IOP Conference Series: Materials Science and Engineering

PAPER • **OPEN ACCESS**

Improvement of brake lever transmission for dump cars

To cite this article: D Voloshin *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **708** 012037

Improvement of brake lever transmission for dump cars

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Abstract. The article deals with issues of improved structures of brakelever transmission forindustrial rail cars.The improved dump car structure is an important engineering problem aimed at higher reliability and better technical and economic characteristics of vehicles.The authors evaluatedthe forces acting in the lever transmission of a dump car at various types of brake shoes.The research is concerned with the capacity calculation of the most important transmission elements with the finite element method.By applying the software suite Solid Edge,an example of the improved structure of a lever transmissionwas implemented.The authors evaluated the forces and stresses in a standard transmission structure of these cars at different modes.With the software suite Autodesk Inventor the authors made a capacity test for specialized levers for composite shoes.The results of capacity calculations for the elements of levertransmissionfor dumpcars made it possible to recommend an application of composite materials in place of iron ones.It will considerably decrease carweight and material intensityintechnical service and increase the total reliability of the car.

1. Introduction

Dump cars (hopper wagons) are specialized industrial rail transport cars.They are used at enterprises of mining and processing industries (metallurgy, chemical industry, construction, etc).Their basic function is provision of freight transportation for internal and technological purposes.

Special aspects of use:

– short-distances transportation (10-15 km at the average);

– limited speed (15–25 km/h on mine tracks and 30–60 km/h on regular and station tracks);

– out-of gauge freight by geometric and mass characteristics (especially for mining industry);

– rather harsh operational environment due to intricaterail track profile (sharp steepness and long gradients), and others.[1].

Difficult operational conditions set upstrictdemands for reliability of structural elements of cars, traffic safety and freight security.Safe and efficient technological transportation directly depends on the state of the braking system in dump cars.

Iron and composite brake shoes are commonly used for freight rail vehicles.Horizontal brake levers have holes which can change the reduction ratio.With iron brake shoes the brake lever has a higher reduction ratio.Its elements transmit greater forces and have biggerdimensions, weight and cost.Additional holes for shifting the reduction ratio weaken the levers and make it possible to mistakenly establish an increased reduction ratio for composite shoes.Higher pressure on composite brake shoes may damage the rolling surface of the wheels and lead to their jamming.Defects on the rolling surface of the wheelsdestroy both wheel and rail track, which hazards the safety of traffic.

Problems of improving brakes forrail vehicles, calculating properties of wheel gear with rails are discussed in articlesby Anisimov P.S. [2], and problems of designing the mechanical part of the braking system forcarsare discussed in articles byAsadchenko V.R. [3].The principle of operation, calculations and operational characteristics of brakes forrail vehicles are considered in studies byA.M. Babayev, D.V. Dmitriev [4], theoretical basics of design and operation of brakes are considered in studiesbyV.M. Kazarinov[5] and other scientists.It should be mentioned that problems of a lower mass of brake lever elements are not covered in the studies mentioned.

Studies by V.H. Inozemtsev and L.O. Vukolov [6, 7] encouraged a wide spread of composite shoes for rail vehicles.However, the studies did not touch uponimprovements in mechanical elements of the brakes.

Problems of modernization and optimization of car body elements are covered in studies by O.V. Fomin, A.O. Lovska [8, 9, 10] and others.Besides, problems of lower material intensity of brake lever elements are not dealt with by the researchers.

The analysis of the above-mentioned studies demonstrate that most of them are aimed at research and improvements in air brake elements, braking shoes, testson various materials for shoes, simulation of their work, and structure of significantcar body parts.Thus, the problem of improved structure for brake lever elements requires additional research.

On the basis of the experience ofbrake application, there is a possibility to provide needed reliability ofthe mechanical part of a braking system by using only composite brake shoes [4].

With this engineering solution it is possible to:

- simplify the lever transmission structure and brake kinematic diagram;
- decrease the car weight;
- optimize the diagram of force distribution in braking;
- improve efficiency of braking processes;
- increase brake sensitivity;
- extend the operational life of levers;
- decrease the maintenance and technical service cost of cars.

2. Evaluation of forces on the lever equipmentof a six-axle dump car at various types of brake shoes

Dump cars have the following diagram of the mechanical part of brake equipment Figure 1 [11].

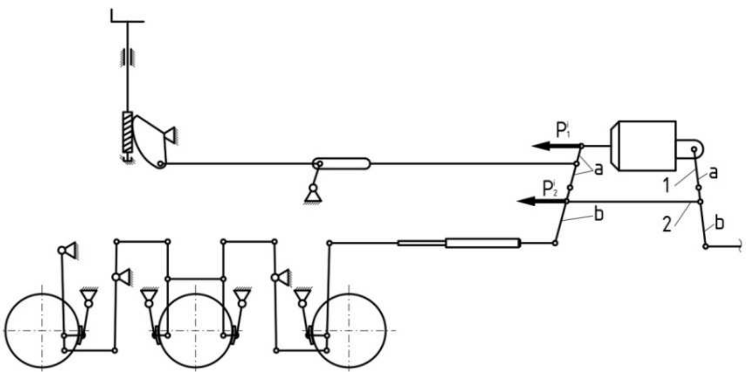

Figure 1. Diagram of the brake leverequipment of a six-axle dump car

On the Figure 1: P_1^i - forces on the brake cylinder rod, P_2^i - forces on levers 1 along the brace, a, b - the sizes of the horizontal lever arms, 1 - horizontal lever, 2 –brace.

In order to substantiate the research intoreasonable improvements forbrakelever equipment the authors evaluated the forces acting in the structure of leverequipment of a dump car at various types of brake shoes.The capacity calculations for important elements of the equipment were made with finite element method and the software suite Autodesk Inventor.By applying the software suite Solid Edge the authors realized an example of the optimal shape of elements for lever equipment.

The maximum forces on the brake cylinder rod at the*i*-th type of shoes can be determined according to [12] by the formula

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$$P_1^i = p^i \frac{\pi d^2}{4}, \quad (1)$$

where p^i – the pressure in the brake cylinder at the*i*-th type of shoes, *kPa*, according to [11] the allowable pressurefor composite shoes is $p^{composition} = 340\,kPa$, for iron shoes $p^{cast-iron} = 450\,kPa$; d – the diameter of the brake cylinder rod, m, for a six-axle dump car $d = 0.4\,m$.

The forces P_2^i (Figure 1) on levers 1 alongthe bracefor various types of brake shoes were defined as

$$P_2^i = P_1^i \frac{a^i + b^i}{b^i}, \quad (2)$$

where a^i, b^i – the sizes of the horizontal lever arms at the*i*-th type of a shoe, m. For a standard lever structure [11] $a^{composition} = 0.222\,m$, $b^{composition} = 0.268\,m$, $a^{cast-iron} = 0.29\,m$, $b^{cast-iron} = 0.2\,m$.

The results of calculation by formulae (1-3) are assembled in Table 1 according to the shoe type;disparities of the forces are also given.

Table 1. Forces in the leverequipment of a dump car withiron and composite brake shoes, kN.

Factor	Shoe type		Force disparity, %
	Iron	Composite	
Forces on the brake cylinder rod, P_1^i	56.55	42.7	24.5
Forces on the brace, P_2^i	138.54	78.1	43.6
Forces on a lever at the brace level, $P_2^i/2$	69.27	39.05	43.6

3. Capacity calculation for brake lever elements of a dump car

The results of capacity calculation for an existing horizontal lever and a brace are given in Figure 2.The hinged support of a lever at the end holes and above-mentioned loads in the shaft hole were chosen as boundary conditions.The brace was considered fixed near the hole on one side and loaded with stretching force near the opposite hole.

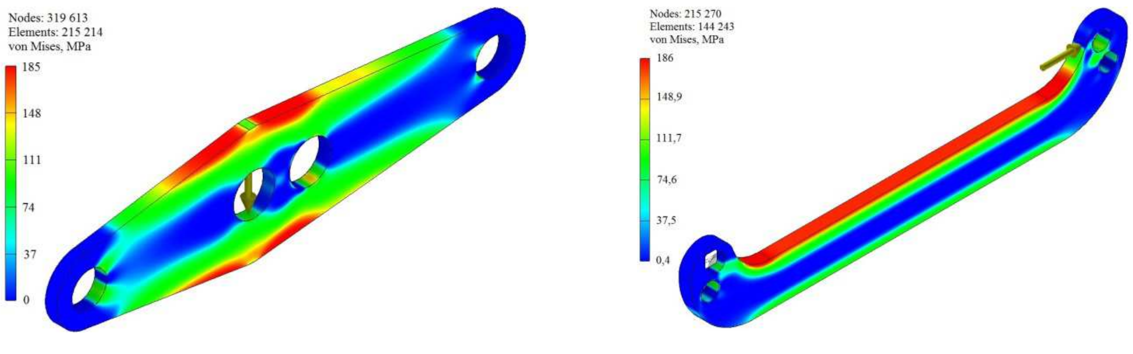

Figure 2. Force distribution in the existing lever structure of a dump car

Analysis of the stresses obtained demonstrated that capacity requirements were satisfied.

As far as nowadays composite shoes are in wide use, let us calculate a specialized lever for them.

According to [12] the bending deformation is the basic type of deformations for levers.And the capacity condition for such a lever is:

$$[\sigma] \geq \frac{M}{W}, \quad (3)$$

where $[\sigma]$ - the allowable stress in alever under bending, MPa; M - the maximum bending moment, kNm; W - the moment of resistance in the maximum stressed cross-section, m^3.

The maximum stressed zonewasa cross-section where the lever connected with the brace, and for a horizontal lever the maximum bending moment could be determined as $M = 0,5P_1^i \cdot a^i$.

The moment of resistance for themaximum stressed cross-section of a rectangular form with a hole of the diameter d_h for a sleeve and shaft is

$$W = \frac{t\left(h^3 - d_h^3\right)}{6h}, \tag{4}$$

where t - the lever width, m; h - the lever height, m.

Formulae (3-4) give the allowablelever height in the form of an equation of third order

$$h^3 - \frac{6M_з}{t[\sigma_з]}h = d_h^3. \tag{5}$$

By solving equation (5) we obtain allowable values of the minimal lever width for certain types of shoes; the lever width is standard $t = 0,014$ м, the hole diameter $d_h = 0.045$ м, the allowable stress for steel St.3 equals to $[\sigma]=0.95\sigma_т$ [13] $[\sigma]=190$ MPa.

The results of capacity calculation for thespecialized horizontal lever and brace are given in Figure 3.

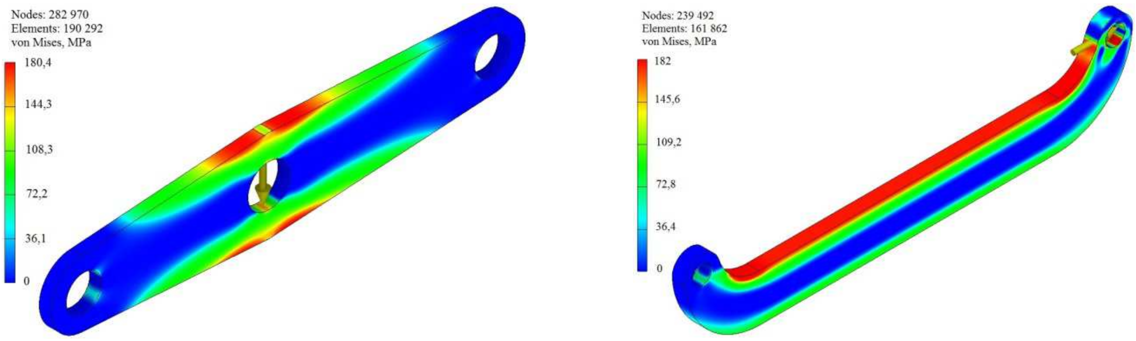

Figure 3. Stressdistribution in specialized levers

The stresses obtained did not exceed the admissible ones, i.e.the capacity wasensured.

4. Shape improvements inlever elements

Using new features of the software suite Solid Edge for buildinga generative design of elements and improvements in their shape, and also considering the positive experience in application of pressed levers of changeable forms on European railways the authors improvedthe shapes of thehorizontal lever and brace.Besides, the support parts of the lever and brace were taken as constant to avoid bearing deformations.The elements were loaded with forces presented in Table 1. The results of improvements are given in Figure 4.

Figure 4. Changed lever and brace shapes

IOP Conf. Series: Materials Science and Engineering **708** (2019) 012037 doi:10.1088/1757-899X/708/1/012037

The mass characteristics of improved and existing levers and braces are given in Table 2.

Table 2. Mass characteristics of improved brake lever elements, kg, and theiralterations.

Element	Existing structure	%	Specialized for composite shoes	%	Improved with software suite	Total, %
Horizontal lever	5.8	-12	5.1	-20	4.1	-30
Brace	30.168	-8	27.692	-20	21.854	-27.6

5. Conclusions:

1. The authors evaluated the forces in the lever equipment of a dump car at various types of brake shoes.It has been demonstrated that application of composite shoes in place of iron ones has decreased the forces on the brake cylinder rod, brace and levers;

2 The authors also conducted capacity calculations for the existing horizontal leverand brace of the brake system of a dump car.The results obtained for design stresses did not show any increase in allowable loads, thus with composite shoes the capacity is ensured;

3 With the software suite Solid Edge and thegenerative design of elements and their optimal shape, the authors improved the shapes of the horizontal lever and brace.

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