (the Regulatory Body, Safety Authority, Licensing Body and the railway accidents Investigation Body) and the institutions that provide different permits for the railway industry products (Notified Body and Designated Body). EU secondary legislation has defined the role, responsibilities and functions of these institutions but not their organizational models and position. Also, there is still considerable freedom or ambiguity regarding the independence of those institutions and their mutual relations, as well as their relations with other institutions of the railway sector and the state. The paper presents the tasks and responsibilities of those institutions according to the EU directives, as well as constrains regarding their position and independence from market participants and other institutions. Starting from the current situation in the market and requirements of the EU directives, possible institutional development scenarios have been presented for the Serbian railway market as an example.*

Keywords - rail market institutions, models, development scenario.

1. INTRODUCTION

It was as early as in 1957, by the Treaty of Rome, that the European Union (EU) defined a transport policy including open and free transport market in the whole territory of the EU, for all transport modes and in all segments of the market. Railway reforms, which have been lasting for more than two decades, enable gradual opening of the railway market which has always been monopolistically organized since its establishment. One of the main elements concerning the functioning of the market includes establishment and functioning of institutions regulating the market. Among them, we distinguish those institutions which directly regulate relationships among the participants in the market (regulatory body, safety authority, licensing body and investigation body) and those which issue different permits for railway industry products (notified body and designated body).

The process of establishment of the above mentioned institutions in Europe, either in the EU member states or outside of the EU, is still in its initial phase. Most countries have not even established those institutions yet and the whole process has been marked by frequent changes and wandering. The establishment of railway market institutions represents a special challenge for small countries having a lack of knowledge, financial, human and other resources. Besides that, taking into account the current economic crises, necessity to reduce budget deficits and government administration, which also represents a general trend in Europe, the problem of establishment of 4 railway institutions appears to be even more complicated.

The most important is to find an appropriate approach to this problem, as well as to define the most important issues to be solved. In order to answer those questions, there has been given an example of how this institutional problem could be solved in the Serbian railway sector. The paper mostly represents the result of work of the Serbian Directorate for Railways and German consulting company Deutsche

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2. RESPONSIBILITIES AND CONSTRAINTS REGARDING THE ESTABLISHMENT OF THE DIFFERENT BODIES

Regulatory Body - RB is an independent state authority which shall regulate the market by preventing discrimination and unfair behavior of certain participants in the railway market and to ensure transparency of the different processes, as well as equal treatment for all participants. RB shall be independent regarding its organization, funding decisions, legal structure and decision making related to the different actors in the market: infrastructure manager (IM) and railway undertakings (RUs).

Safety Authority - SA is an independent state authority, respectively a national authority responsible for railway safety and interoperability issues in accordance with the Directive 2004/49/EC. This authority can be integrated into a Ministry in charge of transport and shall be independent regarding its organization, legal structure and decision making related to any railway undertaking – RU, infrastructure manager – IM, applicant or supplier.

Investigation Body - IB is a permanent body investigating accidents and incidents with the objective to improve the safety system and to prevent accidents by the necessary modifications of regulations. That body needs to have at least one employee capable of exercising the function of investigator in charge in case of an accident or incident. IB shall be independent concerning its organization, legal structure and decision making related to any infrastructure manager, railway undertaking or any party whose interests could be in conflict with the tasks of the investigation body (which means that it shall be established outside of ministry of transport). Besides that, IB shall be independent from safety authority and regulatory body.

Licensing Body - LB is a body which issues licences to RUs and IMs. The only requirement which shall be met by a LB concerns its position and organization: it shall be independent from those who submit application for licences. LB can also be an ad hoc body whose members meet if necessary, that is, when a licence application has been submitted.

3. INSTITUTIONS OF THE SERBIAN RAILWAY SECTOR

The current actors of the Serbian railway sector are: Ministry of Transport, Serbian Railways SA, acting as IM and RU in freight and passenger transport, Directorate for Railways, and several companies for maintenance of railway infrastructure and rolling stock and railway industry. There are also 3 registered RUs which have not been given access to public railway infrastructure yet.

Directorate for Railways is a special organization within the Serbian Government responsible for licensing, safety of transport, market regulation and other professional activities. However, the applicable law does not provide for its competencies regarding market regulation and for most of its functions concerning safety and especially interoperability, as it has been regulated by the EU legislation. IB has not been established yet.

Taking into account transit character of the railway network and the necessity to maintain its competitiveness, it is indispensable to open the railway market, establish all the railway market institutions (RB, SA, LB and IB), define their respective legal responsibilities and start them up. The main problem, which is also the subject of this paper, is to define the form of each of the mentioned institutions (legal form and position of the body, funding sources, independence regarding the other participants) and their internal organization. It should also be kept in mind that combining of the different functions of those bodies in a single institution is allowed with certain restrictions prescribed by the EU directives. All this increases the number of possible models for these bodies and it is therefore necessary to define the criteria to be respected in order to find a solution. It is also necessary to decide whether in this phase of development and restructuring of the railway sector is better to look for a final solution or to envisage a development scenario before finding a long term solution, and what this decision would depend on.

Solutions of such problems greatly depend on the current situation in the railway sector of a country. Characteristics of the Serbian railway sector, regarding the problem in question, are the following: railway network with important transit traffic, process of restructuring of the incumbent railway company has only been started, great difficulties and non productivity in all aspects of its activities (IM, RU in freight and passenger transport), lack of knowledge and difficulties regarding recruiting of human resources for specific profiles of the mentioned institutions, etc. External factors influencing definition and choice of a model or a scenario shall also be taken into account. At the moment, the most important factors are: extremely negative public opinion regarding the establishment of new state authorities, great budget deficit, solving problems of the public sector by the Government is uncertain, especially in the railway sector, uncertain dynamics of the European integration of Serbia, etc.

4. CRITERIA FOR DEVELOPMENT OF MODELS AND SCENARIOS

The main doubt while making a decision in such a situation is whether it is better to look for a final solution for all institutions according to the requirements prescribed by the EU directives or to provide for an appropriate development scenario for those institutions. The main motive in favor of a development scenario is the wish to adapt organizational forms and capacities during different periods of time to the real situation, with all advantages and disadvantages this may bring about. Therefore, DfR required the following criteria to be respected while generating models and development scenarios for the different institutions or, in general, for all institutions.

Criterion 1: Degree of openness of the railway market or current phase in the process of restructuring of the incumbent railway company. Different models of organization and institutional capacities shall correspond to the degree of openness of the railway market and process of restructuring of JSC Serbian Railways.

Criterion 2: Dynamics of EU integrations. Different models shall correspond to the process of EU integrations of Serbia. It is well known that EU requirements regarding the form and especially independence of the mentioned institutions differ depending on the phase of EU accession of a candidate country (without candidate status, candidate status without negotiations and candidate status with negotiations) where the influence of EU is more important towards the end of the integration process.

Criterion 3: Possibilities of implementation of models with respect to the current Serbian legislation. For each of the proposed models it is necessary to make an analysis from the point of view of the possibility for its implementation with respect to the current Serbian legislation.

Criterion 4: Independence of the institution. EU regulations require a certain minimum regarding the independence of each of the discussed institutions. Assessment of one of the models according to this criterion can be realized with regard to its funding, its position in relation to other institutions and its founder, as well as its competences regarding making (and signing) decisions in case of a model where two or more bodies are merged into one institution.

Criterion 5: Current situation regarding the institutions of the railway market and its limitations. A number of limitations regarding the development of an organization model for the different institutions derive from the actual situation. Therefore, it is necessary to carry out an analysis concerning possibilities and difficulties of transforming the institutions from their actual form (Directorate for Railways), their capacities and resources, into the proposed organizational models.

Criterion 6: Expected solutions in the proposed directive SERA. For each of the proposed models it is necessary to carry out an assessment by a comparative analysis taking into account the requirements of the proposed SERA directive, with regard to the position, independence and responsibilities of institutions.

Criterion 7: Flexibility of a model. It is necessary to envisage and assess flexibility of each model regarding its possibility to transform into a new organizational form.

Criterion 8: Implementation costs for different models. Implementation cost estimate shall be done for each of the models (regarding the implementation and functioning of the institution). Such estimate can be done by comparing models without calculation of absolute amounts of costs.

5. DEVELOPMENT SCENARIO FOR SERBIA

According to the defined criteria for definition and choice of models, DBI and DfR have decided to propose to the competent authorities a scenario for development of these institutions. The essential point of this concept is to start by concentrating the activities of RB, SA and LB in one institution, as separate and functionally independent organizational units. Later on, depending on other factors – first of all dynamics of EU integrations – and on different phases of opening of the railway market, the same units can be separated in order to form independent institutions or to be joint to other similar institutions responsible for the market. This would allow human and other resources, as well as capacities and power of those institutions, to be gradually developed in order to finally achieve full functionality in all aspects.

5.1. Development scenario for RB

The figure 1 shows development scenario for RB. Meanings of different models are the following:

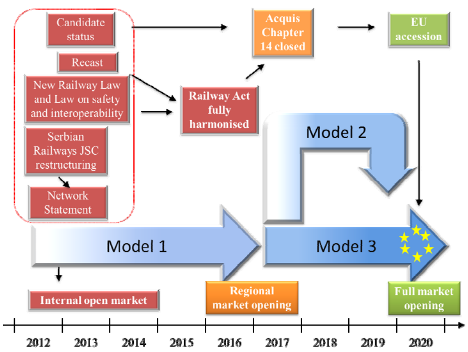

Fig.1. Development scenario for RB

- Model 1 – Directorate for Railways includes, under the same roof, 3 bodies (RB, SA and LB) which will be functionally separated (separate organizational units – sectors) having a common service providing logistic support.
- Model 2 – This model represents (a possible) "intermediate step" between the model 1 and model 3 in order to provide a more independent RB if this

requirement becomes an obstacle to EU integrations or development of the market. This would be achieved by establishment of an independent commission, playing the role of a RB with a judge at the head of it who would sign decisions on behalf of the RB, while the Sector for regulatory matters would stay within DfR and function as a kind of "technical secretariat" for the proposed commission.

- Model 3 – It represents the last step in achieving full independence of RB according to the proposed EU directive ("SERA") which also means separating regulatory functions form the Directorate for Railways. Sector for market regulation shall either become a public agency, join another public agency (for example, Competition Agency) or be established as a unique Agency regulating transport market for all transport modes. Model 3 represents a medium/long term objective (year 2016/2017) within the development of the railway RB in Serbia. Implementation of the model 3 is a complex political decision, which has also been proved by the experiences of most of the EU member states. It is difficult to foresee to what extent political parties and governments are ready to open the railway sector, establish strong and independent railway RBs and strong competition bodies as opposed to national railway undertakings owned by the state.

5.2. Development scenarios for SA, LB and IB

The proposed models for SA does not differ regarding the position and form of the institution, but only regarding its internal structure and capacity which is not the subject of this paper. Therefore, in all variants of the development scenario, SA shal be a special state authority, the same as today. However, there are to different cases in the development scenarion of SA: (1) when SA and RB represent separate sectors merged into one common institution (DfR), and (2) when RB is a separate organization while DfR includes only SA and LB.

Models of Licensing Body (LB) are always connected to DfR and sub-variants of this body within DfR have already been explained in point 5.1.

Investigation Body (IB) has not been covered by this project. Due to specificity of funcionning of this body and great doubts regarding the definition of the necessary capacities, it has been agreed with the Ministry of Transport to establish a special investigation body in charge of railway, air and waterway transport.

6. CONCLUSION

Regulatory Body, Safety Authority, Licensing Body and Investigation Body represent new institutions in the railway sector. The necessity to establish these bodies is due to the opening of the railway market. Those are new institutions with new responsibilites, unknown in a monopolistic market. That is why there are a lot of difficulties regarding their establishment and initial functionning. It is necessary to aquire the indispensable knowledge and skills, harmonize capacities with the needs, gain and impose authority necessary for the functionning of insitutions acting as regulators in a filed having a long history, provide funding sources and political consensus regarding the necessary independence, etc.

The problem of their establishment and functionning is even more important in smaller countries with lack of capacities necessary to establish and enable functionning of these institutions. This problem has also started to be solved in Serbia. Research has shown that, first of all, there should be defined the most important factors, that is, criteria, influencing generation and choice of solutions or institutional models. In this paper have been defined eight criteria.

Taking into account the presented criteria and constraints, there was proposed a single solution in form of a scenario for development of railway market institutions in Serbia. This scenario includes 3 phases in the development of those institutions, where each of the models meets the required cirteria defining the system of railway sector and its environment with regard to the defined problem. In the first phase, 3 organizational units (SA, RB and LB) shall be established within a single institution (the existing DfR), while in the third phase, RB shall be separated from DfR according to one of the three proposed models. The second phase represents a compromise or transitional phase leading towards the third phase.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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SELECTING THE CONCEPT FOR PASSENGER TRANSPORT ON RAILWAY LINE BELGRADE-BAR

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Abstract *– According to the conditions of rail passenger transport on the railway line Belgrade-Bar, infrastructure conditions and human resources, as well as current situation in the restructuring process of railway sector in Serbia and Montenegro, potential concepts are considered, with an aim to increase the traffic volume and total profit. Due to the huge importance of the railway line Belgrade-Bar, it is necessary to determine whether it would be sufficient to improve the infrastructure and rolling stock, and/or change the business concept of the rail passenger transport on this line. A multi-criteria approach – the fuzzy analytic hierarchy process – is applied for choosing the passenger transport concept. The suggested approach enables the consideration of the hierarchy structure problems by defining the relations between the system elements. The uncertainty and imprecision of relations between the system elements are taken into consideration through fuzzy numbers. The main goal of the model is to rank the alternatives based on the relevant criteria, whose relative weights are determined by numerous stakeholders.*

Keywords – railway passenger transport, business concept, Analytic Hierarchy Process, fuzzy numbers

1. INTRODUCTION

Since the Belgrade-Bar railway was completed on 1976, the passenger traffic volume was constantly increasing until 1992. However, starting with 1993 to date, the passenger traffic volume, as well as the quality of the services, has been in a constant fall. The question is what should be done in the forthcoming period to stop the negative trend and achieve growth. And is it really possible in the present transport market conditions dominated by an individualist value system incarnated by the passenger car. Is a renewal of the rolling stock and infrastructure all that needs to be done, or should the passenger transport concept on this line be transformed at the same time.

In order to answer the question, one should first study the present situation, including the causes of the negative trends, both in terms of the infrastructure capacities and the rolling stock, i.e. their condition indicators. In addition to that, an analysis should be made of the indicators of the previous and present passenger transport concepts (trains frequency, departure times, average number of passengers per train, relations between certain categories of passengers, etc), as well as the changes caused by the sovereignty of Montenegro (the change of locomotives in the past and now, the replacement of the locomotive personnel in the past and now, etc). In order to achieve a really feasible passenger transport concept that would attract the passengers to this line, the past premises should be reviewed, based on the present input parameters, and then either create a new concept or renew the old one.

This study defines and researches the alternative business concepts as well. Considering the present characteristics of the railway Belgrade-Bar and the two line operators (Serbian Railways JSC and Railway Transport of Montenegro JSC), as well as the achievements in the process of restructuring the railway sectors in Montenegro and Serbia the business strategies are defined and considered in order to achieve a better transport market position and help these companies deliver better business results. A multi-criteria approach, fuzzy analytic hierarchy

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process (AHP), is applied to select the business concept. The proposed approach enables a consideration of the hierarchy structure of the problem. Fuzzy numbers treat the uncertainty and imprecision of certain relations between system elements.

Fuzzy numbers treat the uncertainty and impreciseness of the relations between the system elements. The aim of this model is to range the alternatives based on the relevant criteria whose relative weights are determined by different stakeholders.

2. DEFINING BUSINESS CONCEPTS AS ALTERNATIVES

When generating the alternatives, the following assumptions have been used:

- State of capacity (of railway infrastructure and rolling stocks) of the existing actors on the rail market of Montenegro and Serbia;
- State in restructuring process of the rail sector;
- The rail market opening degree for the passenger transport and its legal regulation in two countries;
- Human recourses capacity and organizations of existing companies regarding common projects;
- The overall situation in railway environment, especially on political and national level, and its influence on individual solutions.

Taking into account those assumptions, the following alternatives are defined.

ALTERNATIVE 1 – *The existing model of common service with increased frequency of trains.* According to this alternative, the existing monopolistic markets remain in passenger transport on Belgrade-Bar line with current companies ŽPCG AD and AD ŽS. The alternative implies investments in passenger train sets in both companies which provide the train frequency at the 80-ies of the last century. ŽPCG and ŽS would provide traction and passenger cars based on the natural equalization principle. Revenues would be distributed according to the share of the total length of line.

ALTERNATIVE 2 – *The existing model of common service with decreased frequency of trains.* According to this alternative, the existing situation and trends, i.e. the number of train departures, is substantially reduced. That means, based on this alternative, the offer remains on the historical minimum of two pairs of trains out of season and four pairs of passenger trains in summer season. Remain elements of this modal are the same as in the first alternative.

ALTERNATIVE 3 – *The rail passenger market opening on the line Belgrade-Bar.* According to this alternative, the passenger transport services would be achieved by ŽPCG and ŽS on the principal of realization and responsibility for transport on the line of single company. This assumes the open market where routes would be assigned by public tender and the fee for infrastructure use would be paid to infrastructure managers. One single company on total route would be responsible for traction and all transport capacities. In the future, the market will be opened also for other newly formed companies.

ALTERNATIVE 4 - The *formation of „joint venture" company.* According to this alternative, ŽPCG and ŽS would form a new company based on „joint venture". The company would provide passenger transport services only on Belgrade-Bar line.

3. CRITERIA AND MCDM METHODS FOR ALTERNATIVE SELECTION

ŽPCG and ŽS are joint stock companies today with the State as majority owner (ŽPCG) or the State as the only owner (ŽS). General Meeting of Stakeholders, in which the State is majority owner, provides strategic decisions, as this one about the selection of business concept of society is. However, since the capital representatives attend meetings, this kind of decisions are always made on meetings which attend capital owners (Governments) and those who dominantly affect on their opinion. Therefore, one of the crucial issues was to identify the real decision makers and find informal decision making model in which would operate the key stakeholders. The presence of several actors in the process of the winning business concept selection indicates the existing of different interests and also different criteria governing each of them.

Also the different views of railway are unquestionable as well as the future of passenger transport, and therefore different evaluations and actors tendency to individual business concepts. The issue is further complicated by the fact that most of the criteria in the selection of the proposed alternatives are difficult to quantify. Therefore, decision making in the selection of the winning business concept has following features:

- There are a lot of alternatives;
- There are more criteria according to which decision is made;
- A number of persons with different level of significance are involved in decision making;
- The value of individual criteria can be expressed only descriptively;
- The existence of conflicts between criteria;
- Unequal importance between criteria;
- The significance of individual criteria, as well as preference of decision makers change by time.

Obviously that it is a typical task of multicriteria analysis and decision making. There are a number of methods of multicriteria analysis for multicriteria decision making that can be used in those cases. In terms of customers, i.e. decision makers, in multicriteria method selection the easiness of use and method clarity are preferable.

Selection of adequate method MCDM is completely determined by characteristics of the very issue, level of complexity and by customers experience in applying different methods.

Analytic **H**ierarchy **P**rocess – AHP is a method of multicriteria analysis and decision making characterised by scenario analysis and adopting decisions by consistent evaluation of hierarchies consisting of goals, criteria, sub criteria and alternatives. The method belongs to the field of multicriteria decision making in the presence of conflicting interests, and evaluation of potential decisions is conducted in the environment of compromise. This AHP principle enables searching for the compromised (the best) instead of optimal solution, since such practical solution does not exist with issues like this. Therefore, this method has been chosen to support decision making for the considered issue.

When generating criteria (as well as when generating business concepts) the following aspects that should be included have been taken into account: they should regard the existing reality of the situation in companies (ŽPCG and ŽS) and in the very state. Above all, they should regard financial position of stakeholders, ability and knowledge of management and other employees, capabilities of state institutions regulating railway sector and market, and also dedication to requirements of the railway sector at this point.

When defining criteria, other railways experiences have been considered, as well as theoretical findings on necessity to monitor certain performances of this system. Result from previous findings consists of 5 groups of criteria. These include: political, economic, social, technical and technological and organisational criteria. Within these groups, the following sub-criteria are defined:

1) Political sub-criteria: interest of the governments from both states, regional connection, readiness to establish the market, interest in providing passenger transport services, readiness of the governments to support the new project.
2) Economic sub-criteria: revenue, cost.
3) Social sub-criterion: public interest.
4) Technical and technological sub-criteria: rolling stock condition, railway infrastructure condition, frequency, possibility to implement business concept.
5) Organisational sub-criteria: existence of institutions at the state level and their competence, technical and human resources, readiness of company management to accept changes.

4. RESEARCH RESULTS

The assessment consistency of relative relations between system elements has been checked by applying the method of unit vector. These assessments were presented by fuzzy numbers, which, as interval values, enable easier and more precise definition of relations between system elements.

The following relevant stakeholders have been identified in the process of decision-making: Government of Montenegro, Government of Serbia, railway service customers, infrastructure managers and operators (ŽPCG and ŽS). For the simplicity of the model, it is assumed that each stakeholder is equally important, i.e. each stakeholder has the same relative weight. Weight allocation to stakeholders can be particularly complicated task in practice, but it can also serve for the sensitivity analysis of the final result. Having defined relative weights of criteria and sub-criteria by stakeholders, matrices for comparing alternatives in accordance to all sub-criteria have been developed. Final ranking of alternatives is obtained by applying fuzzy AHP approach [7]. The output result is presented in table 1.

Table 1. Final results of applying fuzzy AHP approach

Ranking	*Alternative*	*Overall weight*
I	Alt. 3	0,296
II	Alt. 4	0,270
III	Alt. 2	0,253
IV	Alt. 1	0,180

Results of applying fuzzy AHP approach for selecting passenger transport business concept for the route Belgrade – Bar show that the concept of opening railway transport market is the most appropriate at this moment. This means that the greatest effects both for passengers and the companies and their owners would be achieved by taking over full responsibility for passengers transport on the entire route by one single company. Market competition would increase the quality of service and companies' responsibility towards passengers, which is not the case at present.

Second ranked is alternative 4, creating of joint company by the principle "joint venture". Alternatives 1 and 2 which basically present revitalisation of the existing concept of service provision and company organizations are ranked lower than alternatives representing termination of previous work method and business concept. It is interesting to observe that this is understood by all the stakeholders: governments, service customers and managements of the existing companies, whether they were operators or railway infrastructure managers.

At the same time it can also be noticed that differences between alternatives are minimal which requires further analysis of model sensitivity before making the final decision.

5. CONCLUSIONS

Summarizing the passenger transport trends on the line Belgrade-Bar, the researchers conducted for the purpose of this study, the historic development of Serbia and Montenegro and their respective economies and connections, competition and perspectives of the railway and road infrastructure between Belgrade and Bar, as well as the development of air traffic, the question arises as to what should be done to stop the negative trends and enable a competitive passenger transport between the two countries. The dilemma is whether, in the present situation, only the mobile capacities should be renewed (the rolling stock) keeping the old passenger transport concept or the current concept should be reconsidered and a new one developed.

Four alternatives have been defined for this study purposes: two with new business concepts and two with an innovated current passenger transport concept.

The alternatives were selected through the multi-criteria decision method – fuzzy AHP. Five stakeholders participated by completing the questionnaires: the Government of Montenegro, the Government of the Republic of Serbia, railway service customers, infrastructure managers and operators (Railway Transport of Montenegro and Serbian Railways). The results indicate that the alternatives with the new passenger transport business concepts are better ranked than the alternatives with an innovated existing concept.

The top-ranked concept is opening of the passenger transport railway market. This concept includes complete responsibility and operation of the service by a single company. The point is that in the present situation it is not clear who actually bears responsibility for the passengers and the poor transport characteristics. If Serbian Railways is the one responsible, than the responsibility cannot be recognized within the integrated company while in the Montenegrin public, after the restructuring and creation of four separate companies, all the players in the railway market are not yet clearly recognized. This concept enables the creation of a distinguished operator's image, while the competition will bring about a steady service quality improvement. At the same time, it will enable new railway operators to enter the market.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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CHOICE OF LOCATION FOR THE MAINTENANCE WORKSHOP FOR TALGO TRAINS ON THE RAILWAY NETWORK OF RAILWAYS OF REPUBLIKA SRPSKA

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Abstract *– In order to improve the level of services provided in the field of long distance passenger traffic, Railways of Republika Srpska are currently in the process of purchasing trains manufactured by the Spanish manufacturer Talgo. This project requires construction of a new maintenance workshop for Talgo trains. One of the most complex issues of this project is to determine a location for the train maintenance workshop, taking into account the required characteristics and current circumstances on the railway network of ŽRS. This paper has used a multi-criteria approach to the choice of location applying the method of Analytic Hierarchy Process (AHP).*

Keywords - maintenance workshop, choice of location, AHP.

1. INTRODUCTION

Introduction of TALGO tilting passenger trains system to the Railways of Republika Srpska has sense exclusively and only if, beside exploitation conditions, there are conditions for their regular, correct and consistent maintenance and servicing.

According to the experience of the supplier of these sets, as well as railway managements that have been using TALGO tilting trains for a longer period of time, it is necessary for their maintenance to have specialised and dedicated workshops and services which should be located at a location which best suits transport exploitation conditions and optimal budget-priced conditions. Also, one should study the need for existence of auxiliary workshops at terminals where cleaning, boarding food, drinks, service and other articles into the coach restaurant could be performed. Based on their experience, TALGO company suggested the following parameters for the maintenance workshop and storage:

- total building plot app. 10 000 m^2, of which 4000 m^2 is closed workshop area, and 6000 m^2 is open handling and marshalling area,
- in the open area there should be one gauge app. 150 m long, and in the closed area two gauges,
- inside, there should be canals from which inspection and maintenance will be performed,
- workshop should have electrical installations from 220 AC and 400 AC, installation of compressed air for the minimal pressure of 8 bars and installation of water supply.

Railways of Republika Srpska, as the future owner should provide: 1. marshalling (mobile) locomotive, area for safe accommodation of rolling stock, sufficient number of employees to assist during manoeuvring and other activities during storage of trains.

Based on all these requests a question emerged: where to locate the new maintenance workshop for Talgo trains?

2. MAKING DECISIONS BASED ON MULTICRITERIA ANALYSIS

Making complex decisions has to be observed as a complex process. Dynamic decision-making process depends on total scenario, i.e. decision-making environment. Making complex decisions based on personal thinking or intuition is almost impossible. Phase of selecting the best location for building the maintenance workshop for Talgo trains should be made based on several different, possibly contradictory, criteria.

The problem of making a decision regarding the best alternative, in this case the workshop location represents a typical task of multicriteria analysis and

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ranking. For solving these and similar problems series of methods which belong to the area of multicriteria analysis and ranking Analytic Hierarchy Process (AHP) have been developed.

In order to apply some of the methods of multicriteria decision-making it is necessary to define alternatives and criteria based on which the selection of the best alternative will be done.

3. SELECTION OF REALISTICALLY POSSIBLE WORKSHOP LOCATIONS

3.1. Identification of alternatives

According to current organisation and technical – technological division of tasks in the area of railway rolling stock maintenance of the Railways of Republika Srpska railroad network there are three locations, and they are as follows:

1. Location of Doboj station – Workshop for the repair of the locomotives and carriages;
2. Location of Banja Luka station - Workshop for the repair of passenger carriages and
3. Location of Prijedor station – Workshop for the repair of cargo carriages.

Bearing in mind all the above mentioned, the selection of the workshop location for technical inspection and maintenance of "talgo" tilting passenger trains is based on objective advantages of the mentioned three locations, and for the selection of realistically possible locations these three have been proposed.

Domicile stations have been identified based on previous studies on justification of introducing Talgo trains and performed analysis of the Railways of Republika Srpska timetable, and based on that the following have been proposed: Banja Luka station and Doboj station.

The proposals generate 6 (six) possible alternatives in the process of maintenance of "talgo", shown on figure number 1.

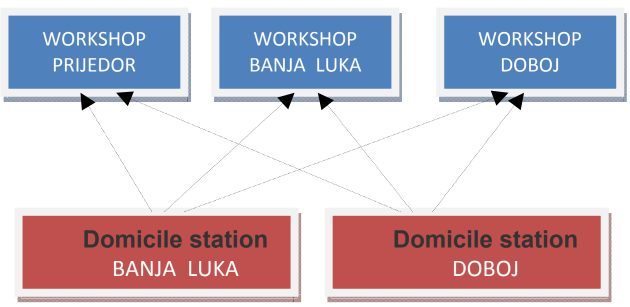

Fig.1. Overview of possible alternatives

3.2. Analysis of alternatives

Analysis of alternatives can be observed from several aspects:

- ***Aspect of number of passenger trains at selected locations.*** Aspect of number of passenger trains at selected locations and according to listed train transport categories (internal, inter-entity and international transportation) has been observed in relation to the current timetable. (Source: Timetable service of Railways of Republika Srpska). The aspect has been observed not only according to types of transportation (internal, inter-entity and international), but also according to selected locations (Doboj, Banja Luka, Prijedor and Novi Grad) ;
- ***Aspect of shipping cost to the potential workshop.*** Aspect of shipping cost to the potential workshop based on EU Directives for access payment to the railway infrastructure by a railway operator has been observed based on several parametres, as follows:
  a) 20 years observation period,
  b) total number of deliveries in the maintenance process according to valid railway regulation (Total = 1.920 deliveries)
  c) Access price to the infrastructure which is paid by the railway operator to the Infrastructure at a cost of 3,71 KM/kilometer (Study „KPMG" - Italians......),
  d) Distance of certain locations: Domicile station – Workshop;
  e) Price of consumed electrical energy (approximately 2,51 KM /kilometer);
- ***Aspect of time spent in delivering trains to a potential maintenance workshop for "talgo" trains.***
  Aspect of time spent in delivering trains to a potential maintenance workshop for "talgo" trains is based on the following data:
  1. 20 years observation period;
  2. total number of deliveries in the maintenance process according to valid railway regulation (Total = 1.920 deliveries);
  3. Commercial delivery speed of approximately 70 km / h;
  4. Distance of certain locations: Domicile station – Workshop.
- ***From the aspect of transported passengers per location: STD Doboj (STD abb. for Tansport and Technological Industry, transl. remark), STD Banja Luka, STD Prijedor and STD Novi Grad.*** Aspect of transported passengers per location: STD Doboj, STD Banja Luka, STD Prijedor and STD Novi Grad is shown based on Travellers' service data for the year 2010, according to types of transport (internal and international transport);
- ***From the aspect of number of people who travel to stations Prijedor, Banja Luka and Doboj from RS and FBiH.***

3.3. Defining criteria

Based on derived and analysed data, we have defined the starting criteria, which undoubtedly affects the investor's commitment in making decision about the selection of best workshop location from the aspect of safety and organisation of railway transport, minimisation of maintenance cost and rational economic valorisation of trains in their exploitation life. To that end the following criteria has been adopted:

1) ***Minimal package of services*** includes the processing of the request for the allocation of infrastructure capacities, usage of rail and station transit railway lines and switches, regulation of traffic and all information needed for regulation of train movement.
2) ***Access to associated or service facilities*** includes the access to shunting stations, facilities for the formation of trains, passenger stations, plants for usage of electrical energy, usage of plants for filling diesel fuel, usage of supply gauge.
3) ***Additional services*** include traction current price, preheating passenger carriages, supply of fuel, manoeuvring and other expenses in the facilities for access services.
4) ***Auxiliary services*** include the access to telecommunication network, giving information regarding train traffic, timetable, reasons for delays etc.
5) ***Organisation of transport and traction*** is defined by the timetable for a certain railway network or railway. Talgo trains are unconventional sets, when the traction locomotive is independent. Optimal rationality of using the locomotive is achieved when the length of traction section, productive time of traction, daily mileage and other organization parameters are maximal, and unproductive time (waiting, way to the workshop) is minimal. According to existing rulebooks, traction vehicles are sent to current and regular repairs to the workshop in Doboj, which directly affects the rationality of the use of locomotives.
6) ***Immobilization due to the delivery of carriages for maintenance*** includes number of days spent in delivering carriages for repair, excluding the time spent on repairs or regular maintenance.
7) ***Number of transported passengers*** influences the choice of domicile or terminal station, and it is observed through the number of sold tickets in organizational areas of Transport – technoclogial industry (STD) Doboj, Banja Luka and Prijedor.
8) ***Population of the transport area*** influences the choice of domicile and terminal station, and covers potential passengers that would use services of Talgo trains in stations Doboj, Banja Luka and Prijedor.
9) ***Care for and settlement of Talgo trains*** includes appropriate conditions, which implies various expenses. At the location of Talgo workshops, for the purpose of cleaning, supply and storage, existing gauges are used, i.e. those activities should be done inside the workshop if the workshop location provides that.
10) ***Intensity of passenger transportation*** includes number of passenger trains that use the selected stations, as well as frequency of Talgo trains passing through the station where the location is planned to be.
11) ***Environmental conditions include the review*** of the location regarding the proximity to the housing areas and urban agglomerations, evacuation of waste, dominant wind direction, proximity of sensitive places etc.
12) ***Microlocation*** includes microlocation area for the workshop location from the point of location, its proximity to the passenger station, possession of a plot app. $10000m^2$ owned by ŽRS with favourable configuration to accommodate the workshop, existing space occupancy, topographic conditions, seismic and geological characteristics of the terrain.
13) ***Connection of the location with the railway network*** includes the possibility and affordability of access to the existing public railway network of ŽRS.
14) ***Connection of the location with the existing workshops*** includes the possibility of using the existing infrastructure and personnel of ŽRS.
15) ***Location of Talgo workshop ŽFBH in Rajlovac*** includes evaluation of the influence of the already built maintenance workshop for Talgo trains for ŽFBH (Railways of Federation BH) in Rajlovac station, to the choice of location for the maintenance workshop for ŽRS (Railways of Republika Srpska).

3.4. Application of AHP Method

For the need of data processing within this task, at the Department for Mechanics and Structures of the Faculty for Mechanical Engineering in Banjaluka, a software has been developed which enables selection of optimal alternative according to the AHP method algorithm. The software was developed in the programme package MS Visual Basic 5.0. It is important to mention that the programme routine, which is responsible for calculation of its own collection matrix vector, operates according to the normalisation of the geometric mean (NGM). It is also important to point out that the maximal matrix value, which is necessary for the calculation of consistency ratio (CR), has been calculated from the condition of the very premise of AHP method, according to which:

$$A \cdot w = \lambda_{max} \cdot w \quad (1)$$

where:

λ_{max} – maximal matrix value

A – matrix from the collection for which the calculation is done

w – own vector of matrix A, calculated according to NGM method.

Now, by applying trivial matrix calculation, numerical value λ_{max} can be determined, according to which the algorithm of the routine responisble for this part of the calculation was formed.

The developed software was tested on a large number of ready examples of the AHP method, which were presented in available scientific publications. For each of the tested examples, the obtained results were consistent with the results in the publications, according to which was concluded that the software was correct and acceptable for practical application.

During the application of the mentioned software to the subject of this paper, the main criterial matrix was obtained by synthesizing the weight vector delivered by a group of experts. The validity of the synthesizing procedure is evident with the regard to the identity of the delivered vector and vector obtained by the NGM method from a matrix generated like this.

Also, during the evaluation of the chosen alternative, it somewhat deviated from the basic Satty scale, because realistic, previously calculated numerical values were available. So the evaluation of the alternatives for each criterion separately, were entered as ratios of values of the alternatives, and in accordance with the evaluation principle according to Satty.

Based on the data and facts for the three alternative locations: Doboj, Banjaluka and Prijedor, 15 (fifteen) criteria was defined and analysed. After the application of scientifically acknowledged Delphi method of the expert forecast, the scoring of criteria for the each of the alternatives was done, and with Satty method the points for quantified criteria were determined. These points were the basis for, by applying AHP method, determining the weight coefficients which include the interaction of criteria and whose value represents the level of preference of each location.

The calculated values of the weight coefficients, i.e. percentual preferences of potential locations normalised with the respect to the largest weight coefficient are:

Doboj	0.433	or	100%
Banjaluka	0.354	or	82%
Prijedor	0.212	or	49%

According to that, based on offered alternatives and defined criteria, it can be concluded that Doboj is the best location.

4. CONCLUSION

Introduction of TALGO passenger trains makes sense only if there are conditions for their regular and consistent maintenance and servicing.

According to the manufacturer's experience and railway managements which use TALGO tilting trains, for their maintenance, it is necessary to build, i.e. adapt specialised workshop and service capacities which should be located in a place which, for the aspect of safety and expenses, best suits transport-exploitation and technological conditions of a railway operator. In this paper we have shown the way of selecting a location by applying the multicriteria analysis where all the key criteria of transport, exploitation and technology were taken into account.

The right selection of the location for building the maintenance workshop for the mentioned trains greatly affects the viability and rationality of the workshop as an investment and gives great chance to the railway operator (ŽRS Operator) to be competitive in the transport market.

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THE SOCIAL ASPECT OF INTEROPERABILITY OF RAILWAY

Bratislav STANKOVIĆ [1]

Abstract *– Integration processes in the European Union in the field of rail transport, based on the concept of market and social Europe, reflected not only in the establishment of an integrated railway and the creation of liberalized markets, but also have a social dimension. Liberalization and deregulation of the railway system has a counterweight to the social dimension, so that the social legislation placed in the very heart of the activities of the European social partners in the field of railways, as an ongoing need for the harmonization of working conditions in the European railway traffic. On these basis, the institute of interoperability, which is not unknown in our legislative and economic practice, should be treated in a broad sense, to include not only technical harmonization, but also social norms. The subject of this paper is a European collective bargaining and conclusion of the European collective contracts, especially in the field of railway transport.*

Keywords - social dialogue, European collective agreement, employers' organizations and trade.

1. INTRODUCTION

“Within the social dialogue it is implied the process of continuous interaction between the social partners in order to conclude collective labour agreements that affect certain variables of economic and social nature, both at macro and micro levels." [1,77] Social dialogue is subject to regulation by the initial contracts, secondary legislation and charters. The first of the initial contracts, contract on the establishing the European Community by the provisions of Article 136 under the heading devoted to social policy, education, vocational training and youth, among the goals of social policy mentions the promotion "of dialogue between management and labour."

We will mention only two charters. The first one, the Charter of Fundamental Social Rights of Workers in 1989, in Sections 17, and 18, "right to information, consultation and the EU, participation of workers," is proclaimed as a fundamental right, in particular regarding the following issues: technological changes that have important repercussions on the labor force and jobs, reorganization of the company in case of transfer, the case of collective dismissals, the case of insolvency. The second one, the Charter of Fundamental Rights of the European Union in 2000 was determined in Article 27 as a fundamental right of employees to information and consultation in the company. It does the following: "To the workers or their representatives, at the appropriate levels, must be guaranteed timely the notification and consultation in cases and under the conditions provided by Community law, national law and practice."

Social dialogue is a key determinant of the European social model. Social Dialogue in the European Union was organized on the bilateral basis between employers and employees or tripartite basis with the participation of employers’ organizations and employees with government representatives. It should be distinguished the inter-branch social dialogue and social dialogue at sector level.

Further, in the case of the European social partners, it should be noted that within the European Union act more organizations of employers and trade unions. They are organized on the inter-branch level, and at branch level, and thereby comprise both private and public sector. Employers' organizations and trade unions at European level, as a rule, have a membership not only from (all) Member States of the European Union but also from other European countries, i.e. the members of the Council of Europe.

First when we are talking on the European social partners in the field of railway transport, the question of the participants in the conclusion of European collective agreements is raised. The European social partners in railway transport are the Community of European Railways (hereinafter CER), as a branch organization of the employers and the European Transport Workers' Federation (hereinafter: ETF), as the organization of trade unions.

And if the employers' association within the pan-European transport corridors exists many years, mainly in the form of administrative committees, by

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establishing of CER is marked the European social partner, the representative of employers in social dialogue in the railway transport, which the member is also JSC Serbian Railways.

On the other hand, the Union of Railway men of Serbia is a member of the International Federation of Transport Workers (ITF), and enrolled in the International Conference of Free Trade Unions (ICFTU), the organization of trade unions at the global level, the European Transport Workers' Federation (ETF), European trade union organization at the branch level.

The goal of the ETF is to represent and protect the professional, economic, social and cultural interests in the transport industry. It is understood that one of the priority objectives of ETF is the conclusion of European collective agreements on work.

2. EUROPEAN COLLECTIVE BARGAINING AND CONCLUSION OF EUROPEAN COLLECTIVE AGREEMENTS ON LABOUR PARTICULARLY IN RAILWAY TRANSPORT SECTORE

2.1. Right to collective bargaining

The right to collective bargaining is understood in general as a part of the consultation process. So if during the consultation "the management and labour inform the Commission of its intention to begin the process of negotiation" within the meaning of Article 139, the procedure should not last longer than nine months, unless the social partners themselves and the Commission agree to extend the deadline. [2, 314]

The Roman Treaties do not contain provisions relating to collective bargaining, but in the Article 118 this issue is left to the cooperation between Member States. The Single European Act of 1986 was first explicitly predicted the principle of social dialogue at European level in Section 118 B, i.e. the opportunity to develop social dialogue and collective bargaining which leads to the conclusion of European collective labor agreements.

Agreement on social policy from 1993, which is related to the Treaty on European Union (Maastricht Treaty), enabled the conclusion of European collective labor agreements [3,314], in the manner that in its articles 3 and 4 is given the authorization to the Commission to improve the dialogue of social partners at European level, and to consult the social partners on any action in the field of social policy.

Between unity and diversity, the affirmation of the European collective agreement happened! On one hand the regulations have direct effect and supremacy, in the spirit of the concept of unity, and the directives are based on the concept of unity in terms of the objectives of the directive with the concept of preserving the diversity in the way of implementation: the law, collective agreements, arbitration decisions, and similar.

On the other hand, the formula of reconciliation of requirements for uniqueness and diversity in relation to secondary legislation (regulations and directives) was found. Hence, in the field of social policy, the collective agreements are instrument for moderation of tension between the requirements for uniqueness and differentiation. [4, 249]

2.2. Concept, types and legal effect of European collective labor agreements

European collective labour contract is sui generis, the autonomous source of the community labor law. European collective labor contract is concluded between the representative trade unions (including other staff representatives) and employers or employers at European level, which governs the rights and obligations of the contractual parties (obligatory part) and working conditions of employees (normative part).

European collective labor agreements are regarded as a kind of collective labour agreement. [5, 49]

Although there is no complete communitarian rules of European collective bargaining agreements in respect of all the essential elements: the contractual parties, the negotiation process, content and form, there are enough elements to talk about their special legal regime. A particular legal regime involves issues of legal effects of European collective agreements.

Legal effect of European collective labor agreements can be analyzed from the standpoint of the contractual parties and individual employees and employers.

Legal effect of European collective agreements to the contractual parties is determined in accordance with Belgian law, the principles of European contract law and ILO Recommendation no. 91, which reveals that the collective labor contract binds the parties.

As there is no the relevant directives of the European legal effect of collective agreements on members, so it may be based on the statutes of the European social partner organizations and the rules of private international labor law.

Legal effect of the normative part of European collective agreement to individual employees and employers exists if the European collective agreement is implemented through national collective labor agreement.

Thus, the legal effect of European collective agreements is directly derived from the legal effect of the national collective agreement. The national collective agreements can not be in conflict with European ones.

This is because the European collective agreements have no direct effect on individuals, because Article 139 (2) of the EC Treaty expressly envisages that the European collective agreement must be implemented properly.

2.3. Implementation of European collective labour agreement

The implementation, as well as the legal effect of the European collective agreement, may be viewed from the standpoint of the contractual parties and from the standpoint of direct (individual) employee and employer.

First, the national organizations can implement the European collective agreement in the way that they would conclude the national collective labour agreement that is not simple and it seems that its implementation is more appropriate by the enactment of the corresponding directive by the Council, and on initiative of the representative European social partners and the proposal of the Commission.

Second, directly in terms of employees and employers, the realization of the normative act of the European collective agreement is possible only on the basis of national collective labor agreements or the law or by-laws.

3. ACTIVITIES OF EMPLOYERS ASSOCIATIONS AND TRADE UNIONS IN INTERNATIONAL REGULATION OF RAILWAY TRANSPORT

Integration processes in the European Union in the railway transport sector, based on the concept of market and social Europe, are reflected not only in establishment of the integrated railway and creation of the liberalized market, but also have a social dimension.

Liberalization and deregulation of the railway system has the social dimension in its counteract, so that places the social legislation in the core activities of the European social partners in the field of railways as a continued need for the harmonization of working conditions in the European railway transport.

Activities of employers' associations and trade unions and in the international regulation of railway transport are reflected in the existence of social dialogue and the conclusion of an agreement at European level between the Community of European Railways (CER) and the European Transport Workers' Federation (ETF).

The European social partners in railway transport, the European federation of transport workers (ETF) and the Community of European Railways (CER), on 27 January 2004, signed two agreements, as follow: (1) Agreement on the European license for train drivers performing service in interoperable cross-border traffic and (2) Agreement on some aspects in working conditions of mobile workers employed in interoperable cross-border services.

The main content of the Agreement on certain aspects of working conditions of mobile workers in interoperable cross-border services, it can be, literally speaking, divided into three parts. In the introducing part, the mandatory and optional implementation of the Agreement is envisaged and the meaning of certain key terms is determined. In the first part, the Agreement regulates the rights of mobile workers in interoperable cross-border services, namely: the minimum duration of daily rest at home and away from home, train drivers and other train personnel breaks, duration of the weekly and annual leave, limited travel time. In the second part, the Agreement provides the control, the deviation clause, monitoring, evaluation and revision of the Agreement.

Second, the Agreement on the European license for train drivers that perform service in interoperable cross-border traffic comprises the following parts, as following: the objectives of the agreement; extent, manner of issuing, the ownership and license structure, obligations of railway company; inspection by national authorities responsible for security, in case of incident or accident: assistance to train driver and informing the staff representatives, monitoring of the Agreement.

Implementation of these agreements was carried out by introduction of the appropriate directives. So for instance, with Directive 2005/47, the Agreement on certain aspects of working conditions of mobile workers in interoperable cross-border services was implemented.

4. CONCLUSION

The concept of market and social Europe in the railway transport sector, implies the conclusion of European collective agreements. It requires and justifies further development of collective bargaining and conclusion of European collective agreements, which includes the contents of certain issues in the case of Community labour law.

It can be expected soon that, not just the social partners in the nationalized and private railways, but almost equally interested institutions of the European Union, offer the conclusion of European collective labour contract in railway transport.

The question is raised on content of collective agreements, in this regard. The European branch collective labour agreement in the railway transport sector between the Community of European Railways (CER), on the employer's side, and the European Transport Workers' Federation (ETF), on the trade union's side, governs the rights and obligations of the parties (obligatory part) and working conditions of employees (normative part), and contain minimum standards and the basis for the conclusion of the national collective labour agreements.

This further means that the relation between European and national collective agreement is based on the notion that the provisions of European collective agreements contain minimum standards, respectively, represent the minimum basis for the conclusion of national collective agreements, which, therefore, may contain provisions more favorable to workers comparing with the European collective labour agreements - in principle *in favorem laboratoris*.

Furthermore, it is raised the question, as the basic one, of possible content of European sector collective agreements in the railway traffic sector. This collective agreement may include the following questions from the case of Community labor law, such as e.g.: Harmonization of working conditions, including the issue of occupational health and safety, limited duration of working time, weekly leave per year, special protection for railway workers that work in dangerous or unhealthy activities, promotion of economic and social cohesion with the participation of the Structural Funds in reorganization status of employees and employers, i.e. their individual and collective rights in the event of reorganization, the protection of employees in the event of termination of employment contract, information and consultation, and the protection of professional, economic social and cultural interests in the rail transport industry.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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FINANCING COSTS AND MAINTENANCE OF RAILWAY INFRASTRUCTURE COMPENSATION FOR ACCESS TO RAILWAY INFRASTRUCTURE

Vahid ĐOZO [1]

Abstract *– Financing the costs of maintaining the railway infrastructure at ŽFBH is insufficient and far the lowest comparing to other countires in closer area. Railway infrastructure is partly funded by railway operator ŽFBH (cargo traffic) in amounts higher than the results given by fees compensation model for access to the railway infrastructure which is not recommended by the EU Directive. During the period 2006 – 2011 an average annual infrastructure costs that are not settled are around € 18 million which are recognized by the owner but they are not provided. There are different models of calculating fees for access to railway infrastructure in the frame of national countries in Europe that are being applied. There are no example countries in the Europe that are paying all the costs of railway infrastructure by the compensation fees. Notwithstanding the positive trend of actual driving miles, especially in cargo traffic, lack of resources is degrading the railway infrastructure, the railway operator bussines system of ŽFBH and Federation of Bosnia and Herzegovina.*

Keywords - railways, infrastructure, costs, access, charges.

1. INTRODUCTION

The concept of organization of railway companies in our environment traditionaly is based on a basis of hierarchical vertical control and management from top to bottom. Management was conducted by the relevant government institutions at the level of a certain spatial entity or state. The period of management and control of railway companies by the elapsed time can be divided into two parts:

- First, when the railways had a monopoly on the transport market,
- Second, when there was a development of competition and loss of monopoly.

Start of creation of a single regulatory framework in the field of railways in Europe is described in the Directive 91/440/EEC from 1992 that talks about the development of railways in EU and was altered with Directive 2001/12 EC of the European Parliament and Council. After that, series of the first set of directives that help create a single market of services, such as:

- EZ Council Directive 95/18/EC from 1995 of railway companies licensing that was amended by Directive 2001/13/EC,
- Directive 2001/14/EC of the European Parliament and Council from 2001 on the allocation of infrastructure capacity and the levying of charges for use of railway infrastructure and safety certification,
- Directive 2001/16/EC of the European Parliament and Council from 2001 about interoperability of trans-European conventional rail system.

The second set of directives from 2004 virtually created the legal and technical requirements for a single rail transport market in the EU. They include development of a common approach to railway safety, which should set clear procedures for the issuance of security testimonial (security certificate) that every organizer of transportation must obtaine before starting to drive trains on the European rail network, and the conditions that infrastructure managers in order to obtain a certificate of safety need to gratify. To simplifie, the new organizational model of railroads organization is based on division of existing public railway company into two parts: Infrastructure, as a public company, Railway operators, which can be both public and private company.

2. INFRASTRUCTURE MAINTENANCE AND MOVEMENT OF TRAINS AT ŽFBH REGULATION

Following the EU directives, the current arrangement at ŽFBH according to the Law on

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Railways of the Federation of Bosnia and Herzegovina (Official Gazette of the FB&H No. 41/01 from october, 02. 2001), which defines the object of their work. Observing the EU directive (2001/12), and the provisions of the law, ŽFBH acts as both manager of infrastructure and transport organizer, and the balance of succes of these two companies are accounted separately.

2.1. Costs for infrastructure maintenance at ŽFBH

Costs for infrastructure maintenance are financed from the Budget of the FB&H fee for the use of the route of the railway operators within ŽFBH (it is about internal relationships within a company) and other infrastructure revenue from other sources (rent, infrastructure services, etc.).

For observed five-year period (Table 1), value of the contract, executed (situated) works and paid costs from the Budget of FB&H on behalf of those works is shown. Looking at the data from Table 1, and established trends in Figure 2, it can be seen that values of contracted projects in averagethey fall and completed contracts grow, but budget transfers virtually stagnate, and cover only 30% of recognized and proven infrastructure costs. If this state maintains, such trends will produce negative effects and will influence the further degradation of infrastructure capacity.

Table 1. View of infrastructure maintenance costs at ŽFBH for the period of 2006 - 2011 [1]

No.	Description of costs (BAM)/year	Contracted works (BAM)	Situated and recognized works (BAM)	Budget Transfers (BAM)
1.	**2006.**	99.797.129	42.225.350	17.164.634
2.	**2007.**	88.615.335	60.611.937	23.100.000
3.	**2008.**	114.755.494	92.375.335	25.900.000
4.	**2009.**	135.834.929	95.953.991	19.400.000
5.	**2010.**	97.892.713	61.779.000	21.340.000
6.	**2011.**	77.242.234	55.240.476	19.400.000

Table 2. Overview of the planned budget for the railways in the region for 2012

No.	Description	Budget funding (BAM)	Railway network (km)	Amount (BAM)/ (km) x10^3
1.	**FBiH**	22.000.000	608	36,184
2.	**RS**	25.000.000	424	58,962
3.	**Montenegro**	19.362.717	331	58,498
4.	**Serbia**	238.824.417	3.809	62,70
5.	**Croatia**	423.038.663	2.722	155,415

2.2. With the railways infrastructure funding with Railways from the region comparison

A similar problem is facing the railways in the closer region. Data on budgetary resources to support the rail sector for 2012 are still better than budgetary resources at ŽFBiH (Table 2). Comparing the investments amount to the current length of the railroad network, the results for ŽFBH are more than disturbing. Croatia, for the maintenance of railway infrastructure investes 4.3 times more than B&H, Serbia 1.73., Montenegro 1.61., Republic of Srpska 1.63.

3. SERVICES AND FEES FOR THE USE OF INFRASTRUCTURE

EU Directives which aim is liberalization of the railway service market in Europe implies maintenance financing costs by the owners and users of infrastructure services (operators).

3.1. Type of services provided by the railway infrastructure

According to the 2001/14 EU Directive Managers of the public railway infrastructure to the organizers of transport (railway operator) offeres the infrastructure using services. Services can be divided into two types:

- Services of the basic package for access to the network,
- Services for advanced package for access to the network.

3.1.1 Services and benefits of the basic package

Basic package services include:

- Use of the assigned capacity of the railway track
- Use of nodal railway stations and railway tracks used by the leased,
- Controling and regulation of railway traffic, signalization, routing and communication of information related to traffic,
- Other information required for the provision or management of the service which has capacity assigned to.

3.1.2 Services and benefits of additional package

Services of additional packet of access include:

- Maneuvering,
- Electricity supply for traction trains,
- Fuel and water supply,
- Ticket sales at passenger traffic,
- Train escort and passing maneuver in freight traffic.

Dangerous goods transport and specific (special) shipment control.

4. CALCULATION OF THE BASIC SERVICES ACCESS MODEL

The publicly released Network statement, in a separate chapter, the infratrukture manager presents a model of basic package approach charge.

Infrastructure managers have developed and released cost calculation model in Chapter VI of the Network statement, but this process is not complete and unchangeable, because it is a new subject which has not yet been fully explored nor confirmed empirically and practically. There is still not a universal model is that is applicable to all sectors of the railways in Europe. Train infrastructure managers in European countries have developed different models for the system of charging fees to access the basic package. Development of the model depended on the social and economic indicators of a certain country, the supply and demand for government services or owner relations towards the railway system in general. Regardless of the type of charging model and size of charge, in no country is reported additional infrastructure funding from the public funds.

4.1. Austria and Germany applied model

Austria applies a model of linear marginal costs, as the unit of measure both gross ton and driving kilometers are being used. The models are derived from research studies that were performed by Munduch et al. (2002), and component of the model are: [2]

- Compensation for wear and tear of rails depending on gross ton kilometer
- The fee for the usage of the railway line by driving kilometers in five different categories, including cargo and passenger trains of lower rank:

$G_{tkm\ train}$ = Route (km) • (gross mass of locomotive + gross mass of wagon) (1)

$IUC_{Train\ and\ high\ speed\ train}$.= (gross ton km • BTK) + (driving km • Z) ± (train km• extras/rebate) (2)

The model was developed to include both rebate and extras, for example:

- Bottleneck fee
- freight traffic on the corridor (decrease) fee
- speed of trains over 160 (km / h) (not awarded 2012) fee.

Germany, DB network also uses a linear tariff, charge for access is determined in three steps:

- by line category
- by product factor
- additional factors

4.2. Croatia, Slovenia and Montenegro applied model

Croatian model of costs recovery for basic package is defined by the following expression:

$$C = Tx\sum LlxC_{vlkm}xK \qquad (3)$$

where: T -equivalent to train track is determined to bring the planned mass in relation to computing train weight, L - parameter lines, is determined depending on: the technical parameters of rail, rail parameter equivalent, and line cost equivalent, l - train track length, C *(kn/driv.km)* – basic costs per driving kilometer, K - coefficient of price correction.

The basic cost per driving kilometer (C_{vlkm}) for infrastructure usage for The Driving schedule (2011/2012) is: [3]

- In passenger traffic: 17,55 HRK/driv.km + PDV
- In cargo traffic 10,09 HRK/driv.km + PDV

Slovenian model of cost recovery for basic package is defined by the following expression: [8]

$$U = (Q_{vlkm(reg)}xP_{(reg)} + Q_{vlkm(g)}xP_{(g)})xC_{vl.km}xKxF \qquad (4)$$

where: U – Infrastructure usage price, $Q_{vl.km(reg)}$ – Driving km, achieved at the regional rail, $Q_{vl.km(rg)}$ – Driving km, achieved at the main rail, $P_{(reg)}$ - Regional rail weight, $P_{(g)}$ – Main rail weight, K – Rail load coefficient, F - Factor that depends on user requirements according to The Driving schedule, C_{vlkm} – Driving kilometer price. Driving price per kilometer (C_{vlkm}) for infrastructure usage for Driving schedule (2011/2012) is € 1,8584.

Montenegro model of basic package of costs recovery is defined the same as in Slovenian Railways considering the fact that driving kilometer price is 3 naplate troškova osnovnog paketa definisan isti kao što se primjenjuju Slovenske željeznice, stim da cijena po voznom kilometru iznosi € 3 including VAT. [4]

4.3. Model of ŽFBH fees published in the Statement of the network for 2011

The basic package model that is applied at the ŽFBH is similar to that used by the Railways in closer region environment. It is a model of nonlinear compensation of the basic package that suits best to the railways which don't have equally balanced load on all lines on the network. Lines that are less burdened have more favorable conditions for the operators, that means that the basic package price is lower. The basis for compensation is driving kilometer and a model for calculation is:

$$U = \sum_{i=1}^{N} Q_{vkmi} C_{vkm} \times P_i \times K \times F \qquad (5)$$

Railroad category (P): PI = 1,0, PII = 0,8

Coefficient of tear track (K), depends on the gross mass of the train: K= 1 cargo trains, K = 0,40 passenger trains, K = 0,30 empty locomotive drives,

and:

F – coefficient related to request in relation to The Driving schedule,

F = 1, If the request is filed prior to the entry of The Driving schedule,

F = 1,2 If the request is filed after the entry of The Driving schedule.
Driving price per kilometer C_{vkm} is 6 BAM

4.4. The annual amount of infrastructure charges for the basic package access at ŽFBH model

The maximum annual value of the actual driving kilometers was made in 2011, and as such is used for the basic package costing approach. Results in annual price of basic package is: [5]

- BAM 3.824.640,00 for passenger traffic
- BAM 8.934.000,00 for cargo traffic

The total amount is BAM 12,758,640. This value should be taken approximately, because in reality there can be deviations when taking into consideration the actual conditions and total compliance of rules from *Network statement*, such as cancellation and the introduction of train rides out of Driving schedule, the operator cost due to reliability reductions of infrastructure capacity, which is compensated by the infrastructure (delays caused by the state of infrastructure). According to the annual contracts for infrastructure maintenance, the fee for basic package approach was from BAM 10 - 15 million. Annual report on the results of ŽFBH operations show significantly highe allocations by infrastructure and cargo transportation in freight traffic.

5. ANALYSIS

Information on annual investment in rail infrastructure is insufficient and the lowest in the region. Realized costs are not supported by the owner that is suggested in the EU Directives. When the average annual carried out costs are taken into account it is around BAM 68 million, the average annual budget allocation of around BAM 21 million, the average annual compensation for the use of the route of around BAM 12 million it can be seen that BAM 35 million is lacking per year. Lack of funds is covered by the actual labor of ŽFBH rail operator in greater extent and other services in smaller extent.

Investments in infrastructure maintenance do not follow the trend of transport quantity growth, observed through the parameter of driving and gross ton kilometers. Financing costs of infrastructure maintenance is defined problem and it is still unclosed including the EU Directives application in the real volume. Different models for calculating the costs of track tenure at railways in Europe are available and are effectively used, especially in developed countries with technically advanced railways. In all analyzed models track tenure expenses and additional services expenses do not meet required costs. Finland and Sweden used models stimulatively affects the train operators, but the largest allocations for infrastructure are still along the national public funds. The closest theoretical set value of 30% of the cost of infrastructure benefits is in France, Austria, Denmark and Italy. Neighboring countries have roughly the same models for the basic package calculations that will ease regional cooperation in the railways field.

6. CONCLUSION

Financing of infrastructure maintenance costs at ŽFBH is insufficient and needs to be at least at the level similar to the countries in closer environment, comparing the indicators of economic development, for example, GDP per capita. If the situation remains with no changes further degradation of both parts of ŽFBH will happen (railway infrastructure and railway operator). This will result in the way that ŽFBH infrastructure will be uninteroperable and will not offer services that would be of interest to the transportation organizers. To cover operating losses of the infrastructure ŽFBH railway operator will be behind further development and will not be competitive on the open market of railway services in Europe. Due to the financing maintenance in volume of lower than necessary the costs in the field of participation of manual labor will increase. Quantity of transportation trends are encouraging and should be promoted and kept concrete as social general benefit index. In contrary, there is a risk of loss of the existing flows and industry branches development stagnation that rely on railways. Infrastructure improvement is condition of efficient and competitive trade in goods from our with Europe. Legislation of FBiH in this area partly follows the EU Directives but only at its organizational part, but it is necessary to further severe measures for preparation in technical and practical term so that prospective business operator, rail infrastructure could be more sustainable. The same applies to the ŽFBH railway operator.

The Europe railway systems follow the EU Directives but with a different approach. There is a large dispersion in the part of participation in the infrastructure fees amount in total infrastructure costs funding. For example in Finland that is about 5% and in England is about 80%.

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CASE STUDY PLAIDOYER: CONCEPT OF INTELLECTUAL CAPITAL AT JSC „SERBIAN RAILWAYS“

Aleksandar BLAGOJEVIĆ [1]

Abstract *– JSC „Serbian Railways“ is a company which should be realized as a big and complex system, the problems of which have to be solved in a systematic manner. Therefore, it is pleaded to research this big transport system by means of a Case study method, and in this context, to pay special attention to certain stratums (layers) within this transport system. The research should enable defining of a modern concept of intellectual capital in JSC „Serbian Railways“, and the managing of this most important factor of the new economy.*

Keywords - Serbian Railways, stratums, intellectual capital.

1. INTRODUCTION

JSC „Serbian Railways“ is a big company, a business system which has had problems in business for a longer time period. In the last years, a lot of effort, assets and money was invested in improvement of business performances and business conditions of this company, but major effects still have not been achieved. There are many reasons for this, but the basic reason is the unsatisfactory management of intellectual capital, and the fact that the problem of this railway system is not being solved in a systematic manner. Therefore, it is necessary to analyze JSC „Serbian Railways“ by means of Case study, as a complex system with numerous sub-systems, and, within this framework, to research primarily the intellectual capital sub-system, as the most important factor for development of each organization.

2. STRATUMS OF THE RAILWAY TRANSPORT SYSTEM

It is necessary to analyze and research the big railway transport system of JSC „Serbian Railways“ through the following sub-systems (stratums):

1. vertical stratum of railway transport system,
2. horizontal stratum of railway transport system,
3. other stratums of railway transport system,
4. mutual connections among the elements in the internal surroundings of railway system,
5. connections of railway transport system with the external surroundings,
6. intellectual capital as a separate synergetic stratum.

2.1. Vertical stratum

In order to create the concept of intellectual capital in JSC „Serbian Railways“ it is necessary to perform a research and complex analysis of a big railway transport system, and primarily the vertical elements of the railway transport system. In this context, it is necessary to explore the following stratums of the vertical system: technical stratum, technological stratum, organizational stratum, economic stratum, legal stratum, and intellectual capital stratum.

Technical stratum consists of technical assets. From the aspect of their role in the railway transport system, technical assets can be classified to transport assets in the strict sense of the word, which serve for the transport process, and to traffic communications, on which the movement of the transport assets is performed, including the transport terminals where the loading and unloading of the transported objects is performed (railway traffic infrastructure). This classification is significant for its technical-technological characteristics, as well as for economical and organizational characteristics.

Technological stratum of the railway transport system is the stratum which is used for defining of the production process in the railway traffic, i.e. the transport service production process.

Organizational stratum is very important from the aspect of the basic development goals and JSC „Serbian Railways“ railway transport system functioning.

Different elements are influencing the organizational stratum factors, and some of them are

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characteristically for all traffic modes, while some of them are characteristically only for certain traffic branches. All factors should be explored, and it must be managed by relying maximally on knowledge management and intellectual capital concept.

Organizational principles have a great influence on all relations and elements of the railway transport system, i.e., to the organization of designing and construction of transport infrastructure, transport infrastructure maintenance, organization of the transport superstructure, organization of transport services production process, organizational form of the enterprises founded by JSC „Serbian Railways“, organization of business policy, etc.

On the macro-economic level, development of a railway transport system, both in EU and worldwide, is based on the four basic principles: financial consolidation of railway enterprises, harmonization of legal regulations, transport market opening, and separation of railway operations from railway infrastructure management. Social-economic responsibility comes from the fact that „Serbian Railways“ are in different ways connected with the surrounding, economic system, economic policy, certain branches of economy, etc.

The market also represents an external factor, with users, suppliers and competitor enterprises, labor, etc. Development of science and technology, especially the available technique and new technology, and new insights into organizational sciences, methods and models, are also significant external factors, which influence the organizational system.

The most important internal factors of the organizational system are: strategies and goals, tasks and technology, employees, size of the enterprise, life cycle of the enterprise, product, and location.

Strategy and goals are the most important internal factor of organizational structure, because they define the future of the enterprise. The tasks and technologies are defining the actors which are to perform the tasks i, deadlines, etc. The size of the enterprise also has a great influence, whether we are talking about the number of employees, total revenues, and size of profit of value of the capital assets. The phase of life cycle in which the enterprise is, is also very important. The employees have special significance, i.e., the structure of human potential, as well as the product characteristics and enterprise location.

Organization, in a wider sense, comprises organizational structure, organization of assets, and organizational processes. Accordingly, the organizational dynamics deals with the issues of changes management, organizational culture, risk management, conflict management, etc.

Organizational culture is especially significant factor of each organization, with all its symbols, values, norms, positions and beliefs, loyalty towards the enterprise, users, etc. Many people think that the organizational culture represents the most important base element of each organization, regardless its size and type of activity.

Economic stratum is a constituent part of all activities in the railway transport system, which refer to the relations between making of the calculations and tariffs, management of all kinds of costs (fixed, variable, margin), quantifying of the ration between the offer and demand, and parameters for the business success (profitability, cost-efficiency, solvency, etc.).

Legal stratum of the railway transport system comprises all legal rules and obligations, and legal responsibility of all active participants in the functioning of the railway transport system. Regulations are governing the relations in the fields of transport activities, passenger transport, freight transport, train traction, civil-engineering infrastructure, electrical infrastructure, financial business operations, investments, planning, personnel affairs, human resources, etc.

Intellectual capital is a synergetic stratum within the vertical stratum and the entire railway transport system. In general, intellectual capital is a key factor, resource, and a basic element of all elements of the railway transport system in the vertical cross-section, and it is considered to be a very important synergetic element. It has a crucial significance for creating and realization of the business profitability and excellence, for the growth and development, and all other aspects of railway transport system functioning.

When it comes to the concept of intellectual capital as a sub-system of the vertical stratum of the railway transport system, it is necessary to make a separate analysis of the following issues related to the intellectual capital: intellectual capital management, value creating, classification of intellectual capital, human capital, structure capital, models of intellectual capital management, knowledge factor, intellectual property, etc.

2.2. Horizontal stratum

For the defining of the intellectual capital concept in JSC „Serbian Railways“, it is necessary to explore horizontally the railway transport system, with a view to its optimum designing, per following sub-systems:

- Railway transport infrastructure
- Transport functions

Important issues for the functioning of the railway transport **infrastructure** sub-stratum, are also the technical structure, technological characteristics, infrastructure elements, economic and legal aspects of the infrastructure, and the concept of intellectual capital, which is here being explored from the aspect of the horizontal stratum.

Within the technological structure, the subject of the research is also transport management, but with the following important issues: timetable, maneuver operation, work technology, transport planning, building maintenance, electric-technical devices and plants maintenance, etc.

Besides that, there are also internal factors of the organizational system, and those are goals and strategies, tasks and technologies, size of the enterprise, life cycle of the enterprise, structure of human potential, product and location.

Special issue of the infrastructure segment is **intellectual capital.** As pointed out**,** the case study especially emphasizes the issue of intellectual capital concept on the level of the entire company, per all horizontal segments of the system. It has been concluded that the intellectual capital has not been introduced in the JSC „Serbian Railways" infrastructure on the level of the enterprise, in the form of official intellectual capital program, nor on the level of separate sub-systems, subsequently. Therefore, it is necessary to define the concept of intellectual capital in the manner which is described in more detail in the point 2.6. of this work.

2.3. Other elements of the railway transport system

This segment of the railway transport system comprises the following: safety and protection, logistics, intelligent transport system, real estate,

Safety in the railway transport system is defined as a group of technical and technological norms and procedures, which have the purpose of safe transport functioning, without incident situations and traffic accidents. Technical-technological norms and procedures are the norms for construction and maintenance of traffic assets and surfaces, norms for the traffic management system, and applying of modern technologies and signalization, etc. By applying of these norms, the risk of undesired situations is avoided.

The task of logistics is to be a part of the supply chain, which plans, implements and controls the successfulness, flows and warehousing of goods, services and information, from the place of production to the place of consumption, in order to satisfy the users' demand. Within this sub-system, the issues, which are wider than the transport itself, are explored: new logistics development, transport costs, transport enterprise marketing strategy and logistics strategies, special particularities of the goods and services, etc.

In this segment, as well as in the others, the special issue is applying of the intellectual capital concept, which has not been introduced as the official program in the organizational model of this sector either, and therefore, it is necessary to define this concept in a way suggested in this study.

2.4. Connections among the elements in the system

There are general connections among the elements within the railway transport system, and also within each stratum, and also among the stratums, because everything is connected with each other. Therefore, it is necessary to take into account the connections of each element of the system with all other elements and systems, during the research.

2.5. Connections of the railway transport system with the surroundings

Besides the elements which make the railway transport system, the case study will also analyze the connections and relations of the railway transport system with the surroundings because the railway transport system is only a sub-system of a higher economic and social system. In that sense, the connection and relations of the railway transport system with the economic system, territorial work allocation, development of undeveloped areas, defense system, environment, and certain business activities will be explored, as well as the significance of the intellectual capital concept for all forms of connections and relations with the surroundings.

Finally, the case study analyzes in detail the existing traffic policy, i.e. goals, instruments, principles, and especially of the part which relates to the effects and influence of the traffic policy to the transport and railway system, i.e. JSC „Serbian Railways".

2.6. Intellectual capital as synergetic stratum

The case study means that all issues of intellectual capital are to be explored on the particular example of the railway transport system JSC „Serbian Railways", as follows:

- Analysis of intellectual capital management benefits
- Monitoring and measuring activities
- value added and wealth as the result of intellectual capital management
- value added chain improvement
- classification and analysis of human capital
- structure capital analysis
- existing knowledge types analysis
- competence analysis
- organizational culture analysis
- innovation capability analysis
- consumer capital
- relation capital, etc.

For JSC „Serbian Railways", as an organized railway transport system on the level of the Republic of Serbia, intellectual capital management is of special importance. Therefore, top management of the company must introduce and motivate different methods of improvement and applying of intellectual capital concept.

Human capital management, i.e. intellectual capital in entirety, should be implemented in three levels:

– on the individual level, by recognizing and motivating the individual potentials of the employees
– on the team level by forming and motivating expert teams as well as supporting them.
– On the level of the enterprise by development of organizational culture, information technologies, leadership, entrepreneurship, knowledge management, and other most important factors of applying the intellectual capital concept in the enterprise.

Intellectual capital management in JSC „Serbian Railways“ should be organized in several phases:

Phase 1: raising awareness on the importance of intellectual capital.

Phase 2: defining of intellectual capital concept,

Phase 3: defining of the management method of intellectual capital basic factors in the enterprise.

Phase 4: defining of the model and methods for monitoring and measuring of intellectual capital

Phase 5: defining of the system of reporting and report writing on intellectual capital

Phase 6: stimulating and motivating of the employees towards the positive attitude on the intellectual capital concept, etc.

JSC „Serbian Railways“ should invest maximum efforts in applying the intellectual capital concept within the enterprise. Having in mind that, at the moment, there is no separate entity for intellectual capital in JSC „Serbian Railways“, and those activities are not systematically followed in the existing Strategy and Development Department, it is necessary to form the teams for intellectual capital on the level of the enterprise. In this way, the process of continuous intellectual capital management would be initiated with the prospects for forming a separate body for intellectual capital management within reasonable period.

The tasks of these teams should be in the function of advisory body of the top management on intellectual capital issues, and to represent the main actors in the project of intellectual capital concept development within the enterprise, knowledge management and education for intellectual capital management. In this way, these teams would make the core of the future department for the intellectual capital in JSC „Serbian Railways“.

It is necessary to analyze and research the big railway transport system of JSC „Serbian Railways“ through the following sub-systems (stratums):

1. vertical stratum of railway transport system
2. horizontal stratum of railway transport system
3. other stratums of railway transport system
4. mutual connections among the elements in the internal surroundings of railway system
5. connections of railway transport system with the external surroundings
6. intellectual capital as a separate synergetic stratum

3. CONCLUSIONS

JSC „Serbian Railways“ should be analyzed as a big railway transport system, within which the vertical stratum of railway system, horizontal stratum, other stratums of railway system, mutual connection of elements in eternal surrounding, and connections of railway system with the external surrounding, is explored by the method of case study. The results of the research will enable establishing of optimum relations among certain elements of the railway system and efficient intellectual capital management, as the most important development factor in the new economy.

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Other Railway aspects

COSTS VERSUS BENEFITS FROM NEW DESIGNS OF INTERMODAL LOADING UNITS

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Abstract *– The main advantage of intermodal transport is in transferring large portion of road transport on railways, thus reducing most of the negative aspects of road transport. In European transport market, there exist various intermodal loading units. Large containers ISO 1 are the most used type, but having some disadvantages - the most serious is the internal dimension of the container when loaded with europallets. On the other hand they are stackable thus reducing substantially storage space both on terminals or when carried on ships. Swap bodies eliminate some disadvantages of ISO containers as they have larger dimensions for europallets with more effective use of loading area. Among the attempts to combine advantages of containers and swap-bodies was the project TelliBox. The objectives of the projects were even higher – increased cargo volume up to 100 m³, openable side walls, solid walls and 3 m internal height. The desired properties are paid by much more complex design and increased weight. The TelliBox project finished with a functional prototype but further refinements will be necessary to fulfill all the expected properties. Only practice will justify benefits against higher costs for the new large size design.*

Keywords - Intermodal transport, large size loading unit, cost – benefit analysis.

1. INTRODUCTION

Intermodal transport is expected to improve effectiveness of goods transportation because of using the one and the same loading unit from sender to recipient as an uninterrupted chain. The main advantages are in transferring large portion of road transport on railways, reduction of traffic congestions on roads, improvement of environment by more environmental friendly railway and waterway transport, increase of transport speed, improvement of safety of transported goods and reduction of costs and time in material handling during transportation process. The intermodality brings about the opportunity to use better the rail, inland waterways and short sea shipping, which are seldom used at present because individually they do not allow door-to-door delivery.

In European transport market there are various intermodal loading units (ILU or UTI – Unité de Transport Intermodal). The use of these UTIs depends on different factors, e.g. the specific relation served and the transport mode used for this relation. Large containers ISO 1 are the most used type of UTI, but they have some disadvantages, while the most serious one is the internal dimension of the container, in particular when loaded with europallets. Swap bodies eliminate some disadvantages of ISO containers: dimensions of loading area are educed from dimensions of europallet, by which more effective use of loading area is achieved. On the other hand containers, are stackable thus reducing substantially storage space on terminals or when carried on ships.

There have been numerous attempts to combine advantages of both above mentioned UTIs. Among them was the TelliBox project, solved under the 7th EU Framework Programme. Besides combination of container and swap body properties the objectives were much higher – increased cargo volume up to 100 m³, openable side walls, solid walls and 3 m internal height. However, these desired properties, rapid loading and unloading are paid by complex structural design and increased weight.

The TelliBox project finished with functional prototype (2011) which itself is a success. However,

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further refinement of the prototype will be necessary to prove in practice all the expected properties.

2. WHY LARGE SIZE INTERMODAL LOADING UNITS?

To have intermodal loading unit with dimensions as large as possible is absolutely natural (possibility to transport higher cargo volume), but these dimensions are limited by maximum allowed dimensions by regulations, especially on road, but also railway and water transport create obstacles, similarly handling operations and storage.

Sometimes few centimetres make problems, which is evident from comparison of classic large size ISO 1 container and a swap body. Advantage of swap body is in ties size that enables better utilisation of internal space, in particular when loading with EURO pallets. This is documented in figure 1, where in container it is not possible to place 2 pallets side by side longitudinally (2 x 1200 mm), or three per width (3 x 800 mm) but it is possible to do so into a swap body. But maximum permissible width of UTIs on road is 2550 mm, there is a little space left for thickness of wall structure (moreover some free space should be allowed between pallets).

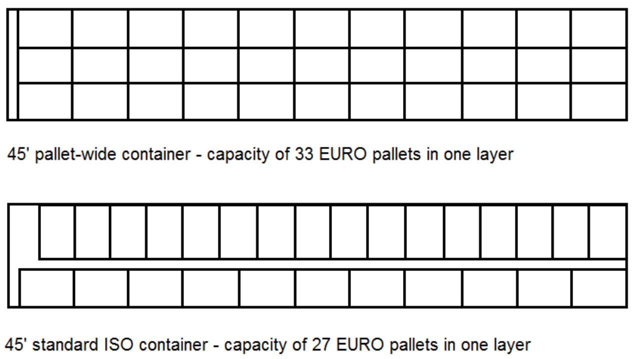

Fig. 1. Stowage of euro pallets in standard and in palletwide 45' container

Other advantage of swap bodies is their smaller weight resulting from design not requiring stackability. However, this is their disadvantage (with exception of stackable swap bodies) as they need large storing areas and similar problem occurs on water transport. From this reason swap bodies are mostly used in road transport.

Solution of this problem is being searched in increased width of containers to the width of swap bodies (2,5 – 2,55 m). These are so called HighCube containers, which mostly have extended height (e.g. up to 10'6½") comparing to standard ISO 1 container with maximum height of 9'6". Together with the maximum standard length of 45 internal space (cargo volume) is near 100 m^3.

In Europe for longer time there has been an initiative towards the so called Eurocontainers (EILU – European Intermodal Loading Unit) with dimensions adapted to EURO pallets [1]. Internal bottom area dimensions should be 2400 x 13 200 mm, plus free space for handling and external height 2900 mm. Stackability is expected up to 4 layers. So far the final solution is out of sight.

There are numerous solutions at present. For instance there are 45' containers 2500 mm width, which solve problems of placing pallets side by side, but they are openable only from the front wall. This solution is simple from the strength, stiffness and weight point of view, but enables loading and unloading only through this front door. This drawback leads to container designs with openable side walls. But this requires structure with much thicker bottom frame to ensure strength and especially acceptable deformation, which is strictly limited for stackable containers. That is why these containers are either shorter or have great thickness (height) of bottom frame (in case of 45' container it is about 430 mm). By this the internal height of a container is reduced and weight is increased [2].

2.1. Answer: Mega Swap Box - TelliBox

One of the answers to the challenge to combine advantages of swap bodies and containers into a new design was the project TelliBox, solved within the 7th Framework programme EU (coordinated by RWTH Aachen) [3].

The basic requirements of the TelliBox system are:

- Tri-modality (road, railway, water),
- Stackability,
- Handling by standard handling equipment during transhipment on individual transport modes (top corner fittings, grooves for grab lifting appliances),
- Compatible for existing low floor wagons for rail transport,
- Adaptable chassis for road transport,
- Cargo volume 100 m^3 and internal height 3 m,
- External length of 45´, width 2,55 m, height 3,2 m,
- Accessible from three sides for loading purposes (front and both side walls),
- Liftable roof for better loading and unloading accessibility,
- Ensured sufficient safety features against pilfering and damage of goods,
- Follow all relevant EU regulations on road and rail transport.

The worst problems within the designing were caused by requirement of maximum external height of 3,2 m (resulting from maximum height on the road 4 m and maximum height of fifth wheel on truck, which is currently attainable in the level of 850 mm) in close relation to the required internal height of 3 m. (railway wagons allow more space). The next demanding requirement was completely openable side walls and liftable roof. When considering length of about 13,7 m this brings extraordinary requirements on ensuring strength and especially stiffness of the container structure.

The basic difficulties were mentioned above. Most of them were solved. Design was carried-out in sequential steps. Staring from as-is analysis, that means analysis of state-of-art technology and market needs, analysis of available high-tech materials possibly used for the structure, proposal of alternative solutions and selection the best one, and finally construction of the prototype.

Search for design that would fulfil all the requirements was really hard. There were efforts to use new advanced materials with higher deformation modulus, but because of high price, very difficult manufacture and also operational properties they were refused. Another possibility was use of pre-bent floor, but this was also not feasible. Finally there were 3 principal solutions:

1. "Shoe box" with supporting structure in the roof that would be liftable;
2. "Air tech" with floor on air cylinders that could be liftable and allowing higher bottom frame;
3. "EC – box" with one solid side and only one openable side.

All these designs had some "pros" and some "contras" and they were very carefully evaluated. The final design was derived from the Shoe-box concept though modified. The principal idea that was even patented by designers was to make folding openable wing doors that in closed position are locked with bottom and upper frame and thus creating supporting structure that bears the loads. However, there is a central pillar on each side so the open side wall has actually an obstacle in the center.

The principal structural design can be seen on the figure 2.

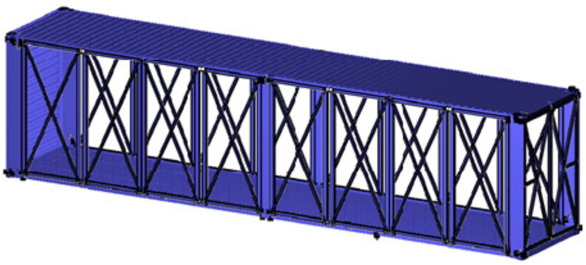

Fig.2. MegaSwapBox structural design

The structure with open doors has to be placed on a solid and straight plain, or on a vehicle. In case of railway wagons the type used depends on railway loading gauge (or railway line category). On road a special chassis and truck had to be developed.

Railway lines are categorised and have number of category (codification). Railway category determines maximum loading dimension, that is for given dimensions of ILU (or in this case MSB) maximum height of loading platform of railway wagon. Most of the German lines has category C379, C400 and C410, in Slovakia C377 and C400. For external width up to 2550 mm the category has two digit code, over 2550 mm 3 digit code (e.g. C45 corresponds to C375).

E.g. at normal height of loading platform 1175 mm for track category C45 the height of container or swap body will be maximum 2900 mm, on C75 it can be 3200 mm, on C80 it can be up to 3250 mm. Respectively, the lower loading platform of a wagon is the lower requirements on track category are.

There are many types of freight wagons for intermodal transport of containers and swap bodies. Most of them has loading platform height about 1 175 mm above top of rail (TOR), what is too much for transportation of MSB on standard railway lines. Only few types of wagons have lowered loading platform and there is limited number of them in operation. These are Sfgmmnss (loading platform height 475 mm above TOR) and Sffggmrrss (loading platform height 825 mm above TOR). Besides these two types, there are only several more with similar parameters. Maximum speed of such wagons for intermodal transport is 120 km/h. But because of fast evolution in intermodal transport during the last years it can be expected growth of numbers of wagons suitable for large size ILUs.

For road transportation of MSB, a special chassis was developed as well as truck with very low height of fifth wheel (only 850 mm). Still the total height of trailed loaded with MSB is few centimetres above permitted 4 metres on the road (fig. 3).

Fig.3. Chassis and truck for MegaSwapBox

The complete set of MSB loaded on trailer is shown in the figure 4:

Fig. 4. MSB TelliBox loaded on trailer set

3. COST / BENEFIT ANALYSIS

The properties of the MegaSwapBox new advanced design are all very desirable. But as usual there are many obstacles to be overcome before the product is ready for operation. So far only the prototype has been made - prototype that required lot of technical skills and innovative and unconventional ideas. However, the final justification of the design will be made by practical use.

To find out in advance whether the new solution will be also economically feasible, value oriented cost-effectiveness estimation has been done within the project. The estimation was done taking into account not only so called "hard factors" such as monetary data (costs and revenues) yet also "soft factors" such as time, quality, flexibility, employee perspectives or organizational environment, that can also be expressed in terms of money.

The evaluation of cost-effectiveness of the MSB (TelliBox) was done in comparison with Megatrailer from a freight forwarder's point of view during a specified time-period (one year). It was supposed that MSB would be made on series production terms.

The evaluation process starts with formation of experts' team, which in case of the projects was guaranteed by the experts from each partner in the project consortium. Then the process go through several steps: Initial situation, Target situation, Collection of actions, Evaluation of investment (where main part is evaluation of costs and benefits) and Creation of implementation plan and finally review of achieved results from the analysis.

The main direct benefit identified within the evaluation was reduction of transport costs (transporting higher volume of goods which ends-up in reduced costs per km).

Another benefit is the special height of 3 meters of the TelliBox. Due to this 3 meters loading height, forwarders are in the position to gain exclusive transport orders – e.g. car body transports, which need more transporting space. However, the monetary benefit of this special loading height is difficult to ascertain.

Further identified advantage of the TelliBox is its high protection against theft. The benefit can be assessed only by comparison of annual losses caused by thefts when magatrailers are used.

Other benefits come from reduction of possible damage of TelliBox comparing with magatrailer during loading. Maintenance costs were also in favour to TelliBox. Megatrailer is fixed on chassis which need to change many components quite frequently (tyres, brakes) but in case of TelliBox it was assumed that only 1/5 of the chassis (most of travel will be on railway or water). However, it should be noted, there are no data on possible damage of the TelliBox itself so rather high uncertainty of these costs still remains.

The maintenance costs for TelliBox are expected especially for door mechanism (locks), which provide function of structural part, thus bearing high loads. Moreover there is high risk of possible deformation or even damage of these mechanisms.

As mentioned in the beginning – the new design is substantially more costly than the conventional ILUs. We cannot publish the estimated acquisition cost (not fixed yet). Additional costs may arise from empty return trips as the TelliBox is especially attractive for specific goods normally transported only in one direction. So optimistic, realistic and pessimistic scenarios should be estimated in this case.

To illustrate the cost and benefit analysis, parts of data tables from the analysis are presented in following:

Benefit aspects:

Box	Benefit Aspect	Probability	Type
TelliBox	3 Meters Loading Height	medium	Difficult to ascertain
TelliBox	Transport on rails Lower transport costs	High	Direct

Cost aspects:

Box	Cost Aspect	Probability	Type
TelliBox	Repair costs Side doors	Medium	Direct
TelliBox	Acquisition costs	High	Direct

Fig.5. Example of Benefit and Cost aspects tables

4. CONCLUSIONS

The TelliBox project finished with a functional prototype and was presented to public in March 2011. The built-in features makes it very attractive for the intermodal transport, but only practice will justify benefits against higher costs for the new large size design.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '12

SMARTSTORE – INNOVATIVE, EFFICIENT AND COSTUMER FRIENDLY LUGGAGE STORING

Bernhard RÜGER [1]
Hans-Christian GRAF [2]

Abstract *– Locking luggage on a railway station is a basic service many passengers want to use. Especially when they try to use their time efficiently, like for shopping, for meetings or for sightseeing luggage often disturbs. Most of today's luggage lockers do not fulfil the needs of modern travellers. The paper gives an overview about all the needs and expectations of passengers regarding to luggage storing on the station and about the benefit for station operators when offering suitable and accepted storing systems.*

Keywords – luggage locking, efficient storing, customers, using time

1. INTRODUCTION

Long distance travellers by train have got much luggage. Depending on the travel purpose the configuration of luggage items looks differently but in an average each passenger has got one piece of luggage and additional every second one hand luggage item.

There are many reasons why offering the possibility of locking luggage at the station is meaningful and required. Business traveller, for example, may lock luggage while having meetings or tourists may use some left time for sightseeing. But one reason which is interesting for both, railway station operators and passengers similarly, is the waiting time at the station until the train is leaving.

Aircraft passengers are used to duty free and shopping areas in order to spend their time till departure. Modern railway stations also mutate more and more into shopping malls offering train passengers the possibility of "using" the time before departure by shopping, eating and drinking etc. The big difference between the offered services on airports and on train stations is that aircraft passengers already have checked in their luggage and are able to go on a shopping tour without being handicapped by their belongings. Train passengers always have to carry their whole luggage what leads to the fact that especially those passengers which are earlier at the station or which have to wait for a connecting train can hardly use all the attractions in the station

Luggage is a big handicap because it's hardly possible to dander with it through the narrow aisles of full shops. Passengers which have no arm left will wait outside of the shops and watch their belongings. Fig. 1 shows an example of countless passengers sitting around and waiting for departure. If passengers had no luggage they could spend their time for shopping this would lead to two advantages: (1) The felt waiting time is much shorter when dandering through shops instead of sitting on a bench in a cold departure hall. The shorter felt time makes the railway more attractive. (2) People dandering through shops will increase the turnover of the shops.

Fig.1. Passengers killing their time when waiting for departure

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These thoughts point up that a very customer-friendly possibility of storing luggage, also for a short term, is necessary and meaningful for the passenger comfort, for the railway undertakings and for the station operators. But today's offered luggage lockers absolutely do not fulfil the requirements of modern travellers. Therefore a study funded by the Austrian Research Promotion Agency (FFG) and the Austrian Federal Ministry of Transport, Innovation and Technology (BMVIT) analyses the basic needs of passengers regarding to locking luggage and will design a concept for a new customer-friendly locker system. This paper focuses on the passengers needs and expectations.

2. PASSENGER NEEDS AND EXPECTATIONS

2.1. Use of waiting time

Depending on the age and the sex of passengers the use of the waiting time differs. For example younger men more often prefer to use the time for working than women or elderly. But in general every fourth passenger prefers going for shopping or dandering through the shops. About one third prefers to sit in a bistro or restaurant to eat something. An additional third prefers sitting in a waiting area or in a lounge (compare figure 2).

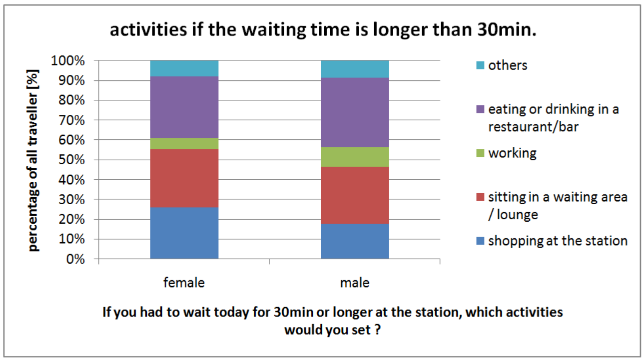

Fig.2. Activities if the waiting time is longer than 30min.

Especially passengers who want to dander or go to a bistro say they feel handicapped by their luggage. In general more than one third of them feel handicapped or very handicapped. But also every fourth passenger who wants to sit in a waiting area or who wants to work feels handicapped because of the luggage (see figure 3).

These numbers are an average over all passengers depending on the planned use of time. The felt difficulties crow by the number, size and weight of luggage items. About 60% of passengers with large and heavy luggage items feel handicapped by the luggage when they want to use the time for shopping or going to a bistro or restaurant. And even 30% of passengers with medium sized luggage do.

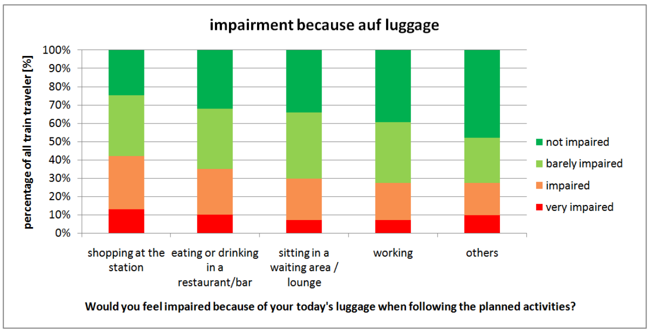

Fig.3. Felt impairments because of luggage while doing different activities

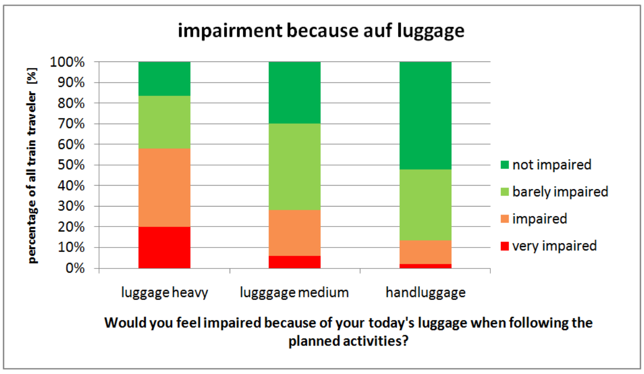

Fig.4. Felt impairments because of luggage

These figures illustrate the large number of potential consumers which want to go for shopping or eating and drinking but can't do that in most cases. This also points out the need and the meaningfulness of short term luggage lockers. But the offered service must be as close to the customer's needs and expectations as possible. What passengers expect under different circumstances will be pointed out below.

2.2. Main problems with usual lockers

Two main problems regarding today's lockers emerge. In general the handling of luggage is often very inconvenient and especially for short term locking the price are relevant parameters of acceptance. There is no system known at railway stations that offers short term locking for free or for a special low price.

2.3. Price

To make short term storing attractive for travellers the price is one of the most important criteria. About 70% of all passengers in general call the price as an essential reason why they don't use a locker. The willingness to pay depends on the duration of storing. About one third of passengers who would like to use a locker for short term storing for easier use of the time at the station does not want to pay for that service, more than one third is willing to pay one euro for one luggage item and hand luggage. Only one quarter is willing to pay more than one euro (see figure 5).

This research results show, if station operators want to have as many shopping passengers as possible short term locking up to two hours should be offered for free. The maximum acceptable amount is one euro. But it must not be forgotten that the inhibition of using the service or not is between paying nothing or pay anything. So even if two third of the asked passengers say they are willing to pay one euro many won't do so in reality.

It seems to be best to offer short term locking for free and calculate with indirect amount. Because many more passengers can go for shopping – and they want to do that – the turnover and the profit will rise.

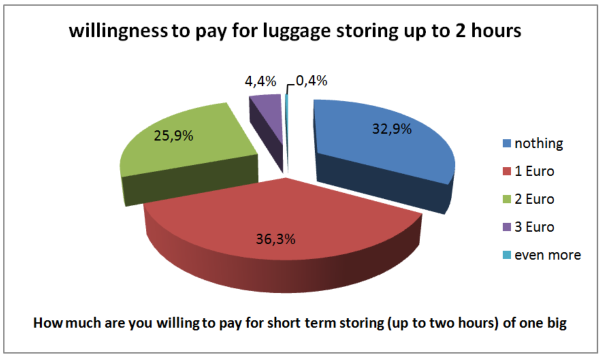

Fig.5. Willingness to pay for short term storage

For a locking-duration of one day passengers are willing to pay more. Only 15% are willing to pay only one euro, one third is willing to pay two euro and an additional third is willing to pay three or four euro. Because the station operator has no immediate benefit like additional shopping passengers a price between two and four euro seems to be acceptably (see figure 6).

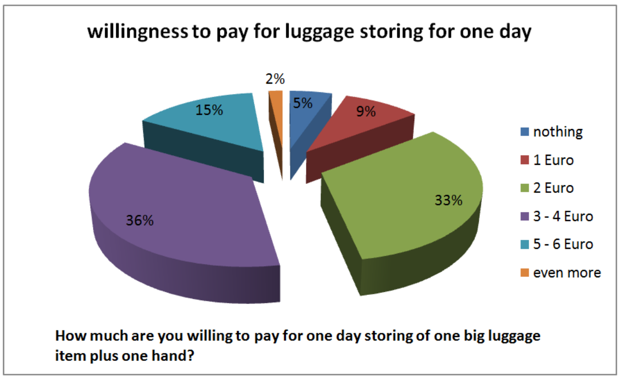

Fig.6. Willingness to pay for one-day storage

But of course passengers who lock the luggage for some hours or a whole day will also come back before departure and maybe will leave the luggage in the locker for doing some shopping in the station until departure.

2.4. Handling

Beside the price the handling of luggage lockers is an essential criteria for acceptance. The handling consists of easy locating, the potential must of lifting up the luggage, the size of lockers, the immediate handling (payment process, central touch screen etc.), the time duration of the locking process and the return of the luggage.

The most important factors are the size of the lockers and the fact whether the luggage must be lifted or not. For short term locking also the time need is essential, especially when passengers want to pick up their luggage in order to go to the train.

2.5. Required lifting of luggage

Depending on the age and the sex travellers have got different difficulties when they must lift luggage. For example about 50% of all female passengers with large luggage are not able or willing to lift it, about 20% are able or willing to lift it up to about one meter and only 30% are able to lift it higher.

For about 70% of all female and 40% of all male traveller storing luggage at floor level is important or very important. Also for 70% of all passengers above the age of 60 this is a must.

Fig.8. Many passengers have troubles when they must lift their luggage

2.6. Time need

The time needed for storing and especially for getting back the luggage is another very important criteria for acceptance. More than 25% of the asked train passengers say the luggage returning must not need longer than one minute, more than 50% accept a time need between one and three minutes (see figure 9). The time need includes the whole process between coming to the locker until getting the luggage and leaving. Especially the subjectively felt time needed when passengers are in a hurry and they are nervous because of the approaching departure of their train is very important. If passengers are in a hurry one minute can be felt as five minutes. For systems that may need a little bit longer – for example central locker terminals – a timer that tells the remaining time in seconds would be very meaning full.

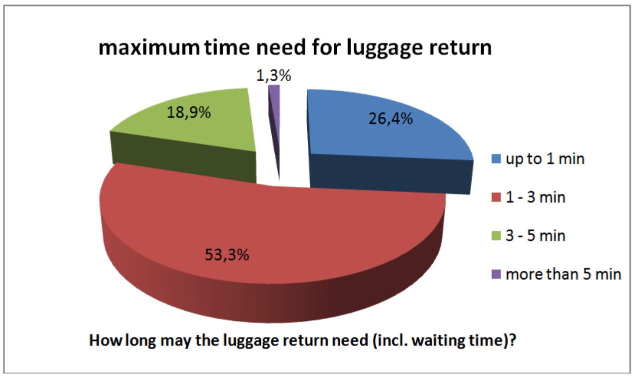

Fig.9. Maximum allowed time need for luggage return

2.7. Luggage size

Many of today's lockers are too small for usual luggage items. The width of many lockers is 33cm but 40% of all luggage items are bigger than this size. That means 40% of luggage items do not fit into normal lockers. Passengers either cannot store it or must use a normally much more expensive locker for huge items.

3. SUMMARY - CONCLUSIONS

About 80% of passengers staying more than 30min at the station think about using a short term locker for easier moving in order to use the station infrastructure like shops or bistros (see figure 10). For half of them the handling must be very quick. One third says they will use it only if no fee is charged. For station operators it may be a very good benefit if they offer short term locking for free. They will get indirect revenue from many more shopping passengers.

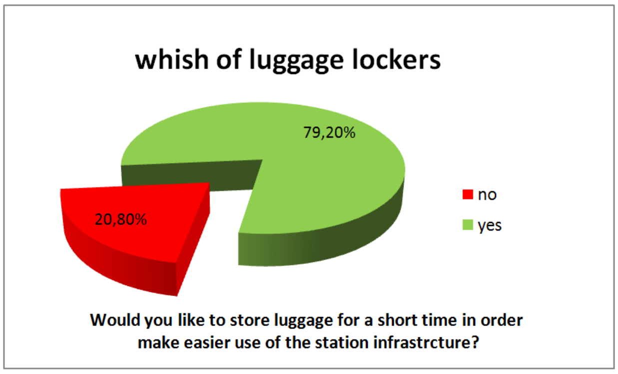

Fig.10. General whish of luggage lockers

Regarding to the acceptance of the system and to passengers comfort, needs and expectations a locker system is required that allows floor level locking or at most a short lifting. The system also must serve the different dimensions of today's luggage!

Therefore many travellers would prefer central locking terminals like in Köln main station (see figure 11). But in this case the handling time is very important.

Fig.11. Central luggage terminal in Köln

In order to fulfil all the different customer's needs an Austrian project consortium consisting of the partners Upper Austria University of Applied Sciences, the St.Pölten University of Applied Sciences and the consulter netwiss GesmbH develop a completely new locking system that allows very customer friendly locking and which will be very efficient for the operators.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '12

FUNDING OF RAILWAY CONSTRUCTION IN BULGARIA AND OTHER BALKAN COUNTRIES UNTIL WORLD WAR I

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Abstract *– The paper presents the different ways of funding the railway construction in the Balkan countries at the end of 19th and the beginning of the 20th centuries. The comparison is made on the basis of Bulgarian experience of taking loans from foreign banks to implement infrastructure projects. For the newly reestablished state it was the only possibility to build a national railway system as state-owned enterprise. It was a costly business but the politicians considered it a prerequisite of great importance for future economic prosperity and social modernization. In most cases the conditions of loan provision were unfavourable and created risks of economic and political influences. However, the railway development in the Balkan region was mostly supported by using credits from international banks, which themselves preferred to invest in public property because the return of funds was guaranteed with railway infrastructure already built or to be further completed. On the other hand, making loans created a lot of difficulties for the underdeveloped countries in the Balkans where rail transport could not utilize its whole capacity due to lack of goods provided by actively functioning national economies.*

Keywords - Rail construction, international loans, Balkan countriest.

1. INTRODUCTION

The railway expansion in the second half of 19th century covered all Europe. The infrastructure projects in the developed countries were funded mainly by private companies except for Belgium where the government took up the construction of railways as a task of national priority. In other regions, due to lack of capital resources and technical experience, to build railways was possible only by foreign investments (loans). That referred to both European periphery (the countries, which were late with the industrial revolution) and the Balkans, which mostly had belonged to the Ottoman or Habsburg Empires.

In comparison to the British "mania" (mid 19th century), the "railway fever" in South-East Europe at the end of the 19th century differed by motivation and performance. The driving force was not the expected profits but the overestimation of railways as a factor for economic growth, a tool to get nearer to modern West Europe and show-off of national pride. The railways were considered to be a symbol of independence, which the different Balkan countries won in a time span of nearly 50 years (1932-1978).

The investment needs in railway construction stimulated the competition of the Great Powers to take advantage on the oriental railway markets Moreover it was also an opportunity for political influence.

Supported by the British lobby in Istanbul, the company of Barkley brothers and Co (included a powerful financial group in London) managed to take concessions for the first railway lines in the Ottoman Empire: Cernavodă-Constanţa line, nowadays in Romania (1960); Rousse-Varna, nowadays in Bulgaria (1866) and Bucharest–Giurgiu line in Romania (1869). Soon it was overrun by the Orient Railway Company (CO), which spread its influence almost on the whole peninsula. It operated with international capitals but was known with the name of Baron Hirsch who was empowered with the right to build and operate railways on the European territories of the empire.

2. FINANCIAL ASPECTS OF "RAILWAY PROBLEM" IN BULGARIA

The "Railway problem" in Bulgaria appeared due to the Berlin Treaty (1878). It included two clauses

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related to railways: the obligation to pay back the debt of the Ottoman government to the Barclays Brothers Company for the Rousse-Varna line and the common task with Austro-Hungary, Ottoman Empire and Serbia to complete the Istanbul-Vienna line with "connecting" sections on the territory of each country.

2.1. Paying back to Barclay Brothers

Because of the lack of money and the high price determined by the seller, the solution of this problem was prolonged for 10 yeas. It was at the end of 1885 when the Bulgarian Parliament voted for payment of the debt but for political reasons the transaction was finalized in 1888. Bulgaria paid three times as much as its annual budget for 224 km of track, at that of poor condition. To accomplish this obligation, the government of Bulgaria took its first international loan lent by English banks.

However, the Berlin Treaty did not include a clause to pay back for the rail line from Belovo to the Turkish border as at that time the track lay in Eastern Rumelia (an autonomous district within the Ottoman Empire). Despite the efforts to transfer its property after the region was united to the Principality of Bulgaria (1885), an opportunity for that appeared after the proclamation of Independence of Bulgaria in 1908. At first the government declared it would not pay for the line but the commercial embargo of the Great Powers made it start negotiations with both Turkey and the Orient Railways Company. In 1909 the track was joined to the national railways thanks to the successful mediation of Russia, which gave a loan to Bulgaria under very favourable conditions for a 75-year period of return. In fact this debt was condoned by the Soviet government much earlier, in 1922.

2.2. Public property of railways in Bulgaria and infrastructure projects

Despite the Parliament voted for the Over-Danube railway being the first project in Bulgaria, the Berlin Treaty and the consequently adopted Convention of the four countries imposed the necessity to start the "connecting" section of the Istanbul-Vienna line earlier than any other construction plan.

The "Conférence à Quatre" could be considered a failure for Bulgaria because it could not preserve the old Baron Hirsch's route, passing through Kyustendil and Skopje as the most favourable for the country. On the other hand, it won an important victory overthrowing the validity of the contract with the Orient Railways Co. on its territory.

The majority of Bulgarian politicians wanted railways to be public property, so that the government could fund, built and operate them in favour of the whole society. The negative examples of a private management were just in the neighbourhood: Baron Hirsch policy for making profits at all costs as well as the difficulties experienced by the Serbian Kingdom in track construction. The use of railways for public welfare was one of priority significance to choose state management fixed in the Rail Roads Bill of 31 January 1885. Another reason was of economic nature: there were no private capitals capable to run such an expensive business. Last but not least, it was more likely for the foreign banks to give loans to a government rather than an individual entrepreneur.

The law voted immediately after Rail Roads Bill was for building Vakarel-Tsaribrod "connecting" section. The works were funded by the Bulgarian National Bank and carried out by the Bulgarian entrepreneur Ivan Grozev. Although completed in 1886, the track was set in operation in August 1888 due to political events known in Diplomatic History as "The Bulgarian crisis (1886-1887)". The newly-opened rail administration for this line and the one for operation of Rousse-Varna line existed separately for a certain period of time. Nevertheless, it is 1888 to be accepted as the birth year of the state-owned Bulgarian State Railways (BDZ) company.

The success with the "connecting section" encouraged the Bulgarian government to build a line between Yambol (the end station of the deviation from Istanbul-Vienna line) to the Black Sear port of Bourgas. The construction was finished with participation of the Army (Engineering Troops) and the local population, which showed the limited possibilities of internal funding through the state budget. Further, for a period of 25 years until the World War I, the railways projects in Bulgaria were almost entirely funded by international loans both general and specially borrowed on the purpose of railway construction.

3. FUNDING OF RAIL CONSTRUCTION IN THE BALKAN COUNTRIES

3.1. Bulgaria

The first loan for railway construction in Bulgaria was given by Lander Bank in Vienna in 1889. The line to be used for was informally called "Parallel" (to the line Belovo-Turkish border operated by the Orient Railways Company) and its aim was to transfer traffic to BDZ and respectively the port of Bourgas. That "secret" goal was soon revealed by Baron Hirsch and then the bank where he was a shareholder not only stopped the expected options but also demanded back the ones previously given. The only possibility for the government was to suggest a new consolidated loan but it caused sharp political collisions in the Parliament. The ministers were accused for bribing and fraud and finally resigned leaving the country in both political and financial crises.

Although the decision to borrow a new loan was voted after long debates, Bulgaria did not take the money. The reason was that the High Porte did not ratify the contract as required according to the country's status of vassal principality. Furthermore, the government had to give the completed Nova Zagora-Chirpan section of the "Parallel" line to Baron Hirsch's company. That was considered not only a shameful act against the law of railways as state property, but also a severe blow to Bulgarian national dignity. People protested in various ways but nothing changed. The lack of funds ceased railway construction in Bulgaria for several years.

Just after a few years the Bulgarian governed was made again to perform according to the will of those who it took money from. In 1904 the Bank of Paris and the Netherlands forced the country to choose the most unfavourable route for the Cross-Balkan railway line. The reason was that it passed near the coal-mining enterprise of the Belgian concessionaire De Sear who was close to that bank.

3.2. Greece

The history of Greek railways began in 1869, when the Athens-Piraeus line was completed. It took 22 years from the appearance of the idea (1835) to the first contract and four different companies, which in the next twelve years laid 8.8 km of track. One of the reasons could be the sequence of defaults on Greek external sovereign debt obligations in 1843 and 1860.

More than a decade passed until the government decided to sign four contracts on standard-gauge railway construction (1881) with the intention of making Greece a pivotal point on the journey between Europe, India and Asia. Next year the newly-appointed prime minister replaced the contracts with four for narrow-gauge track system intended to stimulate the internal growth of Greece. This choice was made for the cheaper initial construction costs but the planned railway system was ready 25 years later including the default on Greek debt in 1894. In 1909 Greece had 1,606 km of railways, including the main standard gauge line to the Greek-Turkish border at Papapouli. However, the main event until the WW1 was that in 1818, the first trains ran the distance of 506 km from Athens to Thessaloniki on standard gauge track entirely on Greek territory.

3.3. Romania

The first railway line on Romania's present-day territory was opened on 20 August 1854 and ran between Oraviţa in Banat and Baziaş, a port on the Danube within the Austrian Empire and was operated by Imperial Royal Privileged Austrian State Railway Company. The second one, as mentioned above was Constanţa–Cernavodă within the Ottoman Empire.

It was so close to the territory of the Romanian Kingdom to make it understandable why in September 1865 the King assigned the construction of the Bucharest–Giurgiu line to the Barclay Broders Co.

A year later the Romanian Parliament voted for the German Strousberg consortium to build the 915-km line from Vârciorova in the south to Roman in the north and connecting the main Romanian cities. Another German establishment, "Offenheim Consortium", was chosen as a contractor for several shorter railways of a total length of 224 km in the region of Moldavia (1868).

Soon after the opening of the final stage on the Vârciorova-Roman line in 1878, its ownership was transferred from the private administration to state one, CFR (Căile Ferate Române). Due to the poor management by the Offenheim Consortium, the lines in Moldovia were also placed under the structure of CFR (1889). Thus the Romanian state became the owner of the railway system with a total length of 1,377 km.

3.4. Serbia

Due to political reasons, Baron Hirsch's projects did not pass through the territory of Serbia. Its railway expansion began after the Berlin Congress (1878), which declared the country as an independent kingdom. In return to Austro-Hungarian support the Serbian government signed a convention to build the railway lines from Belgrade to Vranje and Turkish and Bulgarian borders in three years.

Exhausted by the war, Serbia went into economic recession and in April 1880 had to sign a new convention with a deadline for the construction of three years or 15 June 1883. The tender proclaimed by the Government was won by the French association from Paris – "General Union" but after only a year it went bankrupt. The construction of the Belgrade-Nis-Vranje line was assigned to a group of French and German banks led by "Comptoir d'Escompte de Paris", which established Compagnie de Construction et d'Exploitation des Chemins de fer de l'Etat Serbe. The change resulted in delay of 15 months and the first formal train from Belgrad to Nis ran on 23rd of August 1884. The regular traffic was opened on 3rd September, 1884.

Although King Milan I declared the foundation of the Serbian National Railways in 1881, they took the state-owned operation 8 years later when the government paid property of the Compagnie de Construction et d'Exploitation des Chemins de fer de l'Etat Serbe. The further construction of railways in Serbia was funded with international loans borrowed from different European banks.

3.5. Ottoman Empire (Turkey)

Despite the changes, Baron Hirsch preserved for his enterprises most of the works on the Ottoman territory. The junction line between Skopje and Nis was completed on 25 May 1888, so the Thessaloniki line was connected to rest of the network.

Upon the completion of the railway, Hirsh decided to retire after nearly twenty years of railway buildings in the Balkans. In 1889 he repaid 60 millions francs to the Ottomans an in April 1890 sold the shares of the company to a group of German banks led by the Deutsche Bank. The latter viewed the Company of Orient Railways as a strategic acquisition towards its goal to build the Baghdad Railway. The ownership of CO was transferred to the subsidiary of the Deutsche Bank: the Bank für Orientalische Eisenbahnen headquartered in Zürich.

In general, the Ottoman Empire used widely concessions to private railways companies financed by foreign capital. The Government sponsored only a few projects for strategic reasons and the rest were implemented for business purpose and in interest of the Great Powers.

4. CONCLUSIONS

The history of the Balkans railways has shown that the track construction in all countries until the World War I was implemented mainly with funding by international loans. The return of money was usually guaranteed by the governments with infrastructure already built or to be completed during the repayment period. In many cases, the credit conditions were influenced either by individual interests or political strategy of the creditor countries. On the other hand, the decision whether to borrow and where to borrow from often caused sharp contradictions and long parliamentary debates.

Despite the adverse consequences of international crediting, for the undeveloped Balkan countries at the end of the 19^{th} century and the beginning of the 20^{th} century it was the only way to build railway systems of their own. The problem was that the investments in transport infrastructure did not comply with the overall economic state of the region thus being unable to contribute to loan repaying with the revenues from their operation. Some historians are even much more extreme in their opinion stating that direct investments in industry would have been more effective for the national economies in the pre-war period.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '12

THE POSSIBILITY OF FUZZY LOGIC USE IN THE MODELING OF TRAIN MOVEMENT PROCESS

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Abstract *– Train movement is an extremely complex process that is influenced by many exploitation factors of stochastic character with nonlinear and time changeable dependences. Fuzzy logic is often used for the modeling of complex processes in which it is very difficult to determine the dependences that exist between certain variables using other methods. This paper points out the conveniences and it describes the possibilities of fuzzy logic use in the modeling of train movement process by formulating the suitable fuzzy control models.*

Keywords - fuzzy logic, train movement, modeling, control.

1. INTRODUCTION

The functioning and productivity of railway traffic greatly depend on conditions and velocity of trains. The movement of trains is an extremely complex process that is influenced by many factors. The characteristics and performances of train movement process can drastically vary depending on: working regime (acceleration, constant velocity driving, start-up driving and braking), the elements of railway line layout (curves, tunnels, gradients, etc.), condition of track superstructure, weather conditions, geometry and mutual influence of wheel-rail system, train mass and the disposition of masses in it, types of coaches and locomotives, driver's competence, etc. The rationality of vehicle-track system implies the harmonizing of track and vehicle characteristics in order to get a comfortable, economical, safe and fast transportation as a final goal.

The modeling of train movement process represents a complex problem because of the influence of a great number of stohastic exploitation factors with nonlinear and time changeable dependences. Fuzzy logic is often used for complex process modeling in case it is very difficult to determine dependences existing between some variables using other methods. Fuzzy logic provides many advantages having in mind that fuzzy control models are designed using fuzzy lingvistic IF-THEN rules, based on expert knowledge and specific numeric data without the existence of a suitable mathematical model. Fuzzy controllers have found their use and proved to be effective in many branches of engineering [7]. This paper points out the conveniences and it describes the possibilities of fuzzy logic use in the modeling of train movement process.

2. FUZZY CONTROL

Fuzzy logic is based on the fuzzy set theory [8]. It represents the extension of conventional logic developed to enable work on the accurate values existing between limit values "true" and "false".

If $X=\{x_1, x_2, \ldots, x_n\}$, then fuzzy set A in universal set X is defined as a set of the ordered pairs:

$$A=\{(x,\mu_A(x)) \mid x \in X\} \tag{1}$$

where $\mu_A(x)$ is the membership function of element x in set A, $\forall x \in X$. The degree of membership defines the membership measure of elements in a set. In the classic theory of sets the degree of membership can be:

$$\mu_A(x)=\begin{cases} 1, & x \in A \\ 0, & x \notin A \end{cases} \tag{2}$$

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while in fuzzy sets theory it can take any value from the closed interval [0,1]. If the degree of membership is higher, then it is more likely that element x belongs to set A. Fuzzy set A is described as:

$$A = \begin{cases} \sum_{x_i \in X} \frac{\mu_A(x_i)}{x_i}, & \text{if X is discrete} \\ \int_X \frac{\mu_A(x)}{x}, & \text{if X is continuous} \end{cases} \quad (3)$$

The shape of the membership function may be different. Among linear the triangular and trapezoidal membership functions are often used and among nonlinear Gaussian and Bell membership functions [4].

Fuzzy logic systems are nonlinear systems capable of inferring complex nonlinear relationships between input and output variables [6]. Basically, a fuzzy control system or a controller should be considered as an artificial decision maker that operates in a feedback system in real time. It "collects" data from the output of process *y(t)*, compares it to referent *r(t)* and "decides" on what should be the input of process *u(t)* at that moment in order to fulfill the desired performances and given specification goals.

Fuzzy controller (fig. 1.) consists of four basic elements:

- the fuzzifier;
- fuzzy rule base;
- inference engine;
- defuzzifier.

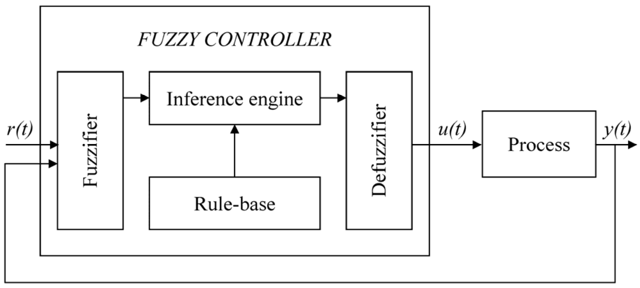

Fig.1. Fuzzy control system

The fuzzy rule base has "knowledge" of the controller in the form of determination rules defined by expert in combination with certain numeric data. It is a collection of heuristic rules of the form:

IF (situation) THEN (action),

which are combined in the inference engine to produce a fuzzy output. The inference engine estimates which control rules are relevant in a certain moment and decides on how the controller output should be. In essence, the inference engine produces mappings from fuzzy sets to fuzzy sets. In most practical engineering applications, minimun inference or product inference for inferential procedure is used. The fuzzifier converts the real inputs into fuzzy sets, which are subsequently used as inputs to the inference engine, whereas the defuzzifier converts the fuzzy sets produced by the inference engine into real outputs. During defuzzification, one (representative) value is chosen for the output variable.

With the help of fuzzy logic that enables a great number of operators, many different copies can be produced to fuzzy controllers. Basically, the designing of fuzzy logic systems can be viewed as approximating a function.

3. TRAIN MOVEMENT EQUATION

The practical problems connected with traction and braking process that are mostly related to defining the train weight, velocity, maximum acceleration, travel time, braking distance, energy consuption etc. can be solved by the train movement equation [5].

The train movement equation is:

$$\frac{dv}{dt} = \frac{F_t - W - F_b}{m_t(1+\rho)} \quad (4)$$

where F_t is the traction force, F_b is braking force, W is resistance force, m_t is train mass, v is train velocity and ρ is rotation mass coefficient. In traction regime $F_b=0$, and in braking regime $F_t=0$.

The mutual relation of traction/braking force and the resistance force defines the type and intensity of train movement that can be:

- an increase in velocity

$$F_t - W > 0 \quad or \quad -(W + F_b) > 0, \quad \frac{dv}{dt} > 0 \quad (5)$$

- constant velocity

$$F_t - W = 0 \quad or \quad -(W + F_b) = 0, \quad \frac{dv}{dt} = 0 \quad (6)$$

- a decrease in velocity

$$F_t - W < 0 \quad or \quad -(W + F_b) < 0, \quad \frac{dv}{dt} < 0 \quad (7)$$

Driving under the influence of inertia force (start-up driving) leaves out the traction and braking force so $F_t=0$ and $F_b=0$.

4. THE CONTROL OF TRAIN TRACTION AND BRAKING PROCESS

In essence, the process of train movement is characterized by [2]:

- the period of acceleration - t_a;
- period of constant velocity driving - t_c;
- period of start-up driving - t_i;
- period of braking - t_b.

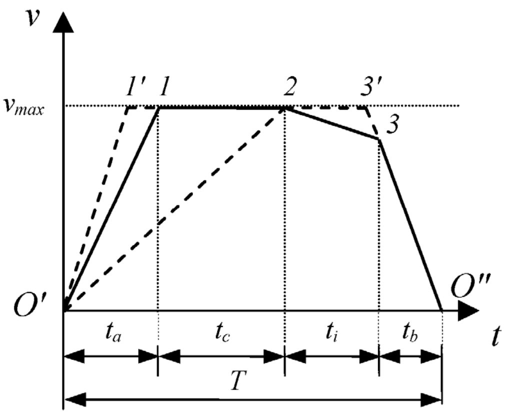

Fig.2. Simplified diagram v=f(t)

The way of train movement on a certain section, that is between two consecutive stops, influences the form of train velocity depending on time (fig. 2.). At higher acceleration the part *O'-1* has a bigger slope and it transforms into *O'-1'*. The smallest value of acceleration part is *O'-2*, where constant velocity driving is left out. Driving on the observed section can be done even without the period of start-up driving, by prolonging the constant velocity driving period *2-3'* and the immediate transition from the phase of active traction into braking *3'-O''*. The total travel time is:

$$T = t_a + t_c + t_i + t_b \qquad (8)$$

With the change of influencing factors, above all train mass, slope of the railway line and velocity, the value of resistance force is changing so it is necessary to adjust the value of traction, that is braking force in order to get the desired train velocity.

The control of train movement process can be realized using a fuzzy controller that has input variables Δv, that represent the difference between the target v_{tg} and current v_{curr} train velocity:

$$\Delta v = v_{tg} - v_{curr} \qquad (9)$$

and the value of acceleration a, while the output variable represents the change of traction ΔF_t, that is braking ΔF_b force depending on the regime of traction or braking. The suggested sets of the linguistic values of input and output variables are: negative big (NB), negative medium (NM), negative small (NS), neutral (NE), positive small (PS), positive medium (PM) and positive big (PB), described by the suitable membership functions.

Based on the fuzzy rule base the control strategy between input and output variables is described by which the modeling of the system is done. Two fuzzy rule bases were formed, for the traction regime (table 1.) and braking regime (table 2.). One of the typical rules in one of the rule bases reads:

IF Δv is *positive big*
and a is *positive big*
THEN ΔF_t is *positive medium*

Table 1. Fuzzy rule base in traction regime

ΔF_t		Δv		
		PB	*PM*	*PS*
a	*PB*	PM	PS	NE
	PM	PM	PM	PS
	PS	PB	PM	PS
	NE	PB	PM	PS
	NS	PM	PS	PS
	NM	PM	PM	PS
	NB	PB	PM	PS

Table 2. Fuzzy rule base in braking regime

ΔF_b		Δv		
		NS	*NM*	*NB*
a	*PB*	PS	PM	PB
	PM	PS	PM	PM
	PS	PS	PS	PM
	NE	PS	PM	PB
	NS	PS	PM	PB
	NM	PS	PM	PM
	NB	NE	PS	PM

Besides that, if Δv is *NE*, then ΔF_t is *NE* that is ΔF_b is *NE*.

The created fuzzy rules will define the nonlinear functions of the system:

$$f_t : (\Delta v, a) \rightarrow \Delta F_t \qquad (10)$$

$$f_b : (\Delta v, a) \rightarrow \Delta F_b \qquad (11)$$

A *max-min* composition can be used for the inference procedure and a center of gravity of the resulting fuzzy set for the choice of numeric value of the output variable.

5. ADHESION MODELS

The realization of traction and braking force high values appears as one of the basic demands for railway exploitation, and the restricting factor on which their realization depends is the adhesion force. The maximum value of the adhesion force F_a and by that also the traction and braking force is reached for the specific value of skidding ratio [1].

The adhesion characteristic (fig. 3.) is of highly stochastic character, time changing, nonlinear, and dependent on many factors from which the most important ones are the train velocity and friction conditions in wheel-rail contact zone.

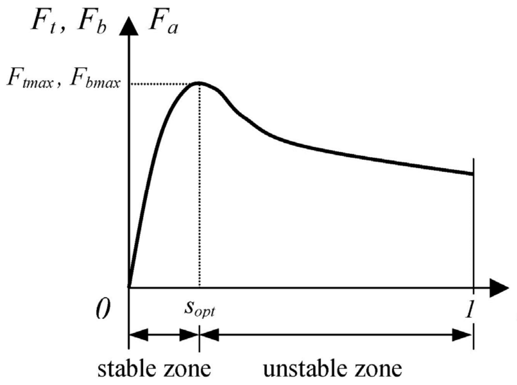

Fig.3. Adhesion characteristic

The skidding ratio in the traction regime is defined as:

$$s = \frac{v_s}{r_w \omega} = \frac{r_w \omega - v_o}{r_w \omega} = 1 - \frac{v_o}{r_w \omega} \quad (12)$$

and in the braking regime:

$$s = \frac{v_s}{v_o} = \frac{v_o - r_w \omega}{v_o} = 1 - \frac{r_w \omega}{v_o} \quad (13)$$

where v_s is the skidding velocity, v_0 is linear velocity of the wheel centre, ω is angular velocity of the wheel and r_w is radius of the wheel. It can range from 0, for the theoretical rolling of the wheel on the rail without skidding ($v_o=r_w\omega$), to 1 when it comes to the complete skidding of the wheels ($v_o<<r_w\omega$) in traction regime, that is locking of wheels ($v_o>>r_w\omega$) in braking regime.

The adhesion models are based on finding the skidding value according to which the maximum value of traction, that is braking force that can be realized in accordance with the adhesion conditions is achieved. Skidding control aims to maintain the operating point in a stable zone as close to the optimal spot on the peak of the adhesion curve as possible because that is how the maximum use of adhesion is achieved.

The analysis of traction/braking force change and skidding ratio change in a certain time interval indicates that the distance between the immediate and optimal value of skidding ratio can be concluded, i.e. traction/braking force that can be realized under conditions for adhesion, with the fact that in the stable zone the changes have the same sign and in the unstable zone a different one. The skidding control is done by regulating the traction/braking torque because if the immediate value of skidding ratio is in the unstable zone of adhesion curve, it is necessary to lower the value of traction/braking torque quickly. On the other hand, if the immediate value of skidding ratio is in the stable zone, then there is a possibility of increasing the traction/braking torque values.

Having in mind that the adhesion curve form and the position of extemum are unknown and stochastically changeable in time, fuzzy logic appears as a suitable tool for solving the above optimization problem [3]. The control strategy is defined by the set of IF-THEN rules based on the value of traction/braking force and skidding ratio change. The fuzzy controller task is to regulate the skidding value and by that also the value of traction/braking force by maximizing its value that can be realized in accordance with the conditions of adhesion.

6. CONCLUSIONS

Because of the extremely stochastic character of the train movement process and the influence of a great number of exploitation factors the fuzzy logic represents a suitable method that can be used for train movement modeling process in the sense of forming the suitable control models.

Traction and braking force can be managed using fuzzy controllers by regulating the power unit, that is the braking system of train and by adjusting their values with the parameters of railway line and the desired velocity.

Besides that, with adhesion models it is possible to achieve the maximum values of traction and braking force that can be realized in accordance with the conditions of adhesion by fuzzy logic as an optimization technique.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '12

CONTAINER TERMINAL DEVELOPMENT CASE OF FREE ZONE "PIROT"

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Vojislav TOMIĆ [3]

Abstract *– The paper puts focus onto the procedure of technological design of a container railway-highway terminal in the free zone "PIROT". Different variants of determining the storage surface as well as the choice of versatile mechanization are given for the four phases of its development. Creating such a terminal is of crucial importance for the development of economy of Pirot and surrounding regions. The aspects such as the location of the free zone next to the corridor X, modernized railway and the future highway E80 are supposed to introduce this terminal into the international transport network and, thus, improve the chances of the city of Pirot in the global economy in the decade to come.*

Keywords – container transport, terminals, reailway, container mechanization.

1. INTRODUCTION

Containerization is a system of freight transport based on a range of steel intermodal containers, built to standardized dimensions (ISO containers). This system of transport leads to greatly reduced transport costs and rationally fitted transport according to the "door to door" principle compared to the classical "piece by piece" transport with unfitted realization phases [1, 2, 3].

A special role within the infrastructure of this mode of modern transport is given to container terminals. They are important nodes of transport networks, where different transport carriers meet, and where loading, occasional warehousing and unloading of containers take place. They link several modes of transport: highway, rail, sea and air transport. They are equipped with mechanization for loading, unloading and transport of containers, and also a storage surface depending on the terminal capacity [4, 5, 6].

Container terminal is complex, serviceable, dynamic and material system defined by its own performances: objectives, functions, components and links. Basic terminal functions are flexibility and efficiency of container loading, warehousing, forming of the units and disbanding of containers, shaping and controlling of load, as well as connecting local and distant transport [7, 8, 9].

In this paper, the process of technological design of a container terminal in free zone "PIROT" is illustrated [10, 11, 12].

2. FREE ZONE PIROT

Free zone is a designated area, in which economic activities are encouraged by guaranteed facilities and benefits as well as favorable regulations defined by national laws and international legal documents. The objective of free zones is to attract investments, thus enabling regional development, providing new jobs, concentration of services and needs by means of logistics centers, business savings and canalization of international marketing. The free zones aim at an accelerated industrial development and increase in the employment rate [10].

Free zones are institutions with a long tradition and an important role in the development of national industries and new projects worldwide. The idea of free zones is as old as the civilization itself. Nowadays, there are over 10000 free zones in 102 countries [10]. In Serbia there were 14 free zones until 2006 and there are 7 functional free zones today (Subotica, Novi Sad, Zrenjanin, Šabac, Kragujevac, Užice and Pirot), and those in Apatin, Smederevo and Niš, are in preparation.

The free zone Pirot is situated in the Eastern Serbia, oriented toward Middle-East, on the international highway E-80, corridor X (Fig. 1), and has about 17 hectares of total area with a developed infrastructure and with a possibility of extending it up to 50 hectares

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(Fig. 2). It began to work in April 1998, with "Tigar" corporation as the very first customer. The main program in the free zone is warehousing of passenger vehicle tires and truck tires, whereby the main investments are provided by Michelin (France) and Tigar (Serbia). Today the list of customers of the free zone includes over 200 companies from the country and abroad [10, 12].

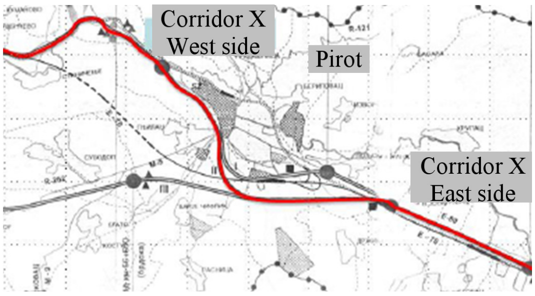

Fig.1. The city of Pirot and corridor X

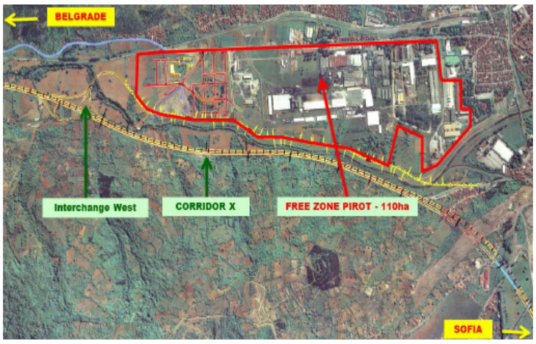

Fig.2. Layout of free zone Pirot

An analysis of the free zone's infrastructures, provided in this paper, discovers certain drawbacks within the logistics of raw-material supply and distribution of final products. The drawbacks are related to the systems of warehousing and transport, and they include: the lack of warehouse capacity, insufficient technical support, outdated mechanization and IT technology, etc. [10, 11].

As a solution to the problem, the paper proposes development of a modern logistic center that would integrate the functioning of the free zone Pirot [11]. Special attention is given to the concept solutions and technological design of the container terminal [12].

3. CONTAINER TERMINAL DEVELOPMENT IN FREE ZONE PIROT

The project of building a container terminal on the territory of free zone Pirot implies technological and structural upgrade of the existing terminal with the aim of: less expensive transport, shorter transportation time, accessibility of the free zone to other customer by offering additional services, integration of the region into the network of container terminals, optimization of logistic supply chain, environment protection, development of multimodal transport, etc.

Demand for transport services on the corridor X is evident. Free zone Pirot has an annual throughput of 6000 trucks, 1000 containers and approximately 1000 rail wagons [11, 12]. Based on the feasibility study of the logistic center Pirot, Fig. 3 depicts the predicted number of trucks and containers per year in 5-year phases in the period from 2012 to 2027, which will be served by container terminal in Pirot [12]. The number of trucks is in the diagram depicted by column 1, while column 2 depicts the number of containers and column 3 only the containers belonging to Tigar. A significant increase of 1000 up to 1500 [FEU/year] is predicted together with the increase in services to customers other than Tigar. The denotation FEU stands here for Forty-foot Equivalent Unit (container 40 ft).

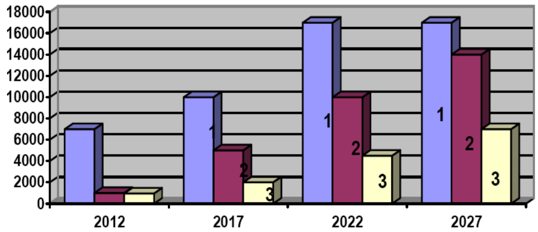

Fig.3. The predicted number of trucks and containers

The future highway-railway container terminal is supposed to be in the vicinity of the existing transshipment station of the free zone Pirot and should be situated so that the capacity increase is always possible. That will be the location of unloading the containers off trucks and trains onto the storage surface and vice versa, transshipment of containers between trucks and trains, sorting containers on the storage surface, forming of the units and disbanding of containers, etc. The main elements of such a terminal are: the terminal building, railway and parking for trucks, storage surface, container transshipment station, handling mechanization and additional equipment.

The terminal capacity, necessary handling equipment and storage surface have been considered in several variants for the 4 development phases that involve traffic of 1000, 5000, 10000 and 15000 containers per year (column 2 in Fig. 3). The development variants over the 4 phases are reflected in the applied transshipment mechanization. The considered variants are:

1. and 2. development phase – 1000 and 5000 containers:

1. variant with Front Lift Tractor (FLT),
2. variant with Side Loader (SL),
3. variant with Reach Stacker (RS).

3. and 4. development phase – 10000 and 15000 containers:

1. variant: a combination of Straddle Carrier (SC) and Rail Mounted Gantry Crane (RMG),
2. variant: a combination of Straddle Carrier (SC^B) and Rail Mounted Gantry Crane (RMG),
3. variant: a combination of Reach Stacker (RS) and Rail Mounted Gantry Crane (RMG).

For the aforementioned variants of container terminal developments according to different phases, the dimensions of the storage surface and the required handling equipment have been determined. The surface needed for storing and sorting the containers in blocks, P_{sk} [m^2], is given as [5]:

$$P_{sk} = C_t \cdot P_{FEU} \cdot \frac{1}{\beta} \cdot \frac{1}{1-k} = C \cdot \frac{t}{365} \cdot P_{FEU} \cdot \frac{1}{\beta} \cdot \frac{1}{1-k}, \quad (1)$$

where:

$C_t = C \cdot t/365$ [FEU] – the needed handling capacity,

C [FEU/year] – the annual container throughput (1000 ÷ 15000),

t [day] – the average storage time per container (5 ÷ 15),

P_{FEU} [m^2/FEU] – the surface per FEU, depending on the applied handling mechanization [5],

$\beta = h_m/h_{max}$ – space usage coefficient, as a ratio of average to maximal height of sorting containers (0.5 ÷ 0.9),

k – the coefficient of surface buffer (0.25 ÷ 0.50).

Upon determining the computational storage surface P_{sk} (1), the following parameters of the terminal storage are to be determined [12]:

$P_{ssk} = L \cdot B$ [m^2] – the real storage surface given as product of length, L, and width, B,

C_{skCON} [con] – the storage capacity, i.e. number of containers,

η – the coefficient of storage surface usage, as a ratio of the base surface of all containers to the terminal storage surface beneath all the containers.

In the computations and analyses, instead of the FEU the smaller standard unit TEU (Twenty-foot equivalent unit) is frequently used.

The number of means of handling mechanization on the terminal depends on the daily container throughput as well as the efficiency, i.e. the realized number of work cycles [8]. This number (n_F) is obtained as follows:

$$n_F = \frac{L_C \cdot K_{UF} \cdot k}{K_F \cdot t_{ef}}, \quad (2)$$

where:

L_C [con/day] – the daily container throughput,

K_{UF} – transshipment factor, which accounts for the number of daily work cycles per container (1 ÷ 4),

k – simultaneity factor, which accounts for possibility of simultaneous transshipment of several containers (here $k = 1$),

K_F [con/h] – efficiency of a mechanization means, determined as: $K_F = 1/T_c(h) = 60/T_c(min)$ [8],

T_c [h , min] – duration of a mechanization means work cycle,

t_{ef} [h, min] – daily effective usage time of a mechanization means.

Tables 1 and 2 represent the obtained computational results for the applied handling mechanization according to the phases of terminal development from 2012 to 2027.

Table 1. Computation variants for the 1st and 2nd phase

Var.		C_t [FEU]	P_{sk} [m^2]	P_{ssk} [m^2]	P_{FEU} [m^2/FEU]	C_{skCON} [con]	η [/]	K_F [con/h]	n_F
FLT	1	41.1	5844	10650	56.3	162	0.350	13	1
	2	206	29292	14200		252			
SL	1	41.1	2390	7275	23	270	0.681	17	1
	2	206	11970	9700		420			
RS	1	41.1	3300	8200	31.8	324	0.300	14	1
	2	206	15040	16072		504			

Table 2. Computation variants for the 3th and 4th phase

Var.		SC, SC^B & RS								RMG	
		C_t [FEU]	P_{sk} [m^2]	P_{ssk} [m^2]	P_{FEU} [m^2/FEU]	C_{skCON} [con]	η [/]	K_F [con/h]	n_F	K_F [con/h]	n_F
(SC & RMG)	3	411	19015	10700	18.32	546	1.760	13	1	14	1
	4	617	28550	16050		858					
(SC^B & RMG)	3	411	22840	10500	22	476	0.927	13	1	14	1
	4	617	34280	15750		748					
(RS & RMG)	3	411	33010	16072	31.8	504	0.300	14	1	14	1
	4	617	49550	20175		748					

Table 1 for the 1st and 2nd phase reveals that the required handling capacity, C_t, increases 5 times, which was expected, whereas the storage space, P_{ssk}, increases only by 33%, and the handling mechanization remains same. Additionally, most adequate for both phases is the 2nd variant with the side loader (SL).

Furthermore, Table 2 for the 3rd and 4th phase of the terminal development leads to similar conclusions, while the best option is the combination of straddle carrier (SC) and rail mounted gantry crane (RMG).

Figs. 4 and 5 depict the design of the most adequate variants according to the development phases modeled by means of software package ArchiCAD.

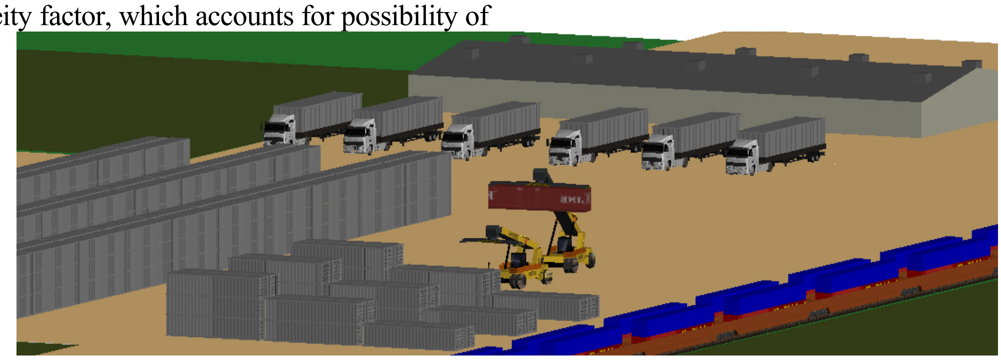

Fig. 4. Terminal layout for the 1st and 2nd development phase

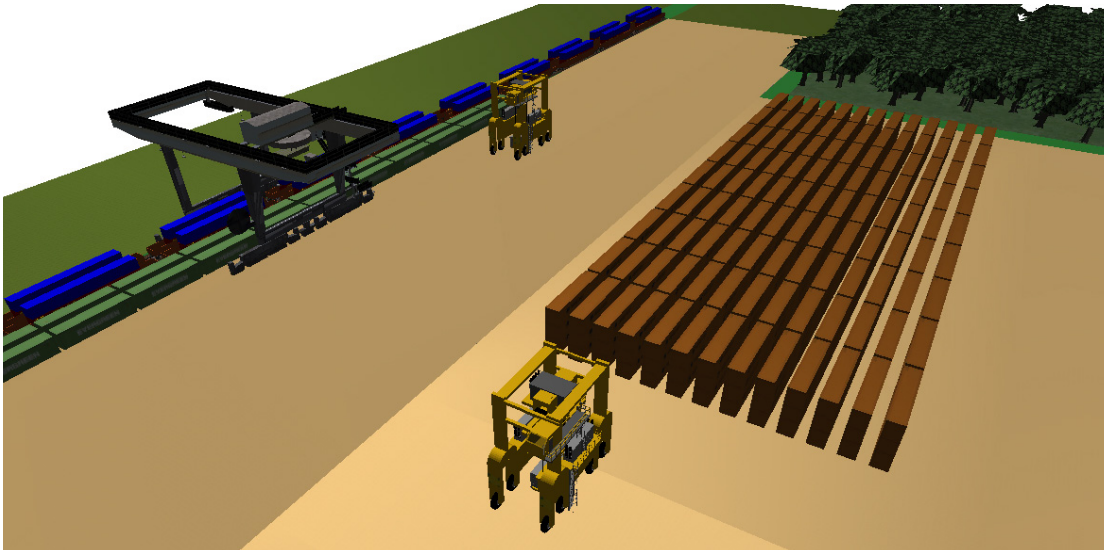

Fig 5. Terminal layout for the 3rd and 4th development phase

4. CONCLUSIONS

The conducted research leads to the following conclusions:

- the container transport plays an important role in the global world economy and manifests a tendency of constant growth,
- container terminals with their infrastructure and handling mechanization represent important nodes of the modern transport networks,
- the storage surface and handling mechanization need to be appropriately dimensioned in order to provide the required surface capacity and equipment efficiency based on the average daily container throughput of the terminal,
- a successful operation of the free zone Pirot requires the development of a modern logistic center with an adequate container terminal,
- modeling the container terminal within the free zone Pirot, according to the development phases and for different choices of handling mechanization, points out the advantages and disadvantages of different variants and enables the choice of the optimal one,
- going from the 1st into the 2nd phase and from the 3rd into the 4th phase, an expansion of the storage surface is needed, while the mechanization remains same, i.e. in the first case those are side loaders (SL) and in the second case the combination of straddle carrier and rail mounted gantry crane (SC & RMG),
- creating a logistic center with an appropriate railway-highway container terminal in Pirot will have a crucial synergic effect and importance onto the economic development of the city, region and even the state.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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RAILWAY TRANSPORT OF 725 MVA POWER TRANSFORMER

Ljubomir LUKIĆ [1]
Mirko ĐAPIĆ [2]

Abstract *– The paper displays the realization of the railway transportation of the biggest step-up transformer, not only in Serbia but in the southern part of Europe, rated 725 MVA, from thermal power plant TENT B in Obrenovac to the ABS Minel Transformatori factory in Ripanj, where the general overhaul of this power transformer is under way. The transportation and manipulation process of power transformers during the overhaul is particularly complex, since it is specified as the railway freight of oversized capital product cargo. Power transformers fall under the category of capital electric energy equipment that have an exploitation period of over 30 years on hydro energy and thermal energy plants or high-voltage substations. Depending on the power and voltage level, the mass of an power transformer can be up to 400t, while the price can reach as much as a million Euros. The overhaul of power transformers of great power is a very specific technological process that is carried out in specially equipped factories.*

Keywords - Railway transportation, manipulation processes, power transformers

1. INTRODUCTION

In March 2010 on thermal power plant TENT B in Obrenovac, there occurred a heavy accident occurred on the step-up transformer of French producer CEM, type TR – 9208, No. H26602, 410/21 kV, 1020/19930 A, 725 MVA, connection group Yn, d5 and 490 tons in total weight. The weight of the transformer oil is 90 tons, and the transport weight is around 360 tons. This step-up transformer has been in exploitation since 1983 (figure 1), when thermal power plant TENT B with two 620 MW power units was let into operation. This is one of the biggest power transformers in the Balkans, transforming an eighth of the total electric energy produced in the Republic of Serbia.

There is a special transformer box on energy units in which are placed step-up transformers and in that place they are connected to the generating power unit and high-voltage electrical grid. Because of transportation and manipulation processes, the transformer box is equipped with a dual-gauge railway of the appropriate bearing, - an appropriate, permitted axial pressure, for dragging the transformer in both directions from the place of unloading on the facility to the place of installation (figure 2). The railway track from the transformer box intersects with the transportation gauge where the places of loading and unloading are projected, as is the position of the power transformer. The transportation gauge is connected to the railways system of Serbia, so the transformer can be transported to a factory for repairs.

Fig.1 Step-up transformer CEM 725 MVA (preparation for transport)

Given its large mass, the step-up transformer is moved along transportation gauges with the tensioner pulley, driver train or is compressed with hydraulic compressors to the place where the transportation gauges intersect the gauge of the transformer box. In

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that place the transformer is with hydraulic cranes lifted, the wheel carts turn by 90° and the transformer is lowered and moved sideways to the place of functional operation.

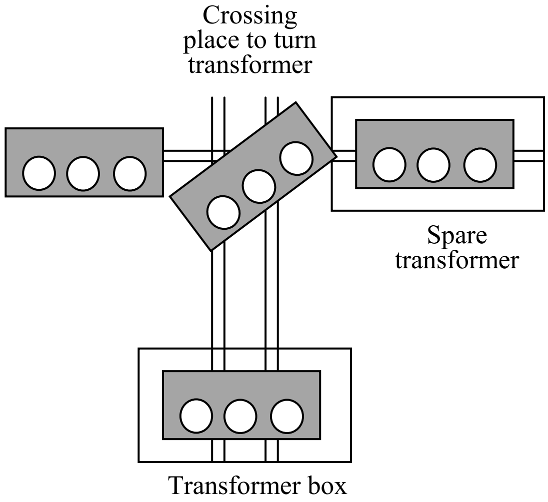

Fig. 2. Transportation system of the power transformer in the electric energy facility

Depending on whether the front or back carts turn at the junction, transport can be carried out so that the HV insulation side is on the left or right against the direction of movement. It's very important to have in mind the position of the HV insulator against the direction of movement during transportation, because of the placement of the transformer box towards the power unit and the correct position of the transformer at the place of unloading.

2. RAILWAY TRANSPORT OF A 725 MVA STEP-UP TRANSFORMER

The value of a 725 MVA step-up transformer is around EUR 5 mn and its rail transport from the transformer box in thermal power plant TENT B in Obrenovac to the ABS Minel Transformatori factory in Ripanj (where the overhaul is being performed) costs around EUR 300.000. All the power transformer factories in the world are built on locations with good possibilities for rail or water transport, so lower transportation costs would enable competitive prices for the clients. Transformers of lower rates are transported via road on trucks with trailers for oversized cargo, on distances where there are no possibilities for railway transport. Given that the 725 MVA step-up transformer from Obrenovac could be transported via rail to the factory in Ripanj, this was executed.

The project analysis for this transport was done, with defined manipulation processes for freighting the transformer from the transformer box to the place of loading, the manner of loading and all questions related to the railway transport to the factory in Ripanj, the unloading and placement at the position of disassembly in the assembly hall of the ABS Minel Transformatori factory. Transport was organized according to all the standing railway transportation regulations with all the necessary permits and special examination of the railway gauges by an authorized institution, which also prescribed the repairs that need to be performed on individual sections of the railway track, as well as all other security measures that need to be taken.

Since this is a transport of oversized cargo of great value, it's important to know the permitted transport profiles on the railways that are defined by the regulations of all national railways through which the transport is taking place. The railway transport of energy transformers is performed by using special wagons of great carrying capacity, depending on the power and transport weight of the energy transformer (figure 3).

Flat wagons are placed on two rotary traps which are used for loads of up to 50 tons, tank wagons, used for loads of up to 100 tons, wagons with carrying constructions, used for weights of 200 – 250 tons and a special multiaxial Schnabel wagon – a wagon with a beak that is used for the transportation of energy transformers of the biggest loads.

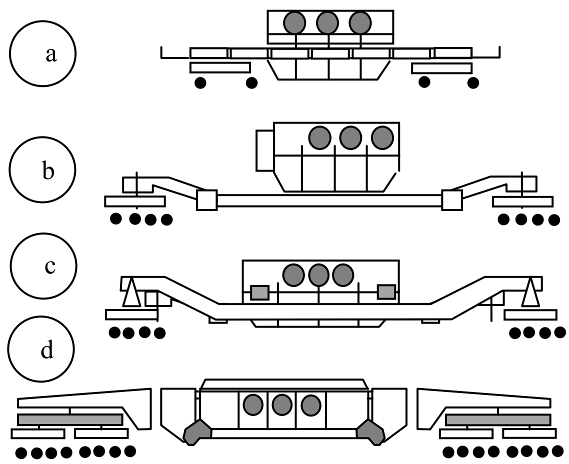

Fig. 3. Types of railway wagons for the transport of energy transformers

a) flat wagon b) tank wagon c) wagon with carrying construction d) "Schnabel" wagon

An power transformer of great power and load must be specially constructed for railway transportation, with elements for tying it to the wagon, which must withstand horizontal or vertical tension in places of hydraulic supports. The special, Schnabel wagons are constructed with 24 and 32 axles depending on the carrying capacity, fluctuating from 300 to 500 tons. The wagons themselves, without the cargo, are over 50 m long, so hydraulic devices are necessary for moving the load sidewise against the axial movement, in order to return it to the axle of the transport profile.

For the transport of the 725 MVA step-up transformer was provided the special "Schnabel" wagon with 32 axles, which no transporter on the territory of the former Yugoslavia possesses (figure 4). The annual timetable of the use of these wagons is prearranged, so that a timely planning of transport is a very important activity in the dynamic plan of the transformer's overhaul.

The transformer is specially prepared for transport, by disassembling all the parts that exceed the permitted loads, which are technologically finally assembled at the very facility, and which reduce the transport weight (insulators, conservator, cooling system, domes, joining pipes, control cabinet, motor drive of the voltage regulator). The disassembled parts are packed into closed containers and transported separately. To reduce the transport weight the insulation oil is transported separately. When transporting a new power transformer, nitrogen is placed into the case and a device for maintaining the overpressure in the container, to prevent the penetration of external air into the transformer container and disable the moisture from penetrating into the cellulose insulation.

Fig. 4. 725 MVA transformer on the loading position for the "Schnabel" wagon at thermal power plant TENT B in Obrenovac

The transport was finally realized on February 6th, 2011 by loading the step-up transformer onto the Schnabel car and shipping it via the TENT railway from Obrenovac to Divci. From Divci to Belgrade the transport was realized via the Belgrade-Bar railway, to finally ship it from Belgrade to Ripanj via the Belgrade-Nis railway (figure 5).

During transport, the entire railway traffic was stopped, while on the Belgrade-Nis track, traffic was halted for an entire 6 hours because of an intervention on the railway switch to the ABS Minel Transformatori factory. The factory tracks are not connected to the railway track by a standard switch but the intersected railway track was moved to the right and the railway tracks welded to the factory's tracks. Such a prepared switch (figure 6) was in function for only a couple of hours, to get the transformer into the factory, unload it from the wagon and return the wagon onto the Belgrade-Nis railway track. All this was done in less than 6 hours, in order to maintain regular railway transport on the Belgrade - Nis line (figure 7).

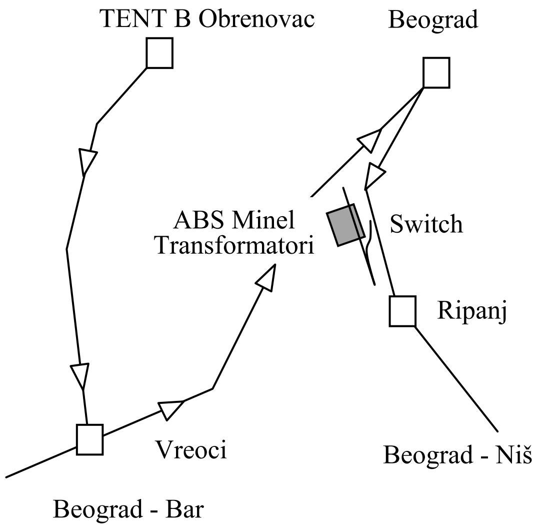

Fig. 5. Transportation route of the 725 MVA step-up transformer from Obrenovac to Ripanj

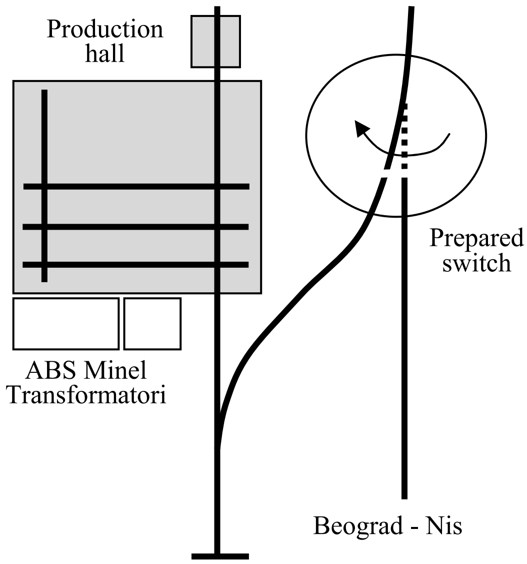

Fig. 6. Switch from the Belgrade-Nis track to the ABS Minel Transformatori factory in Ripanj

The transport of power transformers is carried out by the Schnabel wagon being drawn by a diesel engine, because due to electromagnetic phenomenological occurrences that can arise between the contact grid and the active part of the transformer, the electric contact grid for charging the electric locomotive must be shut down.

Fig. 7. Connected factory tracks with the Belgrade-Nis railway track

By shipping the step-up transformer onto the ingoing/outgoing factory track of ABS Minel Transformatori in Ripanj (figure 8), the entry of the transformer into the assembly/disassembly hall of the factory was enabled. Here, the unloading took place and the unit was placed on a special cart wheel to transport it inside the hall. Upon unloading the transformer, the Schnabel wagon was prepared for no-load stroke and returned via rail to Austria.

Fig.8. Entrance of the Schnabel wagon into the ABS Minel Transformatori factory in Ripanj

It was decided for new LV and HV coils to be made, to install new insulation arrangements and to fit in a new magnetic circuit because of damages that were identified on the magnetic circuit's insulation. The costs of overhauling this step-up transformer of capital worth for the TENT B thermal power plant in Obrenovac and the Serbian Electric Power Industry are around EUR 3.5 mn.

3. CONCLUSIONS

The transport of the 725 MVA step-up transformer, from Obrenovac to Ripanj, is a great technological and transportation venture, primarily because for the first time, the 32 axle Schnabel wagon moved across Serbian railways, transporting a 360ton load. The overhaul of the biggest power transformer in the Balkans is an extreme technical and technological venture not just for the ABS Minel Transformatori in Ripanj but any factory in the world. The company that realized the transport, "Bora Kečić" of Belgrade is the only company in Serbia that has the equipment and capacity to safely realize such a responsible and complex transportation project. The Schnabel wagon doesn't exist in Serbia and Bora Kečić, thanks to the requirements of the ABS Minel Transformatori factory in Ripanj, has arranged for the production of a 32-axle "Schnabel" wagon with the Wagon Production Factory in Kraljevo, for the requirements of their business in the area of oversized transport of energy transformers in Europe. It's safe to say that the design and production of the Schnabel wagon will significantly affect the development of wagon-building in Serbia.

The transport of energy transformers sometimes takes very long (e.g. the transport of a 300 MVA transformer from Subotica to Ripanj lasted over 2 months) due to the combination of road-railway transportation, providing the necessary permits and other approvals for oversized transport. The transport of the 725 MVA step-up transformer in 2 days, Saturday-Sunday, is an extreme venture carried out jointly by the workers of thermal power plant TENT B, the workers of factory ABS Minel Transformatori and "Bora Kečić" company.

ACKNOWLEDGEMENT

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '12

CURRENT PROBELEMS OF USING THE RAILWAY LAND FOR THE CONSTRUCTION AND OPERATION OF THE HIGHWAYS IN SERBIA

Aleksandar NAUMOVIĆ [1]
Siniša MARIĆ [2]

Abstract – *Transport Corridor 10 through Serbia is saptially defined by the railway and highway lines in the same infrastructure corridor. The width of the corridor varies from several hundred meters to less than one hundred meters. In the preparation of tehnical documents for the section of highway E-75, E-75 and Corridor 11 (as well as the sections of the E-763 Corridor 11), the boundary expropriation in some parts of the land sank below the border of the railway land, wich caused formal problems in the domain of property rights. The solution of that problems was found within the tripartite protocol concluded between the Roads of Serbia, serbian Railways and Corridors of Serbia, in which it was agreed that the status of railway land will be formally unchanged, and that the mutual obligatioms governing the conclusion of appropriate agreements between the Roads of Serbia and Serbian Railways.*

Keywords - Infrastructure corridors, highway, railway, boundary expropriation.

1. INTRODUCTION

Transport Corridor 10 through Republic of Serbia is spatiallu defined bu the railway and highway lines in the same infrastructure corridor. This is a consequence that the main road and rail lines followed the route of the ancient Roman roads, laid in the valleys of major rivers (for example, the VIA MILITARIS road on Belgrade - Niš - Preševo and Niš - Dimitrovgrad road and railway lines).

Ancient Roman VIA MILITARIS (or VIA DIAGONALIS) road passed through the main ancient towns of the Balkan Peninsula: Sirmium (Sremska Mitrovica), Singidunum (Belgrade), Naissus (Niš), Serdica (Sofia), Phillipopolis (Plovdiv), Hadrianopolis (Edirne), and finally, Constatinople (Istanbul). This road was conected with other ancient Roman road, VIA EGNATIA, across the valley of Axios (Vardar), exactly like Corridor 10 nowadays (see Figure 1).

Numerous archaelogical sites discovered along the route of the highways in Corridor 10, are irrefutable proof that the road VIA MILITARIS is in fact the forerunner of nowadays Transport Corridor 10 (see Figure 2, which shows the road network of ancient Balkans).

Fig.1. Ancient Roman Balkans with the road network (taken from Wikipedia.org)

The development of transport infrastructure in Serbia, as well as in other parts of Europe, was such that the railway network was completed first. The construction of highways was begun abuot a century later. The result is that the railway lines in Corridor 10 got the best position from the point of the physical conditions, so the highway lines have to comply the railway lines. This can be a significant problem in terms of spatial constrains.

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Fig.2. Archaeological site - VIA MILITARIS on E-80 highway line (taken from the photo documentation of Corridors of Serbia)

2. WIDTH OF THE CORRIDOR

Depending on space constrains, the width of the corridor varies from several hundred meters to less than one hundred meters. The parts where exists minimum width of corridor infrastructure, inevitably leading motorway at minimum legally permissible distance from railway line (eight meters [1, 2] measured from the end point of upper shaft end of the highway to the axis of the railway track), resulting in encroachment into truck area. In addition due to space constrains, these solution reduce the expropriation (road and railway land are both owned by the Republic of Serbia). Thus, in addition to saving the boundary expropriation, preserve the land for other purposes.

Fig.3. Side road R-214 located next to the international Belgrade - Mladenovac - Niš - Preševo - State border railway line in Momin Kamen in Grdelica gorge (photo by Aleksandar Naumović)

By the way, although the minimum distance of eight meters is prescribed by law, it is essentially obsolete. From the point of reduction of the corridor, there is no justification for bureaucratic moving highway away from the railroad at a distance of eight meters only because the highway is not ordinary road. At the same time, the roads with the lower rang can be located at a distance of only three or four meters from the axis of the railway track, with the use of appropriate structural items to prevent physical contact of road and railway vehicles (see Figure 3 and Figure 4 which show examples in Transport Corridor 10, in Grdelica gorge and Sićevo gorge). Reduction of distance between the highway and the railway would be very important in terms of serious spatial constrains (such as river gorges). In addition to less boundary expropriation, there would be also significant savings in earthworks and structures (bridges, tunnels and retaining walls).

Fig.4. Main road M-1.12 next to the international Niš - Dimitrovgrad - State border railway line near Prosek in Sićevo gorge (photo by Aleksandar Naumović)

Fig.5 Locations in Grdelica gorge (between Predejane and Džep) where the existing railway line is planned for relocation

Extreme problem was reported in Grdelica gorge, where the final solution has resorted to the relocation of the railway line in a distance of 2 km, to allow placement of the international railway line , highway E-75, main road and side road to a very limited space (see figure 5). Alternative design solutions would include construction of a long road tunnel (with two tubes) or construction of a road viaduct (two long bridge structures, again) over the railroad. These alternatives were more expensive, and they are dropped in the final solution.

3. PROBLEMS IN THE DOMAIN OF PROPERTY RIGHTS

In the preparation of designs for the section of highway E-75, highway E-80 and highway E-763, boundary expropriation planned in major designs is done in accordance with the needs of the construction and operation of the highway, so that the boundary expropriation in some parts of the land sank below the border of the railway land.

Due to the encroachment of the highway infrastructure in railway land, there have been formal problems in the domain of property rights. In fact, althuogh formally two facilities, highway and railway line in this way are practically single-line facility for the performance of two different forms of transport, laid on state-owned land. The absurdity of the formal problem is reflected in the fact the Corridor 10 is both highway and railway transport corridor.

The resulting probelem, though formal, was essentially meaningless, but at one point blocked the process of issuing the consent of the Serbian Railways to the major designs of highways. The solution was found within the tripartite protocol concluded between the Roads of Serbia, Serbian Railways and Corridors of Serbia, in which it was agreed that the status of railway land will be formally unchanged, and the mutual obligations governing the conclusion of appropriate agreements between Roads of Serbia and Serbian Railways.

4. CONCLUSIONS

Transoprt Corridor 10 through Republic of Serbia is spatially defined by the railway and highway lines in the same infrastructure corridor. Railway lines, especially in Corridor 10, got the best position from the point of the physical conditions, so the highway lines have to comply with the railway lines. Reduction of the corridor is saving the boundary expropriation and preserve the land for other purposes. The boundary expropriation in some parts of the land sank below the border of the railway land. The solution of formal problem in the domain of property rights, was found within the tripartite protocol concluded between Roads of Serbia, Serbian Railways an Corridors of Serbia.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '12

THE IMPORTANCE OF INFORMING AND MANAGING PASSENGERS WAYFINDING AT PASSENGER RAILWAY STATIONS

Predrag ATANASKOVIĆ [1]
Dragan ĐORĐEVIĆ [2]
Emina ĐURĐEVIĆ [3]
Zoran BUNDALO [4]

Abstract – *"How" and "where" are basic questions which have to be answered to every passenger at a passenger railway station. Properly asked questions and the choice of information given to passengers are of great importance. Getting around and finding specific items in the area is particularly important at bigger stations. Being multi-disciplinary, this kind of problem needs to be considered from many aspects such as creating, understanding the ways of showing and presenting information using different types of media. This paper gives an overview of the basic assumptions about the contents and ways of informing passengers at railway stations.*

Keywords – wayfinding, informing, facilities, railway stations.

1. INTRODUCTION

A problem of passenger's travelling can be considered through several phases, figure 1.

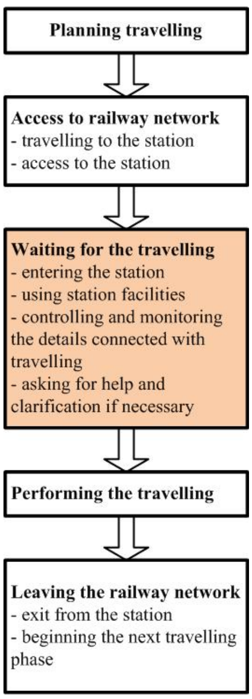

Fig.1. Main phases of travelling by railway

In the process of passenger's moving, a station is a very important segment and that is why the design of station building should be done very carefully. Passenger's needs in finding information, understanding and making decisions in wayfinding at the station area are of crucial importance. Good wayfinding information, properly implemented, supports both users and operators in making the journey experience more efficient and enjoyable.

2. THE BASIC CONCEPT FOR PASSENGER WAYFINDING IN THE STATION ENVIRONMENT

Successful passenger wayfinding systems can measure the way passengers move from point to point using information in the station environment. Such a system must be created in order to make station environment pleasant area which primarily gives necessary answers to all passenger's questions.

Good wayfinding signs in the railway station environment should enable the following information for the passengers, figure 2:

- Identify position within the station
- Identify passenger destination upon arrival
- maintain the flow of passengers

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- reduce passenger stress levels
- improve customer satisfaction
- reduce station crowding
- maintain a safe journey or an exit in case of emergency.

The process of passenger moving and wayfinding depends on the following, figure 2:

- Static information
- Dynamic information
- Temporary information
- Lighting
- Building design
- Passenger's previous knowledge and experience
- Equipment
- Tactile information
- Audible information.

The architectural design and the layout of the building provides strong wayfinding guidance. It is best when these wayfinding toolkit is considered as early as possible during the design and construction of a new station. A well-designed station building may offer all necessary information for the passengers.

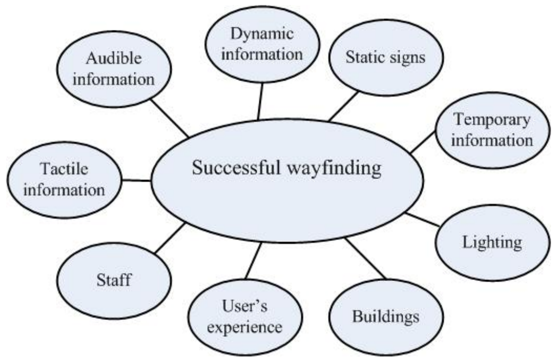

Fig.2. Factors influencing passenger wayfinding

3. THE TOOLS USED FOR INFORMING PASSENGERS

Signage and other static information is provided for passengers, emergency services, station visitors and staff to identify where they are, find out where they need to go, navigate to their required destination and know when they have arrived. A wayfinding signage system should provide the signs for the following, figure 3: station name, access to and exit from platforms and the platform identity, emergency telephones and help points, passenger travel, train and safety information, disabled facilities, accessible routes with appropriate symbols, ticket sales, toilets, waiting rooms, interchanges with other transport models, car parks and emergency escape routes.

Dynamic information is the one which includes content changes at displays, figure 4. Suggested contents for platform displays are the following: platform number, destination of train, timetable departure time of train, revised departure time, all stopping points, status of train departure. The first three points should be presented in a larger font on displays than the other information. All other displays at various station area points may include more information about the position of trains.

Fig.3. Signage showing static information

Fig.4. Signage showing dynamic information (LCD platform display on a Swedish railway)

Audible information provides good quality, accurate information which helps people to make confident decisions. For those with visual impairments, the provision of clear, accurate and timely information is vital for creating an accessible railway.

Tactile information allows users who may be partially sighted or blind to navigate safely and confidently withinh unknown station environments, figure 5. The following key areas within the station should include tactile information: floor signs at stairs, lifts and all buttons within lifts, toilets, other doors where passengers have access. All floor surfaces must be non-slippery.

Fig.5. Tactile flooring at platform edges (Nagoya subway station platform)

Temporary wayfinding information supports passengers in abnormal, pertubed and emergency situations. Such information should primarily be provided outside the station building. This may aid users with local knowledge to make alternative arrangements before they enter the station and thus minimise crowding. This kind of information can be both static and dynamic.

4. NECESSARY POINTS IN PLANNING PASSENGER INFORMING AND WAYFINDING AT A STATION AREA

While planning passenger navigation it is necessary to define the points which enable giving information to passengers circulating at a station area. These points must be of such a kind that one can adapt them and apply them in different situations or projects.

In order to make a succcessful planning, one should undertake the following steps:

- Make circulation routes at a station area (identify key problems in passenger route at a station area)
- Make a wayfinding project team
- Identify passenger needs at a station
- Identify the needs and problems of passengers wayfinding at a station area as seen through a station staff
- Identify the needs of passengers with special needs
- Direct questioning and conversation
- Identify the existing system for informing, wayfinding and navigating the station users
- Identify location of exits and entrances
- Identify main circulation routes
- Identify key decision points.
- Identify wayfinding information which is currently in place (static, dynamic, audible and tactile)
- Identify information legibility and the location of existing signage
- Identify the information which is missing and which would support users to navigate.
- Provide a wayfinding strategy for passenger moving at a station area
- Provide hierarchy of information
- Make guidelines on positioning information
- Choose a type of material to be used for signage
- Make colour schemes of sign material and type faces
- Choose font style and range of sizes
- Make dimensions for layout of text, symbols and arrows
- Test wayfinding information with users prior to implementing
- Implement wayfinding information for passenger moving
- Plan and mark a station with the exact location of each piece of information which is to be given at a certain position
- De-clutter out-of-date information
- Maintain and clean the existing signage.

5. INFLUENCING FACTORS FOR PASSENGER WAYFINDING AND MOVING AT A STATION

A successful wayfinding along the passenger route may be considered within three factors:

- People
- Information
- Environment.

People factors are considered in terms of abilities for making decisions and identifying and finding the right routes at a station area. Due to different individual passenger abilities, all kind of passengers must be taken into consideration, both those with or without special needs (mothers with children, older people, people with impairments, etc)

Information influencing factors should provide visual, audible, or tactile information which is understandable and clear to passengers.

Environmental influencing factors include a station physical layout and architectural features. Complex environments (great number of entrances and exits, different circulation routes and decision points, great number of facilities and platforms) also place greater challenges on developing wayfinding information.

All these factors should be considered together as a whole in order to solve the problem of passenger wayfinding in the station environment, figure 6.

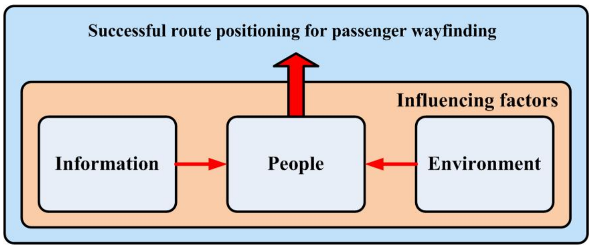

Fig.6. Influencing factors for successful wayfinding in the station environment

6. CONCLUSION

Well-using of the station environment is very important in order to enable correct route formation for passengers' travelling and their arrival to a specific point. Passengers are those who make decisions since they move along the route and collect information in the station environment.

The importance of information is crucial for passenger wayfinding in the station environment and the following principles must be taken into consideration:

- Information boards (signs) must be logically positioned at all points where it is necessary to provide a piece of information for passengers.

- The basic thing in positioning the routes is to know that passengers need the following information: entrance and exit points, trains, platforms, lifts, escalators, station facilities (toilets, waiting rooms, ticket box) and other transport modes.
- All signboards must be clear and with a good colour contrast and typeface legibility for all passengers. Visual signboards in the station environment are very important for people with hearing impairments. The blind and partially sighted need tactile information (station layout, tactile flooring for navigating and moving, and content signs). It is also necessary to pay attention to the choice of materials since they behave differently in various environments.
- All information presented to passengers must fulfill the following basic standards: visibility height and distance, viewing angle depending on the light source, circulation route visible from all station points.
- Appropriate and well-planned lighting schemes help people to see information clearly and make their way around the station environment safely.

When informing passengers in the station environment it is necessary to take into consideration all kinds of passengers and pay special attention to each of these categories.

If all basic principles for positioning information are fulfilled and all influencing factors are regarded, maintaining passenger wayfinding within the station routes will be very successful.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '12

RESPONSIBILITY FOR TRAFFIC SAFETY AT LEVEL CROSSINGS

Dejan VULIĆ [1]

***Abstract** – The paper discusses legislation and joint responsibility for safety traffic at level crossings between the authorities that manages road and rail traffic. It is proposed, in accordance with the division of responsibilities, changing the appearance and meaning of road signs at the level crossing that does not require significant changing the laws and regulations relating to traffic*

Keywords – level crossing, traffic safety, St Andrews Cross sign, road warning lights.

1. INTRODUCTION

Traffic safety at the intersection of rail and road has to be the joint responsibility of road and rail authorities.

Legislation in Eastern European countries requires the full personal responsibility of the road vehicle driver for their safe passage et level crossings. This also applies to level crossings equipped with warning lights or barriers. On the other hand, in most Western European countries road vehicle driver can fully rely on the safety system, so no need to be aware when level crossings equipment is inactive [1]. Considering legislation in Serbia it can be concluded that the responsibility for safety et level crossing lies only to the road vehicle driver [2].

According to Vienna Convention, all signatory countries pledged to harmonize road signs by the appearance and meaning. This is done in almost all European countries, but the road signs at level crossings remained different.

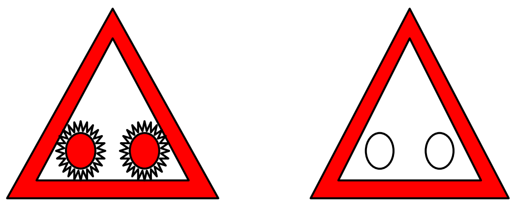
2. ROAD SIGN I-34 „St Andrews cross“

The most common sign for level crossing is the St Andrews cross. Although the design of a sign is different in some countries, a recognizable form of the cross does not confuse road users. But the meaning, and connection with the meaning and behavior of road users, is very different.

Legislation in Serbia defined road sign I-34 „...indicates the place where the road crosses the railway on the same level with no barriers or half barrier“ [3]. As the danger signs are used to warn road users of the danger that threatens them and inform about the nature of the hazard, the conclusion is that a sign I-34 (St. Andrew's cross) warns of the danger of incoming train with right of way and responsibility for safety et level crossing lies only to the road vehicle driver.

3. WARNING LIGHTS VI-9 „Road sign“

Active equipment et level crossing warn participants of road traffic for the incoming train with two flashing red lights on road sign. The appearance of road sign is shown in Figure 1.



a) b)

Fig.1. appearance of road sign (ŽS) a) activated, b) inactivated or failure

The next question that arises is: Who bears the responsibility for safety traffic et level crossing when the active warning equipment is faulty?

The road users can not know whether the active warning equipment et level crossing are inactive or defective because, in most cases, it looks the same. This problem is solved by installing railway control signal, remote monitoring of safety devices, level crossing activation during the creation of train route or issuing an order to a train driver by an authorized person. Train driver is informed that the safety devices are defective and must stop the train in front of the danger zone and miss the road traffic. We conclude that, in this way, responsibility for safety traffic et

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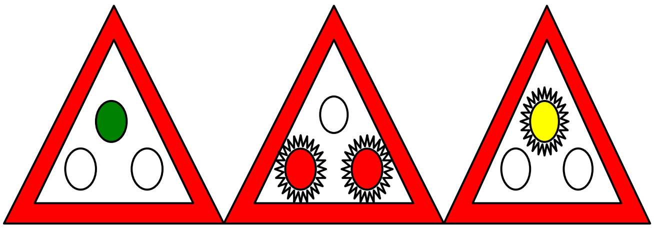
level crossing was transferred exclusively to the train driver. Defective safety device can be recognized by a road users with yellow flashing light that alerts car drivers that they can find a train et a level crossing zone. Train will stop and miss the road traffic. In case of traffic lights malfunction, a danger sign to I-34 (St. Andrew's cross) is valid, placed over the road sign (traffic lights). The proposed appearance of road sign is shown in Figure 2.



a) b) c)

Fig.2. Proposed appearance of road sign (ŽS) a) inactivated, b) activated, c) failure

The mentioned solution does not require a change in the law relating to traffic, do not engage a significant financial investment and would contribute to increasing the number of passing vehicle and traffic safety. Road signal suggests with shape that it belongs to signs of danger.

If you rotate the sign for 180^o it will be identical to the explicit commands - the prohibition or restriction (II-1) "crossing the road with right of way" which indicates crossroads (level crossing) in which the car driver must give right of way to all vehicles (trains) that move along the road (track) in which he finds. The appearance of road sign rotate for 180^o is shown in Figure 3.

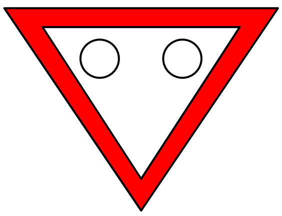
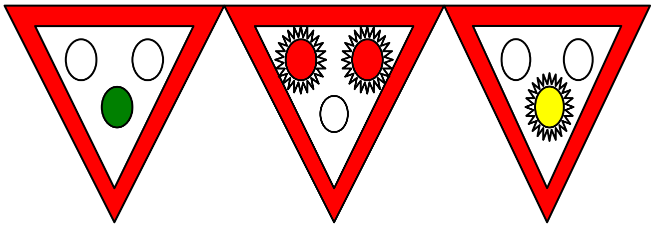


Fig.3. Appearance of road sign (ŽS) rotate for 180^o

This solution eliminates the need of installing the sign of danger I-34 (St. Andrew's cross) but changing the laws relating to traffic is necessary.

The European expert teams are increasingly considering the possibility of equipping the level crossings with semaphores (especially in urban areas) like road junctions. A red light would mean must stop, flashing yellow light would indicate that the device is defective and one can continue to drive with increased caution because it can be expected a stopped train in front of the danger zone. The green light would mean a free pass. Even though unification of appearance has not considered jet, the possible appearance of road signals (which is the recommendation of this paper) is shown in Figure 4.



a) b) c)

Fig.4. Recommended appearance of road sign (ŽS) a) free passage, b) stop, c) carefully

4. CONCLUSIONS

Traffic laws at level crossing are not widely understood. Without the engagement of the road sector, there cannot be expected any significant improvement of level crossing safety. Changing the appearance and meaning of road signs at the level crossing that does not require significant changing the laws and regulations relating to traffic, but it would be more understandable for car drivers and increase the traffic safety et level crossing.

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RAILWAY TRANSPORT AS LOGISTIC SUPPORT OF SERBIAN ARMY

Ljubislav VASIN [1]
Dragan PAMUCAR [2]
Vesko LUKOVAC [3]

Abstract *– The paper is giving the results of military transport by railway with special emphasis on number of passengers and amount of cargo. Detailed explanation of terms logistical support of the Army of Republic of Serbia, traffic support, transportation and railway transportation for needs of Army of Republic of Serbia are given, as well. Analysis of transported passengers and goods by railway, during last few years, is given in detail. Also, paper give quantitative comparison of railway and road transportation for needs of Army of Republic of Serbia, for some time period.*

Keywords - logistical support, transportation, railway transportation.

1. INTRODUCTION

Transportation is nonproductive service that has to fulfill needs of users using appropriate transportation means to transport goods, passengers, information or energy, from one point to another, during some time interval. Service is a product of transportation and it has its economic value that can be realized at the market.

Logistic support (LS) of Army of Republic of Serbia is a complex organization and technological system consisted of numerous and various elements, and complex functional processes whose base aim is to create material, health and informational conditions for development and maintain defined combat readiness. Transportation is logistic function that provides transport of human and material resources with purpose of achieving goals, obligations and demands of certain commands.

In peace Army of Republic of Serbia (ARS) has personal traffic-transportation organization and uses it (under LS) to maintain full transportation ability of all commands, units and institutions. ARS uses transportation means and services of public transportation companies, as well.

As it is given in present ARS regulations, organization of road and railroad transportation in ARS is under ARS traffic service's authority and in following, paper is dealing with the presentation and analysis of railroad transportation for ARS during last few years.

2. LOGISTIC SUPPORT OF ARMY OF REPUBLIC OF SERBIA

The term "logistic" has root in Greek word "logistikos", that defines someone who is good with numbers, calculations and estimation. The first usage of term logistic in modern history is connected with the Byzantium emperor Leo VI the Wise, (886. – 912. AD) which has separated military skills to: strategy, logistics and tactic, where logistics was defined as art of supplying and army maneuvering.

Also, logistic can be connected with the French word "loger" what means marketing, supply, accomoddate. The first application of term logistic in scientific report (1837) is connected with the French/Russian general baron Antoine Henri Jomini, founder of the Military Academy in Petrograd and military historian.

During the World War II (WWII) Anglo-American terminology is using logistics as a term representing planning and managing of the supplying processes for military troops.

After WWII, term logistics is officially involved into rules of armed forces of the United States of America to define aims, goals, functions, tasks, organization and working procedures. Influenced by the USA and as members of NATO almost all West European countries have adopted logistic approach in organization of materialistic and health support of the military.

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During early seventies of the 20th century, term logistics has entered into scientific and practical application of all disciplines that deal with the problem of merchandise, people, energy and information transportation. Differences between military and civil application of logistics can be simply explained over main goals of both of them: military logistics is oriented to military and political motives and involves transportation of army troops and material-technical means while civil logistics is primarily involved in merchandise transportation and all motives of logistics are purely techno-economic and social.

Nowadays, term logistics is used in armies of many countries as well as in other spheres of human interests and logistics can be considered as international, national, furthermore as business logistics or even as logistics of certain processes in industrial, economic, social, service and other spheres of human interests.

Based on many explanations and definitions of logistics, some can extract mutual, essential explanations of the term logistics as activity within planning, shaping, modeling, designing, controlling etc. processes. Logistics is multidisciplinary scientific knowledge applied in almost every human activity.

Logistic within military has to rely on available resources and realize material and health support of army in its goal achieving, plan and decisions realization as well in peace and war. For realization of such a task, adequate system is organized, with emphasis on new high-tech principles in military use and logistic.

LS of ARS is organized and realized by following functions: material resources supply, ammunition and military equipment supply, transportation, health, basic logistic operations, development and maintenance of logistic infrastructure [1].

Logistic functions are fulfilled within subsystems of logistic support (technical, intendant, health, traffic and civil) and expert carriers of realization are logistic services (technical, intendant, medicine, veterinary, traffic and civil).

Materialistic, financial and resource protection are closely related with the planning, organizing and realization of LS tasks.

3. TRANSPORTATION IN LOGISTIC SUPPORT OF ARM OF REPUBLIC OF SERBIA

Transportation is logistic function that provides transportation of people and material goods at land, air or water. Realization of transportation fulfills various demands of other logistic functions and creates conditions for their efficient functioning. That is the reason why the logistic function is actually integrative function of the complete LS – without realization of the transportation function, LS and logistic function cannot be fulfilled [1].

Transportation function consists of adequate processes connected with the movement – organization, regulation and control of traffic.

Traffic support (TS) is the term lately used instead of traffic providing (TP) and it explains the process of planning, organization and realization of transportation service, as expert carrier of LS realization. Separation of transportation into one ot basic and the most important logistic functions, the importance of the transportation is mentioned, since realization of the transportation fulfills various demands of other logistic functions [1].

TS in ARS plans, organizes and realizes traffic service thru moveability of units, transportation of military means and planed traffic realization. TS is intentioned for organization of transportation of people and material goods at land, in air or water, engaging available transportation means of the ARS and society.

It can be said that TS in ARS has two basic functions: transportation and traffic (movement) [1].

Traffic function (often called as operative function of traffic support) has to plan and organize movement on roads.

Transportation function involves planning of usage of automobile units that are under jurisdiction of traffic service as well as organization of all transport tasks for the commands, units and institutions within ARS. If transportation capacities of ARS are not sufficient, traffic service finds usable transportation capacities from the territory.

System of traffic support of ARS is constitutional part of unique traffic system of the country, backing up on traffic – transportation organization of the territory, using its transport capacities, companies, organizations and communications.

4. RAILWAY TRANSPORT FOR NEED OF THE ARMY OF REPUBLIC OF SERBIA

Railway traffic is part of the unique traffic system of the country and it is part of the system of LS – traffic support of the ARS, as well. Place and role of the railways within traffic system determines its obligations and tasks in transportation of people and material goods.

With its railroad networks, objects and factories, wagons, locomotives etc., railway is the greates technical and transport system that covers over complete country. Railways are especially fruitful in mass transport in any weather conditions, by day or by night.

Railway has wide application in traffic support of ARS in peace or, eventually, at the beginning of war. Peace-period usage of railway considers transportation of human and material resources, with goal of normal life and work behavior in units and institutions of ARS. Technical and transportation capabilities of railway, mass and different transportation and independency from the weather conditions give them the priority in transportation of heavy and special cargos needed for the ARS.

Mass railway transportation is assumed for the mobilization tasks, whereas it is mobilization of the ARS or any other mobilization in any special situation at the country. Railway can be used for mass transportation in human and material resource transportation in early phases of the war, until its functionality is not corrupted by hostile acts of the enemy. This fact was proved during 1999. when NATO air force has bombed the most sensitive objects, infrastructure of the railways and functionality of the railways was highly difficult or totally impossible.

5. ANALYSIS OF PASSENGER AND CARGO TRANSPORTATION BY RAILWAY FOR NEEDS OF ARMY OF REPUBLIC OF SERBIA

During last years, railway capacities have been used for transportation of people and cargo of ARS. Transportation was for purpose of training, maintenance of combat or noncombat vehicles etc. Lately, intensive transportation of special cargos has happened by railways due organizational changes in ARS as well as relocations of certain military units.

In 2009 railway has transported 90 persons (cargo guardians), 803.5 tons of cargo and 40 combat and noncombat vehicles. For these transportations, railway has hired 4 passenger and 41 cargo wagon [2].

During 2010 railway has transported 476 persons, 10247 tons of cargo and 296 combat and noncombat vehicles. Railway has engaged 23 passenger and 290 cargo wagons [2].

In 2011 railway has transported 364 passengers, 3881 tons of cargo and 131 combat and noncombat vehicles. Railway has engaged 12 passenger and 131 cargo wagons [2].

According to the statistical data of ARS, during 2009, by road ARS has transported 38450 tons of cargo (ammunition, medicine supplies, fuel, water, massive pieces etc.) and 207 combat and noncombat vehicles (tanks, different vehicles and constructive machines) [2].

During 2010, by road, ARS has transported 50631 tons of cargo and 978 combat and noncombat vehicles [2].

In 2011 ARS has transported 61533 tons of cargo and 521 combat and noncombat vehicles by road[2]. Tanks, other combat vehicles and construction machines have been transported by ARS's transport means and freight trains. Only few vehicles were transported by private transportation means (automobile transport companies). It is evident that number of transported vehicles is dropping during years as expected. Main reasons for such decrease in transportation should be found in reconstruction and transformation of ARS what has happened during 2010.

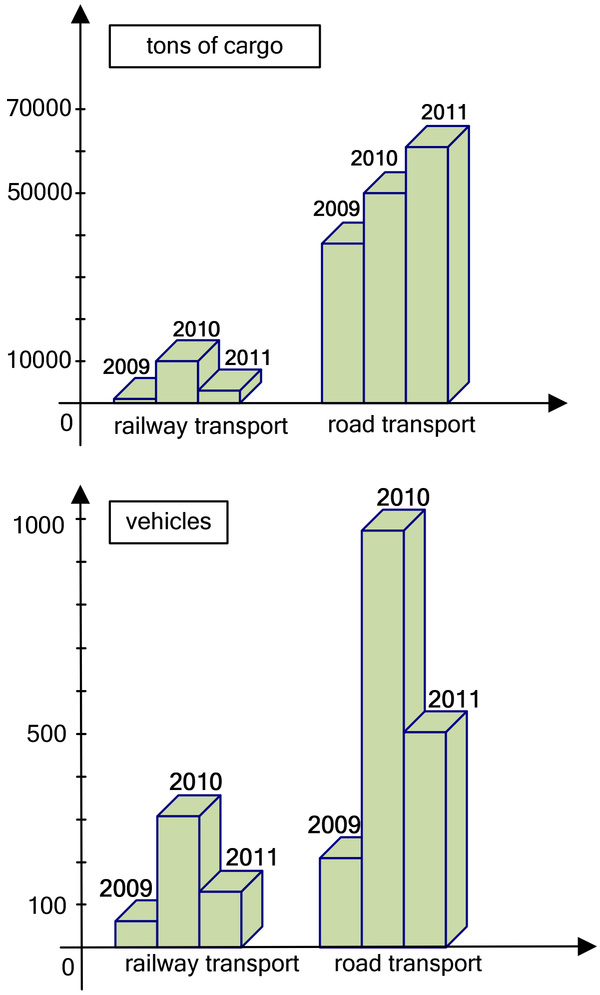

Fig.1. Road and railway transportation chart of ARS

During 2011 ARS has transported 86347 passengers. 36641 passengers by military busses (42 %) and 49706 passengers by rented busses (58 %) [2]. This information shows that ARS does not have sufficient transportation means for human transportation and it is clear that mass transportation like railway is can be used in military purposes.

If some analyses transport of cargo and passengers by railway and by road (Figure 1), it is clear that railway is not sufficiently used even thou the railway has much lower transportation costs than road. Some nonofficial data show that transportation of a tank or other massive combat vehicle costs up to five times less when transported by railways than with any road transportation mean.

6. CONCLUSION

Based on presented quantitative data about transportation within ARS, it is obvious that railways of Serbia are minimally used for transportation of military equipment and personnel without concern on lower transportation prices than for any other transportation mean.

Main reasons for this are: numerous manipulations with cargo while loading and unloading from railway wagons, need for adequate manipulative machines, uncertain safety of cargo while transporting, bad infrastructure of railways, slow transport, difficult planning and realization of transport, no direct contact between ARS and Railways of Serbia (military consultant within railways has been canceled etc.).

Railways of Serbia have to work on quality of its transportation in order to attract passengers and companies to use it. Army of Serbia has large scale need for transportation of its personnel and cargo and railway should use it. On other hand, railway could provide enormous logistic support of ARS.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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HYDRAIL-WHERE ARE WE NOW?

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***Abstract** – In order to achieve global stabilization of CO_2 levels in the atmosphere and ocean surface layers, reducing CO_2 emissions by 80% or more will be achieved by developed countries. Three aspects of the transport sector are particularly suitable for the transformation of hydrogen: rail, water and air. Among them, "Hydrail" should take the lead. Hydrail is a generic term for all types of rail vehicles, large or small, using the vehicle of hydrogen as an energy source to power traction motors, and auxiliary drives, or both. Hydrail vehicles convert the chemical energy of hydrogen to mechanical energy either by burning hydrogen in internal combustion engines (ICE), or the reaction of hydrogen with oxygen in the fuel cell to run the electric motor. Widespread use of hydrogen as a fuel in the rail transport is a key element of the proposed savings in the consumption of fossil fuels by using hydrogen. The second effect is that the engine has more pulling power and work smoothly. However, Hydrail rail systems are not used by the public. The possibility of launching a new approach to Serbia for the use in diesel engines with the addition of hydrogen to reduce consumption. Describing the effect of insertion of hydrogen (made by hydrogen generator) in ICE made and use it in the car ride more than two years. The experience I gained in the document.*

Keywords – HHO, Hydrail, Rail.

1. INTRODUCTION

The term **hydrail (hyd**rogen **rail)** was coined on April 17 2004 in the International Journal of Hydrogen Energy as a search engine target word to enable scholars and technicians around the world working in the hydrogen rail area to more easily publish and locate all work done in the discipline.

Hydrail is simply rail that uses hydrogen to carry energy onboard.

This means is that intermittent renewables energy sources including wind, tide and sunlight can be harnessed to power something running on exact schedules, such as a train.

The primary advantage of hydrail is that it runs on ordinary track and the only new infrastructure needed is trains and/or locomotives and a very few fuelling points along select lines using the technology.

hydrail is a concept that fits into the broad perspective of future energy supply for the planet. An 80% reduction in current global CO_2 emissions is needed to stabilise greenhouse gas (GHG) levels - a task that is made more difficult by the rapid expansion in energy demands from emerging economies.

As electricity supply continues to grow, CO_2 emissions from fossil-fuel-fired electricity generation need to be sharply curtailed, so it is essential that non-emitting technologies penetrate new areas of use. Transport is one such area and there are two, possibly three, ways in which this could happen, namely electricity, hydrogen and possibly biofuels.

2. TIMELINE OF HYDROGEN TECHNOLOGIES

In 1671, **Robert Boyle** discovered and described the reaction between iron filings and dilute acids, which results in the production of hydrogen gas. In 1766, **Henry Cavendish** was the first to recognize hydrogen gas as a discrete substance, by naming the gas from a metal-acid reaction "flammable air". He speculated that "flammable air" was in fact identical to the hypothetical substance called "phlogiston"and further finding in 1781 that the gas produces water when burned. He is usually given credit for its discovery as an element. In 1783, **Antoine Lavoisier** gave the element the name hydrogen (from the Greek ***ὕδρω hydro*** meaning water and ***γενῆς genes*** meaning creator) when he and **Laplace** reproduced Cavendish's finding that water is produced when hydrogen is burned.

Lavoisier produced hydrogen for his famous

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experiments on mass conservation by reacting a flux of steam with metallic iron through an incandescent iron tube heated in a fire.

Hydrogen was liquefied for the first time by **James Dewar** in 1898 by using regenerative cooling and his invention, the vacuum flask. He produced solid hydrogen the next year. *Deuterium* was discovered in December 1931 by **Harold Urey**, and *tritium* was prepared in 1934 by **Ernest Rutherford**, **Mark Oliphant**, and **Paul Harteck**. *Heavy water*, which consists of deuterium in the place of regular hydrogen, was discovered by **Urey's** group in 1932. **François Isaac de Rivaz** built the first internal combustion engine powered by a mixture of hydrogen and oxygen in 1806.

3. WHY HYDROGEN?

The environmental advantage of hydrogen at the point of use is significant compared to diesel, as only water is emitted as exhaust gas, providing significantly lower well-to-wheel Green House Gass emissions than both diesel and electric power in many countries.

Hydrogen converted from electricity is preferable to extracting the gas from hydrocarbons, asserting that the latter is not useful unless the co-product, CO_2, can be sequestered by carbon capture and storage (CCS) - a dubious and as yet unproven technology.

Hydrail vehicles are usually hybrid vehicles and also have renewable energy storage solutions like batteries or super capacitors, for regenerative braking, which improves efficiency and lowers the amount of hydrogen storage required. Potential hydrail applications include all types of rail transport, like commuter rail; passenger rail; freight rail; light rail; rail rapid transit; mine railways; industrial railway systems; trams; and special rail rides at parks and museums.

4. HYDROGEN FUEL TECHNOLOGY-CURRENT STATUS

Hydrogen is widely considered to be an essential part of a low carbon future, because of its potential role in the transport sector and as an energy carrier for other low carbon technologies. Major potential applications include:

- Use in hydrogen fuel cells and/or internal combustion engines (ICEs) in all areas of the transport sector. Of particular importance is that, when produced from renewable energy sources, hydrogen also has the potential in the long term to reduce and potentially remove transport's dependence on fossil fuels. Alternatively production from nuclear electricity would also be a low carbon production option;
- Use in large stationary applications to provide heat and power more efficiently (particularly in remote/isolated areas), and;
- Use of hydrogen as an energy store to facilitate load levelling and balancing of intermittent renewable energy sources.

Hydrogen fuel technology is attracting great political and industrial interest in Europe, as in the rest of the world, and investment in research and development has risen steadily over the last 10-15 years, with virtually all European countries now having some research or demonstration activity on hydrogen. The EU has made hydrogen a priority technology, along with fuel cells, and has recently established a technology platform on fuel cells and hydrogen which it hopes will accelerate European research activities

4.1. Hydrail initiatives around the world

In 2002 the first 3.6 tonne, 17 kW, hydrogen-powered mining locomotive, "Little Workhorse" (Figure1) was demonstrated in Val-d'Or, Quebec, Canada in which it pulled underground ore cars. The first hydrogen train was created by Vehicle Projects from Golden, Colorado. This hydrail system was a working mining train demonstrated in Ontario. Nuvera supplied the PEM fuel cell stack.

Fig.1. Little Workhorse

The hydrogen mining train had twice the power of the battery-powered train that it replaced and could be refuel with hydrogen in just 30 - 45 minutes. The battery-powered train took 8 hours to recharge.

In April 2006 came the world's first hydrail railcar (Figure2), which was developed by East Japan Railway Company

Fig.2. Railcar East Japan Railway Company

In October 2006, the Railway Technical Research

Institute in Japan conducted tests on a fuel cell hydrail vehicle by Nuvera Fuel Cells.

In April 2007, China also recognised the potential of hydrogen fuel with the announcement of the superpower's first hydrail - termed a "new energy fuel cell train". The train uses hydrogen fuel cells as well as an advanced permanent-magnet synchronous motor and frequency converter, which conserves 10% to 20% of integrated energy and, according to China's People Daily, "will also aid China's motor industry to adjust its industrial structure toward a new developmental direction." The mini-hydrail from the Taiwan National Science and Technology Museum and Taiwan Fuel Cell Partnership combination made its first educational ride.

In 2007, The Railway Technical Research Institute in Japan built two 62 ton passenger cars, each with a 450 kW PEM fuel cell and a 150 kW battery.

In 2008, the East Japan Railway Company in Japan tested its experimental "NE Train"(Figure3) hybrid train fitted with two 65 kW PEM fuel cells and 19 kWh lithium ion batteries for a short period in the Nagano area.

Fig.3. NE Train

In 2009, BNSF unveiled the first hydrail locomotive (Figure4), powered by hydrogen fuel cells.

In 2010, a 357-kilometre (222 mi) high-speed hydrail line was proposed in Indonesia. The rail link, now under feasibility study, would connect several cities in Java with a hydrogen-powered maglev system.

In November 2010, China demonstrated their first hydrail prototype.

Fig.4. BNSF Hydrail locomotive

Diesel-electric road switcher is being converted to hydrail by Vehicle Projects of Denver, Colorado. But the first freight hydrail locomotive, a fuel cell hybrid, 1Q08 in a joint project of the Vehicle Projects LLC and the Burlington Northern Santa Fe Railroad and others, using RailPower Green Goat chassis.

Fig.5. 1200 kW locomotive the U.S. Army Tacom Command

This 1200 kW 109 tonne locomotive is being built for the U.S. Army Tacom Command.

4.2. The Time Schedule for Hydrogen on Rails

It has been a general assumption, that hydrogen technology could develop as a "spin-off" from a future commercial use of hydrogen on the road. Part of the technology from cars and busses could then be transferred and modified for railway use, and at that time the market price for fuel cells and other components would be reduced as a result of mass production for the growing automotive market.

In this scenario the use of hydrogen on rails will perhaps not be realistic until somewhere after 2020-2025. However recent projects and feasibility studies could indicate that this schedule is too pessimistic.

For the automobile industry the price target is somewhere between 40 and 100 € /kW and the point of introduction is near the end of the curve. For busses, the technology will be attractive at a price of 250 – 300 €/kW and for niche applications as trucks for various kinds of internal transport, the technology could be relevant at an even higher fuel cell price.

Expected price development for PEM fuel cell in transport.

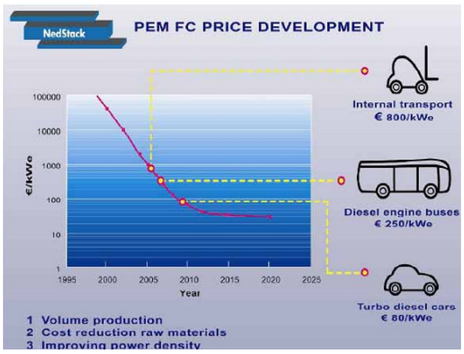

Fig.6. (From presentation at the 2nd International Hydrogen and Hydrail Conference, Herning, Denmark, June 7, 2006 by Jan Piet van der Meer, Nedstack Fuel Cells)

It is expected, that the "learning curve" for hydrogen technology as in the example illustrated here gradually will make fuel cells commercially available for various purposes and products.

For railway applications the "point of interest" on the price scale could in be somewhere between the truck and the bus case illustrated in the figure..

5. ICE - POINT OF INTEREST

There is much less information available on hydrogen ICEs, compared to fuel cells. The attractiveness of hydrogen ICEs is that they may allow rapid deployment of hydrogen-fuelled vehicles, thereby enabling hydrogen refuelling infrastructure to become more economically viable (EERE - US Energy Efficiency and Renewable Energy, 2005). Hydrogen ICEs are much closer to commercial deployment for transport applications than fuel cells.

Hydrogen ICEs can currently be manufactured more cheaply than fuel cell powertrains – they are only about 15% more expensive than conventional petrol engines (EERE, 2005) used in road vehicles. They also have the additional advantage that they can run on pure hydrogen or a blend of hydrogen and compressed natural gas (CNG), and emit lower amounts of NOx than conventional petrol engines.

6. TRANSFORMATION OF DIESEL ICE INTO HYBRID ICE

Diesel fuel burns slower than gasoline. It burns so slow that not all of it gets combusted by the time the piston has reached the critical angle on the crankshaft. About 30% of the available air/fuel mixture is still burning after the piston has reached the critical angle in diesel engines.

Many manufacturers employ different methods to burn more of the fuel before it reaches the critical angle including double injecting fuel before and after TDC, redesigning the piston heads, leaning the mixture as much as possible and still keep the engine from over- heating and managing the fuel with electronic sensor systems (EDC). These methods are all helpful but even the best system still has ca. 20% unburned fuel in the cylinder after the piston has reached the critical angle.

An important characteristic of HHO is that it accelerates the burn rate of the air/fuel mixture. When the correct amount of HHO is injected into the combustion chamber of a cylinder, the speed of that combustion is increased. This means that if enough HHO is present in the cylinder when the flash combustion occurs, the air/fuel mixture will be totally combusted by the time the critical angle is reached by the piston. This increases the efficiency of the engine by 20- 30%. This translates into 20-30% more km per liter of fuel. Adding HHO moves the red line in the diagram (Figure 6) to the critical angle. In this configuration, the diesel engine burns 100% of its fuel and operates at optimum efficiency.

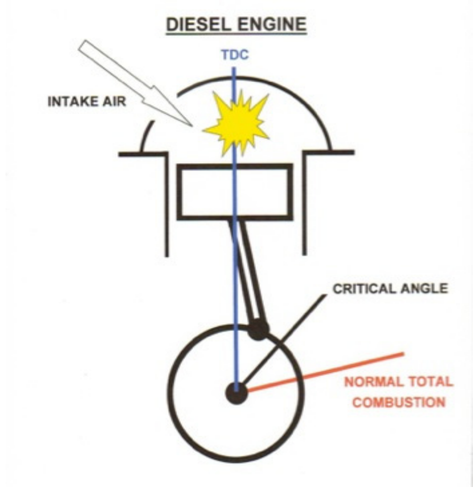

Fig.7.

7. CONCLUSIONS

In October 2009 I maid HHO generator and install it in my Opel Kadett 1.3 1986 engine. Up to that time comsuption of this (at that time) 25 years old engine was 7.5 L/100km. After installing HHO generator and whole equipemet for using HHO as fuel combustion stimulator, the comsuption was reduced on 5.8-6L/100km. Also the power increased from 60 BHP to 84BHP (measured on dyno machine). Level of CO_2 was reduced from Euro 1 to Euro 3 level. In a period of use I passed over 75000km with HHO gas and the condition of the engine was as is on Figure 8.

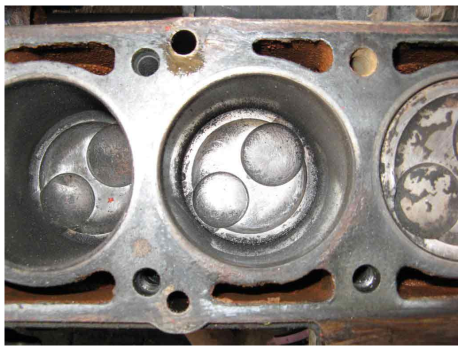

Fig.8. Piston head on C13N engine after 200000km

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DETERMINATION OF RESIDUAL STRESSES AND DEFORMATIONS IN THE WELD METAL

Georgi STOICHEV [1]

Abstract *– Railway carbody and bogie frame have many welded joints. Residual stresses at thermal zone are caused by welding deformation. The conventional strain method was only considering strain area as temperature changing region. Proposed methods in this paper focus on the two different the strain area at thermal zone. The new method is development for calculating the strain by incorporating the heat equilibrium area effects into the heat transfer analysis.*

Keywords – welding, thermal zone, residual stresses and deformations, railway industry.

1. INTRODUCTION

Broad using the welding in all branch of modern industry, including in railway industry, is conditioned integer beside her(its) advantage in contrast with other technological process of the reception non breaking join. Simplicity of the join pertain To such advantage, reduction of the weight to designs, greater possibilities for mechanization and automations of the process, recovery of the conditions of the work, reduction to work content and reduction of the periods of the fabrication complex design and others.

However, alongside with advantage, welding possesses some defects, sort of "disease", which often reduce efficiency of this activity. This group includes for instance changing of physic-mechanical characteristic in the zone of the thermal influence. One of the essential defects is an arising the welding stresses and deformations in consequence of uneven heating of the designs at welding.

First of all, as a result of the welding activity to remaining deformation, obstruct the process of the assembly oversize design from separate welded block, nodes and section. So, for instance, mismatch of the form and sizes nearby section frame coach, reaching sometimes several groups of ten millimeter, requires the greater expenseses of the work on his(its) removal. Very often work content operation removal welding deformation commensurable with work content strictly welding work. Residual welding deformation worsen the exterior and field-performance parameters of the construction.

The problem welding deformation and stresses called to itself attention in 30-h year past centuries. Introducing the welding in industry required the close examination to toughness welded design.

The modern theory of the welding stresses and deformation has been developed the best in works of V.A. Vinokurov and V.M. Sagalevich, V.I. Mahnenk, K.M. Gatovskog, P.B. Baize, S.A. Kuziminov, I.M. Zhdanov and their multiple pupil.

In spite of essential development of the theories of the welding stresses and deformation, does not exists a common opinion about dug these voltages at estimation of toughness transport design. The analysis of the reasons of the damages and destructions design often brings about conclusion that one of the reasons of the damages is presence of the welding remaining stresses.

2. NECESSARY FOR THE RAILWAY INDUSTRY

There are many welded joints in the railway carbody and bogie frame. Residual stresses at thermal zone are caused by welding deformation. The welding deformation affects negatively the required precision and stability of structural materials. For the last twelve years, among the methods used to predict welding deformations, the equivalent loading method based on the inherent strain [1] has been successfully applied to calculate welding deformation due to its effective and reliable results.

It is important to determine the inherent strain regions. The inherent strain method does this by calculating the temperature distribution during welding [2] and converting it into equivalent loads, from which it is able to determine the deformation. Because this method independently generates a term related to the angular deformation, it can be applied

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very efficiently to precision deformation processes.

3. STRAIN IN THE THERMAL ZONE

The total strain can be divided into the elastic, thermal, plastic, and phase transformation strains [3],

$$\varepsilon^* = \varepsilon^{th} + \varepsilon^{p} + \varepsilon^{tr} + \varepsilon^{e} \quad (1)$$

where: ε^{e} is elastic strain; ε^{p} - plastic strain; ε^{th} - thermal strain; ε^{tr} - phase transformation strain; ε^* - inherent strain generated by the loading condition.

The inherent strain is defined as the irrecoverable strain after removing structural restraints and loads, or the sum of elastically irrecoverable strains that induce permanent deformation of the material, i.e., the total strain with the exception of the elastic strain [4, 5].

$$\varepsilon^* = \varepsilon^{th} + \varepsilon^{p} + \varepsilon^{tr} = \varepsilon - \varepsilon^{e} \quad (2)$$

such as: $\varepsilon = x/L$ and $\varepsilon^{e} = -\sigma_{yb}/E_b$

where: ε is total strain; σ_{yb} - yield stress of the temperature change region; E_b - Young's modulus of the temperature change region.

$$\varepsilon^* = \sigma_{yb}/E_b \cdot [(E_s/E_b) \times (1+\nu_b)/(1-\nu_s) + 1] \quad (3)$$

where: E_s - Young's modulus of adjacent region; ν_b - Poisson ratio of the temperature change region; ν_s - Poisson ratio of the adjacent region.

4. DETERMINING THE STRAIN REGION

The 2-D geometry of inherent strain region was introduced in Fig 1.

Fig. 1 shows the maximum breadth (**b**) and maximum depth (**d**) of the inherent strain region.

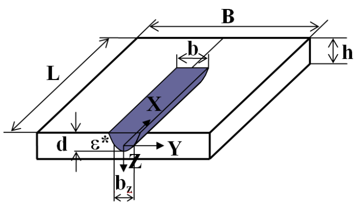

*Fig.1. The geometry of inherent strain region (**b** - maximum breadth of the inherent strain region; **d** - maximum depth of the inherent strain region; **h** - thickness of the plate; b_z - breadth of the inherent region)*

5. THE MODEL FOR ANALYSIS OF THE STRESSES

The FEM model, which used for thermal analysis, used and gave the analysis of the stresses. At modeling hard body was shown still. Type element SOLID 45 is chose for modeling of the field sprain-compression.

At thermo mechanical of the analysis of the given thermal analysis are taken as thermal load. They are required under each increase parameter during thermo mechanical of the analysis. We take that plastic deformation material runs according to von Mises' yield criterion and corresponding to law to fluidity. The Correlation between thermal stresses **ij** and deformation ij is described by following equation:

$$\varepsilon_{ij} = \frac{1+\nu}{E}\sigma_{ij} - \frac{\nu}{E}\sigma_{kk}\sigma_{ij} + \lambda s_{ij} + \left[\alpha + \frac{\partial \alpha}{\partial T}(T - T_0)\right]T \quad (4)$$

where **E** - Young's modulus; ν - Poisson ratio; α - factor of the heat expansion; $s_{ij} = \sigma_{ij} - 1/3\ \sigma_{kk}\sigma_{ij}$ - forming deviation of the stresses; λ - factor to plastic deformation, $\lambda = 0$ - for springy deformation or $\sigma_e < \sigma_s$ and $\lambda > 0$ - for springy deformation or $\sigma_e \geq \sigma_s$, here σ_s - a limit to fluidity, $\sigma_e = (2/s_{ij}s_{ij})^2$ - an efficient stress Mises, **T** - a temperature to surfaces, **°C**; T_0 - a temperature surrounding ambiences, **°C**.

6. RESULTS OF MODELING

Fig. 2 shows the distribution of the temperature in plate at moment of time **t = 35 s**.

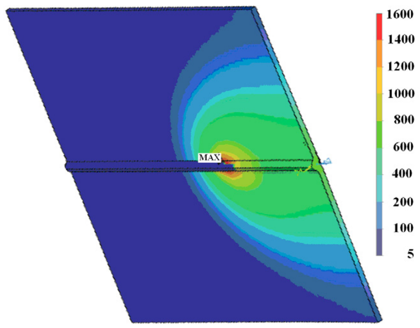

Fig.2. The temperature distribution in the zone of the melting

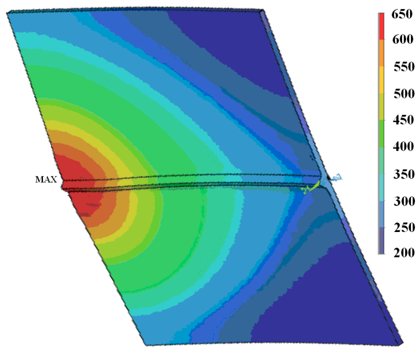

Fig.3. The temperature distribution after completion of the process of the welding

It is established that temperature maximum in the centre of the welding bath and quantitative is **1600°C**. Thermal influence of the process crystallization welding bath are taken into account in FEM models. In Fig.1 is presented the temperature distribution after termination of the welding. It is seen that maximum temperature is fixed in the field of moving the source of the heat.

In Fig. 4a, b is shown change the temperature on upper and lower surface of the plate depending on time. It is established that maximum temperature element on upper surface of the plate more, than on lower.

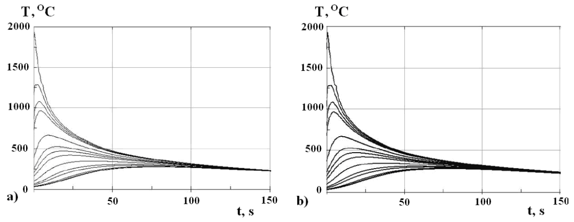

Fig.4. The temperature distribution in average part of plate depending on time: a) - upper; b) - a lower surface; ***min = 25°C; max = 1950°C***

7. RESIDUAL STRESSES IN THE WELD METAL

Modeling has allowed to reveal the stresses condition an residual stresses in the weld metal and deformation in welding join. It is established that because of relative deformation, occurring after welding, exist the differences between longitudinal stress on upper and lower surface of the plate. Due to the form of the plate on lower surface actualities spraining stresses. In the same time for upper surface, on edge of the plate, actualities the compressing remaining voltages. This causes longitudinal bend for seam.

There is a great deep difference between bending remaining stresses on upper and lower surface. As a result of angular deformation on upper surface there is a spraining stress, but on lower surface - compressing that causes bend plates across seam. It is established that on upper surface of the plate with increase the distance from seam appear spraining stresses, reaching maximum value of **200MPa**.

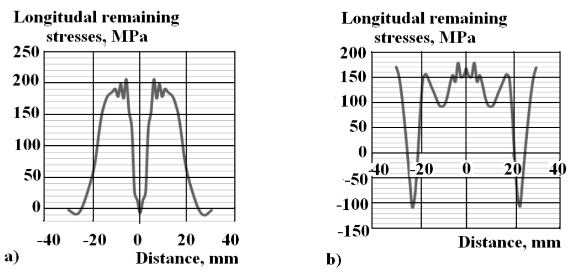

Fig.5. Distribution of the longitudinal remaining stresses in average part of plate: a - upper surface; b - lower surface

In Fig.5 is shown sharing the longitudinal remaining stresses in the central part of plate. It is established that (fig.5a) on upper surface plate with increase the distance from seam appear spraining stresses, reaching maximum importance **200 MPa**. In Fig.5b is shown distribution the longitudinal remaining stresses in average part of plate on lower surface.

It is seen that spraining stresses appears on edge of the plate. On lower surface of the plate appear compressing stresses. The value spraining stresses on upper surface plate more, than on lower.

8. DETERMINING THE EQUIVALENT LOAD

Equivalent load in equation 5 was earned by substituting the geometrics values determined in Sections 4 [7]

$$\mathbf{m_y = \frac{1}{b}\int_{-h/2}^{h/2} E_b \varepsilon * b_z z dz = \frac{1}{6} E_b \varepsilon * dh\left(\frac{3\pi}{4} - 2\frac{d}{h}\right)} \quad (5)$$

where: $\mathbf{m_y}$ - moment on the welded line (Equivalent load).

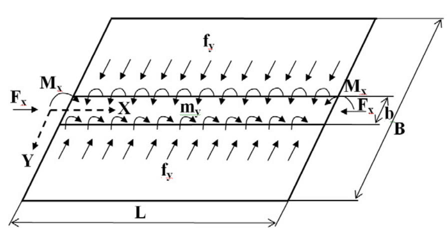

Fig. 6. Distribution of the equivalent load along the welded line equation [6, 8]

9. ADVANCED EQUIVALENT LOADING METHOD

We already discussed fundamental knowledge of conventional inherent strain method in section 4. It was only considered inherent strain area and other area. These areas were used to drive prediction formula of conventional welding deformation.

But the main idea of advanced inherent strain method is to define additional layer at the thermal zone and applied its geometry dimensions to equivalent loading method. The additional area is defined between inherent strain and adjacent region is named heat equilibrium zone.

The advanced method is considered the heat equilibrium zone as the adjacent area based on the region in the direction of its depth and its temperature dependence material properties.

The heat equilibrium area in advanced inherent strain method is performed additional heat layer to calculate reliable inherent strain results. So three different layers existed in advanced inherent strain method such as $\mathbf{k_1}$, $\mathbf{k_2}$, $\mathbf{k_3}$. The $\mathbf{k_1}$ - spring constant of the inherent strain region and $\mathbf{k_2}$ is core theory of this formula. $\mathbf{k_3}$ is in spring constant in heat equilibrium zone is divided into ring and disk types spring constants based on the springs restrictive conditions on the level of depth in thermal zone [8].

$$\mathbf{m_{y1} = \frac{1}{b_1}\int_{-h/2}^{-h/2+d_1} E_1 \varepsilon *_1 (z) b_{z1} z dz} \quad (6)$$

$$\mathbf{m_{y2} = \frac{1}{b_1}[\int_{d_1-h/2}^{d_2-h/2} E_2 \varepsilon *_{2disk}\, b_{z2} z dz +}$$

$$+ \int_{-h/2}^{d_1-h/2} E_2 \varepsilon^*_{2ring} \left(b_{z2} - b_{z1}\right) z dz] \quad (7)$$

where: E_1 - Young's modulus of the inherent strain region; E_2 - Young's modulus of the heat equilibrium zone; b_1 - maximum breadth of the inherent strain region; b_2 - maximum breadth of the heat equilibrium zone; d_1 - maximum depth of the inherent strain region; d_2 - maximum depth of the heat equilibrium zone; b_{z1} - breadth of the inherent region; b_{z2} - breadth of the heat equilibrium zone; ε^*_1 - inherent strain with disk type and ring type area; ε^*_{2ring} - inherent strain with ring type area; ε^*_{2disk} - inherent strain with disk type area; **h** - thickness of the plate;

Depend on definition the area of temperature changing zone at thermal zone, equivalent load can be expressed as Eq. 6 and 7. The total summation of the results from Eq. 6 and Eq. 7 are total equivalent load in thermal zone in advanced inherent strain method.

10. APPLICATION THE EQUIVALENT LOAD TO FEM MODEL OR SIMPLE BEAM FORMULA

The welding deformation of the specimen can be calculated using the elastic analysis method introduced by Jang [1, 2 and 5]. It can also be calculated using a simple beam deflection formula.

11. APPLICATION THE EQUIVALENT LOAD TO RAILWAY ROLLING STOCK

Many railway rolling stocks are manufactured by welding process. But many assembled and welded railway rolling stocks had been evaluated their structural stability by using FEM without considering post welding plastic and elastic mechanical properties of the line along welded jointed.

Equivalent load can be applied to FEM model of all extruded aluminum carbody. And equivalent load was also applicable to the line along the welded joint to verify distribution residual stress in full assembled FEM model. It is possible a numerical modeling of welding parameters influence on temperature field [9].

12. CONCLUSIONS

1. The conventional strain method was only considering inherent strain area as temperature changing region:

- For mathematical modeling by flap of the temperature and stresses applying programs ANSYS and FEM;

- It is established that electric arc welding causes the difference of the thermal stresses. The bending plate with size **100 x 80 x 7 mm** toward along seam forms before **2 mm**, but bend in transverse direction before **- 3 mm**;

- Offered methods of the calculation is recommended for determination of the value to deforming the welded plates and directed material from steel with a thickness of **7 mm**.

2. The new method is development for calculating the strain by incorporating the heat equilibrium area effects into the heat transfer analysis. The following conclusions may be drawn.

- An equivalent loading method was introduced based on the inherent strain.

- Main as advantage of inherent strain method is not to require an elasto-plastic finite element analysis.

- The strain method that incorporated the heat equilibrium area effects produced more reliable results than the conventional method.

- The new method considers additional heat equilibrium area to second temperature changing region at thermal zone. It provides more accurate results.

Therefore, we can use the proposed strain method to predict welding deformation as well as its residual stress at welding joint of railway rolling stock.

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The Young and the Future of Railway

XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '12

A PROJECT TO DESIGN A RAILROAD LINE FOR DESIGN SPEEDS OF 130 KILOMETERS PER HOUR

Student: Ilian TRIFONOV [1]
Mentor: Maia IVANOVA [2]

The terrain topography used for this project is a real map of the terrain between two train stations in Bulgaria, railway station Kazichane and railway station Vakarel. Currently there is a railroad line that connects these two train stations, and that line is a part of the Sofia-Plovdiv railway line. The current speed of this line is insufficient, that is why the aim of this diploma thesis is to establish a new route profile and alignment with specifications that allow design speeds of 130 km/h.

To allow for sufficient capacity at Novi Han and at Elin Pelin the thesis contains a preliminary design of railway station Novi Han. The category of the railroad line is calculated on the basis of a technical and economic substantiation from design specifications and terms of reference. The public and freight traffic volume per day are determined on that basis. The ruling grade is determined for a locomotive series 41-00, with the maximum length and weight of the train. The minimum horizontal and vertical curve radius, the superelevation of each curve, minimum distance between vertical and horizontal alignment elements and other design criteria are all on the basis of the terms of reference and regulation 55 (Regulation №55 for design and building of rail ways, stations, crossings and other elements of the rail road infrastructure).

The thesis contains:

- Three route profile and alignment options (including tractive effort and power calculations) connecting railway station Kazichane and railway station Vakarel, a technical and economic comparison between these three options.

- A more detailed development of the chosen option.

- A preliminary design of the Novi Han train station.

- A design calculation of a culvert.

Keywords – Infrastructure, Train station, Culvert, Railroad line.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '12

CONVENTION CONCERNING INTERNATIONAL CARRIAGE BY RAIL - COTIF

Student: Vladimir MALČIĆ [1]
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Abstract – *Today's regulation of the European Union is based on the aspiration of establishing a single European market. Striving for integration of transport markets and increase of harmonization and standardization of technical and other regulations and standards in Europe and in the world, the development of multilateral framework regulating international transport is put in the foreground. Adequate realization of international railway traffic requires the existence of common rules on the basis of which it has to take place. Today, the international railway transport mainly takes place on the basis of the COTIF convention. This paper presents a structure of international organizations OTIF as the most important organization in the field of transport law and explains its role in creating modern, market-based principles of the single European market. Scope of the use and COTIF convention structure is analyzed. In particular, the regulations of the COTIF convention, primarily related to transportation of goods in international railway traffic, which is carried by the CIM Unique rules, are analyzed. Concept of the transport contract and international way-bill is introduced and the duties, rights and responsibilities of the parties, that are railway carrier and transport users, are explained.*

Key words: international convention, single market, harmonization, transport contract.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '12

ENGINE-DRIVERS IN EU REGULATIONS

Student: Mario ĐUKIĆ [1]
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Abstract *- Integration of the European transport market and the increasing harmonization and standardization of technical and other regulations and standards in Europe included engine-drivers, and the conditions and procedures for certification of engine-drivers who run locomotives and trains in the railway system. Sector of BiH integration within the EU accession process has to resolve the issue of harmonization of regulations in this area in accordance with directive 2007/59/EZ. The paper presents the reasons for the creation of the directive, explains the aim and scope of such directives and deadlines to implement this directive. It presents the necessary documentation of the staff of freight vehicles in the European Union and describes the procedures and requirements for licensing and certification of engine-drivers. It also presents the necessary documentation of the staff of freight vehicles in Bosnia and Herzegovina. It shows the differences between necessary documentation of the staff of freight vehicles in the European Union and Bosnia and Herzegovina.*

Keywords: harmonization, engine-driver, license, certificate.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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WHEEL SET OF ELECTRIC LOCOMOTIVE SERIES 441

Student: Aleksandar ĐORĐEVIĆ [1]
Mentor: Dušan STAMENKOVIĆ [2]

Abstract *– Modeling, design and manufacturing of machine elements currently is inconceivable and almost impossible without the use of computers and appropriate software packages. In this way, the process of design - modeling for manufacturing of the final product is easier, the time for development is reduced as well as the cost of the entire process. Thesis work is focused on the role and importance of the wheel set of electrical locomotive series 441, because it is the most complex subsystem in terms of security on the locomotive. Wheel set is the most important part of railway vehicle according the running safety, and because of that during the locomotive operation special maintenance measures are implemented for wheels and axles. The geometry of the elements of the axle assembly has been standardized and regulated by UIC standards and can not be exceeded. The main task of thesis is the modeling of 3D solid model of electrical locomotive series 441 wheel set, on the basis of the technical documentation. Technical documentation, dating back to 1976, was made at the "Đuro Đaković" from Slavonski Brod, for the purposes of "Rade Končar" from Zagreb. The modeling was done using the software package SolidWorks 2007. Also, within the thesis, analysis of the static axle load was performed. The static structural analysis was performed using the software package Ansys.*

Keywords – locomotive, wheel set, axle, modeling, static structural analysis.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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THE ROLE OF RAILWAY IN SUSTAINABLE DEVELOPMENT

Student: Sanja ILIĆ [1]
Mentor: Dušan STAMENKOVIĆ [2]

Abstract – *Sustainability demands transport solutions which are energy efficient and minimise their contribution to climate change whilst effectively and efficiently taking people and goods where they want to be, when they want. Contemporary understanding and interpretation of the concept of sustainable development in transport is based on economic, social and environmental principles. The transportation sector accounts for approximately 13% of the world's greenhouse gas emissions, less than 1% is caused by rail transportation. Indeed, all electric rail transport is free of local air pollution from exhaust emissions. The rail sector continues to make efforts to reduce its environmental impact and include greater use of renewable sources of energy, reducing noise emissions and minimising the impact on flora and fauna. As a low-carbon mode, rail has a major role to play: if the railways can attract passengers from other modes, then the overall carbon footprint of the transport sector will be reduced. The best way to attract new passengers to rail is to provide reliable, punctual and safe services. Rail benefits the global economy by enabling congestion-free access to employment and facilitating freight deliveries. In major cities around the world, due to the congested streets, railway is the most reliable urban transport. Also rail plays a positive role in society, by providing millions of green jobs worldwide and offering access to employment and leisure opportunities. Intermodal and urban rail transport will form an important part of the future sustainable transport infrastructure. This is why we should believe that rail have a great role in the development of truly sustainable transport systems.*

Keywords - rail transport, sustainability, environment.

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MODELING THERMAL EFFECTS IN BRAKING SYSTEMS OF RAILWAY VEHICLES

Student: Miloš B. MINČIĆ [1]
Mentor: Miloš MILOŠEVIĆ [2]

Abstract *– The thermal analysis is a very important stage in the study of braking systems, especially of railway vehicles where it is necessary to brake huge masses, because the thermal load of a braked railway wheel is prevailing compared to other types of loads. In the braking phase kinetic energy transforms into thermal energy resulting in intense heating and high temperature states of railway wheels. In that way induced thermal loads determine thermomechanical behavior of the structure of railway wheels. In cases of thermal overloads, which mainly occur as a result of long-term braking on down-grade raillines, the generation of stresses and deformations are occurred whose consequences are the appearance of cracks on the rim of a wheel and the final total wheel defect. Therefore, the thermal analysis of a block-braked solid railway wheel of a locomotive of the type 444 of the national railway operator Serbian Railways using analytical and numerical modeling of thermal effects during long-term braking for maintaining a constant speed on a down-grade railline is detailed processed in this paper.*

Keywords – railway, braking, solid wheel, thermal load.

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Poster presentations

MATHEMATICAL MODELLING OF WORK OF MODERN FRICTION-POLYMER SHOCK ABSORBERS BY TAKING INTO CONSIDERATION EXPLOITATION FACTORS

Hristijan MICKOSKI [1]
Ivan MICKOSKI [2]
Dame KORUNOSKI [3]

Abstract *– Shock absorbers are main elements into construction of train wagons that secure protection from longitudinal forces which appear during transitional regimes of movement. Therefore, dynamical load of the train wagons depends of the technical characteristics of the shock absorbers. Beside development of new constructive solutions for shock absorbers is quite popular development of their working mathematical models. This paper presents modern shock absorber with elastic block made from polymer elements that increment quantity of absorbed energy. This is achieved by increasing the stiffness characteristic of polymer elastic block. The construction is relatively simple and technology used to create the construction is with more less low price. If, there is not enough elastic stiffness of the polymer block possibility for not meeting the UIC norms for absorbed maximal and nominal energy is possible. Therefore, according to mentioned characteristic, shock absorbers are divided into three groups. Given mathematical model in this paper allows calculating necessary elastic characteristic of the polymer block for short time. Differential equation of movement of the shock absorber elements is presented in this paper. In the differential equation of movement participates force change of polymer block for various impact velocities where initial velocity* V_0 *and current meaning of the velocity* $\dot{x}$ *are taken into consideration. So for, this fact was taken experimentally, approximately or not taken into consideration. Presented equation is solved by using program language MATLAB/Simulink by development simulation model.*

Keywords – shock absorber, mathematical modeling, MATLAB/Simulink, simulation.

1. INTRODUCTION

Rail freight transport occupies an important role in the transport system of each country in the world. Increasing the transport of goods in recent years, respectively lead to increased weight of train wagons and speed collision during their manoeuvrability and during forming the compositions of arranged stations. All this significantly increased the level of activity of the longitudinal forces acting on the train wagons as a result of load occurrence of massive repairs which appreciably reduce revenue from transportation of goods.

The main element for reducing the level of longitudinal forces in the operation of railway vehicles, especially freight vehicles are shock absorbers that are embedded on the front of each train wagon. Therefore, for such their role in recent years are developed new constructive solutions, where adsorption capacity - efficiency of longitudinal forces takes a package made by polymeric materials which are embedded in the shock absorber.

Influence of the speed impact on shock absorber is studied factor for a long time from many authors, but it remains unexplored issue regarding influence of the speed impact on the characteristics of modern polymer elements.

According to the experimental data, a

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mathematical model was created for changing the force F acting on the retaining polymer package which takes into account the impact of initial speed V_0 as well as change of the current speed $\dot{x}$. The error of this resulting force does not exceed 6% in terms of maximum 1% compared to the maximum of [1].

Strict UIC requirements for towing shock absorber devices for freight wagons and locomotives defining demands for forces smaller than 2,0 [MN] to achieve energy absorber capacity of not less than 70 [kJ], and the full force of or less than 3,0 [MN] to achieve energy capacity not less than 90 [kJ]. Then, when we have insufficient stiffness of embedded polymer block, there will not be achieved the required energy capacity if we increased rigidity there will be increase of the pressing forces. Therefore determination of stiffness characteristic of embedded polymer block is an important and responsible issue.

In this paper, calculation of the dynamic force acting on the polymer block during collision is given, movement of the swept elements of shock absorber expressed with differential equation where dynamical force is taken, from where it can accurately determine stiffness characteristic of polymer block that can satisfy the above requirements.

Principle scheme of elastic - frictional absorption device (shock absorber) with package of polymer elements is given below figures 1 and 2. A complete shock absorber is given on figure 3.

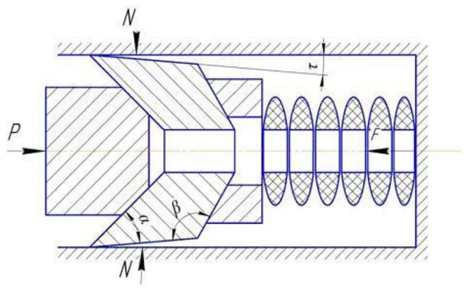

Fig.1. Principle scheme of elastic - frictional absorption device

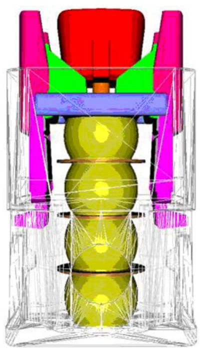

Fig.2. Principle scheme of elastic - frictional absorption device (shock absorber) with package of polymer elements

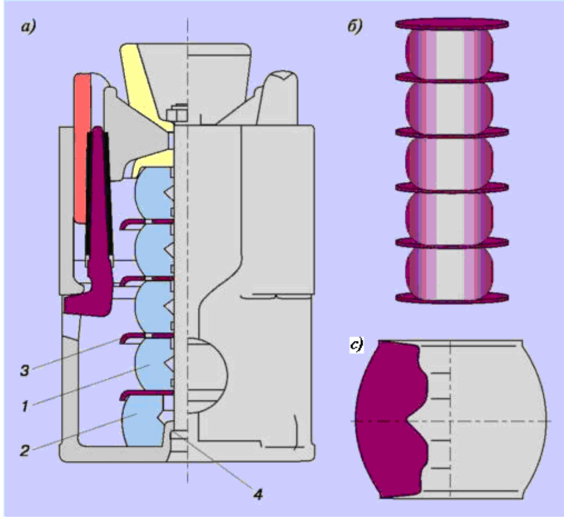

Fig.3. Complete shock absorber

a) - Constructive scheme where:
- 1 – polymer elements,
- 2 – embedded element,
- 3 – centred elements,
- 4 – body.

b) – Polymer elastic package from Durel material.
c) – Construction of elastic polymer element.

2. MATHEMATICAL MODELLING

Due to the above mentioned requirements imposes need of development of mathematical modelling of absorption devices through which would be determined an optimal stiffness characteristic of embedded polymer block and would reduce the cost of obtaining them. The differential equation of motion of the elements of the system swept parts (see Figure 1) has the following form:

$$\ddot{x} = g - \frac{\psi \cdot F}{M} \tag{1}$$

Where:

x – Displacement of cone pressure part.
$\dot{x}$ – Velocity of cone pressure part.
$\ddot{x}$ – Acceleration of cone pressure part.
ψ – Coefficient of transmission, showing for how much pressure force of the shock absorber P, oversize the pressure force of the embedded polymer block F. At our case is taken $\psi = 5$. Calculation of ψ is given in [2] and [3].

$$F = a(V_0 - \dot{x})b \tag{2}$$

$$a = 101,2 \cdot x^3 - 30,66 \cdot x^2 + 3.98 \cdot x - 0.062$$

$$b = 0.0083e^{24x}$$

Force F expressed in [kN] has nonlinear characteristic and up to now was estimated experimentally. M is the mass of moving system. Force P depends from system velocity and system position, which can be calculated from known estimation in which angles of cone metal element participating and friction coefficient between them, so force P can be estimated with bellow equation (3), nevertheless up to now same force was estimated experimentally.

Force F can be expressed with equation:

$$P = \frac{d\left(M\dot{x}\right)}{dt} \tag{3}$$

with replacing the expression $dt = \frac{dx}{\dot{x}}$ into equation (3), will have first order differential equation:

$$Mx d\dot{x} = P dx \tag{4}$$

$$P = M \cdot g - \psi \cdot F \tag{5}$$

With replacing equation (5) into equation (4), we will have equation of movement (1).

3. MATLAB/SIMULINK MODELLING

For solving equations (1) and (2), imitational models are developed by using program package MATLAB/Simulink. On figure 4 is given block diagram of imitational model for solving dynamical force F given with equation (2). On figure 6 is given block diagram of imitational model for estimation of displacement and velocity of moving system from shock absorber, equation (1). Results are shown on Figures 5 and 7.

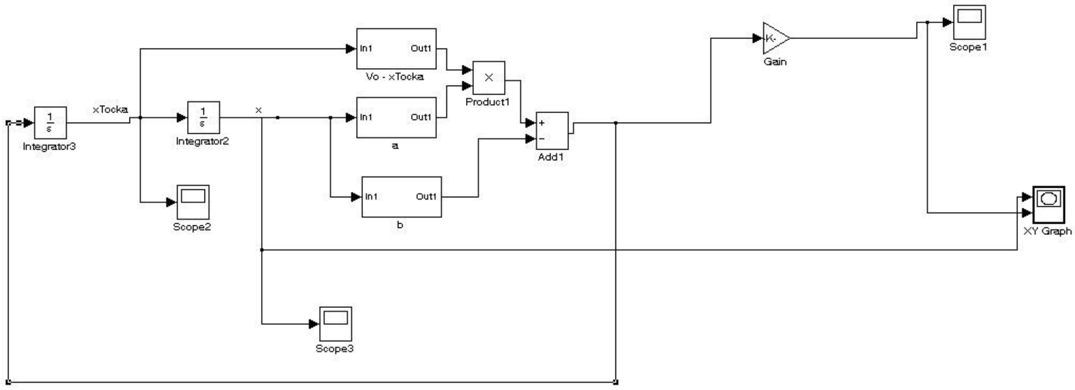

Fig.4. Block diagram of imitational model for solving dynamical force F

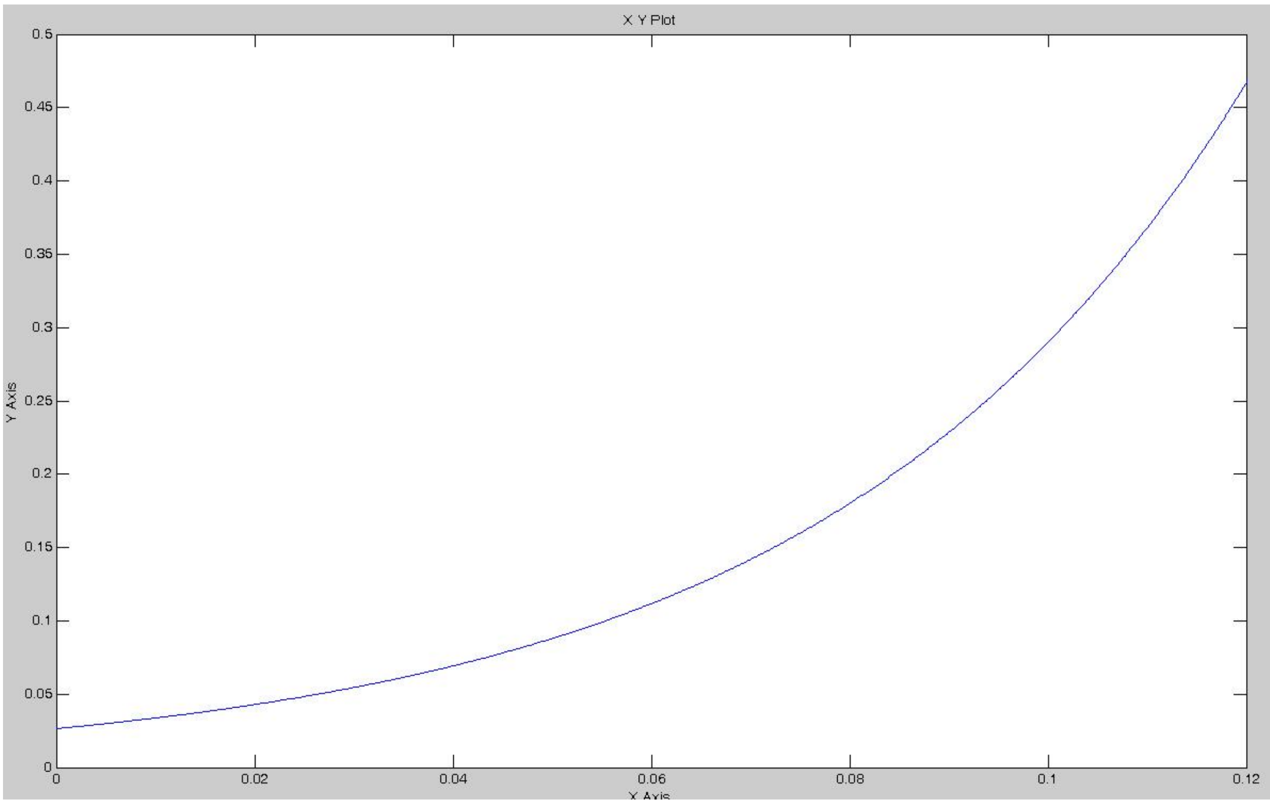

Fig.5. Changing of dynamical force F , estimated from imitational model from figure 4

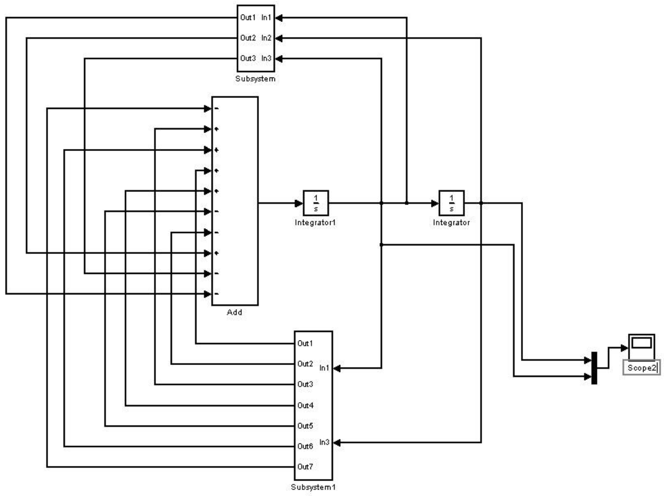

Fig.6. Block diagram of imitational model for estimation of displacement and velocity

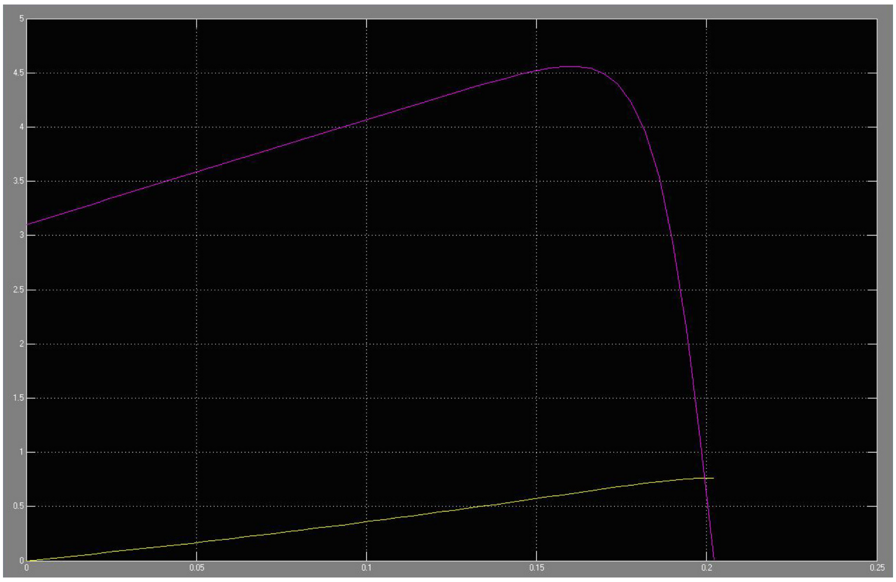

Fig.7. Displacement (yellow line) and velocity (pink line) obtained with simulation of imitational model shown on figure (5)

4. CONCLUSIONS

Based on mathematical model for changing the dynamic force *F* acting on polymer embedded package that takes into account influence of initial speed of the impact v_0, as well as change of the current speed $\dot{x}$, developed is imitational model for force calculation, from where it can be accurately determined stiffness characteristic of the polymer block that can satisfy the requirements of UIC without doing any further tests, which are from a economical point of view very expensive.

Developed is imitational model for calculation of displacement and velocity of moving system from shock absorber during period of collision (collision of the train wagons).

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EPDM/CSM RUBBER BLEND COMPOSITES IN RAILWAY VEHICLE

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Abstract *– The use of chlorosulphonated polyethylene (CSM) rubber for partly substituting ethylene propylene diene terpolymer (EPDM) was determined. Mechanical and thermal aging properties as well as resistance to irradiation of the rubber blends composites were also investigated. The amount of CSM in blends significantly affected the properties of the rubber blends. The mechanical properties were determined by Instron tensile dynamometer. The EPDM/CSM rubber blends with CSM content up to 40 phr possessed similar tensile strength to that of pure EPDM even after irradiation or thermal aging. Modulus, tensile strength and hardness of the blends appeared to increase progressively with increasing CSM content. Tensile properties after thermal and irradiation aging decreased significantly for the blends with low CSM content. EPDM/CSM rubber blend with 60/40 ratio showed maximum values for hardness, tensile strength and modulus and best thermal and irradiation resistance, also. This is suggesting an interfacial interaction between the two phases probably caused by the co-vulcanization in EPDM/CSM rubber blends. This rubber blend composites will be used in railway vehicles for rubber sealing.*

Keywords - EPDM/CSM rubber blend, thermal aging, irradiation, railway vehicle.

1. INTRODUCTION

Polymer blending was recognized in the last few decades as the most promising way to prepare new material with tailored individual properties. Polymer blends are defined as a mixture of two or more polymers or copolymers. Elastomeric blends are known for a long time and are technologically important materials due to their several applications. Their chemical and physical properties make them suitable as engineering materials, for chemical industry, electric insulators and many other uses [1]. Generally EPDM rubber blended with diene rubbers like NR, SBR, NBR etc. substantially improves the ozone resistance of the resulting vulcanizates that are reported to exhibit inferior physical and dynamic mechanical properties [2]. The driving force of curative and filler diffusion from EPDM to more polar diene rubber phase containing high amount of unsaturation is the saturated backbone of EPDM (less polar) [3]. Due to the slow curing nature of the EPDM elastomer (low unsaturation content) curatives react and get depleted faster at the unsaturation sites of the other diene rubber phases present in the blend. In a blend of elastomers which differ in polarity there occurs a concentration gradient for the fillers and the curatives which further leads to diffusion of curatives from the less polar EPDM phase to the more polar elastomer. Evidently EPDM phase in the blend remains severely undercured even on prolonged vulcanization. Recently we have observed that NR [4] and SBR [5] could be effectively covulcanized with EPDM in presence of the multi-functional additive like bis(diisopropyl) thiophosphoryl disulfide (DIPDIS) using a new vulcanization technique. To produce more versatile blend system with combination of high performance properties like ozone resistance, oil and solvent resistance, heat (age) resistance, better set properties etc., EPDM-NBR combination is conceived.

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Several studies have been reported by the earlier researchers [6] regarding this blend system, especially to compete auspiciously with costlier polychloroprene rubber (CR). The present exploratory study is very much concerned with the covulcanization of EPDM-NBR rubber blends containing reinforcing carbon black and silica fillers so as to get blend vulcanizates suitable for various industrial applications.

Degradation of elastomeric materials by irradiation is also a serious problem, mainly by gamma rays, which are usually used in sterilization. The mechanism of the changes in irradiated polymers includes both the degradation and the cross linking processes.

In this study the effect of gamma irradiation on mechanical and thermal properties of the ethylene propylene diene/chlorosulphonated polyethylene rubber blends (EPDM/CSM) based composites were investigated as potential compositions for rubber sealing in railway vehicles.

2. EXPERIMENTAL

Ethylene propylene diene terpolymer rubber used in this study was Vistalon 2504 type was provided by Exxon Co.Belgium. It is characterized by having ethylene content of 60 wt%, propylene content of 32 wt% and wt% norbronene. It has a specific gravity of 0.86 g/cm^3. Chlorosulfonated polyethylene rubber (CSM) used was Hypalon 40 DuPont Dow Elastomer Company, Ltd., USA, with Mooney viscosity of 63 [ML (1+4) at 100°C], which appears in structure. It contains 34.40% chlorine and 0.98% sulfur, by weight. The sulfonyl chloride group is a reactive site for crosslink reaction.

Ingredients of the recipe were mixed carefully through a two roller mill of size 300 x 600 m with a gear ratio of 1.14 : 1 at 40 ^{o}C to obtain sheets, which were pressed to 1mm thickness using a hot electric press at 160^o C for 20 minutes at a pressure of 16 MPa. Vulcanization time was determined by using a moving die rheometer (MDR2000). Formulations of the rubber compounds are shown in Table 1.

Table 1. The formulation of EPDM/CSM rubber blend compounding

Compounding (phr)	1	2	3	4	5	6	7
EPDM	100	80	60	50	40	20	0
CSM	0	20	40	50	60	80	100

Other ingredient in phr: MgO -4, Zink oxide-5, Stearic acid-2, Parafinic oil-40, Carbon black N-330-40, MBT-0.5, TMTD-1, Sulphur-2

The mechanical properties, namely tensile strength (TS), tensile modulus at 100% elongation (M100) and elongation at break percentage (Eb) were carried out using a universal testing machine of the Instron tensile dynamometer model 1195, England. The given results are the mean value of five separate specimens. The error in these measurements is 5%.

The γ-irradiation was carried out with 60 Co γ-source at an ambient temperature with the dose rate of 10 kGyh^{-1} and total absorbed dose of 100, 200 and 400 kGy. Radiation dose of 400 kGy can be considered as the relatively large dose which many times exceeds the doses for degradation of radiation degradable polymers and is also above the typical doses used in practice for radiation modification of polymer based products. After aging, sample sheets were cut into a dumbbell shape. The samples were strained at ambient temperature at 500 mm/min using an initial jaw distance of 50 mm. At each aging condition three samples were tested and the data were averaged to obtain the result.

3. RESULTS AND DISCUSSION

3.1. Cure characteristics

Figure 1 shows the effect of CSM content on the scorch t_{s2} and cure time, t_{c90} of the EPDM/CSM rubber blends. It can be seen that the t_{s2} and t_{c90} of these blends increases with increasing CSM content. EPDM is nonpolar rubber.

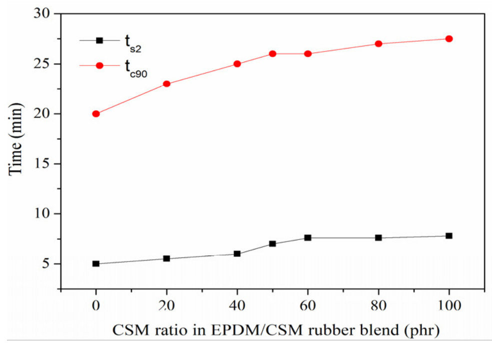

Fig.1. The effect of CSM ratio on t_{s2} and t_{c90} in EPDM/CSM rubber blend

As the content of CSM in the blends is increased, the curative agent, i.e. sulphur, becomes more soluble in CSM compared to EPDM. Consequently the curing rate of the blend increases with increasing content of CSM reported that for blends of two rubbers with dissimilar polarity, distribution of crosslinks can be nonequaly through phases.

The effect of CSM content on the maximum torque (M_h) and torque diference (ΔM) is shown in Figure 2.

It can be seen that the M_h increases with increasing CSM content in the EPDM/CSM blend. Figure 2 also shows that above of 40 phr of CSM, M_h of EPDM/CSM blends has higher values than EPDM and CSM rubbers alone as a result of the co-vulcanisation presence between CSM and EPDM rubber. The relationship between the torque difference, $\Delta M=M_h-M_l$ and content of CSM is shown in the same figure.

It is known that the torque difference indirectly relates to the crosslink density of the blends. The decreasing torque difference for EPDM/CSM indicates that a distribution of crosslink occurred which results in an over-crosslinked phase and a poorly crosslinked one.

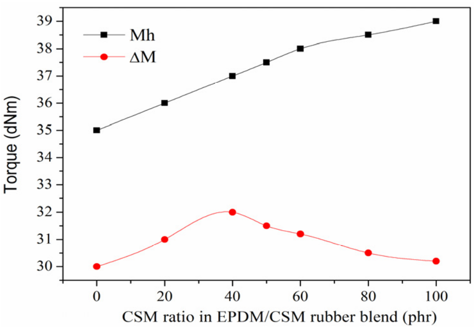

Fig.2. The effect of CSM ratio on M_h and ΔM in EPDM/CSM rubber blend

Markovic at all [7] reported that with normal sulphur vulcanizing systems, the efficiency of CSM vulcanization seemed to be improved. The isolated double bonds in EPDM inhibit the formation of intramolecular sulphide links thus resulting in the increase of the crosslinking rate.

3.2. Mechanical properties

The variation of tensile strength (TS) with the addition of CSM to EPDM is shown in Figure 3.

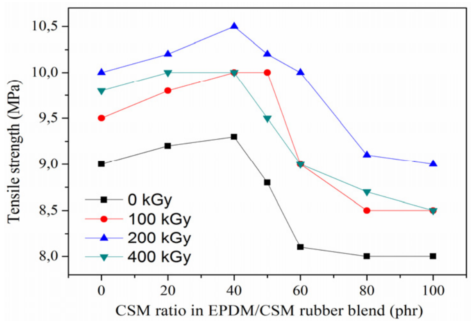

Fig.3. The effect of irradiation dose on the tensile strength of EPDM/CSM rubber blend with different CSM ratio

It is noticed that the tensile strength (TS) value decreases by increasing CSM content in the blend. This can be explained on the fact of that unirradiated CSM is a gum rubber. On other hand, by irradiation at similar CSM content almost higher Ts values were reported with respect to a level off at 40 phr CSM content. High-energy irradiation of polymers creates free radicals by the scission of the weakest bonds. These new entities react with each other or with molecular oxygen if the exposure environment contains it. The effect of gamma irradiation on TS of EPDM/CSM rubber blends with various compositions at different radiation doses is shown in the same figure; the TS of the samples increased with the increase in irradiation dose up to 200 kGy, and after that Ts values are become lower.

Figure 4 shows the variation of modulus M100 (modulus at 100% elongation) with the EPDM/CSM rubber blends compositions.

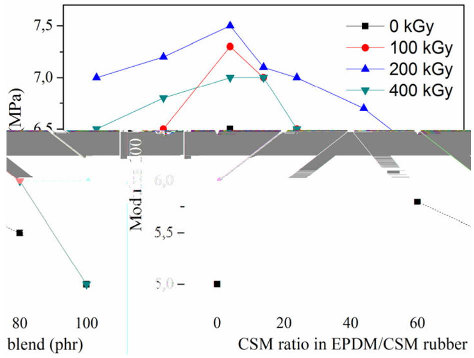

Fig.4. The effect of irradiation dose on the modulus (M100) of EPDM/CSM rubber blend with different CSM ratio

It can be seen that the M100 of the blends decreases with increasing CSM content. At lower CSM content, the elastomer phase remains as dispersed particles.

Smaller size and uniform dispersion of the dispersed phase contribute to the higher elastic modulus of EPDM/CSM blends. As the CSM content further increases, agglomeration and hence particle–particle interaction of the EPDM accounts for the observed decrease in elastic modulus of EPDM/CSM blends. Apparently, unsystematic behavior at similar radiation dose predominates.

The effect of CSM content on the elongation at break of EPDM/CSM rubber blends is shown in Figure 5.

The significant increase in elongation is referred to the increase of CSM content. According to recent theories, the most accepted mechanism for rubber toughening is rubber cavitations, followed by ductile shear yielding.

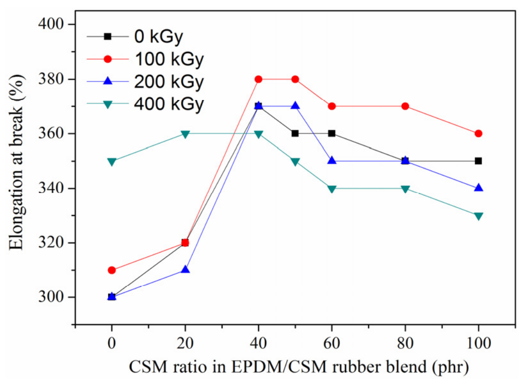

Fig. 5. The effect of irradiation dose on the elongation at break of EPDM/CSM rubber blend with different CSM ratio

In rubber blend, under tensile stresses, voids can be initiated inside the rubber particles. Once the rubber particles are cavitated, the hydrostatic tension in the material is relieved. This new stress state is favorable for the initiation of shear bands. EPDM/CSM blend markedly shows initially increase in elongation by the radiation dose up to 200 kGy, which tends to decrease till the dose of 400 kGy. It is also noticed that elongation at break increases by irradiation as CSM ratio increases up to 40phr.

On the Figure 6 show dependence of hardness of the rubber blends on CSM content.

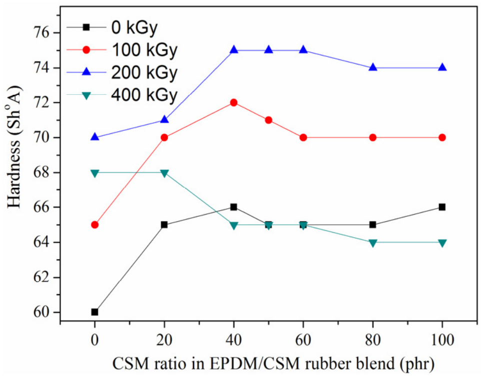

Fig.6. The effect of irradiation dose on the hardness of EPDM/CSM rubber blend with different CSM ratio

All the blends show a tremendous improvement in hardness (Figure 6) on irradiation at lower doses. For EPDM/CSM 60/40 blends as well as lower proportion of EPDM (20/80), a remarkable decrease in the hardness is observed beyond a radiation dose of 400 kGy as compared to those containing 40phr of CSM. This higher hardness of blends confirms the predominant occurrence of cross-linking in the crystalline regions of CSM as well, which enhances the hardness of these blends.

3.3. Thermal Aging Properties

Thermal aging properties of the compounds studied are shown in Table 2.

Table 2. Mechanical properties of EPDM/CSM rubber blend after aging at 100 °C during 72h in hot air

Compounding (phr)	1	2	3	4	5	6	7
Tensile strength (MPa)	9.2	9.5	9.5	9	8.5	8.5	8.5
Modulus at 100% elongation (MPa)	5.5	6.5	6.6	6.6	6	5.9	5.6
Elongation at break (%)	310	320	380	370	365	358	355
Hardness (Sh-A)	61	65	66	66	65	65	66

Generally, properties of all compounds decrease after aging. The magnitude of the decrease in mechanical properties depends on blend ratio. It is known that EPDM and CSM exhibits good resistance to thermal aging. Thus, by blending CSM with EPDM, it was initially expected that the blends would show a sharp decrease in properties after aging, because of the dilution effect is presence. A significant decrease in tensile strength and hardness are observed with the 80/20 EPDM/CSM rubber blend, but elongation at break is increase. The modulus of all compounds is relatively sensitive to thermal aging A significant decrease in modulus after aging is observed. Also, the modulus of all specimens decreases progressively with increasing CSM content in blends; this result is attributed to the dilution effect.

4. CONCLUSIONS

When CSM rubber incorporation in EPDM/CSM blends the rheological properties such as scorch time t_{s2}, cure time t_{c90} and the maximum torque (M_h) are increases, but torque difference (M_h-M_l) decrease, which is attributed to the distribution of crosslink between the two rubber phases. Tensile strength and modulus are increase up to 60/40 EPDM/CSM rubber blends compositions. After that the values are decrease with CSM content increase, but elongation at break and hardness increase, which is ascribed to the decreasing effect of strain-induced crystallization of CSM content is increased in the blends. During irradiation process, tensile strength, hardness and modulus increase, but elongation at break decrease up to 200kGy. After that degradation process in rubber blends is occurred. Properties of all compounds decrease after thermal aging. These EPDM/CSM rubber blend composites, with obtained properties will be used in railway vehicles for rubber sealing.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '12

THE EFFECT OF CARBON BLACK IN EPDM/NBR RUBBER BLEND USED IN RAILWAY INDUSTRY

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Abstract *- Rubber has had a very long history in railway service. Because of its excellent physical characteristics, the production of rubber springs is one of the most important usages of rubber. The rubber elastic element is used as a component of the elastic wheel of the urban transport vehicles, of the suspension system or as a part of the railroad infrastructure. Rubber products are always explored to specific conditions. A request of a maximum importance for the rubber used in the railway vehicles industry is represented by a strongly decreasing of the life-time resistance of these elements. Aging temperatures play important role in changing the mechanical behavior of rubber compounds for railway vehicles. So thermal aging test was carried out to investigate the effect of aging temperatures on the tensile strength (Ts), elongation at break (Eb) and hardness (H) of ethylene-propylene-ethylidenenorbornene and acrylonitrile-butadiene rubber blends (EPDM/NBR=40/60 w/w) reinforced with different carbon black (CB) loading. The obtained results of four different EPDM/NBR compositions with 50, 60,70, and 80 phr of CB were compared and will be used in railway vehicles for oil resistant seals.*

Keywords: EPDM/NBR rubber blends, carbon black, mechanical properties, railway vehicle.

1. INTRODUCTION

The study of blends of polymer materials has been the subject of a great deal of intense research in the last few decades [1-4]. The processing of polymer nanocomposites reinforced with various nanofillers is believed to become a key technology on advanced materials for next generation, in that the unique characteristics of nanoparticles made it possible for them to be used as promising nanofillers in polymer nanocomposites [5-8]. Elastomers based on more network precursors have become technologically important material for their diverse applications. Their physical and chemical properties recommend them as engineering materials for electric insulators, chemical industry, automotive and aircraft production, and many other areas. The blending of NBR and EPDM rubber was performed to achieve the best properties from each component. NBR has high resistance to swelling in oils and solvent but suffers from poor ozone resistance and heat aging properties. EPDM has good heat aging and ozone resistance (as its unsaturation sites are in the side chain and not in the backbone) but it possesses poor solvent resistance [9]. The blend of such two polymers attracts the attentions of many researchers to tailor a blend which withstands ozone, heat aging, oil and solvents swelling with desirable mechanical characteristics. Thus, the product of this blend will have excellent oil resistance, ozone resistance, heat resistance and mechanical strength. It could be used for the production of known rubber products requiring such properties, e.g. automotive brake hoses, automotive radiator hoses, motor mounts, transmission belts, conveyor belts, sheets and rolls. One of the important methods to form carrier path in an insulating rubber matrix is the

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incorporation of conductive additives like carbon black, carbon fiber, metal or metal oxide.

Most commonly used filler is CB, because it is easily processed and reinforcing effect on the material is produced, also. These conductive composite materials have been of low cost, high flexibility, and good mechanical properties. These are widely used for rubber contact switches, floor heating, electro-magnetic interference shielding and various other electronic and electrical applications. The curing process is the final step in the production of elastomers whereby rubber goods are formed to the desired shape. In press, heat is transferred to the compounds from the surfaces, which are maintained at high temperatures, inducing the network formation i.e. obtaining the strong elastic material.

The objective of the work was to prepare compatible, coherent, and technologically feasible blends comprising non-polar EPDM and polar NBR rubber and to study the effect of loading the reinforcing nano-filler such as carbon black N330 on the rheological and mechanical properties NBR/EPDM rubber blends before and after aging. This research work investigated EPDM/NBR/CB rubber blends as potential compositions in railway vehicles for oil resistant seals.

2. EXPERIMENTAL

2.1. Materials

The following materials were employed in the study reported here.

Rubber: Acylonitrile-butadiene rubber (NBR Kraynac 34-50, „Polysar"Canada) with acrylonitrile content 33,2%: Moony viscosity at 100°C, 50; specific gravity 1.17 gcm^{-3}; ash content 0.5%. Ethylene propylene diene monomer (EPDM Vistalon 2504, „Exxon"Belgia) with 4% ethylidenenorbornene (ENB): Mooney viscosity (ML (1+4)) at 125°C, 37; ethylene content 58%, oil content 0 phr (part per hundred part resin). *Filler:* High abrasion furnace carbon black, N-330 („Degussa"Germany): Black granulated powder has a particle size of 46 nm and specific gravity 1.78-1.82 gcm^{-3}. CTAB surface area 83 ± 6 m^2/g. The loading of CB in the NBR/EPDM rubber blend were is 50,60,70 and 80 phr. *Accelerators:* N-cyclohexyl-2-benzothiazole sulphen-amide (CBS): pale grey; non hygroscopic powder; melting point 95-100°C and specific gravity 1.27-1.31 gcm^{-3}. Tetramethylthiuram disulfide (TMTD): non hygroscopic white powder. Melting point 140°C, specific gravity 1.33-1.40 gcm^{-3}. *Antioxidants:* N-isopropyl-N-phenyl-p-phenylendiamine (Vulkanox 4010 NA): specific gravity 1.14-1.18 gcm^{-3}. *Curing agent:* Sulphur: Pale yellow powder of sulphur element; purity 99.9%; melting point 112°C; specific gravity 2.04-2.06 gcm^{-3}. *Activators:* Zinc oxide: fine powder; purity 99 %; specific gravity 5.6 gcm^{-3}. Stearic acid: melting point 67-69°C; specific gravity 0.838 gcm^{-3}.

2.2. Methods of preparations

Formulation of the composites is given in Table 1. The compounds (Table 1) were prepared using a laboratory mixing roll mill of dimensions 400x150 mm at a speed ratio of the rollers $n1/n2$ = 28/22, at a roller temperature of 40–50ºC. NBR was masticated for 3 min and blended with EPDM. After the homogenization of the rubber blend (for about 7 min), the other ingredients were added (Table 1). The processing time after each component addition was about 2 min. The compound rubber was allowed to stand overnight before vulcanization. The rheometric characteristics were assessed by a Monsanto Oscillating Disc Rheometer R-100, according to the ASTM D2084-95 standard testing method. The optimum curing time (t_{c90}) was determined at 150°C. The compound blends were molded using an electrically heated hydraulic press (Indexpell, Kerala, India) under a pressure of 60 MPa at a temperature optimum curing time. These cured sheets were conditioned before testing (24 h maturation at 25°C).

Mechanical properties, such as TS, modulus (%) and Eb were measured with a Zwick-1425 tensile tester according to the ASTM D412-98 standard testing method using a crosshead speed of 500 mm/min and at 25°C. The tensile properties of the blends were examined according to the ASTM D-412 standard testing method. For the tensile experiment, dumbbell samples were cut from a 2 mm thick molded sheet. The H of the samples was measured, as per the standard ASTM D-2240 testing method.

To investigate the influence of thermal aging on the mechanical properties, the obtained reinforced elastomeric materials were performed in an air circulating oven operated at 100°C during 50 h. The retained percentage values of TS and Eb were calculated. After aging, H is given in point. The tensile properties and hardness were measured before and after thermal aging.

Table 1. The formulation of EPDM/NBR rubber blend compounding

Compounding (phr)	Sample			
	1	2	3	4
EPDM/NBR	40/60	40/60	40/60	40/60
CB	50	60	70	80

Other ingredient in phr: ZnO-5, Stearic acid-1, 4010 NA-, CBS-1.5, TMTD-0.1, Sulphur-0.8

3. RESULTS AND DISCUSSION

3.1. Cure characteristics

For filled compounds, type and content of filler affect the cure characteristics. Lots of functional groups such as hydroxyl, carboxyl, lactone, pyrone, ketone, quinone, and phenol exist on the carbon black surface but the amount is small. Table 2 show the rheometric characteristics, such as scorch time (t_{s2}), and optimum cure time (t_{c90}) and CRI of the compounds at 150°C.

Table 2. Rheometric characteristics of EPDM/NBR/CB rubber blends

Sample	Mh (Nm)	Ml (Nm)	t_{S2} (s)	t_{C90} (s)	CRI (s^{-1})
1	7,62	3,16	108	324	0,46
2	7,68	2,60	138	396	0,39
3	7,60	2,60	134	372	0,42
4	8,13	2,37	132	360	0,44

Minimum torque (Ml) is directly related to the viscosity of the compounds at the test temperature. The minimum torque can be taken as a measure of the viscosity of the masticated rubber. Whenever there is excessive mastication, the viscosity registers a sharp decrease. The maximum torque (Mh) increases but minimum torque (Ml) decreases with the CB content increase in the NBR/EPDM rubber blend. Both scorch time and optimum curing time are decreasing noticeable with increasing the active filler content in EPDM/NBR rubber blend. The cure rate index (CRI) values are decrease with CB content increase in EPDM/NBR rubber blend.

3.2. Mechanical properties

Technical rubbers represent an important class of materials with a wide range of applications. The macroscopic properties of the rubbers can be strongly modified by compounding with plasticizers, fillers and other additives, by changing the crosslinking system and cross-linking conditions. The mechanical properties of rubbers are strongly improved by reinforcing with active fillers. The most frequently used filler in the rubber industry is carbon black [10]. The addition of fillers to polymeric materials leads to improvement in the mechanical properties of the polymer matrix. The reinforcement effect is directly related to the properties of the interphase and depends on the nature of the specific interactions between polymer and reinforcing fillers. The incorporation of filler into elastomers imparts many interesting and useful properties to the particle filled composite material. It is well known that the properties mainly depend on the dispersion condition of filler particles and their principal relevant properties: particle size, surface area, aggregate structure, surface activity and on rubber-filler interactions. The surface chemistry of CB has a significant effect only on the vulcanization behavior of filled compounds. Optimal reinforcing power can be achieved only if the filler is well dispersed in the rubber matrix. The chemical or physical interaction between the filler and the rubber is a further important factor in the reinforcing effect. In the case of carbon black the filler–polymer interaction is mainly of physical nature (physisorption).

Table 3. represent the effect of CB loading on tensile properties and hardness of the rubber vulkanizates. Obviously, the tensile strength increases with increasing CB loading in the EPDM/NBR rubber blend.

Table 3. Mechanical properties of EPDM/NBR/CB rubber blends.

Sample	Tensile strength (MPa)	Elongation at break (%)	Hardness Shore A
1	2,99	260	61
2	3,63	260	63
3	4,02	310	64
4	3,72	240	66

3.3. Thermal Aging Properties

The resistance of the rubber vulcanizate to thermal ageing is considered as an essential requirement for the long service life of products. In general, thermal stability of the polymer composites plays a crucial role in determining their processing and application, because it affects the final properties of the polymer composites such as the upper-limit use temperature and dimensional stability. For the fabrication of advanced composites with better balance in processing and performance, it is very instructive to characterize the thermal decomposition behavior of the polymer composites [11]. The percentages of values in tensile strength and elongation at break as a result of aging at 100°C for 50 h are presented in Table 4. It can be seen that the change in tensile properties are icrease with concentration of CB increase. The value of hardness increase, but the value of elogation at break decrease with CB loading increase in EPDM/NBR/ rubber blend.

Table 4. Changing of mechanical properties of EPDM/NBR/CB rubber blends after aging.

Sample	Tensile strength (MPa)	Elongation at break (%)	Hardness Shore A
1	-1,67	-23,8	2
2	+13,5	-12,9	1
3	+2,5	-16,1	1
4	+21,2	+10,4	1

It can also be seen that sample 4 with 80 phr CB show better ageing resistance than that of all samples. The hardness of all cross linked samples increases with increasing contents of CB filler, as shown in Table 4, which can be attributed to the crosslink density being increased after thermal aging. The tensile strength is a complex function of the nature and type of crosslink's, crosslink densities, the chemical structure of the used elastomers and the changes associated with degradation. Maximum value of tensile strength, before and after aging, for EPDM/NBR rubber blend is by sample 3 and sample 4, respectability (Table 3). Values of elongation at break decreased with increasing of CB loading except sample 4.

4. CONCLUSIONS

The maximum torque (Mh) increases but minimum torque (Ml) decreases with the CB content increase in the EPDM/NBR rubber blend. Both scorch time and optimum curing time are decreasing noticeable with increasing the active filler content in EPDM/NBR rubber blend. The cure rate index (CRI) values are decrease with CB content increase in EPDM/NBR rubber blend.

Organic functional groups of carbon black surface lead to an increase of the adhesion at interface between carbon black and the rubber matrix, resulting thermal stability and mechanical interfacial properties of the EPDM/NBR/CB = 40/60/80 rubber blend.

The results show that EPDM/NBR/CB rubber blend composites will be used in railway vehicles for oil resistant seals.

ACKNOWLEDGEMENT

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '12

MODERN RAILWAY TERMINALS AS RELATED TO SUSTAINABLE CITY DEVELOPMENT

Ksenija STEVANOVIĆ [1]
Milica PAJKIĆ [2]

Abstract *– In the era of integration of all means of transportation, as well as expansion of railway networks for high speed trains, there is a revived interest in railway transport. The renaissance of railway, led to a great production of exclusive new generation terminals, multimodal traffic interchanges. In this paper, attention was dedicated to terminals in major cities. We list a number of demands that terminals have to fulfill regarding efficiency and environmental protection. Since the adoption of pass-through type terminals is of crucial importance, we recognize their advantages used to exploit the concept of vertical content development. This superposition of content provides for easy transition from one method of transportation to another, as well as independent surfaces for movement for individual transportation systems, reduces the occupancy of city property and easily fits into a unique architectural form. Finally, the paper also notes the importance of architectural prevalence as part of the ambiance and the city as a whole. The goal of this paper is to identify the importance of modern railway passenger terminals as related to city transformation.*

Keywords - Railway terminals, multi-modal traffic interchange, pass-through terminal concept, integration in urban matrix.

1. RAILWAY TRAFFIC REBIRTH

Sustainable growth philosophy in transport sector has a key role in battle for environmental protection.

In the era of integration of all means of transportation, there is a revived interest in railway transport, which can not any long exist as a transport system on its own or as an independent part within the growing cities.

Railway transport is considered relatively clean and energy efficient using electricity instead of non-renewable energy resources.

The renaissance of railway transport, led to a great production of exclusive terminals in recent days. It is easy to pinpoint the importance of activating railway systems to reduce pollution and traffic jams, once that the railroad traffic underwent transformation due to new technologies of high-speed trains. Constant expansion of railway networks for these trains, as well as comfortable and fast travel they offer, reduced the use of cars and are also taking over passengers who travel on relations between 500 and 1400 km from airlines.

2. MODERN RAILWAY TERMINALS AS MULTIMODAL TRAFFIC INTERCHANGES

The aforementioned phenomena and facts also caused an extremely fast construction of modern railway terminals. With their functional concepts and shape solutions, they represent the paradigm of new railway station facilities. They are straightforward, materialized examples of the idea and imperative of merging all traffic systems in order to achieve more efficient and healthier functioning as related to the environment [1]. In this regard, new-generation terminals are multi-model traffic interchanges, places where people switch modes of transportation, resulting in use of adequate transportation both on the regional level and the metropolitan level [2]. These landmarks within the traffic network make it possible to emphasize the advantages of a certain traffic system, as well as to reduce its flaws, and reduce traffic jams and pollution by providing better propulsiveness. These points are formed on airport terminals, on intersections of important regional and main traffic lines in big cities (Figure 1).

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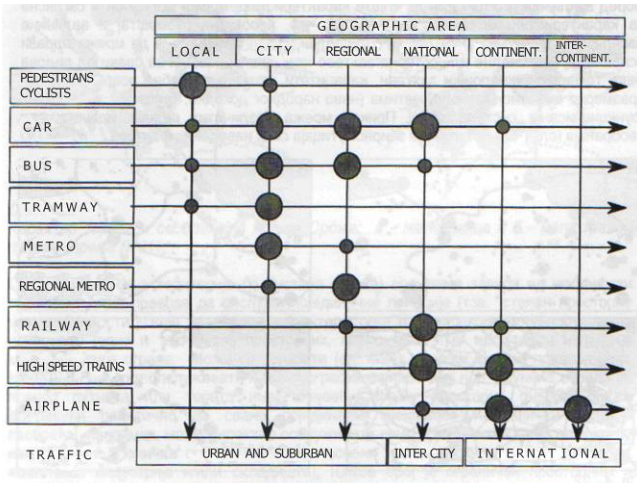

Fig.1. Geographical aspect and importance of transportation mode

In this paper, special attention is dedicated to terminals in major cities, since they are the most complex – encompassing both systems of non-urban traffic and city transportation (Figure 2).

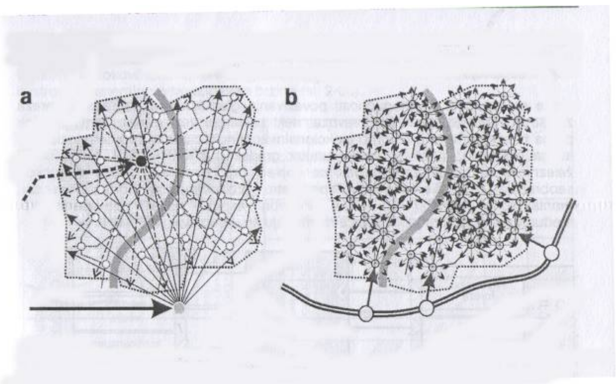

Fig.2. Non urban traffic entering city: a/ trough terminals-hierarchy; b/ dispersive, making more pollutions, traffic jams, noise…

On the other hand, these mega city structures have their specific features in cooperation with the urban matrix, unlike the incompatible old ones, which makes them even more important to the development of healthier cities [4].

For 25 years, in major European cities, new railway terminals are being constructed and old, historical ones are being improved.

Modern railway terminals have to fulfill regarding efficiency and environmental protection.

By determining the phenomenon that railway station poses by it presence in the city and by their analysis we are able to recognize what are the conflicts that it is posing, but also which are the advantages for the town. New railway terminals give the experience for the interaction, mutual progress of the station and the city.

The adoption of pass-through type terminals is of crucial importance, not only because of their advantages in comparison to oldness, but in using the methods to exploit the concept of vertical content development. This type is more suitable for city giving large abilities for smooth and easy interchanges (Figure 3).

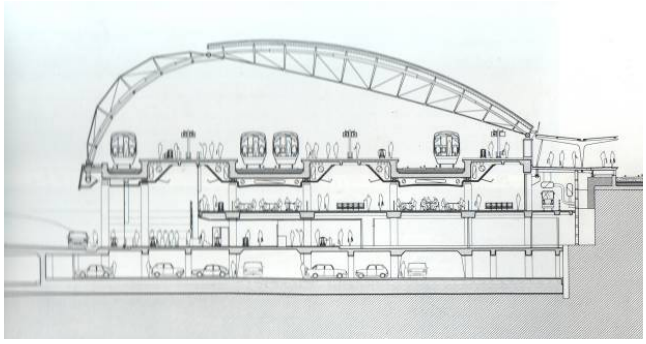

Fig.3. Transit type of railway station concept Vertical superposition of New Waterloo station in London;

Among the list of pas-trough type terminal advantages we recognize the most important ones:

- Superposition of content provides easy transition from one method of transportation to another, as well as independent surfaces for movement for individual transportation systems (Figure 4);
- Avoidance of conflicts with urban matrix;
- Reduces the occupancy of city property and easily fits into a unique architectural form [8];
- The accessibility from different sides and levels makes better propulsiveness for great number of users [5];

Fig.4. Complexity of Lerter station in Berlin, traffic intersection: Stadtbahn above, regional rail below and the multifunctional hall in between

- The aspect of ecology and environment protection, the effects station have on their immediate surrounding, as well as microclimatic conditions within the station itself (Figure 5);

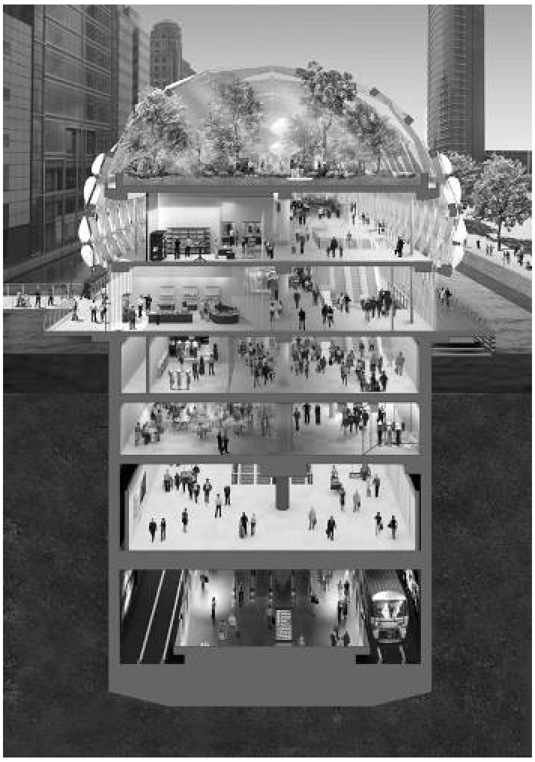

Fig.5. Idea for Canary Warf Station, London, 2017, 12000 square meters of retail space proposed with a park and glass covered square

- The importance of architectural prevalence as part of the ambiance and the city as a whole, making movement and speed visible and active part of modern urban life (Figure 3);
- Specific features regarding the quality and comfort of terminals concerning good orientation, the presence of natural light, climate conditions of big voluminous spaces…[3]

3. CONCLUSIONS

Global outstanding architectural production appears as consequence of fast comprehensive technological and economical improvement.

Traffic infrastructures also run out the transition and rationalization all over the world. The all kind of traffic is going to be integrated in unique system improving all their advantages, minimizing their drawback. According to those tendentious becomes revival of railway traffic as well as importance of city railway terminals, the key check points in whole railway network.

Modern station facilities are adopted to the continual railroad network, as well as other forms of public transport, thus creating the traffic interchange. These interchanges make traveling more efficient, more comfortable, offering various services to users (Figure 6).

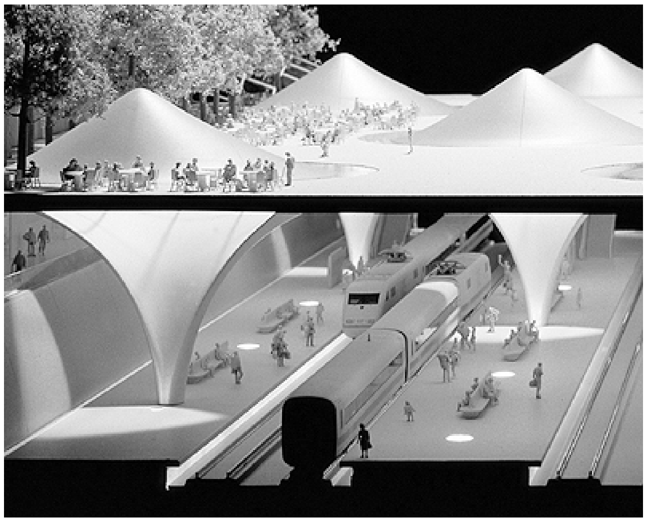

Fig.6. Stuttgart, pedestrian city square above tracks with lantern day lighting platforms;

Contemporary railway terminals use pass-through station concept exploiting vertical content superposition. This concept allows continuity of urban matrix, reduces the occupancy of city property thus leaving possibilities for more suitable land-use (Figure 6). These terminals provide better accessibility as well as great propulsivness through station itself.

Stations of a newer date fulfill the aspect of sustainable development and environmental protection reducing pollution and noise and making new city centers (Figure 7).

Modern city railway terminals with their functional concepts and shape solutions represent the paradigm of new railway station facilities. They are straightforward, materialized examples of the idea and imperative of merging all traffic systems in order to achieve more efficient and healthier functioning as related to the environment.

Fig.7. Tiburtina station in Rome, 2001, „bridge“ station as city boulevard with shopping mol connecting two separated part of town

Finally the renaissance of railway terminals offer certain specific features regarding the quality and comfort concerning good orientation, the presence of natural light, climate conditions of big voluminous spaces…

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS RAILCON '12

QUALITY OF WORKING LIFE AND SATISFACTION WITH RAILROAD CAR INSPECTOR'S JOB

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Abstract *– Railroad car inspector's position is one of the very important and responsible duties because the safety of the railroad transport as well as human lives greatly depend on his work. If we have a look at railroad car inspector's work at railroad stations in lay terms, we come to a conclusion that it is a very easy position and that all of his work consists of standing and tapping the wheels of a railroad car. However, when we get to know the work of a railroad car inspector better, we see that it is a very complex and responsible job. This work explains the importance of this position, the satisfaction with the job and with the quality of life of a railroad car inspector. While seeking money, something much more important is neglected- the quality of life.*

Keywords - Railroad car inspector, railroad station, quality of life.

1. INTRODUCTION

According to the methodology of European Foundation for the Improvement of Living and Working Conditions life-satisfaction is a part of overall well-being. High quality of life is the objective of all individuals and societies. An important factor for being successful on work is job-satisfaction.

This paper explains the importance of a railroad car inspector as an irreplaceable position in a complex system of the railroad transport. It also presents the concept of quality of life, the interdependence of all parties involved as well as the model of integration of work operations, quality of life and job satisfaction.

2. THE SAFETY OF THE RAILROAD

Permanent safety and regular transport are the responsibility of the Railways of Serbia. In order to achieve this, a railroad car is put to use only after it passes inspection during which it is confirmed that the car conforms the regulations regarding safety in railroad transport.

The train can leave the station only after the car inspector has inspected the train completely and signed a report sheet which it is stated that the train is connected properly, and the cars and the brakes are in order. In the railroad car maintenance department the car inspector is the most important position. His duty is to verify that the railroad cars function properly. Thus, he checks each car separately. According to all said above, it is concluded that the position of an inspector is difficult and responsible [1].

3. THE CAR INSPECTOR AS AN IRREPLACEABLE POSITION IN THE RAILROAD TRANSPORT

The job of a car inspector includes a set of

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permanent tasks and duties that are done by one or more individuals. The title of the position derives from the essence of the job or represents the basic features of the position. The duty is to inspect the operating condition of a train, because it is the basis of the safe, comfortable, economical and regular railroad transport.

Any failures in functioning can cause severe damages, put the lives of passengers in risk, harm the goods transported etc. The car inspector is the chief responsible person as far as the inspection is concerned. New technological solutions that modernize the cars demand better education and constant learning and improvement of the inspectors. The fact that car inspection (consisting of series of operations) must be done within short periods of time accounts for possible mistakes and failures. The job of a car inspector demands physical and mental efforts. The duties that demand speed, nimbleness and physical strength can be fulfilled only by a person physically fit. Since this job belongs to most difficult, most demanding and most responsible jobs, it can be done only by a highly qualified and well trained person [2].

3.1. Shift work

Shift work is specific for a work organization in the railroad transport, especially for practitioners and is a significant difficulty in doing this job. Shift work is harmful to the physical and mental health of a practitioner due to disorder in wake and sleep cycles. It is difficult for an inspector to rest during the day, when the rest of his family lives its ordinary life. Disorders in rest after night shifts don't allow practitioners to recover and regain energy, which diminishes their abilities. The social aspect of an inspector's responsibility increases emotional and mental stress, because of the fact that mistakes in his work can lead to severe damages even causing deaths. The practitioners can perceive this job as a barrier to normal private life, which causes negative state of mind. This job doesn't provide enough time for private or social life and causes difficulties especially in synchronizing them [1].

4. RISK ASSESSMENT FOR THE POSITION OF THE CAR INSPECTOR

The risk is a result of uncertainty regarding future events and is part of every process or a system. It is a factor that should be considered by any organization, because uncertainty can affect it, regardless of its activity. Even in cases of best organizations, the risk cannot be avoided, because it cannot be identified in advance.

Since the risk accompanies and affect all processes as well as the relations between them, then the risk management should refer to the whole system.

The balance between the potential failures due to risks and potential benefits is the key to successful risk management [3].

On the basis of a work organization analysis, safety precautions, risk management and a degree of danger, an estimation of risk level was carried out according to the established methodology and risk matrix (5X5). The result was that the car inspector was a position with an increased risk level.

According to the Rule book of job positions (Official gazette RS num. 105/2003), the position of a car inspector has got a higher health insurance of 12/14 months.

The safety precautions are established on the basis of estimated risk, as well as on the demands related to a specific position.

5. THE QUALITY OF LIFE CONCEPT

The arguments on life quality have been going on since Plato or Aristotle. The quality of life (QOL) is basically a subjective life-satisfaction of each individual. In their paper, Ilić et al [4] ,from the biopsychosocial aspect, consider the quality of life as an ideal of modern medicine, because it also enables an ethical progress in the clinical evaluation methods. The quality of life, as an academic discipline, emerged at the beginning of the seventies in the last century and was discussed and confirmed in 1974. by a scientific journal Social Indicators Research. Journal of Happiness Studies as a multidisciplinary journal discusses two basic axioms in researches in happiness:

- Theoretical essays on good life
- Empirical researches in subjective well-being

International association for researches in quality of life (ISQOLS) serves as a base for academic researchers in this field encouraging interdisciplinary researches, methodology discussions and development. Organizations such as UNESCO, OECD and World Health Organization are sponsors of many works concerning the quality of life [4]. The quality of a career includes: safety and health at work, respect from others in the organization, equal opportunities for improvement and development, freedom in expressing different opinions, creativity, care for children and elders, etc.

Databases contain a fact that in the seventies in last century there were only a few publications dealing with the quality of life, whereas in the last decade that number increased to more than 60 000 papers, which clearly indicates people's huge interest in life quality.

6. INTERDEPENDANCE OF SATISFACTION OF ALL PARTIES INVOLVED

When basic requirements of one party are not met, then it affects the level of satisfaction of other ones (the principle of connected vessels). An organization that gains a bad reputation within a local community, reflects the same reputation to employees.

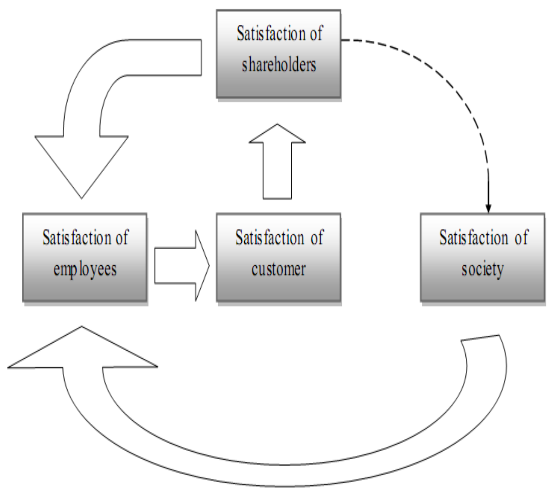

Fig.1. Interdependence of satisfaction of all parties involved [5]

A certain number of organizations that are currently facing that situation don't develop well. When employees are not satisfied, the attention to customer demands is diminished, and so the overall capacity of the organization (Figure 1). In his paper, Vuković M., [5] emphasizes that in many cases there is a positive feedback when all parties involved are satisfied. If one party is satisfied successfully, than it can contribute to the satisfaction of other parties. If the management staff of an organization can understand the needs of all parties involved, then it is capable of developing in several fields.

In developed countries many studies have been carried out showing how satisfying of all parties affect each other. The results of some researches carried out in Scandinavian countries show a strong correlation between the satisfaction of employees and the satisfaction of customers. Where the level of satisfaction of employees is high, the level of customers' satisfaction is high as well [5].

7. INTEGRATION OF WORK OPERATIONS AND QUALITY OF LIFE

In their paper, Arsovski S. and Miličević R. [6] list six key fields of life quality, which affect the work operations differently:

- being employed
- economic resources
- having a family and one's own home
- the position in the social environment
- health and healthcare
- general knowledge, education and trainin

Figure 2. shows how work operations affect the quality of life and vice versa.The relations in this model haven't been researched completely yet, they need being observed for a longer period of time, after which the correlation between the variables will be determined. In this model the effects of work operations to key fields of life quality are specially numbered from one to six, and the opposite effects are marked with R. The life quality includes:

- safety and health at work
- respect from others in the organization, equal opportunities for improvement and development
- freedom in expressing different opinions, creativity
- care of children and elders [6]

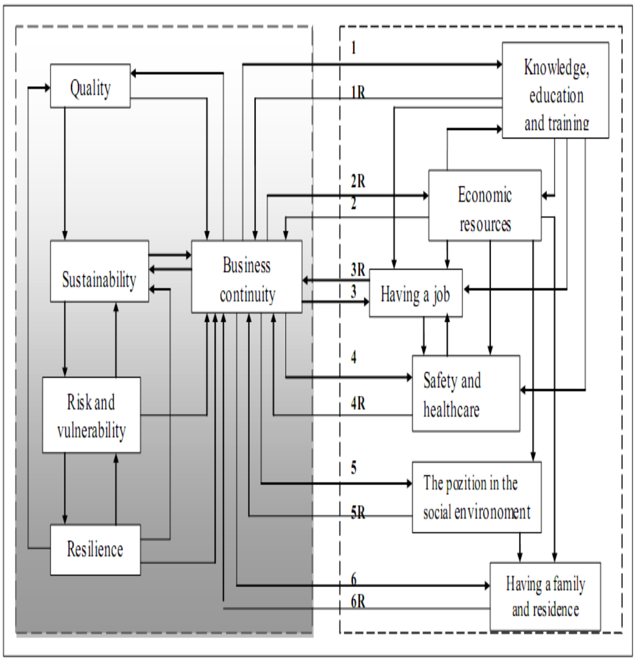

Fig.2. The model of integration of work operations and quality of life [6]

8. JOB SATISFACTION

Job satisfaction is a huge support to personal happiness and life-satisfaction. Happiness is the basis of life-satisfaction and it can be subjective and objective. There are many definitions of job satisfaction. Job satisfaction is considered a constant phenomenon. According to Spektor, [7] job satisfaction is what an individual feels about his job and all its aspects. In his paper, Riggio [8] argues that job satisfaction concerns the attitudes of a person towards his job. The aspects, whether good or bad, contribute to satisfaction or dissatisfaction. Most definitions determine job satisfaction on the basis of attitudes and emotions related to the job. In measuring the satisfaction there are two approaches: holistic and indirect. The holistic approach defines job satisfaction as a love for the job, i.e. the extent to which one loves his job or as a basic attitude towards the job. Job satisfaction means a person's loyalty to his job and importance of the job in his life. According to indirect approach, job satisfaction is a total of satisfaction with several aspects of the job. Different factors contribute to job satisfaction to different extents, depending on how important they are to an individual.

Job satisfaction consists of many factors: relationship with a group, satisfaction after completing certain tasks, feeling of belonging to an organization, income and how necessary the position is.

Sheridan and Slocum [9] listed what the employees would be satisfied with: work well done, a chief who understands the employees, a fair income, opportunities for improving, good workplace interpersonal relations. A large number of researches indicate that there is a strong correlation between various aspects of a job.

Personal factors such as: sex, age and character also contribute to job satisfaction. If a person's character is nice, the job satisfaction is greater. Job satisfaction is strongly related to life-satisfaction.

Life dissatisfaction is compensated with job satisfaction or job dissatisfaction is compensated with satisfaction from some other field of life-love, hobbies, friends etc. [10].

9. CONCLUSIONS

The results of researches showed that in case of railroad car inspectors there is correlation between emotions and job satisfaction. Both emotions are vital factors for successful work. All informants claimed that they were satisfied with their job, in spite of negative aspects: low salaries, shift work, long distances from home to workplace, responsibilities, lack of necessary equipment for work etc.

It can be concluded that the satisfaction with job primarily depends on the emotional profile of employees, i.e. the factors of character. It can also be concluded that if occupation is chosen to suit one's personality and if the occupation promotes one's personality, then one is satisfied with his job. When the awareness is raised, the life attitudes are changed, and so is the quality of life.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '12

THE INFLUENCE OF THE STARTING MATERIAL STRUCTURE ON THE REDUCTION OF MBW RIMS DURING OPERATIONS AT HIGHER TEMPERATURES

Radojica GRUJIČIĆ [1]
Aleksandar HINIĆ [2]

Abstract *– In addition to well-known and examined parameters, the condition of vehicles, the condition of the line and adopted wheel profile as well starting structure of cast ingot-preparatory structure for obtaining the large forging, i.e. monoblock wheel have their influence on quick wear of monoblock wheel flange. By means of a special metallurgical procedure of ingot casting and annealing regime, ferrite crystallization is prevented, whereas the ingredient of pearlite is increased and undesirable banded structure is removed, so that the material could have the most favourable structure for technological improvement process, thus providing good mechanical properties and homogenous structure resistant to wear along the entire flange section, to the border duct of the use of monoblock wheel.*

Keywords - Railways, railway vehicles, wheel-set, monoblock wheel

1. INTRODUCTION

During the usage of rolling stock, particularly during the summer, on the lines having big gradients and curves, such as the Beograd – Bar line, in course of long braking with cast brake shoes, due to thermal oscillations up to temperature of 600°C and large loads of bogies, mechanical properties of wheel are worsening due to the decrease in hardness, which results in increasing wheel flange wear.

Monoblock wheel (Figure 1) with the axle and the other wheel form the wheel-set that is installed on the bogies of rolling stock, and it is made of low-alloy carbon steel, grade R7T with good mechanical and plastic properties in accordance with European standard EN 13262.

Carbon steels as well as R7T are known to be highly sensitive to the change of temperature and their hardness dramatically decreases during slight rise in temperature, whereas during the decrease of hardness the material wear resistance is reduced.

Starting ingot structure is obtained by means of casting of molten metal into metal moulds in order to get specific shape suitable for further mechanical processing (forging or rolling).

Fig.1. Monoblock wheel in phase of fabrication

2. MATERIALS AND METHODS

Molten metal in contact with cold walls of mould is supercooled and solidification occurs whereby a big number of crystals are created on the walls of moulds forming polygonal fine grained structure, given in the Figure 2, as the Zone 1.

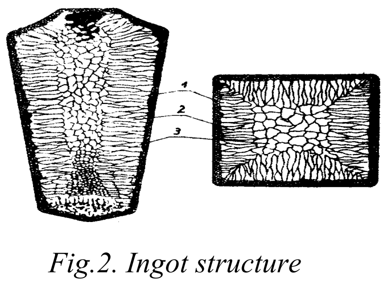

Fig.2. Ingot structure

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Further removal of heat is carried out through the Zone 1 and the wall of the mould, to the wall of the mould. Crystals rise further parallel towards the middle of the ingot and since they cannot develop laterally, they get elongated shape. Because of such shape they are named columnar crystals and form trans-crystal structure, given in Figure 2 as Zone 2.

During further cooling, trans-crystals push forward the impurities that are gathered in the core and act like germs, generating equal-axis crystallization.

This coarse grained preparatory structure, obtained by die casting of medium carbon low-alloy steel, given in the Figure 2 as the Zone 3 is named Widmannstätten structure. It has better solidity and hardness, but bigger brittleness, because of which it is deemed unfavorable (Figure 3).

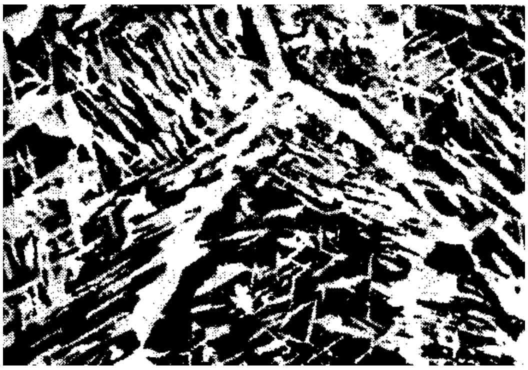

Fig.3. Widmannstätten structure

With a view to improving cast structure, during further technological procedure of monoblock wheel fabrication, special attention should be paid to casting in the mould. Having in mind the ingot size, cooling is carried out at slow pace, which results in complete diffusion of carbon from the edges towards the middle of the grain, therefore a bigger quantity of undesirable ferrite is generated on the edges of the grain. Ferrite singled out at the edges of the grain is unfavorable and should be eliminated because it restricts the increase in hardness and solidity of material (Figure 4)

Fig.4. Structure with less cooling speed

Increasing the speed of ingot cooling, there is not enough time for complete carbon diffusion; therefore considerable crystallization of ferrite on the edges of the grain could not occur, however, generating of pearlite starts. By bigger participation of lamellar pearlite, fatigue in deformation process is avoided, i.e. cleavage along the grain border eliminating the network of hot cracks (stains) and gashes along the rolling circle increasing the wheel wear (Figure 5).

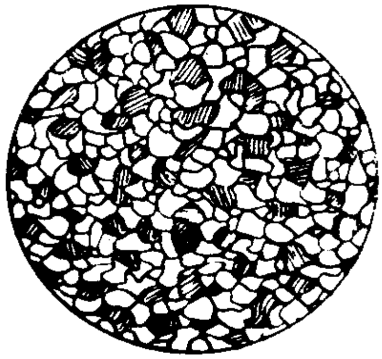

Fig.5. Structure with higher cooling speed

With a view to obtaining smooth and even structure, the following measures should be undertaken: adding the modifier during casting, accelerated cooling of the cast and use of mould coating. Hot processing completed by means of forging or rolling, monoblock wheel will undergo normalization regime, quick heating to the temperature Ac1 and Ac3 (727- G-S line), additional heating by only 30° to 50°C above Ac3, retaining for about 1h for 25mm per diameter, i.e. 3h for this section, and then cooling at calm or compressed air (Figure 6)

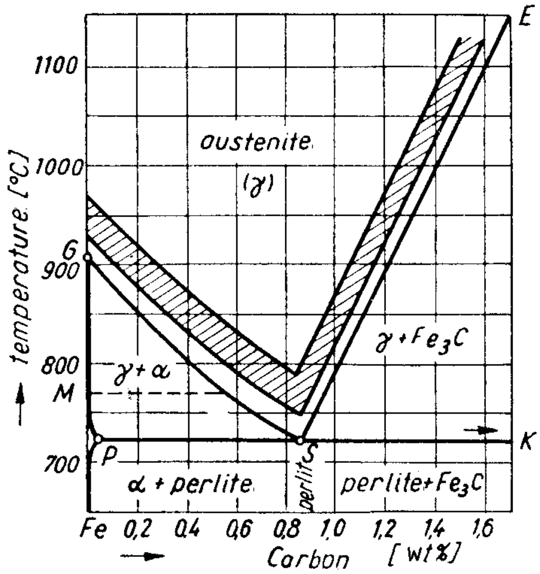

Fig.6. Normalization diagram

By means of double α/γ transformation, steel will be converted to fine-grained homogenous condition, which is reflected on the change of mechanical properties, increase in material solidity and properties of plastic (Table 1).

Table 1. Change of mechanical properties of steel cast with the same carbon contents during normalization

Steelcast	% C	Reh [N/mm^2]	Rm [N/mm2]	A5%	ψ%	KU (J)
Unannealed	0.53	25	62	7	4	1.3
Annealed at 820°C	0.53	35	72	16	8	1.5

By correctly selected normalization regime, (complete annealing), particularly when it comes to larger sections such as monoblock wheel flange, rough Widmannstätten structure occurred during casting is removed eliminating banded structure occurred due to forging of preparatory structure that has negative impact on the constant wheel load (Figure 7).

Fig.7. Banded structure

The structure after normalization should be equally pearlite-ferrite along the entire section of the wheel flange, for as favorable thermal improvement processing as possible, i.e. higher % of released martensite (pearlite and ferrite) with cementite lamellas along the flange depth and less % of residual austenite) increasing the resistance to wear of monoblock wheel at high temperatures during usage (Figure 8).

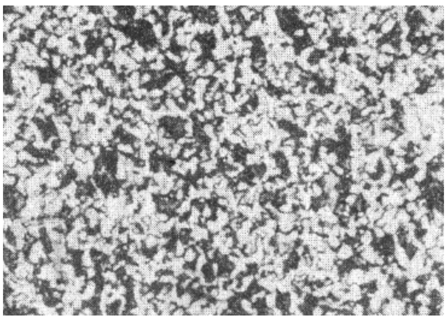

Fig.8. Pearlite–ferritestructure after normalization

Improvement efficiency indicator is the increase in resistance to wear of monoblock wheel and it is represented by bigger ratio Reh/Rm, given in the Table 2, by examined mechanical properties, replaced wheels, from the samples 1, 2 and 3, after plastic deformation or wear.

Table 2. Results of mechanical properties examination

Sample	Rm [N/mm^2]	Reh [N/mm^2]	A5%	KU (J)	Re/RM
1	912	590	19	70	0.64
2	866.6	570.5	16.8	29	0.66
3	865	721	14.9	45	0.84
Technical conditions	820/940	>520	>14	>17	

By means of sample analysis, it is found that the sample 3 has the most favorable ratio Reh/Rm, even by 30% better compared to other samples. This implies that the technological process related to the fabrication of sample 3 (batch), was carried out under more strict technological control, starting from the phase of casting of ingots, via annealing to final thermal improvement processing, which is the main reason for reduced material wear (wheel) compared to other two samples.

3. CONCLUSIONS

Increase in resistance to wear of monoblock wheel, at high temperatures of usage, in case of lines with big gradients and curves, may be realized by the implementation of adequate measures undertaken in stages: casting, forging and final thermal processing. In doing so, the most favorable material structure is achieved, which is more resistant to wear, extending thereby the life cycle of monoblock wheel.

Specified standard for the fabrication and delivery of monoblock wheel under normal conditions of usage is EN 13262; however, it may be modified by the agreement between the buyer and the seller in case of special purposes and climate conditions.

By the amendment of technical conditions for the fabrication of monoblock wheel, as well as by foregoing measures the life cycle would be extended, less immobilization of vehicles would be achieved, and at the same time the rolling stock maintenance costs would be reduced.

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XV SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
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HIGHER LEVEL OF TECHNO-TECHNOLOGIC DISCIPLINE AND CONTROL IN MANUFACTURING OF SPRINGS FOR RAILWAY VEHICLES

Radojica GRUJIČIĆ [1]
Nebojša IVKOVIĆ [2]

Abstract *– The objective of the work was to clarify the problems of sudden fracture of the flat springs, spiral springs and coil springs in railway vehicles. The work should indicate how to resolve the respective problem with more strict and proper technical-technological production and control, and accordingly, to achieve considerable effects of rationalization and savings in maintenance of railway vehicles. Besides poor railway operation conditions and condition of the equipment, the cause of higher incidence of fractures can be the structure of springs, which are the vital elastic elements of bogie suspension of railway vehicles.*

Keywords - Railway, railway vehicles, bogies, springs.

1. INTRODUCTION

Leaf and coil springs are mechanical elements which make the connection of the bogie construction parts of the railway vehicles. (Figure 1).

Fig.1. Railway springs

Steel assigned for manufacturing of springs requires high mechanical properties. Besides high strength, yield strength limit, plasticity and toughness, the steel must have elastic characteristics as well, in order to counteract the cyclic loading causing the material fatigue and leading to sudden spring fracture.

2. MATERIALS AND METHODS

For the quality and longer service life of the spring, is essential, which must be normalized. It implies the improvement of mechanical characteristics and grain refining eventually along the whole cross-section, in order to complete more successfully the process of quenching. Other than this condition, the purity of material must be maximal, containing no inclusions or oligo elements, otherwise these impurities may act as notches causing the accumulation of stress that will result in sudden brittle and fracture.

Besides providing the high-quality material, the condition of final top-quality spring lies in the proper quenching procedure resulting in as high as possible percent of martensite. Hardness of the base material is HB 700 through the whole cross section, where the microstructure consists of lath martensite with ferrite and cementite according to required mechanical properties, as it can be seen in Figure 2.

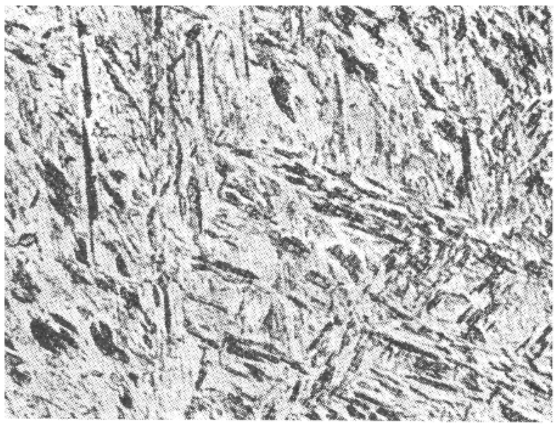

Fig.2. Tetragonal martensite

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All types of springs are manufactured by defined standard (JŽS, UIC 820) containing the following issues: technical regulations for manufacturing, testing of mechanical characteristics and structure, receipt of elements and finished springs for delivery. (Table 1 and Figure 3).

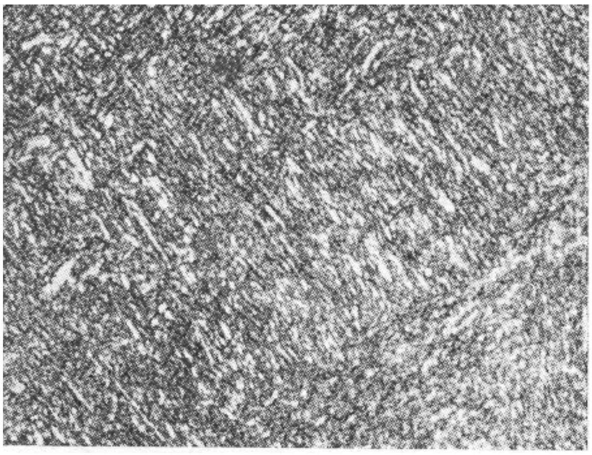

Fig.3. Tempered microstructure

Table 1 Required mechanical characteristics

Ultimate tensile strength R_m, MPa	Yield strength limit $R_{p0.2}$, MPa	Elongation A_5, %	Impact toughness, J
1300-1500	>1100	<6	>10

According to above-mentioned standard, qualitative and quantitative receipt of springs includes: dimensional control, hardness measurement, testing of deformation under gradual loading and unloading, measurement of the spring deflection, but without checking the individual phases and the whole process of manufacturing (testing of mechanical characteristics) with submitted attestation of the improved material, which together with the confirmation of receipt will be handed over to customer.

The seller guarantees only the springs with certificate of acceptance issued by Authority for controlling admission of JSC "Serbian Railways" (KPO JP „ŽELEZNICE SRBIJE" in Serbian). After a certain period of service, the railway vehicles are often excluded from traffic due to spring fracture.

For clarifying this continuous problem, the following steps were taken: the specimens were taken from long-standing spring supplier; these specimens were regenerated (tempered) and their mechanical properties were subsequently controlled. The used flat spring was then replaced by regenerated one.

Testings were carried out at the Institute for Testing Materials, Belgrade (IMS AD), Laboratory for testing of metals, with the obtained reports no. 421116-075 and no. 421116-056 presented in Tables 2 and Tables 3.

Table 2 Report no. 421116-056

Specimen number	Ultimate tensile strength R_m, MPa	Yield strength limit $R_{p0.2}$, MPa	Elongation A_5, %	Contraction Z, %	Impact toughness, J
1	1000	917	17	27.33	5.24
2	954	895	18.33	26.93	6.54

Table 3 Report no. 42116-075

Specimen number	Ultimate tensile strength R_m, MPa	Yield strength limit $R_{p0.2}$, MPa	Elongation A_5, %	Contraction Z, %	Impact toughness, J
1	1682	1556	7.00	19.00	5.56
2	1691	1563	6.67	19.00	5.56

The obtained results presented in Table 2 and Figure 2 refer to specimen number one of the flat spring leaf testing, which was thoroughly quenched, that is, a new leaf had no required elasticity; the second specimen, shown in Table 3 and Figure 3 was over-quenched, what typically leads to brittle fracture and no plasticity of leaves or springs.

Fig.4. Longitudinal cross-section of the flat spring leaf with laminated microstructure and tempered martensite, bainite, retained austenite, coarse-layered perlite, and carbides.

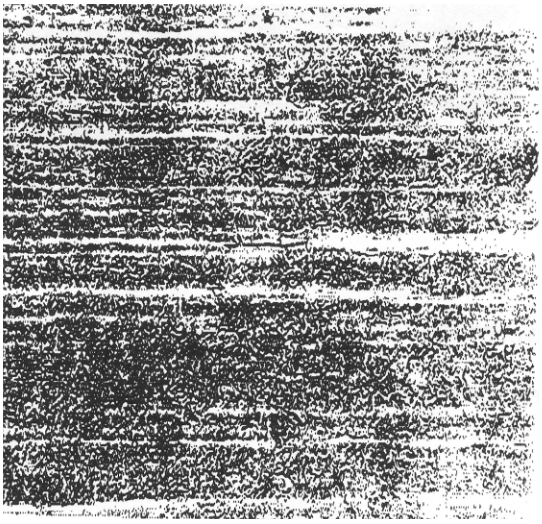

Fig.5. Longitudinal cross-section of the flat spring leaf with marked laminated microstructure, tempered martensite and some bainite with elongated nonmetalic inclusions

Properly quenched martensite has mechanical characteristics presented in Table 1. Figure 6 shows fine grained microstructure, and Figure 7 shows steel fracture surface containing 0.8% wt of C, quenched in water at 700°C.

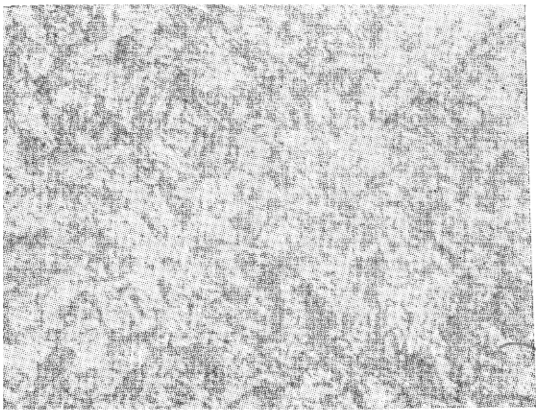

Fig.6. Surface martensitic microstructure

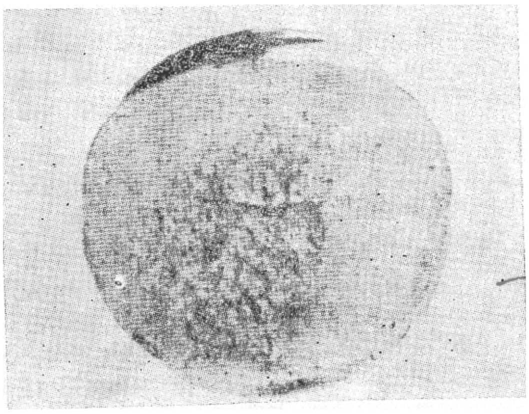

Fig.7. Steel fracture surface

It is apparent that the surface area is smooth and fine grained, that is, martensitic, while the softer core containing the trustite is characterized by weaker fibrillar rough surface.

Post-quenching microstructure for vehicle springs of up to 16 mm diameter should be as shown in Figure 6, and of 25 mm diameter as shown in Figure 7.

3. CONCLUSIONS

The chapter Conclusion which summarizes the paper is obligatory. At the end of the last page of the paper quote references.

For eliminating and reducing the sudden fracture of leaf, spiral and coil springs as well for disobeying the technological procedure of manufacturing and control, the following steps have been suggested:

[a] Interphase control of every batch after quenching is mandatory in order to obtain martensitic microstructure of required hardness.

[b] Final control of manufactured springs after tempering of each batch by mechanical and metallographic testing; the obtained results will represent spring quality certificate for client

As described in this paper, this higher level of technical-technological discipline and control will enable the continuous quality of spring manufacturing and rationalization of vehicle maintenance.

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