INTERACTION OF COMPONENTS AND PARTS OF UNDERCARRIAGE PARTS OF A CAR

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ABSTRACT

A variant of modernization of a bogie of 18–100 freight cars through installation of roller guides, which will make its frame more rigid, is being considered. The problem of rigidity of a three-element frame has long been one of the basic ones. Many scientists suggested installing cross connections, but this design was not always reliable, the cross connection was often simply deformed or broken, because, along with other aspects, it added 150–200 kg to the sprung mass of the bogie. Others suggested to put on the bogie wear-resistant, elastic elements, wheel sets with cassette bearings. Such changes in the design led to an improvement in dynamic performance, but did not solve the main problem. In the published article, the task is to uncover a new idea of modernizing the bogie, which is intended to reverse the trend that marked the transition of domestic cars to Barber S-2-R and Motion Control bogies.

Keywords: *railway, freight car, bogie 18–100, modernization, guide rollers, dynamics, cross connection, undercarriage parts of a car.*

Background. *The most loaded part in a freight car is associated with undercarriage parts. They serve as a support for a vehicle on a track and ensure safety of movement of a train. The designs of undercarriage parts are diverse, the number of models exceeds one hundred models. Undercarriage parts of cars are combined into independent units, called bogies.*

Over the past thirty years, an obvious problem has emerged for the Russian railways that is the high cost of repairing undercarriage parts of cars. JSC Russian Railways spends a lot of money to solve the problem. There are two directions: a) coating a rail with lubricants; b) increase hardness of a rolling surface of a wheel. But as practice shows, it helps a little, and then the companies-owners begin to buy cars on more expensive imported bogies Barber S-2-R and Motion Conrol. They have increased overhaul mileage, which attracts cargo carriers.

Objective. *The objective of the author is to consider interaction of components and parts of undercarriage parts of a car and to suggest a new variant of its modernization using roller guides.*

Methods. *The author uses general scientific and engineering methods, comparative analysis, evaluation approach, mathematical method.*

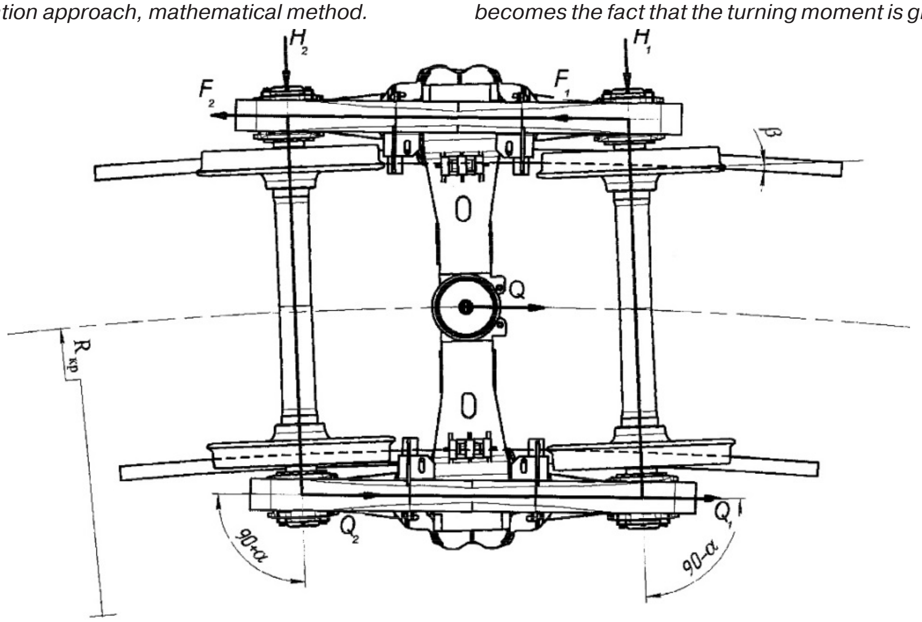
Results.

1.

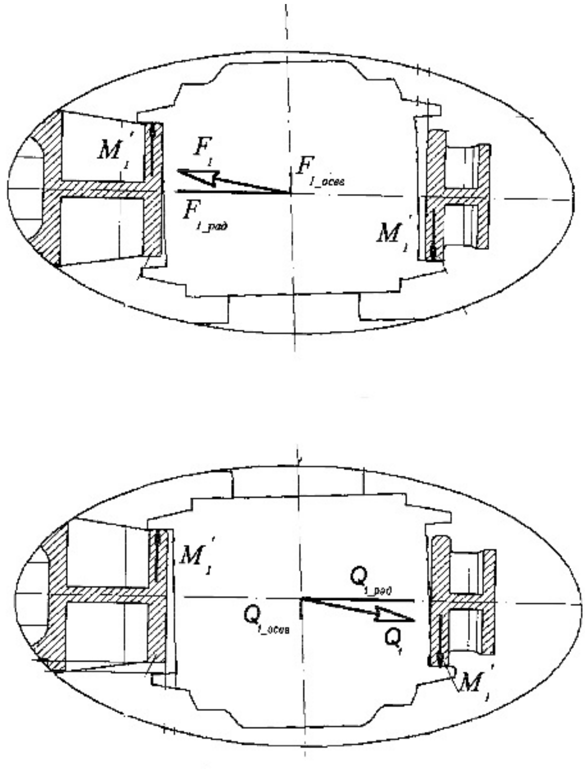
Taking into account the fact that a significant number of 18–100 type bogies (over 2 million) are in operation on Russian railways, it is advisable to modernize them in order to make them more competitive (Pic. 1). But for this it is necessary at least to analyze the reasons for frequent repairs of domestic bogies.

When a bogie is moving on a curved section of the route, the inner wheel passes a smaller path than the outer one, as a result of which slippage occurs. The reduction in slippage is achieved by varying the diameter of the rolling surface of the wheel.

As a result, when a bogie enters a curved section of a track with a radius R (Pic. 2), the first set of wheels moves with its outer wheel onto the inner face of the outer rail. Because of this, a guide force Y1 arises between the wheel flange and the rail, which causes the bogie to turn. The same phenomenon occurs with the second wheel set but concerning its inner wheel [2]. And again, a moment is created which makes the bogie to turn. In this case, an important condition for safe passage of the curve becomes the fact that the turning moment is greater



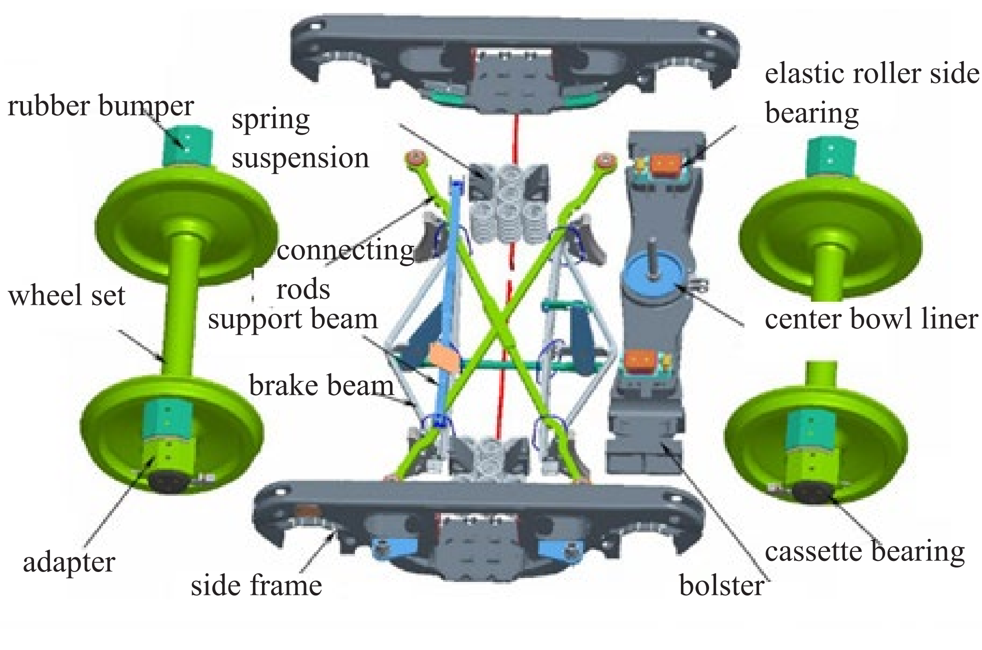
Pic. 1. Bogie 18–100 in the plan.



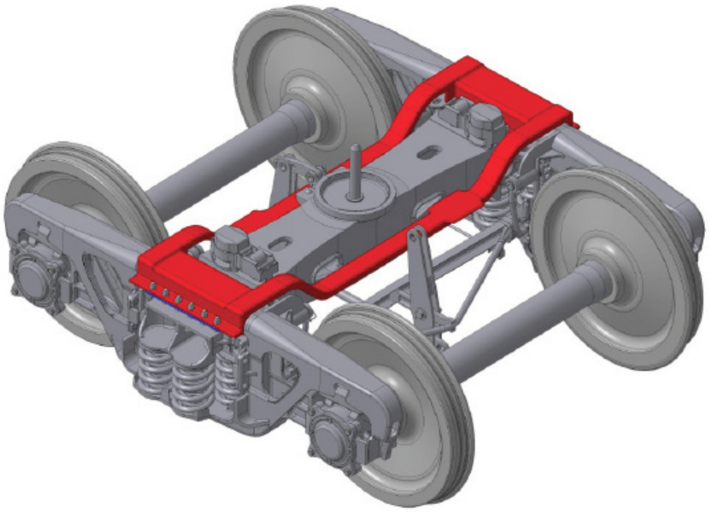
Pic. 2. Diagram of the forces acting on the axle box of the first wheel set in a curve when fitting a typical bogie on a curved section of the track: a) outer axle box; b) internal axle box.

than the moment of resistance to the bogie turning. Moreover, the rotational resistance consists of resistance in the unit of the center plate-center pad, in the side bearings and the friction forces at the contact points of the wheel and the rail.

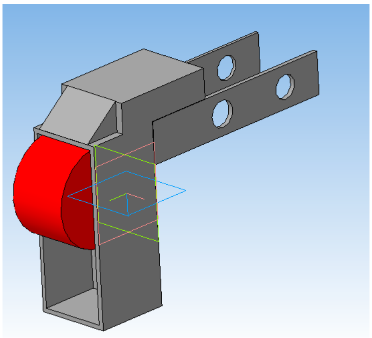
The design of the bogie 18–100 has a non-rigid frame of two side frames and a bolster, with a connection in the horizontal plane. This connection is created due to the transverse stiffness of the spring set and horizontal friction forces in friction vibration dampers. However, these structural features do not allow the frame to retain a rectangular shape. There is a lack of stiffness of the connection, the installation of the side frame on the



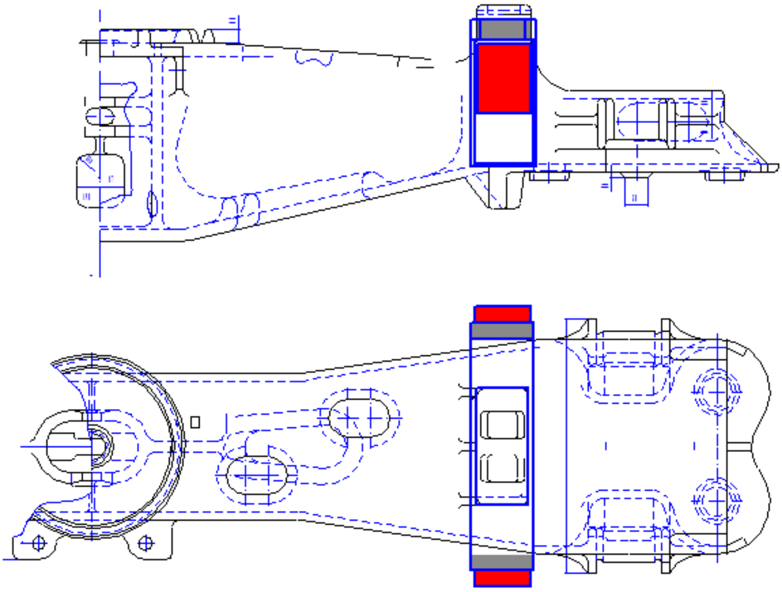
Pic. 3. Bogie ZK-1.



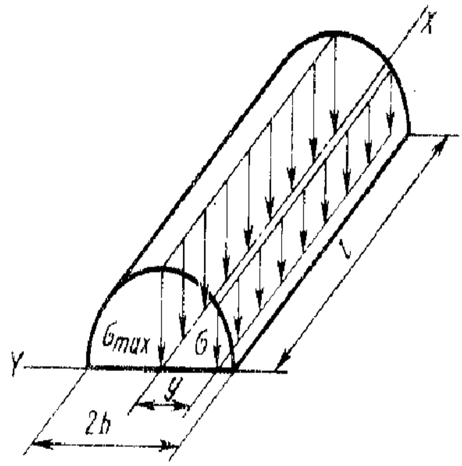
Pic. 4. A three-piece bogie with an installed cross link.



Pic. 5. Roller guides.



Pic. 6. Installation of guide rollers on the bolster.



Pic. 7. The stress distribution at the linear contact of the cylindrical roller.

axle boxes with gaps between the axle boxes and the jaw opening in the longitudinal and transverse directions does not give the proper effect. The side frames are provided to be displaced relative to each other by the amount of gaps, while in operation the displacement reaches 30–35 mm.

The skew of the side frames contributes to the jamming of the vibration damper, as a result of which the dynamic load on the side frame increases and leads to fractures or cracks.

The gaps in the sprung unit (between the bolster and the columns of the side frames) play a significant role in formation and transmission of horizontal dynamic forces. According to the results of tests, the value of understating (overestimation) of wedges practically did not affect the coefficients of relative friction obtained during static tests of the spring suspension of cars. So, in bogies with an almost utter overestimate of wedges, and bogies with low wedges, the coefficients of relative friction were almost equal. From this it follows that for the normal operation of the wedge vibration dampers it is necessary to ensure the transverse rigidity and squareness of the shape of the bogie [2].

An excessive increase in transverse and radial clearances in the axle box reduces the forces that create the moment, causing the bogie to rotate around the axis, which reduces the load on the bearings. But at the same time, it increases the intensity of wheel set wobble in the straight section of the track. On the other hand, a reduction in the transverse and longitudinal clearance in the axle box leads to a pinching of the axle box body in the jaw opening, which causes an overload of the bearings [2].

It is known that when a bogie moves along a small radius curve, any deviation of the frame contour from a rectangular shape leads to an increase in the radial load of wheel flanges on the rail six times, and the transverse tangential forces at the points of contact of the wheel and rail increase four times. As a result, the wear of both the rail and the rolling surface of the wheel increases [2].

Analyzing the above, we can assume a solution to the problem thanks to the inclusion of a cross connection between the side frames. One of the transverse coupling options is implemented in the ZK-1 bogie (Pic. 3).

Another option was proposed by the department Cars and car economy of RUT University (Pic. 4). The model will meet all the criteria, however, the use of three-element connection is hampered by the method of fastening and needs to have refined side frames.

The main disadvantages of the transverse connection in operation were the frequent occurrence of cracks in the middle part of the structure and places of transition from the high side to the low side, as well as the presence of an additional 100–200 kg bogie in the additional sprung mass. The breaking of the link can be explained by the fact that the gap between the cross link and the bolster is often filled with pieces of ore, coal and stones. In this case, the bolster of the loaded car rests not only on the spring sets, but also touches the transverse connection with its middle part, leading to the destruction of the former. The same is observed when compensating for the action of total longitudinal sliding friction forces.

2.

In my article, I propose another solution to the problem – installation of roller guides on the side bearings of the bolster (Pic. 5, 6), which will remove the drawbacks of the cross connection, while maintaining its positive qualities. This is to ensure a constant rectangular shape and a reduction in the sprung mass by removing the transverse shape.

Firstly, the forces between the rollers of the bolster and the guide surfaces of the sidewalls compensate for the action of the transverse friction forces that occur at the time of the bogie turn in the plan, and thus it is possible to maintain the rectangular shape of the frame.

Secondly, the modernization provides an improvement in the horizontal dynamics of movement of the bogie in curved sections of the track, leads to a decrease in wheel attack angles and the intensity of wear of the side rail head and wheel flanges, while at the same time increasing traffic safety. Fastening roller guides is performed using two rollers.

The geometrical dimensions of the contact pad of the deformation of the guide roller are shown in Pic. 7

The half width of the contact pads formed as a result of the action of the force Q for the mating surfaces of the rolling bodies is determined by the formula:

$$b=\left\{\frac{4Q}{\pi l\sum\rho}\left[\frac{\left(1-\varepsilon_I^2\right)}{E_I}+\frac{\left(1-\varepsilon_{II}^2\right)}{E_{II}}\right]\right\}^{1/2},$$

where l – length of the contact surface of the rolling elements, mm; $\sum\rho_n$, $\sum\rho_v$ *– sum of the curvature of the contacting surfaces of the rolling elements;* ε_I, ε_{II} *– Poisson's ratios for rolling elements;* E_I, E_{II} *– elastic modul for rolling elements.*

Provided that the materials are identical, we get:

$$b=1{,}6\sqrt{\frac{Q}{l\sum\rho}\left(\frac{\left(1-\varepsilon^2\right)}{E}\right)}.$$

The sum of the curvature $\sum\rho$ *characterizes the geometric ratio of the contacting surfaces of the elements with a linear contact:*

$$\sum\rho=\frac{2}{D\left(1-\gamma_1\right)},$$

where γ *– an auxiliary value, taking into account the ratio of the geometric dimensions:*

$$\gamma=\frac{D\cos\alpha_1}{D_0}.$$

Conclusion.

Having accepted the assumption that the second body is a plane ($D_0=\infty$*), we get:*

$\gamma\approx 0$;

$\sum\rho = 2/D$

Normal stresses in any plane of the pad in the area of the pairing of the roller and the guide surface are respectively equal to:

$$\sigma=\frac{2Q}{\pi lb}\left[1-\left(\frac{y}{b}\right)^2\right]^{1/2}\le[\sigma].$$

The maximum stress in the plane of the contact pad is formed at (y = b) and will be equal to:

$$\sigma_{max}=\frac{2Q}{\pi lb}\le[\sigma].$$

where [σ*] – allowable stress when calculating rolling bodies for strength, MPa.*

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Information sources on this topic [1, 3–15].

REFERENCES

1. Chizhov, V. A. Development of a multi-level modernization of a 18–100 bogie to create a promising standard-sized series of undercarriage parts of freight cars of 1520 mm gauge [*Razrabotka mnogourovnevoi modernizatsii telezhki 18–100 dlya sozdaniya perspektivnogo tiporazmernogo ryada khodovyh chastei gruzovyh vagonov kolei 1520 mm*]. *Rolling stock of 21st century: ideas, requirements, projects: Abstracts of 3rd scientific and technical conference*. St. Petersburg, 2003, pp. 13–15.

2. Melnichenko, O. V., Chuprakov, E. V., Gorbatok, S. A. A method of reducing wear of a wheel–rail system and the design for its implementation. Patent No. 2449910, application. 2010129656/11 dated 15.07.2010. Publ. 10.05.2012. Bul. No. 13 [*Sposob snizheniya iznosa sistemy koleso–rels i konstruktsiya dlya ego osushchestvleniya. Patent № 2449910, zayav. 2010129656/11 ot 15.07.2010. Publ. 10.05.2012. Bul. № 13*]. [Electronic resource]: http://www.freepatent.ru/images/ patents/0/2449910/patent-2449910.pdf. Last accessed 15.10.2018.

3. Vershinsky, S. V., Khusidov, V. D. Dynamics of a car: Textbook [*Dinamika vagona: Uchebnik*]. 3rd ed., rev. and enl. Moscow, Transport publ., 1991, 860 p.

4. Chelnokov, I. I., Churkov, N. A., Osinovsky, L. L. Criteria for limiting the speed of a vehicle in a curve [*Kriterii ogranicheniya skorosti dvizheniya ekipazha v krivoi*]. *Dinamika vagonov*, 1977, Iss. 403, pp. 45–57.

5. Filippov, V. N., Zuykov, P. I., Podlesnikov, Ya. D., Reduction of the undercut of flanges of wheel sets of freight cars [*Snizhenie podreza grebnei kolesnyh par gruzovyh vagonov*]. *Zheleznodorozhny transport*, 2014, Iss. 3, pp. 70–72.

6. Lysikov, N. N., Kovalev, R. V. Complex studies of the mechanical characteristics of structural elements by the computer simulation method [*Kompleksnye issledovaniya mekhanicheskih kharakteristik elementov konstruktsii metodom kompyuternogo modelirovaniya*]. *Tyazheloe mashinostroenie*, 2009, Iss. 1, pp. 14–17.

7. Sladkovsky, A. V., Pogorelov, D. Yu. Study of dynamic interaction in a wheel–rail contact in the presence of sliders on a wheel set [*Issledovanie dinamicheskogo vzaimodeistviya v kontakte koleso–rels pri nalichii polzunov na kolesnoi pare*]. *Visnik*, 2008, Iss. 5 (part 1), p. 11.

8. Kovalev, R. V., Danilenko, D. V. Introduction to modeling the dynamics of mechanical systems [*Vvedenie v modelirovanie dinamiki mekhanicheskih system*]. *SAPR i grafika*, 2008, Iss. 4, pp. 26–31.

9. Pogorelov, D. Yu. On numerical methods for modeling the motion of systems of solids [*O chislennyh metodah modelirovaniya dvizheniya system tverdyh tel*]. Bryansk, BSTU, 1997, 153 p.

10. Pisarenko, G. S. Resistance of materials [*Soprotivlenie materialov*]. Kiev, Naukova Dumka publ., 1988, 736 p.

11. Orlova, A. M. Influence of design schemes and parameters of bogies on stability, road performance and loading of freight cars. Abstract of D.Sc. (Eng) [*Vliyanie konstruktivnyh skhem i parametrov telezhek na ustoichivost, khodovye kachestva i nagruzhennosti gruzovyh vagonov. Avtoreferat dis... dok. tekh. nauk*]. St. Petersburg, 2008, 34 p.

12. Mikhalchenko, G. S., Pogorelov, D. Yu. Improvement of the dynamic qualities of rolling stock of railways by means of computer simulation [*Sovershenstvovanie dinamicheskih kachestv podvizhnogo sostava zheleznyh dorog sredstvami kompyuternogo modelirovaniya*]. *Tyazheloe mashinostroenie*, 2003, Iss. 12, pp. 2–6.

13. Gushchin, P. A. To the question of improving the dynamic qualities of cars [*K voprosu uluchsheniya dinamicheskih kachestv vagonov*]. *Modern concepts of scientific research: Proceedings of 4th International Scientific and Practical Conference*. Moscow, 2014. Part 5, pp. 136–138.

14. Petrov, G. I., Kaletin, S. V., Panachev, O. I. Some Features of Computer Simulation of Power Relations of Freight Wagon in Wheel Pair. *Modern science,* 2016, No. 10, pp. 26–34.

15. Rouse, J. E. Dynamics of a system of solids. Volume II: Trans. from English. Moscow, Nauka publ., 1983, 544 p.

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