STUDY OF THE STRESS-STRAIN STATE OF THE BRAKE LEVER TRANSMISSION OF THE 18-100 CARRIAGE MODEL

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ABSTRACT

The object of research is the brake lever transmission of the 18-100 freight car carriage.
The investigated problem: the destruction of the elements of the triangle, which leads to the occurrence of failures during the car operation. As a result of such refusals, total losses for the railway infrastructure of Ukraine during freight transportation amount to hundreds of thousands of hryvnias.
The main scientific results: the strength of the brake lever transmission of the freight car carriage is investigated and the most loaded components of its structure are identified. It is proposed to improve the triangle string by making it from a round pipe filled with energy-absorbing material. Aluminum foam is used as an energy-absorbing material.
To justify the proposed solution, a calculation of the strength of the brake lever transmission is performed using the finite element method. The calculation results show that the maximum equivalent stresses that occur in the string do not exceed the allowable ones.
The peculiarity of the obtained results is that the proposed improvement of triangle elements can be applied not only at the stage of designing the mechanical brake system, that is, during the manufacture of car assemblies at car-building plants. It is advisable to apply the proposed solutions when carrying out depot or capital type repairs at car repair enterprises.
The field of practical use of the results is car-building and car-repair enterprises of railway transport of Ukraine.
Innovative technological product: the improvement of triangle elements will increase the efficiency of the braking systems of freight rolling stock, increase the speed of cars, reduce the time for the delivery of goods, reduce operating costs due to the failure of freight car units in operating conditions, and guarantee the level of safety of traffic on the railway. Also, the conducted research will contribute to the creation of developments in improving the reliability of the braking systems of modern rolling stock.
The scope of application of the innovative technological product: the fleet of freight cars of JSC "Ukrzaliznytsia", as well as its own industrial transport cars.

1. Introduction

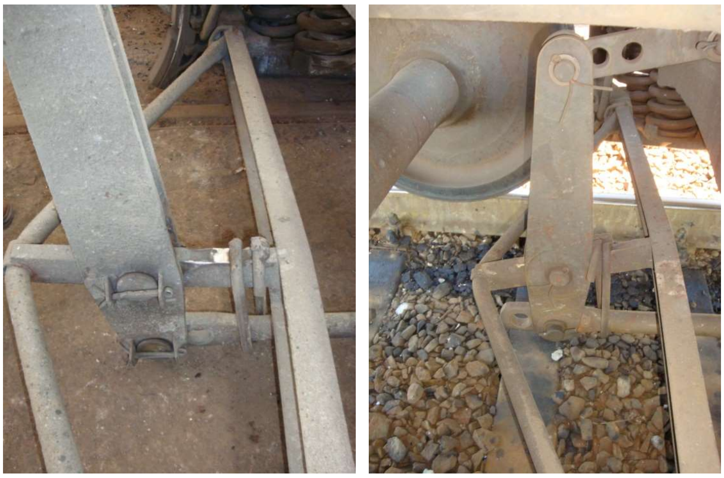
1. 1. The object of research

The object of research is a typical brake lever transmission (BLT) of a freight car model 18-100.

1. 2. Problem description

Currently, modern freight cars use BLT, which was developed as far back as 1898 for "Diamond" type cars. The construction of the lever transmission in these carriages is built in such a way that a change in it at least of any structural element or size violates the dimensional chains and regulatory regulations within the limits of the entire regulatory period of wear of composite brake pads and wheels.

During the inspections of the mechanical part of the brakes of freight cars, the facts of the complete destruction of devices of uneven pad wear, local wear of the triangle spacer (**Fig. 1, *a***), blockage of the two-shouldered vertical lever with its attached parts (**Fig. 1, *b***), etc., were established. Due to such malfunctions, during the movement of freight cars in the traction and coasting modes, abnormal wear of the composite brake pads occurs, which rest against the wheels of the cars with their upper ends, as well as the destruction of the triangle elements.



a *b*

Fig. 1. View of the damaged elements of the carriage lever transmission: *a* – local wear of the triangle spacer and a damaged device for uniform pad wear; *b* – blockage of the triangle due to a damaged device for uniform pad wear

According to the conducted production studies, the total losses from the destruction of the mechanical brake system, their failures and non-standard wear of pads for the railway infrastructure of Ukraine during freight transportation amount to hundreds of thousands of euros.

Therefore, for the theoretical prerequisites for the design of modern BLT, it is necessary to investigate the stressed state of its structure and propose measures to reduce the load on its parts. This will contribute to increasing traffic speeds and traffic safety on the railways.

1. 3. Suggested solution to the problem

The issues of ensuring the movement of freight trains are quite urgent and depend on many factors, in particular the technical condition and load of their brake components. So, for example, in the work [1] it was proved that too many elements and redundant connections in the BLT of the carriage (mod. 18–100) prevent the self-alignment of the friction surfaces of the brake pads relative to the rolling planes of the wheels. In particular, the number of redundant connections in the kinematic scheme is equal to the value q=12. In the same study, proposals were also formulated that allow to reduce this indicator to the desired level due to constructive changes in the triangle. However, they have not yet been realized and this node has not been perfected. Although such a decision could contribute not only to the self-installation of blocks and wheel pairs, but also to increase the efficiency and safety of braking in curved sections of the track.

In the work [2], a BLT with a device for the removal of pads in cars of freight cars with automatic correction of the relative position of the brake pads relative to the rolling surfaces of the wheels is proposed. However, the number of parts in the proposed lever gear is very large. In connection with this, the design of the BLT is significantly complicated, also in the conditions of operation it requires periodic time-consuming adjustments, because of this its use is impractical.

The work [3] analyzed the dynamic forces acting on the load-bearing structure of the bodies of freight cars and related to the guarantee of traffic safety during operation in international traffic. However, at the same time, the authors did not consider the load on the components of the brake system of three-element carriages.

In China, a promising carriage design (mod. ZK1) made of BLT [4] with improved dynamic characteristics has been created. The lever gear of the carriage has a non-rigid triangle suspension, which rests on conical bushings through rubber. Although it also has some shortcomings. To use the brake transmission in the side frames of the ZK1 carriage, it is necessary to pour special additional tides that hold the triangular brake system. Fatigue cracks spread in the points of contact between the triangle spike and the side frame, so there may be threats to traffic safety here as well. In addition, in the process of operation, there is an increased wear of conical bushings and a decrease in their resource.

A special method is proposed in [5] for predicting braking efficiency. The expediency of this method takes place if a new brake system of the carriage is used. For example, a pneumatic brake with electronic control, or when the number of cars in a train changes. Also, this method can be used to accurately predict the amount of impact on the rail, if a defect has appeared on the rolling surface of the wheel due to an imperfect design of the carriage's mechanical braking system.

The team of authors in work [6] proposed measures to improve the safety element to compensate for the angular movements of the brake cylinder rod at its maximum exit from the housing, which will prevent such movements at its exit from the housing. The optimal parameters of the safety element of the brake cylinder rod were determined according to its permissible moment of resistance. To determine the strength of the brake cylinder, a calculation was carried out using the finite element method, the results of which showed that the strength condition is met. It should be noted that an equally important factor that affects the efficiency of the entire brake system of the car is the operation of the lever gear. However, the work did not pay attention to this issue. Also, no measures are given to ensure the repairability of the improved safety element.

Over the past decade, specialists from foreign countries have conducted research on various aspects of railway vehicle braking in order to improve the reliable operation of the railway transport system. The work [7] provides calculations for the braking force of a vehicle equipped with a UIC pneumatic brake for passenger trains. And in the study [8], an attempt was made to spread this idea to cars of freight trains, which will make it possible to improve braking efficiency.

The analysis of literary sources [1–8] makes it possible to conclude that the issue of ensuring the movement of trains by improving their brakes is relevant and requires research and development.

The aim of research is to determine the BLT stress-strain state of the 18-100 freight car carriage under operating conditions.

2. Materials and methods

To study the strength of a typical BLT of a freight car carriage, its spatial model was built in the environment of the SolidWorks software complex (**Fig. 2**).

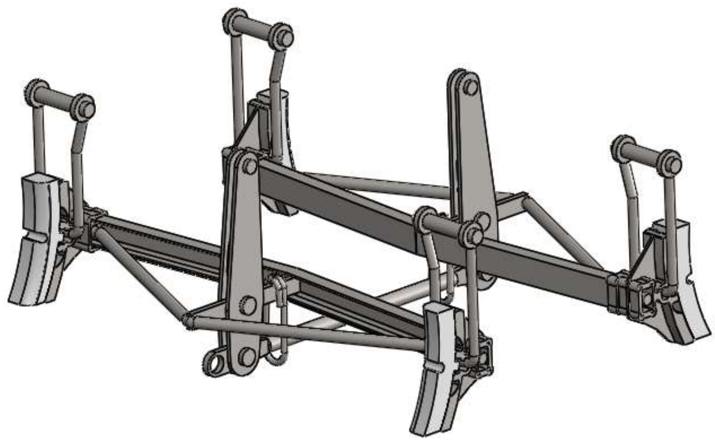


Fig. 2. A typical BLT of a freight car carriage

The strength calculation is carried out using the finite element method implemented in the environment of the SolidWorks Simulation (CosmosWorks) software complex. Isoparametric tetrahedra are used as finite elements. The optimal number of elements of the finite element model (FEM) (**Fig. 3**), determined by the graphoanalytic method. The main FEM characteristics of a typical BLT are given in **Table 1.**

The calculation scheme of a typical BLT carriage is shown in **Fig. 4.**

At the same time, the force acting on the vertical lever N1 was divided into two components, taking into account the angle of application.

Table 1
The main FEM characteristics of a typical BLT

Parameter name	Value
Number of Jacobian points	4
Number of nodes	72445
Number of elements	276335
The maximum size of the element, mm	15
The minimum size of the element, mm	3
The minimum number of elements in a circle	7
Element size increase ratio	1.8

The load transmitted to the brake pad from the wheel during braking was also divided into two components, taking into account the angle of inclination of the pad. At the same time, the vertical component P_v of this load on the first pair of blocks in the course of movement is directed upwards, and on the second – downwards.

Fixing of the model was carried out by the suspension elements of a typical BLT to the frame of the freight car carriage. At the same time, the fastening was modeled as a "fixed hinge" (**Fig. 5**).

As the material of the BLT elements, steel grade St. 3sp was used and the brake pads are composite.

The results of the calculation of the typical BLT of the carriage are shown in **Fig. 6, 7.**

At the same time, the maximum equivalent stresses occur in the string and amount to about 156 MPa, that is, they do not exceed the allowable ones. Therefore, the strength of a typical BLT is ensured. At the same time, under conditions of increased movement speeds and excessive loads, the tension in the string may exceed permissible values. This causes its damage, and accordingly threatens traffic safety.

Fig. 3. FEM of a typical BLT carriage

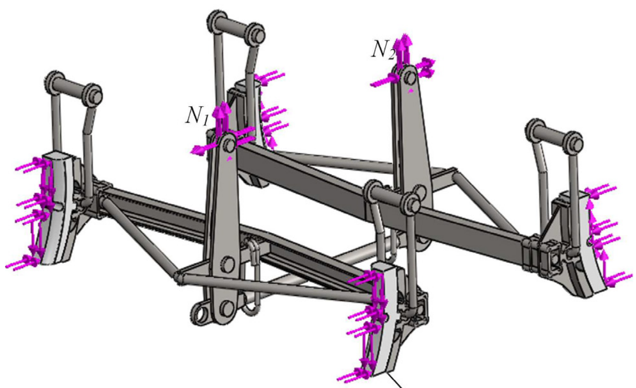


Fig. 4. Calculation scheme of a typical carriage BLT

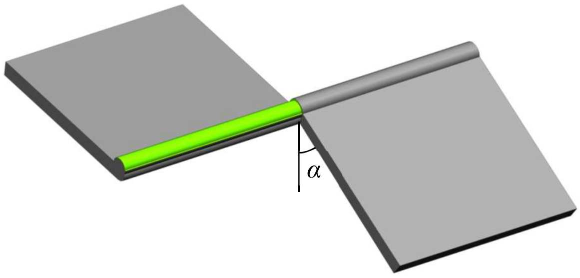


Fig. 5. Fixed hinge

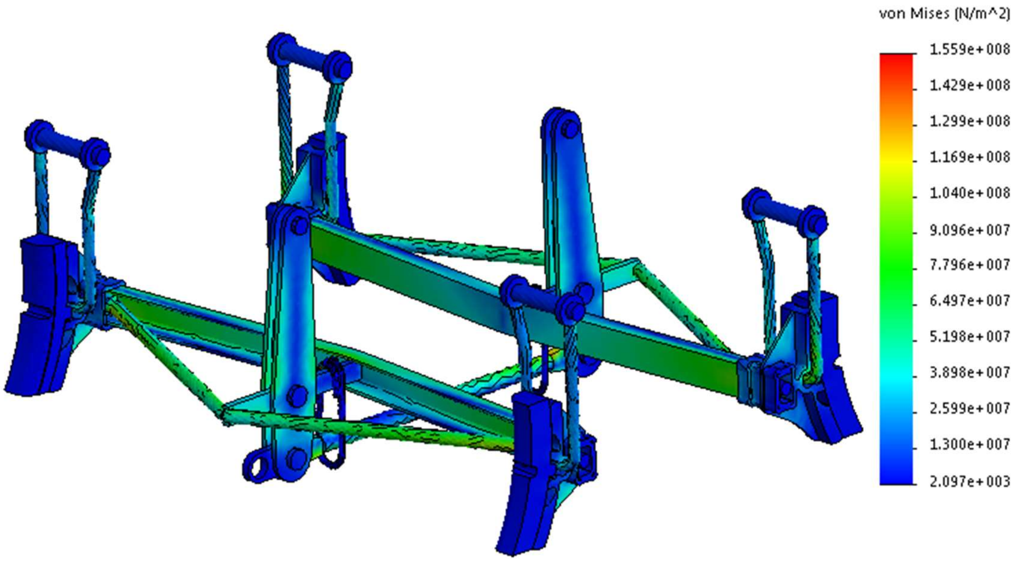


Fig. 6. Stressed state of a typical carriage BLT

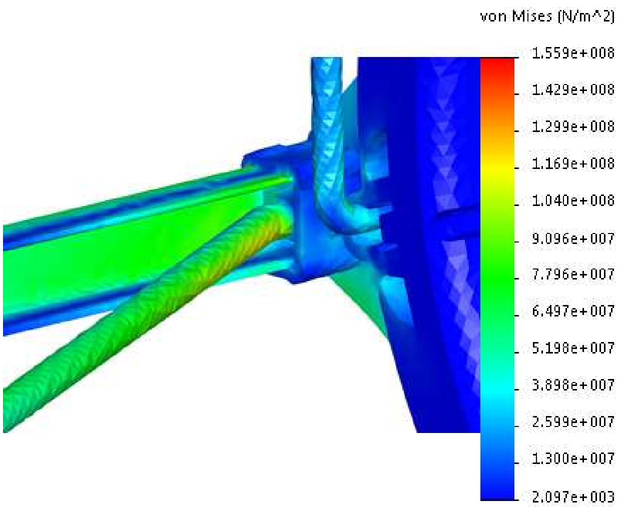


Fig. 7. Tension in the BLT string

5. Research results and their discussion

In order to increase the efficiency of the brakes of the freight rolling stock, it is proposed to improve the design of the BLT elements of the carriage [9]. This improvement consists in the fact that the string is made of a round pipe filled with energy-absorbing material (**Fig. 8**). The diameter of the pipe is determined by the strength reserve of a typical string design. Aluminum foam is used as an energy-absorbing material. To justify the proposed improvement, a strength calculation is carried out.

Modeling of aluminum foam in the string was carried out by placing a body in it with parameters identical to it. The main FEM characteristics of the improved BLT are given in **Table 2.**

The stressed state of the improved BLT construction is shown in **Fig. 9.**

The maximum equivalent stresses in the BLT amounted to 141.3 MPa and were concentrated in the draw. In the string, the stresses are equal to 138.6 MPa, that is, 11 % lower than in the typical design.

The advantage of this study in comparison with [1–8] is that the improvement of the strength of the mechanical brake system is achieved by the introduction of an energy-absorbing material in the BLT. This contributes to an increase in the moment of resistance, and, accordingly, the indicators of the strength of the BLT elements.

The disadvantage of this study is that the calculations were performed only for one mode of operation of the cargo air distributor conventional No. 483.

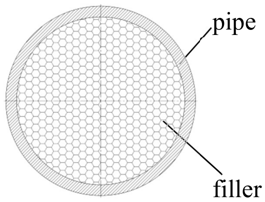


Fig. 8. String section

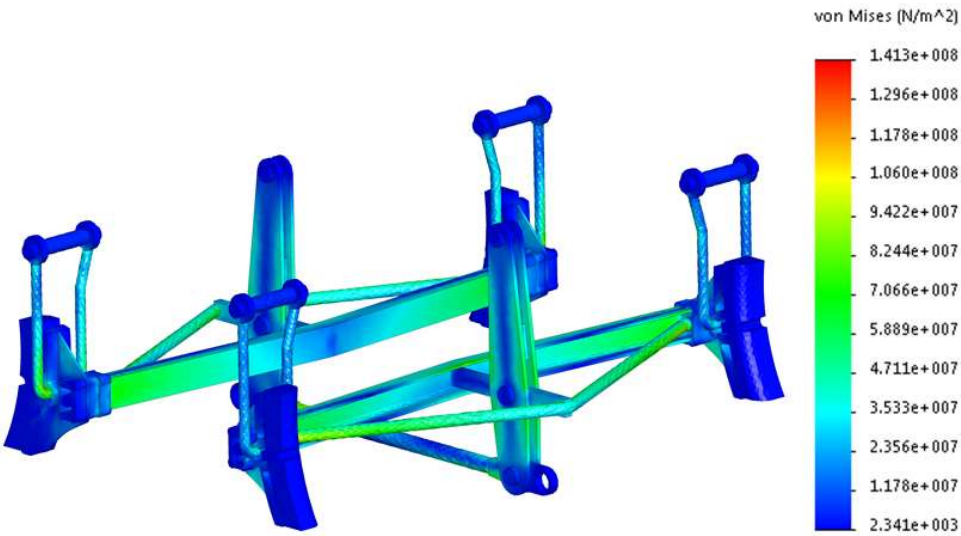


Fig. 9. Stressed state of the improved carriage BLT

Table 2

The main FEM characteristics of the improved BLT

Parameter name	Value
Number of Jacobian points	4
Number of nodes	80814
Number of elements	314719
The maximum size of the element, mm	16
The minimum size of the element, mm	3.2
The minimum number of elements in a circle	9
Element size increase ratio	1.7

The further direction of this study is to take into account all modes of operation of the cargo air distributor conditional No. 483 during braking: empty, medium and cargo. It is also important to take into account the BLT operation with functional devices for uniform wear of brake pads in cars during movement in traction and run-out modes of freight trains. The issue of determining the BLT influence on the work of the tribotechnical pair – "brake pad – wheel" needs attention. An equally important stage of research is the introduction of new materials into the design of component brakes of rolling stock [10, 11], including BLT.

6. Conclusions

1. The calculation of the strength of a typical BLT of the model 18-100 freight cars carriage is carried out. It is established that the maximum equivalent stresses occur in the string and are about 156 MPa, that is, they do not exceed the permissible ones. However, under conditions of increased movement speeds and excessive loads, the tension in the string may exceed permissible values. This causes its damage, and accordingly threatens traffic safety.

2. Measures to improve the strength of the BLT elements of the carriage are proposed and strength calculations are carried out. The results of the calculation showed that the maximum equivalent stresses in the GVP are 141.3 MPa and are concentrated in the draw. In the string, the tension is equal to 138.6 MPa, that is, 11 % lower than in the typical design.

Conflict of interest

The authors declare that they have no conflict of interest in relation to this study, including financial, personal, authorship, or any other, that could affect the study and its results presented in this article.

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Data availability

The data cannot be provided for the reasons stated in the data availability statement

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