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Study of the operational properties of the bolster of a freight car bogie

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Abstract. Different optimal designs of bogie bolster for model 18-100 freight car are examined in the article. There is an analysis of existing bolster designs. Full-fledged fatigue tests by the method specified in GOST 32400-2013 are carried out on the stand designed for dynamic strength tests. The values of experimental studies on the stand were compared with the calculated ones, with maximum loads from 735 to 755 kN. The best results were observed at a maximum load of 745 kN, and the beam lost its bearing capacity at 6.182 million cycles, which is 39% more than the required strength index. The minimum cycles before cracking and before the loss of bearing capacity of the freight railway bogie bolster beam were established.

1 Introduction

The issue of ensuring traffic safety and, at the same time, reducing the metal consumption in railway transport has always occupied not the last place and the bogie bolster plays the most direct role in this. The solution to these issues must be considered as a whole since the reliability and durability of cars, which are directly responsible for traffic safety, should preferably be carried out without increasing their material consumption.

Improving the operational and technological properties of industrial products and increasing the technical level and quality of manufactured products is one of the main tasks of science and technology. The continuous tightening of requirements for the reliability of the operation of structural elements makes it necessary to analyze in more detail the specific conditions of their operation. Most parts are subjected to cyclic loads during operation. Therefore, the problem of the endurance of materials is also relevant to the railway industry [1].

An important role in ensuring traffic safety is played by cast parts of freight car bogies, in particular, the bolster, which is its most important part. Transferring the load from the car body through the spring sets to the wheelset performs the most important function. The general view of the car bogie is shown in Fig.1. The improvement of the operational performance of rolling stock parts depends on their technical condition.

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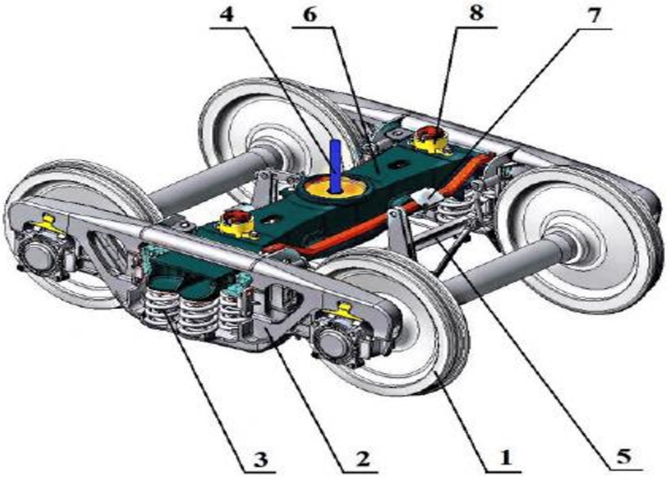


Fig. 1. General view of freight car bogie: 1 is wheel pair, 2 is side frame, 3 is spring suspension, 4 is pin, 5 is brake linkage, 6 is bolt, 7 is beam supporting auto mode, 8 is beam.

One of the problems with bolsters is kink. According to the statistics in railway transport, with the growth of freight traffic, the problems of cast parts of model 18-100 bogies have sharply increased, and over the past 15 years, fractures of bolsters have increased by 3...5 times. A fracture leads to its decommissioning, respectively, to economic losses, and most importantly, if a defect is detected late, it can also lead to human casualties. Lately, bolster fracture has increased, and manufacturers are trying to reduce the risk. Despite changes in the design and manufacturing technology of bolsters to reduce the risk of an accident on railways, the number of problems associated with this defect does not decrease and, in some cases, increases, according to statistics [2]. The statistics for 2023 are also disappointing. Therefore, the relevance of work to further improve bolsters' reliability remains.

2 Objects and methods of research

The strength and reliability of the bolster is directly related to traffic safety. There are cases of failure of bolsters due to the appearance of fatigue cracks [3], wear of beams in the area of the thrust bearing and friction damper, and so on. All this speaks of their insufficient strength. Therefore, the study of the stress-strain state of bolsters is an urgent task.

The growth of freight turnover in railway transport requires the creation of new designs of cars with load-bearing elements of increased reliability. This circumstance affects the choice of design solutions in favor of increasing the safety margins of structural elements of the rolling stock of railways, the use of high-quality materials and expensive technologies for their products and increasing the service life, strengthening and restoring technologies based on a detailed study of the surface layer of the material of the parts [4, 5].

Despite the measures taken recently, the collapse of freight cars has become more frequent due to the low reliability of the load-bearing parts of the bogies. Therefore, the issue of increasing the accuracy of predicting the resource of the bearing parts of bogies at the stage of their design is extremely important.

The existing methods for calculating the durability of irregularly loaded structures do not provide a reliable forecast for some reasons [6-11]. The developers of new designs rely on the results of bench tests of individual elements and running tests of cars. This requires a lot of time and material costs. Therefore, the issues of predicting the reliability of car structures at the design stage are relevant.

The bolster is part of the design of the wagon bogie. Such a part is made by casting. It is made as a bar, a closed box section. The beam requires increased strength and wear resistance requirements, as well as for all parts of the train. The bolster serves as a connecting link between the two side frames. That is assembled - this is the basis of the wheeled bogie of the car. Details of the shock-absorbing system of the car are attached to it. Since the invention of the railway, research has been constantly carried out to improve the design of the spring beam. Special requirements for this type of part are primarily due to high loads. The wagons must cover more than one million kilometers before requiring repairs.

As a result of research conducted worldwide on the creation of the design of the rolling stock of railways, in particular, the design of the bolster, some scientific results have been obtained.

A typical bolster contains an upper chord, a lower chord, and side walls. The upper belt has support platforms for side bearings and a cylindrical thrust bearing. The lower belt is made with supporting surfaces for elastic elements of spring suspension, which pass into inclined belts through thickened zones. The upper chord is connected to the lower chord by vertical longitudinal ribs. Vertical ribs are made of different thicknesses. The thickness of the vertical ribs in the area of the elastic elements and the cylindrical thrust bearing is increased. The radius of rounding of the transitions of the inclined walls of the pockets into the bearing surfaces is greater than the radius of the rounding of the transitions of the vertical walls into the bearing surfaces. An increase in the strength of a freight car bogie bolster is achieved [12].

In [13], the technical result is achieved due to the beam of the bolster bogie of a freight car, consisting of the upper and lower chords, connected by side walls, having a thrust bearing placed on the upper chord in the central part with a hole in the middle and a support column, and in the end parts having supporting platforms for the spring set and pockets for placing wedges of friction dampers in the side walls, the inner central rib located in the end parts of the bolster, on both sides is made from the ends of the beam with a smooth transition, consisting of a radius R1 and two radii R2, to the inclined part the lower belt and the inner flange of the technological hole of the upper belt, while the rib has a constant thickness S, which is in the range from 13 to 25 mm along the entire length of the rib, and two technological holes.

The authors of [14] propose a bolster for a wagon bogie bolster, which contains two longitudinal side walls and a bottom sheet rigidly connected to each other by the upper chord, as well as two internal stiffening ribs located across the longitudinal axis of the beam. The sheet is connected to the bottom sheet repeating its configuration, and the upper edge is set concerning the upper chord with a rectangular gap cutout made in the vertical sheet covers two internal stiffeners forming a one-piece connection butted together by welding

To improve the manufacturability and reliability of the bogie bolster of a freight car, the design of the bolster [15] was proposed. SUBSTANCE: freight car bogie bolster contains an upper chord with an internal vertical rib, a thrust bearing with a flat base plate and a thrust annular shoulder, a lower chord, vertical side walls, and a bearing support column located between the upper and lower chords, an internal vertical rib connects the upper and lower chords throughout the length of the beam with an increase in thickness towards the center, on the inner surface of the transition of the base plates to the lower chord, symmetrically located stiffening ribs 300-350 mm long are made. In the inner vertical rib, eight technological holes are made of a shape elongated along the vertical axis of the beam with short radius sides, inscribed in rectangles with sides no more than 400 mm and 100 mm, with four holes on each side relative to the axis of the thrust bearing support column.

In contrast, the distance from the axis of the thrust bearing support column to the nearest side of the rectangle is 240-250 mm. Under the internal risers of the thrust bearing in the vertical rib, technological holes of oval or round shape are made, coupled with the horizontal surface of the riser with a chord of 35-45 mm, and at the interface on the surface of the riser, a cone-shaped recess is made, with a base diameter of 30-40 mm and a height 20-25 mm.

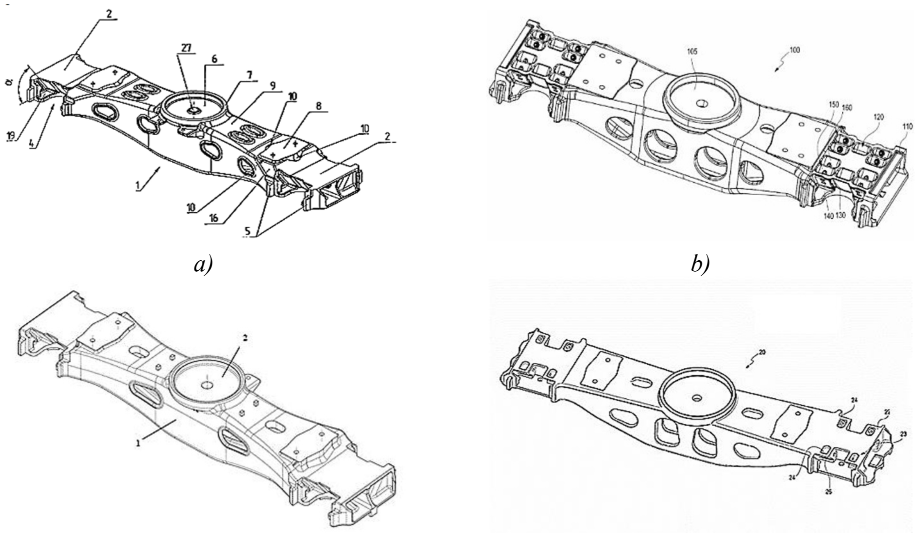
Next, consider several types of bolsters.

Figure 2.a shows the bolster of a bogie of a freight car with increased carrying capacity, the upper belt of which, in the transition zones from the platforms for side bearings to the end parts, is reinforced from the inside with ribs of limited height, located symmetrically relative to the longitudinal axis of the beam at a distance from it. The central segment of the inclined wall of the pocket for the wedge of the friction damper is deepened to the longitudinal axis of the beam concerning the side segments. It has a flat surface parallel to the longitudinal axis. The side segments have flat surfaces directed towards each other at an angle β to the plane parallel to the longitudinal axis of the beam. Support platforms for side bearings are connected with the upper chord of the beam by segments of surfaces of variable radius,

The next bolster whose design was studied contains an end, while the end contains an upper end surface and at least one surface for a wear-resistant plate containing upper and lower bolt holes (Fig. 2.b). Two structural recesses are made in the upper end surface, which contains connecting surfaces and surfaces with adjustable inclination. The connecting surfaces are parallel to the wear plate surface [17].

Authors [18] a bolster is proposed (Fig. 2.c.) containing two vertical side walls and a bogie bolster coupled with the mentioned vertical side walls; this bogie bolster additionally includes stiffeners made in the areas of a juxtaposition of the thrust bearing and vertical side walls outside the bogie bolster, while the distance between adjacent ribs is from 0,4 to 5,8 mm from the thickness of the vertical side wall 2 adjoining them.

On (Fig. 2.d.) presents a variety of images of a comparative bolster, which contains many bolts passing into the hole in the upper element [19, 20]



a) *b)*

c) *d)*

Fig. 2. Bogie bogie bolster of freight car with increased carrying capacity

Based on the requirements and capabilities of the SC "Casting and Mechanical Foundry" in the Republic of Uzbekistan and the program for the localization of manufactured products, we set the task of developing a new design for the bogie to bolster, taking into account the mechanical characteristics of the material properties. Under production conditions, experimental laboratory studies of the bolster for fatigue were carried out.

3 Results and Discussion

Conducting experimental studies in the laboratory
The fatigue resistance of cast bolsters was checked according to the requirements of GOST 9246. Experimental laboratory tests were carried out in the SC "Casting and Mechanical Foundry" laboratory on the ISRB-1000 bench (the bench diagram is shown in Fig. 3).

The stand is designed for fatigue testing of castings of the side frame and bogie bolster of the 1520 mm gauge freight car bogie. The stand allows loading B of the vertical plane with constant and variable loads in the compression area up to 1000 kN. The width of the support element is equal to the width of the horizontal part of the support surface of the bolster between the surfaces, and the length is 150-200 mm.

On the bolster mounted on two supports, the test load is applied through an insert made of a center plate. During testing, the number of cycles is recorded before the appearance of the first, as well as other macrocracks with a length of (10-15) mm, determined visually, and the number of cycles before the loss of bearing capacity or destruction, indicating the number of the macrocrack along which the destruction of the part occurred.

The values obtained during the tests for the number of cycles are rounded down to the nearest thousand cycles. After the termination of fatigue testing in the presence of a macrocrack, the part should be loaded with an increased quasi-static load until the macrocrack opens to study the features of the fatigue fracture zone.

The principle of operation of the stand is electrohydraulic. The oil flow generated by the pumping unit is directed to the actuators of the loading device using electrical signals from the control system. Table 1 lists test criteria such as amplitude, maximum load, number of cycles, and test time.

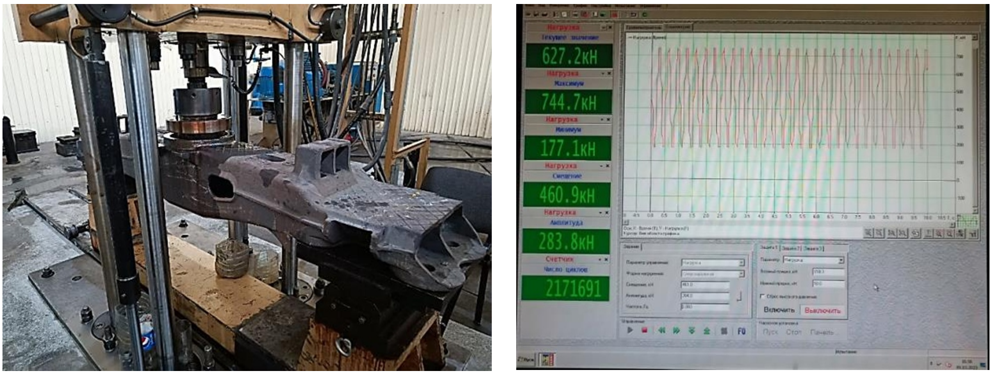
Table 1. Specifications

Highest reproducible and measurable compression load	1000 kN (100 Tc)
Limit of permissible error of load measurement during the forward course of static loading in the ranges:	from 40 to 1000 kN ± 1% from 0 to 40 kN +0.4%
Frequency range of cyclic loading	0.1 to 10 Hz
The largest working stroke of the plunger of the power cylinder	100 mm
The greatest amplitude of deformation of the tested structure at maximum load	at a frequency of 5 Hz - 3.5 mm; at a frequency of 10 Hz - 1.7 mm
Installed capacity	230 kW

The methodology of full accelerated tests is used during preliminary, acceptance, qualification, and type tests of bogie bolsters and side frames (test parameters are given in Table-2). According to the methodology for conducting experimental laboratory tests, the bolster is tested under an asymmetric loading cycle until failure or reaching the base number of cycles $N = 10^7$.

Table 2. Full dynamic fatigue testing of bolsters

№	Bolster beam			
	Amplitude kN	Maximum load Ts	The number of cycles	Time hour.
1	363	84	3049000	212
2	343	82	2444000	170
3	343	82	3768000	261
4	343	82	3205000	222
5	323	80	3242000	225
6	323	80	5519000	383
7	294	77	7128000	495
8	284	76	4440000	308
9	274	75	10000000	695
Total test time				**2971**



a) loading bolster on stand b) test results

Fig. 3. General view of ISRB-1000 test bench during dynamic fatigue testing of bogie bolsters

Table 3. Results experimental studies of bolster in laboratory stand

№	Options	Experiments		
		1	2	3
1	Loading form	sinusoidal	sinusoidal	sinusoidal
2	Average load, kN	461	461	461
3	Amplitude, kN	274	274	274
4	Maximum load, kN	735	745	755
5	Minimum load, kN	187	177	167
6	Loading frequency, Hz	4	4	4
7	Number of cycles before the appearance of cracks, mln	8.997	4.642	5.343
8	Number of cycles before loss of bearing capacity actual, mln	10.126	6.182	7.206
9	The number of cycles before the loss of bearing capacity for ND, million	10	4.44	7.128

4 Conclusions

An experimental study of the bolster according to the method of full accelerated tests must be carried out 9 times under various conditions:

- amplitudes;
- maximum loads;
- number of cycles.

All tests will be carried out per Table 2, after which we will fully analyze the effects of dynamic loads on bolster fatigue. Based on the results obtained, it is planned to develop a new design of the bolster in the conditions of the SC "Casting and Mechanical Foundry".

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