CONDITION MONITORING TECHNOLOGIES IN RAILWAY MAINTENANCE

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Abstract – Condition monitoring of track and vehicles is very important activity in railway maintenance. Condition-based maintenance operations should be planned on the base of real time measuring data in order to prevent failures. Monitoring process consists of periodical or continuous inspection of track or vehicles. Infrastructure managers use specialized track monitoring vehicles to assess the state of infrastructure and operators use wayside or on-board detection systems for monitoring the vehicles state in service conditions. Possibility of use the real time locomotive vibration measuring for assessing the state of vehicle and track was the purpose of the performed research, which is described in this paper.

Keywords – Railway maintenance, condition monitoring, on-board diagnostic, vibration measuring.

1. INTRODUCTION

Maintenance of railway infrastructure and vehicles is very important due to rail traffic efficiency, safety and costs. In order to improve the maintenance and availability of rolling stock, on-board and stationary diagnostics are introduced [1]. Stationary diagnostic systems are used for a casual-periodic inspection of railway vehicles and these are installed near the track [2]. On-board systems are installed on vehicles and used for continuous monitoring of vehicles in service conditions. Using the collected information from on-board diagnostic systems it is possible to analyze the condition of the vehicle components, but also the condition of the railway infrastructure can be assessed.

Tsunashima et al [3] describe the tests which were conducted in Japan Railway in order to research the possibility of condition monitoring of railway track using in-service vehicle. This track-condition-monitoring system based on measuring the vertical and lateral acceleration of the car body, as well as measuring noise in vehicle cabin. The field results showed that the condition monitoring of railway track using the developed probe system provide the useful information for condition-based-maintenance.

Sakellariou et al [4] present the method for vibration based fault diagnosis for railway vehicle suspension. The similar subject was researched by authors in the papers [5, 6]. They describe the research and development of rubber springs for locomotive primary suspension. In this project the measurement and data acquisition system is developed in order to analyze the railway vehicles dynamic characteristics.

Failures of axle bearings are often the cause of great wagon damage like derailment. The paper [7] describes onboard acoustic emission measurements carried out on freight wagons with purposely damaged axle bearings. Acoustic emission signal envelope analysis has been applied as a means of tool to detect and evaluate the damage in the bearings.

The purpose of the paper [8] is investigation of methods for condition monitoring in railway applications. The focus of the work is the condition monitoring of vehicle running gear and track condition. Authors investigated the use of different sensors and fault detection methods for vehicle and infrastructure condition monitoring.

This paper describes the condition monitoring process in railway maintenance. Further, the paper presents the vibration measurements obtained on Serbian railway electric locomotive in regular service, in order to investigate the transfer of vibrations from the wheels to the locomotive body. Vibrations were measured at the axle box, at the bogey frame that is under the primary suspension and at the locomotive body that is under the secondary suspension.

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2. MONITORING PROCESS IN RAILWAY MAINTENANCE

Condition monitoring is the main activity in condition-based maintenance of technical means. Frequently inspection of equipment or component and analyze the real time data are the base of planning the maintenance operation which can be performed just in time to prevent faults. Condition monitoring can be performed as periodic or continuous. Condition monitoring on railway infrastructure and vehicles are both important in railway maintenance.

2.1. Inspections in process of track maintenance

Track inspection is an essential task in railway maintenance and periodically it is performed. Inspection was manually operated by trained human operator who walking along the track searching for visual anomalies. This manual inspection is slow and unsafe, and the results depend on the capability of the observer to detect possible track failure.

Today, infrastructure managers use specialized track monitoring vehicles with a variety of advanced measurement equipment that are used to monitor the track, often on an annual or semiannual infrequent basis. By passing the measurement vehicle on a certain track section and performing measurements, a software package analyzes the measured data and generates a report. The report contains data about specified section of the track for the certain geometrical parameters like track width, track construction, cant deficiency and other track faults.

With the growth of the high-speed railway, automatic inspection systems are developed. These systems are able to detect rail defects thus increasing the ability of the inspection and reducing the needed time.

Some kind of track faults can be detected by measuring the vibrations of railway vehicles, some faults can be detected by visual or ultrasound detection. Visual inspection can be used to detect and monitor defects originating on the surface and to monitor the growth of defects in the track. Ultrasound scanning can be used to detect certain internal defects [6].

2.2. On-board detection of railway vehicle

Development of electronics, sensor and computer technology enabled development of on-board and stationary diagnostic systems, which are in use in rolling stock inspections in process of maintenance.

On-board systems are installed on the vehicles and they are used for vehicle’s components continuous monitoring in period of regular service. In that way, by condition monitoring the maintenance activities can be planned and the out of service time can be minimized. However, these diagnostic systems are very expensive because of the fact that each component need own diagnostic equipment.

Installation of these systems is economically justified for locomotives and trains or for traction units, but not for freight cars.

Wayside detection systems (stationary diagnostic systems) are used for a casual-periodic inspection of rolling stock and these are installed directly on the track or very near track. Condition monitoring of vehicles is performed in time of regular service, without stopping. Wayside detection systems are much more reasonable in terms of expenses. There are different types of wayside detectors as: hot bearing detectors, wheel impact load detectors, overload and imbalanced load detectors, truck performance detectors, wheel profile detectors, hot wheel detectors, acoustic bearing detectors, etc.

Most of the condition-monitoring systems (wayside and on-board detectors) for railway vehicles are focused on the wheel and bogies. The wheel-rail interface is one of the most important parameters in the vehicles’ operating condition. It is important to monitor condition of railway vehicles and infrastructure to avoid accidents, as a derailment which is very costly and may cause injuries.

One of the challenges with implementing condition monitoring is to find the right measurement technologies, since reliable and valid measurements are a necessity for an effective condition monitoring approach. There is the question of finding relevant and correct parameters that can be measured to provide the most relevant measuring data, because the measurement data must then be transformed into relevant and understandable information that can be used as decision support in the maintenance management process. Vehicle vibration in running condition is parameter which can authentically present the real state of vehicle’s running gear but also the state of track. Because of that measuring of the vehicle vibration in service condition can be very useful.

3. CONDITION MONITORING USING VIBRATION MEASURING

Wheel-rail interaction depends on wheel and track geometry state, wheel condition, track irregularities, vehicle suspension condition etc. However, measuring of vehicle vibrations and comparing measuring data with referent data or measuring data in past period we can assess the state of vehicle’s integral parts and state of track.

Research team from Faculty of mechanical engineering in Nis performed the measuring of vibration on electric locomotive type 444 owned by of Serbian Railways. The measuring and data acquisition system was designed for measuring vibrations in three axes and at six autonomous points, traveled distance and vehicle speed.
Vehicle vibrations are a result of dynamic forces that are caused from roughness of the rails, gaps on the joints between the rails, cone of the rolling area of the wheels, presence of unevenness on the rolling area of the wheels, physical properties of the materials of the rails and the wheels, type of suspension, changes of the speed of the vehicle, etc. Suspension of the railway vehicles reduces the influence of dynamic forces and ensures a stable motion. Defects of the suspension may cause an unstable contact between wheel and rail and increased vehicle body oscillations, thus increasing the wheel and rail wear, and may lead to a failure of some bogey parts, and in the worst-case to derailment.

Two field tests were performed with the same locomotive (Figure 1a) on the same Serbian railway line Nis-Leskovac (40 km distance) in regular service pulling the freight trains (1076 t in the first field test and 1145 t in the second test) and measuring data are analyzed.

The primary suspension of electric locomotives type 444 consists of the rubber-metal springs of the type "shevron". Figure 1 b) shows the locomotive bogy. Secondary suspension of this locomotive consists of coil springs and hydraulic absorbers.

The developed measuring-acquisition system for analysis of dynamic characteristics of consists of six sensor modules with triaxial accelerometers, microcontrollers, a local memory, a system for synchronization of measurements, the Global Positioning System (GPS) and a communication module data acquisition. A special computer application (CALMNESSdrive - Figure 3) for acquisition and processing the measurement data in real-time, permanent storage in a database, filtering, displaying and generating reports on the recorded results has been developed. Six triaxial sensor modules were installed on the locomotive at three levels (first level-axle boxes, second level-bogy frame and third level-locomotive body). Triaxial accelerometers installed on axle box and bogy frame are presented in Figure 2. The GPS receiver was placed on the roof of the locomotive cabin. The sampling frequency was 200 Hz.

The experimental plan was to research the locomotive’s dynamic behavior in relation to the position of the locomotive on the railroad and its current speed. In this way, direct connection can be identified between locomotive’s dynamic behavior and properties of the railway tracks. In addition, state of primary and secondary suspension can be evaluated.

The figure 4 shows measured vibrations on locomotive axle box in vertical, lateral and longitudinal direction on rail section of 250m. As expected, the acceleration in vertical direction is the largest. The figure 5 shows measured vibrations on locomotive bogy frame in vertical, lateral and longitudinal direction measured on the same rail section. Accelerations in vertical and lateral direction
are larger than in longitudinal direction.

![Fig.4. Measured vibrations on locomotive axle box](image)

**Fig.4. Measured vibrations on locomotive axle box**

![Fig.5. Measured vibrations on locomotive bogie frame](image)

**Fig.5. Measured vibrations on locomotive bogie frame**

Acceleration in vertical direction measured on three locomotive levels (axle box, bogie frame and locomotive body) during train running on rail section of 250m long is presented on Figure 6. It can be seen that acceleration on axle box is significantly larger than on the bogie frame and locomotive body. It means that primary suspension is performing its function properly as absorbs vibrations significantly.

![Fig.6. Vertical vibrations on axle box, bogie frame and locomotive body](image)

**Fig.6. Vertical vibrations on axle box, bogie frame and locomotive body**

![Fig.7. Lateral acceleration at axle box and bogie frame](image)

**Fig.7. Lateral acceleration at axle box and bogie frame**

Figure 7 presents the lateral accelerations measured on axle box and bogie frame at 10 m long rail section at 75 km/h speed.

### 4. CONCLUSION

Condition-based maintenance is new concept of technical means maintenance which main activity is condition monitoring. There are many methods for condition monitoring like visual, acoustic, temperature inspection. Measuring of vibrations is method, which can detect a malfunction in early stage.

Based on performed research some conclusions can be established:

- The most effective maintenance of railway vehicles is a common control without interrupting operation.
- Testing of equipment and vehicle components is the most proper in service condition.
- On-board diagnostic systems are installed in a vehicle in order to perform continuous monitoring of vehicle components in period of regular service. This system controls only one vehicle, but it also controls the state of track on service line.
- Measuring of vehicle vibration in running condition can provide useful data of vehicle components state and of track state.

### REFERENCES


