Analysis and Study of the Problems Arising in Movable Joints of Freight Car Bogies

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Summary.The process of wheel - rail interaction is largely determined by dynamic properties of the car, improvement of which is possible by improving design of the bogie and its basic elements.

The article analyses and discusses the problems that have arisen in recent years in the course of operation of bogie 18-100. Tribological and mechanical properties of a friction wedge-type oscillation damper are studied.

Key words: railway track, freight car, three-piece bogie, friction oscillation damper, dynamic coefficient, operation.

INTRODUCTION

Changes in the quality level of the rail track, maintenance and operating conditions of cars have increasingly been leading to appearance of fatigue cracks of bogie frames of freight cars, their breakages and failures, derailments and train accidents in recent years [1].

The prime and urgent tasks are modernization of outdated rolling stock of railway and creation of the new rolling stock, satisfying the modern requirements on parameters of operational properties and reliability [2].

Improving design of freight cars, especially cars with high axle load, improvement of their dynamic properties, oscillation damping and absorbing systems, reducing force impact on the track superstructure elements is one of the most important issues, which is constantly being studied.

The solution of this problem directly influences the technico- economic indexes of railway transport work and determines its competitiveness in the market of transport [3].

OBJECTIVES

Analysis of design features of movable joints of bogie 18-100, assessment of their influence on dynamic and high-speed indexes. Suggestions for improving dynamic and tribological properties of freight cars.

MATERIALS AND RESULTS OF THE RESEARCH

The whole economy of the country directly depends on the state of transport facilities.

A railway transport on the modern stage is most claimed at implementation of mass loads and passengers transportations. The basic structural elements of railway vechicular process are an aggregate of railway rolling-stock (locomotives, carriages) and railway. Exactly co-operation of these constituents results in the perfomance of the put transport objective. For continuous work realization a railway transport have been used with the purpose to decline the economic expenses on transportation, objects which are included in a general complex, have to provide whole system functioning reliability [4].

Freight transportation speed depends on quality and age of the rolling stock. The park of freight cars in Ukraine has more than 146 thousand cars, among them about 95 thousand cars are in working condition, and the rest is actually excluded from operation and in stock or being repaired.

Currently approximately 80% (105,000 units) of freight cars exceeds the normative operating life. Moreover, age of some units exceeded 40 or even 50 years a long time ago [5].

During the period January 2002 – September 2015, there were 166 breakages of side frames (Fig.1). The number of breakages had been steadily increasing until 2014 and reached a record of 34 cases in 2013 [6, 7].

Reducing the number of breakages in 2014 and 2015 is connected with increase in uncoupling of freight cars for the current repair due to cracks in side frames, which, in its turn, is related to implementation of new criteria for rejection of moulded details of bogies.

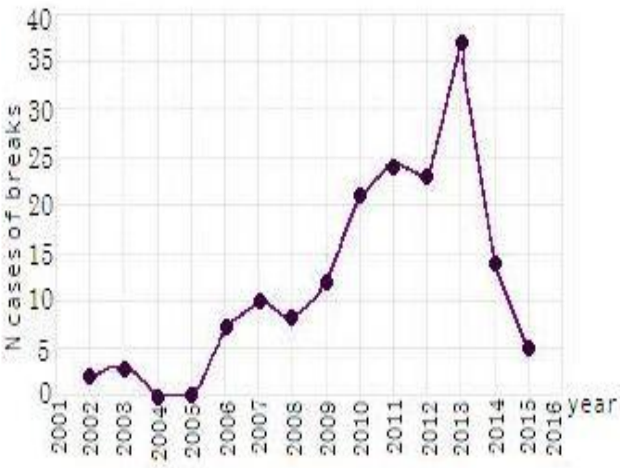

Fig.1. Statistics of breakages of side frames of bogies 18-100 per 2002 - 2015

Cast power brackets of the truck frames are critical parts [8]. Before its specified lifetime (30 years) there are refined less than 1/4 of bolsters and side frames under real conditions.

In the area of concentration of tensions damages develop very intensively [9].

There is always the possibility of breakage of details in transit. Statistical data on breakages, corresponding to a certain manufacturing plant stamp are shown in Fig.2.

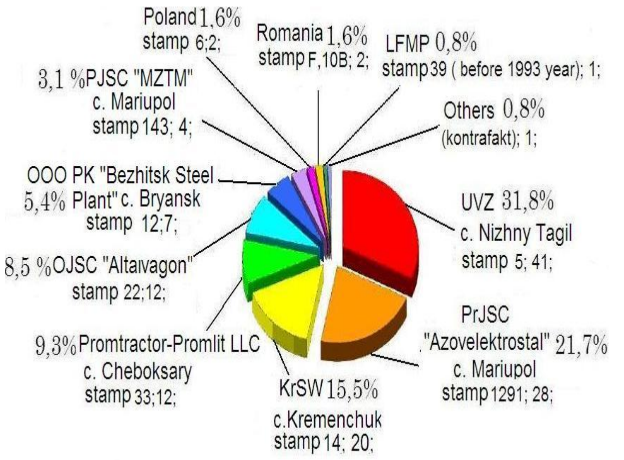

Fig.2. Distribution of breakages of side frames of freight car bogies by manufacturing plants of car casting per 2006 - 2014

There are several versions of causes of this problem:

1) Lack of quality manufacturing of side frames;

2) Poor maintenance of the railway track;

3) Violation of rules of operation and repair of the rolling stock;

4) Inadequate rolling stock design.

Conducted studies of compliance of side frames steel of different manufacturers by the test centre of production of car-building and foundry of the State Enterprise "Ukrainian Research Van-Building Institute" (IC PVGP "UkrNIIV") show that characteristics of mechanical properties and chemical composition of side frames steel is generally above today's regulatory requirements for these products [10, 11].

Bogie 18-100 differs by insufficient connectedness of side frames and a lack of hunting oscillations damping. As a result, transverse frame forces on the bogie frame reaches 80…100 kN, and lozenging oscillations (overtaking) of bogie sides reaches up to 20 mm. This bogie has unsatisfactory characteristics of negotiation into curves, and it is inclined to hunting oscillations when driving on the straight.

It should also be noted that disadvantages of this bogie worsen with wear of its structural elements. As a result, critical speed of, for example, empty freight cars, decreases, and at the speed of 60...70 km/h there can be intense self-oscillating processes, leading to increased wear of bogie elements and increased probability of derailment [12].

Cumulatively, while reducing the relative friction coefficient of the spring suspension, dynamic stresses in side frames, and especially in cantilever arms of pedestal jaw openings, increase. Emerging critical stresses and torques may cause design breakages. Elimination of these negative factors is possible only due to certain design changes in the bogie undercarriage.

Dynamic characteristics of undercarriages of the rolling stock of railways directly affect safe operation of trains in different modes of cars loading throughout the speed range of their movement.

The results of dynamic indexes of disturbances acting on the empty and loaded open car on bogies 18-100 are shown in Fig. 3 - 4 [13, 14], taking into account established on the railways of Ukraine speed limits for freight cars: 80 km/h for empty and 90 km/h for loaded cars [15]. In these figures, the horizontal line indicates acceptable values of dynamic indexes of freight cars, the curve line shows behaviour of the freight open car while increasing the speed.

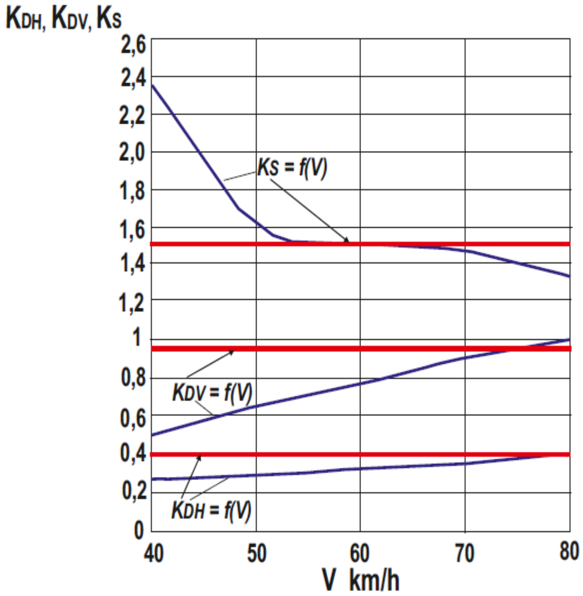

Fig.3. Dependence of the vertical dynamic coefficient (K_{DV}), the horizontal dynamic coefficient (K_{DH}), the stability coefficient (K_S) on the speed of movement of the empty open car

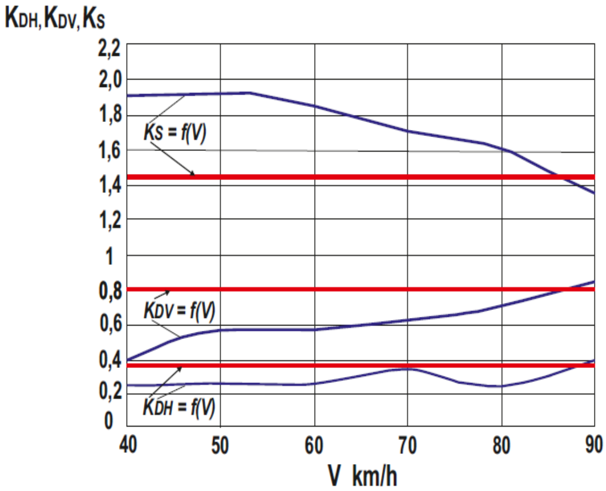

Fig.4. Dependence of the vertical dynamic coefficient (K_{DV}), the horizontal dynamic coefficient (K_{DH}), the stability coefficient (K_S) on the speed of movement of the loaded open car

Current recommended and acceptable values of dynamic indexes for cars are shown in Table 1 [13, 16, 17].

Maximum acceptable values of the main dynamic indexes for freight cars with bogie 18-100 are shown in Table 2 [18].

Table 1. Acceptable dynamic indexes for freight cars

Criterion	Loaded	Empty
K_{DV}	0,8	0,85
K_{DH}	0,40	0,40
K_S	1,30	1,30

Table 2. Maximum acceptable values of the basic dynamic indexes for freight cars with bogie 18-100

Criterion	Loaded	Empty
K_{DV}	0,8	0,95
K_{DH}	0,38	0,40
K_S	1,45	1,45

As we can see, all three dynamic indexes are out of the acceptable range of values at speeds close to 80 km/h for the empty and 90 km/h for the loaded open cars. Further increase in the speed of freight cars will lead to degradation in dynamic indexes.

The greatest negative impact on dynamic qualities indexes of freight cars with bogies 18-100 is caused by such factors as blocking of the spring suspension and self-excitation of intense hunting oscillations in the operating range of speeds.

Seizure of the suspension leads to increase in the roll motion (rolling) of the body, as well as to increased impact of vibrations on both the bolster structure of the car body, the freight, and the track structure [12].

Transport strategy of Ukraine for the period up to 2020 envisages provision with the rolling stock that can significantly improve the technical and technological parameters, in particular:

- Increase the speed of freight trains up to 100-120km/h;
- Increase the lifetime and improve performance of the rolling stock;
- Reduce specific consumption of energy resources and materials intensity;
- Reduce the time of freights delivery [19].

Based on the current requirements, it can be argued that dynamic characteristics of freight bogie 18-100 do not comply with the assigned tasks.

Due to the limited maximum acceptable value of static deflection of the spring suspension of freight cars under the terms of adhesion in the empty and loaded states, the full range of operating speeds lies in the subcritical and critical areas of the train oscillations. It means that oscillation damping is the determinant factor to provide satisfactory running characteristics of cars.

Various imperfections of wheelsets together with the increased track elasticity modulus are causes of accumulation of defects of nodes of the car undercarriage and defects of the track superstructure, reducing their technical operating life [20]. During train movement on the track with ferroconcrete sleepers, increased track rigidity in comparison with the wooden sleepers, large unsprung weight, as well as considerable hardness of through-hardened rails and wheels, cause increase in dynamic forces in wheel-rail contact.

It is known that at the speed of 70 km/h and static wheel load of 100,45 kN irregularity on the tread surface with length of 250 mm and depth of 1 mm causes increase in pressure of the wheel on the rail up to 215,6 kN for ferroconcrete sleepers and up to 192,1 kN for wooden sleepers [21]. A compulsory measure to cope with such a phenomena is the current speed limit of 60 km/h in tight curves, which negatively affects railways capacity.

Theoretical analysis of the research issue and operating experience have shown that one of the conditions restricting speed increase and improving dynamic indexes of the spring suspension of the crew, and, above all, friction wedge-type oscillation dampers, is power frictional bounds of undercarriages of railway crews, which determine speed characteristics of the rolling stock.

In the empty mode of movement of the freight car on the track irregularities, due to insufficient static deflection, generally not exceeding 8 - 10 mm, as well as inevitable wear of the elements of the “wedge - friction plate” friction pair in the spring suspension, there is a lack of damping of almost all the forms of the freight car oscillations.

Intensive wear of contacting surfaces of friction oscillation dampers is one of the problems in the area of improving reliability and durability of freight cars undercarriages [12].

Based on the conducted studies there has been found that friction force that occurs in the damper depends on the wear profile configuration.

In the process of operation of the friction oscillation damper of bogie 18-100, operational surface plane of the friction wedge wears unevenly.

Geometry analysis of rounding of the friction wedge and conducted studies of wear have shown that during reduction of the radius of rounding of the friction wedge surface, a gap between the wedge adhesion and the friction plate increases [1].

Thus, at the initial stage of the running, wear of the wedge inclined surface is twice as intense as the vertical one, and then the inclined surface wears about 10 times more intensively. Varying value of the wedge wear for the same run is determined by many factors: initial pressure during installation in the bogie suspension; type and actual loading of the car in operation; route of the car; materials properties of contacting surfaces. Deterioration of the vertical oscillation damping process, increase in the oscillation amplitude, and hence stress in the body elements are caused by changing the wedge geometry by 12 mm. In this case, the friction force of the oscillation damper reduces by 30...35% in the loaded car, and full discharging of wedges takes place in the empty car [1, 7].

Transmission of forces and motion from one detail to the other takes place under pressure in the contact area.

It has been found out that during friction along with the purely mechanical forces in the zone of the frictional contact of heavy loaded details, friction results and wear of contacting bodies are greatly influenced by forces, connected with physical, chemical, mechanochemical, thermal processes, developing directly in the friction zone, where properties of interacting bodies and their micro-relief are changing greatly [22, 23, 24, 25].

The reason of it are complex conditions of their operation characterized by a high level of working temperature, frequency of interaction and the stressed state of contact area of working elements, and influence of climatic factors also. The consequence of it is deterioration of stability of operational characteristics both mobile mating units and a rolling stock as a whole [2].

The most wearing details of the oscillation damper node, according to the state of which time between overhaul of freight cars is appointed, are the friction wedge, the friction plate and the inclined surface of the bolster. The oscillation damper node "friction wedge - friction plate" works under hard conditions of dry friction, abrasive action of the working environment and exposure to moisture. Therefore, in the first place, there must be considered tribological properties of the wedge material and its impact on durability and strength. These characteristics not only determine the quality and efficiency of friction wedges, but also allow forming development directions and improvement criteria for design and manufacture.

The main progress trend transport consists in quality improving of the casting, increase of dimensional accuracy and reduction of steel intensity [26].

Work of the tribological "wedge - plate" interlinkage is determined by operational factors and depends on the material of the friction surfaces (steel and steel, cast iron and steel, bolster steel and urethane covering plate).

Currently, "Instructions for Repair of Freight Cars" of Ukrzaliznytsia stipulate manufacturing the friction wedge of freight car bogies 18-100 of steel 25L according to GOST 977 - 88 [27, 28].

This detail makes the friction pairs during operation with the inclined surface of the bolster (20L, 20GL, 20GFL - GOST 977 - 88) and the vertical wall of the side frame, armoured by the friction plate of steel 45 in accordance with GOST 1050 - 88, 40KH and 30KHGSA according to GOST 4543-71 in the thermally hardened state.

Hardness of the bolster made of steel 20GFL as-cast is 160...180 HB. Hardness of friction plates in the thermostrengthened state made of steel 45/40KH is 300...320 HB and is almost 450 HB for steel 30KHGSA [28, 29, 30].

Working hours of new freight cars on bogies 18-100 with friction wedges of steel 25L in accordance with the current regulatory documentation should be (before roundhouse servicing) at least 3 years.

Regulatory run of bogie 18-100: before the first repair – 210 thousand km, after roundhouse servicing – 160 thousand km, after overall repair – 160 thousand km. Run of the open car with friction wedges made of grey cast iron SCH25 shall be no less than 160 thousand km or 2 years of operation after roundhouse servicing and overall repair [31].

Friction work "steel on steel" (steel friction wedge on the inclined surface of the bolster of steel 20GL) leads to strong abrasive wear, scuffing, seizing, hanging of the car body and then its sharp downward movement, causing impact force of the body on springs, side frames, bolsters and other bogie details, leading to their premature failures.

That is why Ukrzaliznytsia has provided production of this item using cast iron SCH25 according to GOST 1412 as an alternative to steel 25L according to GOST 977 – 88 [32].

During analysis of influence of mechanical properties, structure and chemical composition of steel 25L and grey cast iron SCH25 on technical and service properties of the friction wedge, it has been found that the main factor is influence of the material hardness on the detail wear properties.

When using cast iron wedges, work of the oscillation damping node of freight car bogies improves due to elimination of negative phenomena that occur when using steel wedges.

Unlike the steel ones, cast iron friction wedges provide a normative range of the relative friction coefficient (0,08 - 0,16) during the time between overhauls of the car. The wedges made of grey cast iron sharply (in 2,5...3,0 times) reduce wear of inclined surfaces of bolsters due to the presence of graphite in cast iron, which plays the role of solid fat. The structural strength of the wedge has multiple stock and its tribological properties, defined by a rated parameter – the relative friction coefficient, are in a wide range of applied materials and are largely dependent on external operating factors.

During quantitative assessment and statistical analysis of experimental data on the total wear of vertical and inclined surfaces of friction wedges, run before the next scheduled repair and an average residual hardness of the material in the wear areas, there has been revealed a characteristic dependence of run on the given residual hardness of the wedge material.

Currently, there are commercially manufactured steel friction wedges, installed on new freight car bogies, and friction wedges made of grey cast iron, used during their scheduled repair.

While studying the stress state appearing in friction wedges of steel 20GL, 25L and cast iron SCH25, assessment of structural strength showed load holding of 600 kN without any signs of destruction, which corresponds to more than 10 times stock of structural strength. In this case, the actual load on the wedge during operation of freight cars does not exceed 50 - 60 kN.

Consequently, design of commercially manufactured friction wedges made of steel and grey cast iron has multiple safety margins, resulting in relatively low stresses during loading forces, greatly exceeding them.

CONCLUSIONS

Conducted studies of modern operating conditions of the rolling stock indicate that at present due to the increased wear of the operational park of freight cars, as well as a lack of working capital for purchase of active fixed assets, a leading role is played by: - Ensuring rated operating life of side frames by improving quality of casting and work of friction oscillation dampers;

- Using new technologies and materials in manufacture of friction oscillation dampers and other details and nodes;
- Using advanced design of the friction wedge to improve work of the oscillation damping system;
- Using continuous welded railway tracks with rails of R65, R75 type;
- Laying the railway track on ferroconcrete sleepers with stabilized macadam foundation.

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АНАЛИЗ И ИССЛЕДОВАНИЕ ПРОБЛЕМ, ВОЗНИКАЮЩИХ В РАБОТЕ ПОДВИЖНЫХ СОЕДИНЕНИЙ ТЕЛЕЖКИ ГРУЗОВОГО ВАГОНА

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Аннотация. Процесс взаимодействия колесо – рельс в значительной степени определяется динамическими свойствами вагона, улучшение которых возможно путем совершенствования конструкции тележки и ее основных элементов.

В статье выполнен анализ и рассмотрены проблемы, возникшие в последние годы при эксплуатации тележки 18-100. Исследованы трибологические и прочностные свойства фрикционного клинового гасителя колебаний.

Ключевые слова: железнодорожный путь, грузовой вагон, трехэлементная тележка, фрикционный гаситель колебаний, коэффициент динамики, эксплуатация.