XIX SCIENTIFIC-EXPERT CONFERENCE ON RAILWAYS
RAILCON '20

RELIABILITY AND SAFETY OF AXLE-WHEEL ASSEMBLY

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Abstract *– The reliability of the axle wheel assembly is very important for the safety from railway accidents that can cause human losses, high material costs and environmental impact. The reliability value should be near one, however its value never reaches its maximum. Many parameters affect its size and are related to the formation of the assembly and its monitoring during operation. Therefore, it is necessary to anticipate and implement sensors that indicate in a timely manner the identification of parameters that affect the decline in reliability and the possibility of assembly failure. The UIC regulations for this assembly have approximate values, and every participant in the creation of this assembly and its operational monitoring remains a technological secret of the participants. In the formation of the assembly, the parameters are: the size of the overlap, the quality of the machinig surfaces, the direction of the unevenness, the geometric accuracy of the shape and position, the lubricant and its parameters, and the application technology. During use: number of variable loads, monitoring the influence of the possibility of temperature rise in the zone and around the assembly zone, the influence of microcracks, etc.*

Keywords – wagon axle, reliability, safety, axle assembly

1. INTRODUCTION

The reliability of elements and assemblies in construction and devices is very important for the safety of their use. In railway vehicles, reliability is very important because the consequences of accidents cause high material costs and often inevitably loss of human lives and severe injuries. Vital assemblies on railway vehicles are: brake devices, axle assemblies, traction-buffer devices, bogie, etc. This paper deals with axle assemblies.

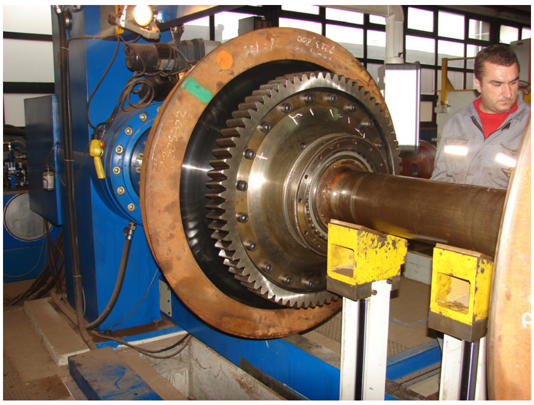

Fig. 1. Axle assemblies of traction vehicles

There are differences between axle assemblies for traction vehicles [1], Figure 1, and for towed vehicles [2], Figure 2, in terms of their load and the complexity of the stress state that occurs in operation. Axle assemblies (axle + shaft) for traction vehicles have significant torsional stresses comparing to the axle assembly of towed vehicles. Therefore, in practice, they have more frequent failures compared to the axle assemblies of towed vehicles. The parameters that are important for these assemblies are: the bearing capacity of the assembly, the appearance of microcracks in the elements of the axle assemblies, the contact profile of the wheel - rail [3], residual stresses after the process of forming the pressed assembly, etc.

Fig. 2. Axle assemblies of towed vehicles

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Regulations, International Union of Railways (UIC), give approximate values for these assemblies [4], while the details are defined by designers and technologists in the production of these assemblies. In the formation of the assembly, the influential parameters are: geometric characteristics (diameter, contact length and shape of contact surfaces), pressure on contact surfaces (force during realization of pressed assembly, inhomogeneity of component materials, material stiffness, variation of shape of contact surface, quality of machined surfaces, direction of propagation of contact surfaces unevenness), lubricant (machining method of contact surface, surface hardness, pressing speed, types of lubricants, surface roughness, surface cleanliness) and microclimate conditions. The characteristics of material are defined and, as a rule, there should not be any deviation from it [4,5,6,7]. The history of materials is kept throughout the service life of the components of the assembly, because in the event of a breakdown, it is obligatory to check it detailly in order to detect possible causes that led to the accident. The technological process of preparation and manufacture of assemblies is a secret and property of the manufacturer of the assembly.

2. BASIC PARAMETERS FOR PRODUCTION OF AN AXLE ASSEMBLY

When preparing the elements for the production of the axle assembly, in addition to the geometric preparation of the assembly elements, it is obligatory to control microcracks and various possible inclusions in the axle and the body of the wheels before machining and after machining. The control is performed by non-destructive methods. For the assembly, the approximate maximum and minimum values of geometric measures and pressing forces are prescribed by the standard UIC 813. Force used for forming assemblies for wheels of diameter ∅ 920 must be in the range of F = (555 ÷ 1100) kN. The approximate calculation of the allowed force is defined by equation

$$F = a \cdot D \ \left[kN\right] \tag{1}$$

where:

a - coefficient in a function of friction, ie. the types of lubricant used in pressing process,

D - diameter of the hub, mm.

As a lubricant in the formation of the assembly, it is recommended to use: flaxing oil or rapeseed oil, tallow and MoS_2, and a combination of oils and tallow. In order to achieve the force in the prescribed range, the following are very important: tolerances of the hole in the hub and the diameter of the shaft on which the hub rests, the centricity of the shaft and its ovality at the point of retraction of the wheel, roughness of contact surfaces, direction of propagation of the contact surfaces unevenness, lubricant properties, centricity and ovality of wheel hub openings and microprocessing of pressing technology. Positions of deviation of ovality and centricity of a hole and a shaft during pressing can significantly affect the force of the pressing regarding the same overlap sizes. Therefore, it is necessary to determine the directions of the position of the contact surfaces of the hole and the shaft during pressing as a function of ovality and centricity.

3. CARRING CAPACITY OF THE ASSEMBLY

Since axial and radial forces occur in operation of the axle assembly, as well as torques and dynamic shocks, the bearing capacity of the assembly is very important. The condition that the force and torque to which the pressed assembly is exposed in operation is less than the guaranteed bearing capacity of the assembly must be fulfilled.

The carring capacity of the assembly depends on the size of the contact surface, the size of the lap, the coefficient of adhesion and the contact pressure. For cylindrical contact surfaces it can be determined by the equation [8]

$$F = \frac{\pi \cdot l \cdot \mu \cdot z_p}{\xi_e + \xi_i} \cdot 10^{-4} \ \left[kN\right] \tag{2}$$

where:

l - contact surface length, cm

z_p - actual lap, μm

ξ_e, ξ_i - parameters of deformation of the outer and inner element of the assembly, cm^2/kN

μ- adhesion coefficient.

Equation (2) shows which elements affect the carrying capacity of the assembly, which is calculated theoretically. If the lap is larger and the roughness of the contact surfaces is lower, the carrying capacity of the assembly is higher. However, the actual carrying capacity differs from the theoretically calculated one and it changes when the assembly is in use, depending on: the dynamics of the motion of the pressed assembly, microclimate conditions, imbalance masses, etc. Due to safety, these assemblies must be constantly monitored during their use. Reliability parameters are achieved during the manufacture and maintenance of the axle assembly. The level of safety is affected by regular maintenance, and in order to increase that level, it is necessary to introduce modern monitoring methods for some parameters that can provide information about changes that may affect the safety of the operation of axle assemblies [8, 9]. This can be done by use of various sensors and digital technology which sends data to certain databases on the basis of which it is possible to obtain information on the safety of the use of the assembly [10]. In order to implement the modern monitoring methods, some material costs, which are not small, are required. However, the consequences of accidents can always be far expensive than investments in safety monitoring systems of vital elements of traction and towed railway vehicles.

4. EXPERIMENTAL RESEARCH

The goal of every user of certain systems and devices is that they perform their function without failure as long as possible. A longer period brings higher profits and reduces costs. For axle assemblies, it is known that the service life depends not only on the quality of their construction and maintenance, but also on: dynamics of motion, number of kilometers passed in loaded and unloaded condition, quality of railway infrastructure on which they move and quality of maintenance. The wheels of the axle assemblies have a shorter service life which in practice is about 5 to 10 years, depending on the quality of other contact elements and the number of kilometers passed. The axles may last much longer and user requirements are that their service life would be unlimited. In this research, axles aged 25 to 40 years were used, and the wheels were newly manufactured. During the research period, 40 axle assemblies for freight wagons were manufactured and assembled. During the production, all the elements that affect the value of the pressing force, which directly affect the bearing capacity of the assembly and its reliability, were monitored. MoS_2 was used for lubrication.

Other parameters of the process are defined within the regulations of UIC 813. Detection of pressing force was performed on a press that has a digital measuring chain (detects force and pressing path in a real time), Table 1. After processing axle assemblies, their control on compliance with UIC standards 813 was performed.

Tab. 1. Pressing force

No.	Difference of the lap [mm]	Pressing force [kN]		
		Wheel A	Wheel B	Difference
1	0.000	871	965	-94
2	0.050	973	826	147
3	0.030	1077	840	237
4	0.010	759	813	-54
5	0.020	1076	841	235
6	0.030	802	902	-100
7	0.020	980	923	57
8	0.020	985	882	103
9	0.000	773	905	-132
10	0.040	870	806	64
11	0.000	827	903	-76
12	-0.040	720	820	-100
13	0.000	762	792	-30
14	0.010	797	961	-164
15	-0.010	849	917	-68
16	-0.040	832	729	103
17	0.010	823	821	2
18	0.010	904	888	16
19	0.040	880	664	216
20	0.040	913	871	42
21	-0.030	857	909	-52
22	0.000	783	786	-3
23	0.020	833	709	124
24	0.000	888	775	113
25	0.070	755	768	-13
26	0.030	674	725	-51
27	-0.020	804	812	-8
28	0.020	932	759	173
29	-0.010	745	725	20
30	0.000	732	714	18
31	0.020	792	765	27
32	0.010	722	792	-70
33	0.000	771	699	72
34	0.020	865	782	83
35	0.020	747	905	-158
36	-0.010	743	803	-60
37	0.010	688	678	10
38	0.020	918	685	233
39	-0.010	768	697	71
40	0.000	752	965	-213

Pressing is achieved with a speed of 50 mm/min. The diagrams of the increase of the pressing force as a function of the contact length of the contact surfaces are given in Figure 3 and Figure 4.

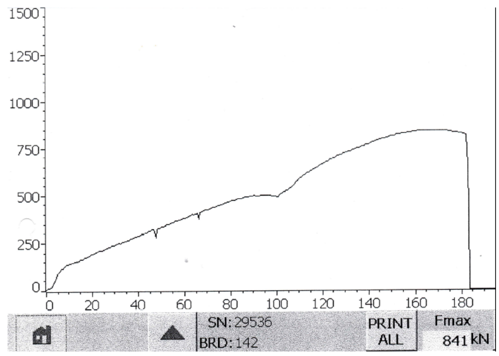

Fig. 3. Functional dependence of the pressing force on the contact length, different centricity and ovality (wheel B, smaller the lap, larger roughness, narrower tolerance of the cylindricality of the hub opening, number 5 in Table 1)

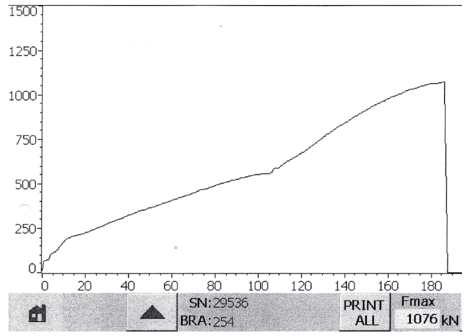

Fig. 4. Dependence of pressing force on contact length, equal centricity and ovality (wheel A, larger lap and lower roughness on the seat of the wheel hub)

3.1 Analysis of the causes of deviation of the pressing force

The difference in pressing force is up to 20% on the same shaft. There is a question what are the causes of this deviation. The causes of deviation are: the size of the overlap, the uniformity of the thickness of the layer of lubricant, the centricity and ovality of the surfaces forming the assembly, the height of the unevenness, ie. quality of machining surfaces. If the overlap is the same, then the intensity of the force is influenced by the technological parameters of the machinig of contact surfaces, the centricity and ovality of those surfaces. When the overlap is equal (on the left and right wheel) of the pressed shaft assembly, the pressing force can vary up to 10%, which is influenced by: roughness, centricity and ovality of the contact surfaces and the technological process of pressing. Since the quality of the material is defined by the UIC standard, the reliability of the assembly is influenced by the geometric and technological parameters of the preparation of the surfaces through which the assembly is realized and the pressing process itself. The maximum force applied in this research was 1077 kN and the minimum 664 kN. It can be stated that, in addition to the size of the overlap, the intensity of the force is significantly influenced by the centricity and ovality of the contact surfaces, their roughness and the direction of unevenness. If the roughness is higher, larger plastic deformations of the unevenness occur, which affects the pressing force. The pressing force is of lower intensity, which affects the bearing capacity of the assembly.

5. CONCLUSION

In order to bring the reliability of assemblies to a higher level, in addition to the tolerance of the dimensions of the assembly elements, it is necessary to pay significant attention to: the roughness of the contact surfaces, the shape and position of these surfaces and technological parameters. Since the length of the shaft is over 2000 mm, it is important the centricity of the contact surfaces be within the narrower limits during the assembling process, because if the deviations are higher, the pressing force exceeds the upper allowed limit. If this limit is exceeded, the assembly cannot go to further procedure. It can be concluded from this research that the deviations for approximately the same tolerance measures of pressing forces, which is relevant for the bearing capacity of the assembly, can vary up to 20%. The safety of the use of the assembly can be increased by modern monitoring methods of the assembly in operation and their quality maintenance. It has been realized that users do not have a database of the number of kilometers passed of axle assemblies in the loaded and unloaded state, which is very important due to the number of stress change cycles in the axle assemblies. When processing new assemblies with used axles, all non-destructive testing methods must be implemented in order to increase the level of reliability and safety. It is necessary to introduce modern monitoring methods of possible disturbances on these assemblies that may endanger the safety of the use of traction and towed vehicles in railway traffic. These methods need to be improved in order to increase the safety.

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