DOI: https://doi.org/10.30932/1992-3252-2019-17-74-81

Design and Methodology for Studying Wheelset Load

Lyubov A. SLADKOVA **Alexey N. NEKLYUDOV**

Sladkova, Lyubov A., *Russian University of Transport, Moscow, Russia.*
Neklyudov, Alexey N., *Russian University of Transport, Moscow, Russia*.*

ABSTRACT

The wheelset is one of the most vulnerable parts of a carriage in terms of failures. As a rule, the failure is revealed at the stage of operation and depends not only on the type of material, of which wheel and rails are made, but also on the technology of their manufacture and operation. The main malfunctions of wheelsets, the nature and causes of their appearance are considered from the point of view of train operations.

The objective of the study is a brief analysis of wheelsets' failures, measures to fight them, as well as development of approaches to introduction of new design decisions.

As a debatable problem, the authors suggest a thesis that the existing methods for repairing wheels flanges by surfacing are less promising compared to the technical solution proposed by them. The study proposes to increase reliability of wheelsets at the design stage by making minor changes to the wheel design without changing its geometric characteristics and parameters. Taking into account the cause and the places exposed to the greatest defects (wheel flanges and rims), it is proposed that a rim (hoop) made of a material whose hardness is commensurate with hardness of the rail is pressed onto the wheel of the existing structure in places of the most likely occurrence of the defect. The inner surface of the hoop should completely repeat the outer contour of the wheel in contact with the rim, which provides the necessary bond strength. The proposed technical solution will reduce the stress-strain state of the wheel flange, which is the main cause of failure.

To assess the suggestion by calculating total stresses arising on the contact surface of the wheel, it is proposed to use the classical theory of strength.

The same method is proposed to solve other problems referring to calculation of solutions aimed to increase the life of wheelsets.

So, the main idea of the research is to develop goals and objectives and main directions related to making fundamentally new decisions to increase the life cycle of wheelsets during their operation, as well as to develop relevant theoretical principles and a scientific and methodological apparatus.

Keywords: transport, railway, technical solution, wheelset, wheel, carriage, railway wagon, research, loading, wear, failure.

---

*Information about the authors:
Sladkova, Lyubov A. – D.Sc. (Eng), Professor of the Department of Land Transport Vehicles and Technology of Russian University of Transport, Moscow, Russia, rich.cat2012@yandex.ru.
Neklyudov, Alexey N. – Ph.D (Eng), Associate Professor, Head of the Department of Track & Construction Machines and Robotic Complexes of Russian University of Transport, Moscow, Russia, neklyudov.an@gmail.com.

Article received 04.06.2019, accepted 12.11.2019.

For the original Russian text of the article please see p. 74.

Introduction

The scientific interest in the wheelset is determined by the fact that the wheelset is one of the most important, responsible but also vulnerable parts of a carriage in terms of failures. Also, it is necessary to consider that its reliability, like of any product, is laid at the design stage.

It was revealed that the main malfunctions of wheelsets, the main of which are shown in Pic. 1, are milling bars, sliders, cracks, undercuts, chips and flaws on the surface of the wheels, wear of the wheel flange, etc., which require replacement of the wheels [1, p. 1; 2, p. 8; 3, p. 56]. Their emergence is associated, as a rule, with operation of the equipment and vehicles.

It is considered that the wear rate of wheels and rails depends on more than sixty factors [4, p. 7], some of which are part of the design group.

The author [4, p. 2], believes that according to experts, in Russia «in the early 80s of 20th century, the service life of bandages of locomotive wheelsets was 6–7 years, and in the 1990s it reduced to 2–3 years. In 2010, about 3 million wheelsets were subjected to repair with turning when restoring the configuration of their profile» [4, p. 1].

The main reason for increase in the number of failures of wheelsets is the difference between hardness of the wheel and the rail. Currently, hardness of rails is 400–450 HB, and hardness of bandages of wheelsets of traction rolling stock remains at the level of 275–315 HB, which determines the increase in wear of bandages and rails. When switching to the rail type R65 (from R50), wear of wheelsets more than doubled [4, p. 1; 5, p. 156; 6, p. 181], with a predominance of lateral wear (with a predominance of wear on the lateral surface) [4, p. 12], which cannot but affect the increase in the wear rate of the wheel.

This problem will have a steady upward trend because of increased traffic speeds of railway transport [7, p. 13].

In Russia at a moment, about 50 % of wheelsets of freight cars were in operation with a rim thickness of less than 40 mm, of which 50 % with a thickness of less than 30 mm. The standards set the average service life of the wheels up to 12 years [8, p. 17], but in fact the service life of the wheels is significantly less.

It has been established that, on average, when repairing wheels along a ridge by a machining method, 12–15 mm of rim thickness from each wheel goes to shavings (see Pic. 2 [9, p. 48], and when repairing thermo-contact-fatigue defects 5...7 mm or more does [4, p. 1; 5, p. 156; 6, p. 181]. Given that at present the wheelset of an intensively operated working fleet of wagons is machined per year because of one of the defects at least once, the average service life of the wheels is about 3–4 years [4, p. 32; 6, p. 181].

The existing method for restoring wheelset flanges by surfacing is ineffective in terms of material consumption and complexity of the process. When restoring the wheels by surfacing, after two or three turns, the layer hardened at the plant during heat treatment is cut into chips. As a result, for the rest of the service period, the wheelsets wear out more intensively and are affected by defects of thermo-contact fatigue origin [4, p. 32; 6, p. 181; 9, p. 48].

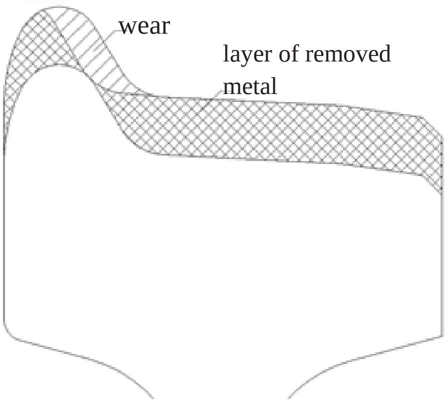
The fact is obvious that an increase in traffic volumes inevitably leads to an increase in operating costs by the enterprises, comprising Russian enterprises, paid for restoration and repair of wheelsets [10, p. 11; 11, p. 4; 12, pp. 13–14; 13, pp. 21–22; 14, p. 24].

Suggestion for discussion

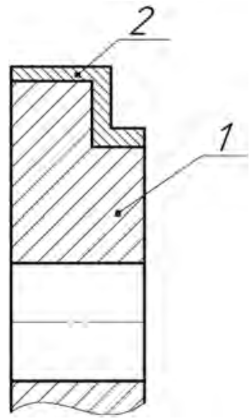
We propose to increase reliability of wheelsets at the design stage by making minor

a) b) c)

Pic. 1. Main failures of a wheel of a wheelset: a – sliders; b – chips; c – wrecks [2].



Pic. 2. Repair of all-rolled wheel by mechanical processing method [9].



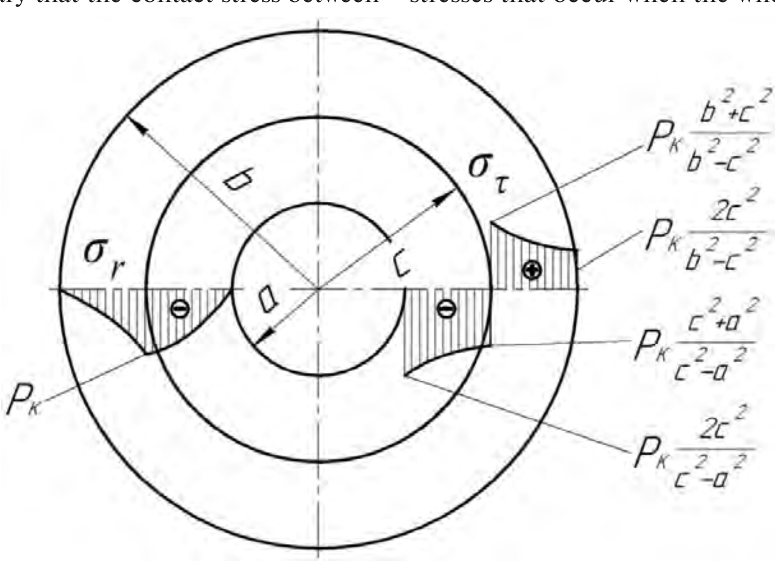
Pic. 3. Design of a wagon's wheel.

changes to the wheel design without changing its geometric characteristics and parameters. Considering the cause and the places that are subject to the greatest defects (wheel flanges and rims), a rim (hoop) 2 is pressed onto the wheel 1 of the existing design (Pic. 3), made of a material whose hardness is commensurate with hardness of the rail. The inner surface of the hoop should completely repeat the outer contour of the wheel in contact with the rim, which provides the necessary bond strength.

To assess the stresses arising on the contact surface of the wheel, we use the classical theory of strength [15, p. 287, Pic. 314; 16, pp. 356–358] (see Pic. 4).

In Pic. 4 it is seen that to ensure strength, it is necessary that the contact stress between the wheel and the rim corresponds to the permissible interference tension. During operation, the wheel will suffer, in aggregate, various types of stress-strain state.

Contact stresses arising between the wheel and the rail will vary depending on the distance from the contact point; they have been studied in detail in the works [5, p. 46; 8, p. 17; 10, p. 11; 11, p. 4; 12, pp. 13–14]. Besides contact stresses, tangential and radial stresses will arise depending on the forces transmitted from the axis to the wheel hub, which in calculations will be taken as the pressure *p* per unit surface (see Pic. 4). Temperature stresses arising in the structure are the result of contact stresses between the wheel and the rail. Here you can add cyclic stresses that occur when the wheel rolls on a



Pic. 4. Stress-strain state of a wheel of a proposed design [15, Pic. 314].

rectilinear surface. The stresses arising in the wheel should not be excluded, taking it for fast-rotating disks.

Thus, the total stress arising in the wheel of the selected design is defined as the vector sum of stresses:

$$\sigma = \sigma_1 + \sigma_2 + \sigma_3 + \sigma_4 + \sigma_5 + \sigma_6, \quad (1)$$

where σ_1 are contact stresses;

σ_2 are tangential stresses;

σ_3 are radial stresses;

σ_4 are temperature stresses;

σ_5 are cyclic stresses;

σ_6 are stresses arising when moving along the joints of rails.

Following the calculation the total stress in the wheel of selected design will not differ negatively compared to the wheels of now existing design, allowing thus to continue research to develop the suggested design.

Using suggested technique to consider stresses to solve other problems

Consideration of all the listed types of stresses and the study of their influence on the stress-strain state of the wheel will allow:

• to identify the physical nature of occurrence of defects on the surface of the wheel of the existing structure;

• to evaluate wheel parameters of an existing design;

• to evaluate feasibility of manufacturing a wheel of a new design.

In addition to the above, a deep analysis conducted in these areas will allow:

• to study the kinetic environment of interaction of the wheel with the rail;

• to develop a concept of design and technological changes in the manufacture of wheels;

• to develop a methodology for multivariate analysis of interaction of the wheel with the rail;

• to carry out modelling of the kinetics of technological processes in the manufacture of wheelsets;

• to develop forms and ways to increase the service life of wheels of wagons.

The further research in those areas is prevailing in identifying the physical nature of wear of wheelsets, which will allow development of technically competent and practical solutions to eliminate the causes of wear as well as to create a fundamentally new design projects, and to to extend the service life of the wheelset.

REFERENCES

1. Defects and malfunctions of wheelsets and axle box [*Defekty i neispravnosti kolesnykh par i buksovogo uzla*]. [Electronic resource]: http://www.вагонник.рф/2018/01/blog-post_21.html. Last accessed 04.06.2019.

2. Malfunctions of wheelsets of rolling stock [*Neispravnosti kolesnykh par podvizhnogo sostava*]. [Electronic resource]: https://poznayka.org/s62361t1.html. Last accessed 04.06.2019.

3. Korzhin, S. N. Analysis and selection of technological solutions to increase wear resistance of wheel flange ridges. Ph.D. (Eng) thesis [*Analiz i vybor tekhnologicheskikh reshenii po povysheniyu iznosostoikosti grebnei kolesnykh par. Dis.. kand. tekh. nauk*]. Moscow, MGUPS (MIIT) publ., 2000, 196 p.

4. Buinosov, A. P. Methods of increasing the resource of bandages of wheelsets of traction rolling stock. Abstract of D.Sc. (Eng) thesis [*Metody povysheniya resursa bandazhei kolesnykh par tyagovogo podvizhnogo sostava. Avtoref. dis... dok. tekh. nauk*]. Yekaterinburg, UrGUPS, 2011, 44 p.

5. Dumpala, R., Chandran, M., Rao, M. S. R. Engineering CVD diamond for machining and tribological applications. *JOM*, 2015, Vol. 67, No. 7, pp. 1565–1577. DOI: https://doi.org/10.1007/s11837-015-1428-2.

6. Pefiffer, H., Solf, W. Fortentwicklung des Fristensystems für die Instandhaltung elektrischer Triebfahrzeuge in den Wertatten des Betriebsmaschinen-dienstes des Dentschen Bundesbahn. *Elektrische Bahnen*, 1978, No. 7, pp. 171–186.

7. Sohst, D., Greschke, K. H. Wirtschaftliche Underhaltung der elektrischen Lokomotiven im Bahnbetriebswerk. *Eisenbahntechische Praxis*, 1979, No. 3, pp. 12–17.

8. GOST [Russian state standard]. Wheelsets of railway rolling stock. Methods for determining strength indicators [*Kolesnie podvizhnie pary zheleznodorozhnogo podvizhnogo sostava. Metody opredeleniya pokazatelei prochnosti*]. Moscow, Interstate Standard, 2018, 99 p.

9. Savrukhin, A. V., Kiselev, S. N., Neklyudov, A. N., Kuzmina, G. D., Kiselev, A. S. Computer diagnostics of formation of structural composition during quenching of an all-rolled wheel [*Kompyuternaya diagnostika formirovaniya strukturnogo sostava pri zakalke tselnokatanogo kolesa*]. *Kontrol'. Diagnostika*, 2008, Iss. 6, pp. 45–49.

10. Vorobyov, A. A., Sorokin, P. G. Study of the stress state of the contact spot between the wheel and the rail [*Issledovaniya napryazhennogo sostoyaniya pyatna kontakta kolesa i rel'sa*]. St. Petersburg, PGUPS, 2017, 17 p.

11. Sladkovsky, A. V. Features of the contact interaction of wheels and rails with different profiles [*Osobennosti kntaktnogo vzaimodeistviya koles i relsov s razlichnymi profilyami*]. *Visnik skhidnoukrainskogo natsionalnogo universitetu imeni Volodimira Dalya*, 2004, Iss. 8, p. 4.

12. Tarikov, G. P., Akulova, E. M. Determination of stresses under the contact area in the rail–wheel system [*Opredelenie napryazhenii pod ploshchadkoi kontakta v sisteme «rel's–koleso»*]. *Vestnik GGTU im. P. O. Sukhogo. Mashinostroenie i mashinovedenie*, 2015, Iss. 3, pp. 10–18.

13. Epp, C. J., Fuller, R. N. The influence if suspension characteristics on wheel wear: Prepr. Pap. Conf. Railway Eng. Manag. Assetts., 23–25 Sept. 1991, pp. 18–25.

14. Tulecki, A. Renewal of the external profile of the road wheel of wheelsets. Monogr. Techn. Univ., Cracow, 1988, No. 72, pp. 1–59.

15. Feodosiev, V. I. Resistance of materials [*Soprotivle-nie materialov*]. Moscow, Publishing House of Bauman MSTU, 2016, 416 p.

16. Lyuboshits, M. I., Itskovich, G. M. Handbook of resistance to materials [*Spravochnik po soprotivleniyu materialov*]. Minsk, Higher. Shk., 1969, 464 p.