Original Research Article:
full paper

(2022), «EUREKA: Physics and Engineering»
Number 6

INFLUENCE OF STRUCTURAL SOLUTIONS OF AN IMPROVED BRAKE CYLINDER OF A FREIGHT CAR OF RAILWAY TRANSPORT ON ITS LOAD IN OPERATION

Sergii Panchenko[1]

Glib Vatulia[1]

Alyona Lovska✉
Department of Wagon Engineering and Product Quality[1]
alyonaLovskaya.vagons@gmail.com

Vasyl Ravlyuk
Department of Wagon Engineering and Product Quality[1]

Israil Elyazov
Department of Transport Engineering and Technology Management[2]

Ilham Huseynov
Department of Transport Logistics and the Spirit of Safety[2]

[1]*Ukrainian State University of Railway Transport*
7 Feuerbakh sq., Kharkiv, Ukraine, 61050

[2]*Azerbaijan Technical University*
25 Hussein Javid ave., Baku, Azerbaijan, AZ 1073

✉**Corresponding author**

Abstract

The object of research is the processes of occurrence, perception and redistribution of loads in the design of the car brake cylinder in operation.

To compensate for angular shifts of the brake cylinder rod at its maximum exit from the housing, improvement measures are proposed. This improvement consists in the use of a safety element to limit the angular movements of the rod when leaving the body.

The load of the brake cylinder rod during its angular displacements is determined. The condition for ensuring the strength of the rod is obtained.

The optimal parameters of the pipe of the safety element (limiter) of the brake cylinder rod were determined by its allowable moment of resistance. For the possibility of moving the levers interacting with the stem, special windows are provided in the limiter. It is proposed to fix the limiter to the cover by welding.

To determine the strength of the brake cylinder, a calculation was made using the finite element method. The results of a robust calculation showed that the maximum equivalent stresses occur in the brake cylinder cover and amount to 118.5 MPa. Therefore, the strength of the brake cylinder is ensured.

A feature of the obtained results is that the proposed improvement can be applied not only at the stage of designing a brake cylinder, but also at the stage of modernization.

The sphere of practical use of the obtained results is railway transport. The conditions for the practical use of the results are the absence of deformations of the brake cylinder rod.

The research carried out will help to improve the efficiency of rolling stock brakes, ensure traffic safety, increase rolling stock speeds, deliver goods, etc. Also, the conducted research will contribute to the creation of developments to improve the reliability of the rolling stock brakes.

Keywords: transport mechanics, brake cylinder, rod load, brake cylinder strength, brake reliability, traffic safety.

DOI: 10.21303/2461-4262.2022.002638

1. Introduction

The transport branch is a generator of the development of the economy of many states. At the same time, the most important component of the transport industry, which accounts for the weighted volume of traffic, is the railway [1, 2]. To ensure the reliability and safety of cargo transportation by rail, special attention should be paid to its technical condition [3, 4]. One of the most important components on the technical condition of which traffic safety depends is the brake. Currently, the most widely used railways on a wide track are pneumatic automatic brakes. The main power device of the brakes, which converts the kinetic energy of compressed air into mechanical work, is the brake cylinder.

At present, industrial enterprises produce a large number of brake cylinders according to the design features. An analysis of their designs made it possible to conclude that one of the main drawbacks is the impossibility of compensating for the angular displacements of the rod at its maximum exit from the housing (**Fig. 1**). This contributes to the bending of the rod, disruption of the brake cylinder, and, accordingly, is fraught with the safety of train traffic.

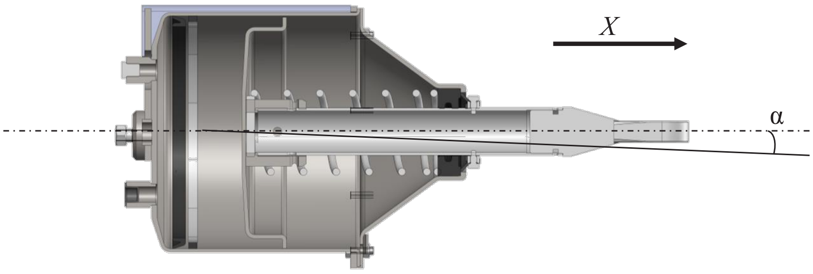

Fig. 1. Scheme of the brake cylinder rod movement

In the brake cylinders used on Belarusian locomotives, this drawback is eliminated by placing the rod in the pipe, that is, its movement is limited by the inner diameter of the pipe [5]. But this solution has not been widely adopted. In addition, the authors did not indicate the features of the interaction of the rod with the components of the brake linkage. Also, there is no data in the work on the possibility of using such a solution on freight cars that experience significant longitudinal loading in operation.

In this regard, in order to ensure the safety of the movement of freight cars as part of trains, as well as to increase the efficiency of the brakes, it is important to conduct research to improve the brake cylinders, as one of the most critical and loaded brake units.

To determine the state of the issue of increasing the efficiency of rolling stock brakes by improving the design of its components, an analysis of recent publications was carried out.

Thus, the issues of increasing the efficiency of the pneumatic brake of a hopper car are covered in [6]. The problem is solved by improving the design of the brake linkage. Justified and optimized the design of levers using the software package Solid Edge Siemens PLM Software. However, the effective operation of the brake linkage largely depends on the technical condition of the brake cylinder. It is important to say that the authors of the article did not take into account this factor, and the calculation was made without taking into account the joint operation of the levers with the brake cylinder. In this case, the action of the brake cylinder on the brake linkage was modeled by a longitudinal force on it.

Simulation of the load of the brake linkage under operating conditions is carried out in [7]. The loads acting in the components of the brake linkage are determined. Calculation of brake pads is done. The requirements for improving the operation of the brake linkage are determined. At the same time, the authors did not investigate the effect of the brake cylinder on the load that is transmitted from the levers to the pads. This may contribute to the error in the conduct of relevant studies.

Features of ensuring sTable frictional properties of the brakes of railway rolling stock are covered in [8]. A new approach is proposed to ensure the stability of the friction coefficient in different braking modes. Structural solutions for improving the elements of a tribotechnical pair are proposed and its characteristics are confirmed experimentally. However, these studies were carried out with respect to a disc brake, mainly used on passenger rolling stock.

Improving the efficiency of using brakes by using a multifunctional method for controlling adhesion in the system «wheel – brake pad – rack» was proposed in [9]. Proposed measures to reduce the likelihood of wheel slip relative to the rack. A mathematical and computer substantiation of the proposed solutions is presented. It is important to say that the work does not take into account the influence of the operation of the brake cylinder on the effectiveness of the adhesion of the wheel to the rail.

A promising design of the brake system for delivery braking of freight cars is reflected in the publication [10]. The optimal design of a unified linkage for two-axle bogies with 670 V cylinders placed on the bogie was chosen. A scheme for adjusting the brake linkage has been developed. However, when carrying out calculations, the standard loads transmitted to the brake linkage from the brake cylinder are taken into account. That is, the work did not determine the actual loads acting from the brake cylinder on the linkage. The factors influencing the braking efficiency were determined in [11]. The research was carried out on the rolling stock of the Indian Railway. At the same time, as a determining factor, the authors considered the heating temperatures of the wheels of the locomotive and wagons that form the train. It is important to say that an equally important factor affecting the efficiency of the brakes is the work of the brake cylinder. However, the authors of the article did not pay attention to this issue.

Prospects for the use of modular brakes on the rolling stock of China are covered in [12]. The requirements that the brakes of modern urban rolling stock must meet are determined. The paper also noted the further development of the improvement of modular brakes. However, the authors did not pay attention to the issue of improving the power devices of the brakes and their impact on the efficiency of the modular brakes.

An analysis of the design features of modern rolling stock brakes is given in [13]. The main factors influencing the efficiency of the brakes are determined. The temperature load on the components of tribotechnical pairs during braking is calculated. It is important to say that the authors did not take into account the effect of loads from the brake cylinder rod on the elements of tribotechnical pairs.

The analysis of literary sources [6–13] allows to conclude that the issues of improving the brake cylinders of freight cars to improve the efficiency of the brakes have not yet been given due attention. Therefore, there is a need for appropriate research in this direction. This will help ensure the reliability of the brake cylinder and increase the efficiency of the rolling stock brakes.

In this regard, the study is to improve the efficiency of the brakes of freight rolling stock by improving the design of the brake cylinder. This will help to reduce the operating costs for holding the brakes of the freight train and improve the safety of train traffic.

To achieve the aim, the following objectives are defined:

– determine the load of the brake cylinder rod during its angular displacements;

– improve the design of the brake cylinder in order to prevent the angular displacement of the rod;

– determine the strength of the improved design of the brake cylinder;

– calculate the weld in the zone of interaction between the safety element and the cover.

2. Materials and methods

To determine the load of the brake cylinder rod during its angular displacements, classical methods of material resistance were used. The design diagram of the brake cylinder rod is shown in **Fig. 2**. In this case, the rod is considered in the form of a rod system as a beam with cantilever pinching.

The maximum load on the rod is calculated by the formula [14]:

$$P = p_c \cdot \frac{\pi \cdot d^2}{4} \cdot \eta_c - \left(P_r + c_s \cdot f\right), \tag{1}$$

where p_c – air pressure in the brake cylinder; d – inner diameter of the brake cylinder; η_c – efficiency factor of the brake cylinder; P_r – pre-compression force of the release spring of the brake cylinder; c_s – stiffness of the release spring; f – maximum allowable piston stroke of the brake cylinder.

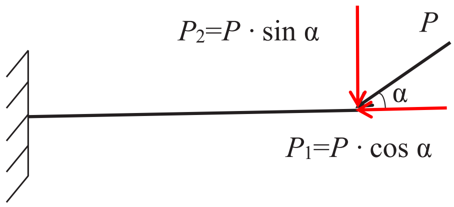

Fig. 2. Calculation scheme of the rod of the brake cylinder

On the basis of carried out in accordance with the scheme shown in **Fig. 2**, calculations plots of the transverse force and bending moment acting on the rod are plotted. The maximum stress on the rod of the brake cylinder will be determined as the sum of the stresses arising from the force P_1 (compression strain) and P_2 (bending strain) [15, 16]. The diagram of the transverse force during compressive deformation is shown in **Fig. 3**, and the diagram of the bending moment during bending deformation in **Fig. 4** [17].

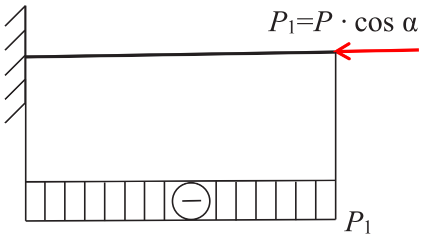

Fig. 3. Diagram of the transverse force

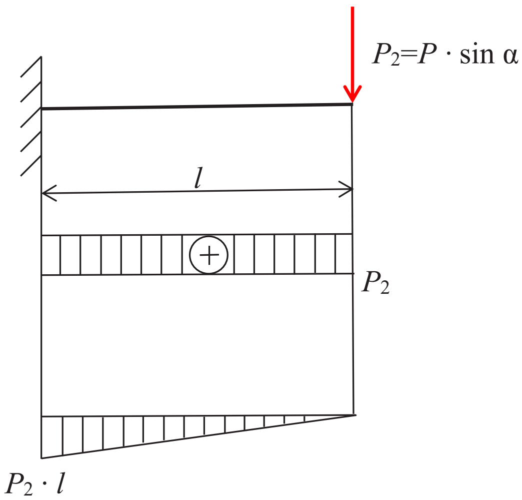

Fig. 4. Diagram of the bending moment

Then, the maximum stresses acting on the rod of the brake cylinder will be determined by:

$$\sigma_{max} = \frac{P_1}{A} + \frac{P_2 \cdot l}{W}, \tag{2}$$

where A – cross-sectional area; l – rod length; W – moment of resistance to the cross section.

The strength condition in this case has the form:

$$\sigma_{max} \leq [\sigma], \tag{3}$$

where [σ] – allowable stresses, MPa.

In order to prevent bending of the brake cylinder rod in operation, it is offered on cover 1 (**Fig. 5**) in the area of the rod outlet, the installation of a safety element 2 in the form of a round tube, the type of solution, is indicated in [5]. Along with this, the authors proposed a scientific justification for the implementation of such an idea on a brake cylinder conv. No. 188 B of a freight car, taking into account further improvement of the safety element. The fastening of the cover 1 and the bottom 3 to the body 4 remains the same as in the typical design of the brake cylinder, which makes it possible to introduce such a solution not only at the manufacturing stage, but also at the modernization stage.

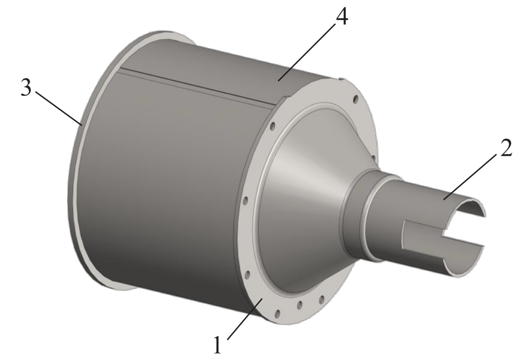

Fig. 5. Brake cylinder, taking into account improvement measures:
1 – cover; 2 – safety element; 3 – bottom; 4 – body

For the possibility of moving the levers interacting with the rod, special windows are provided in the safety element. The pipe diameter is slightly larger than the rod diameter, which limits its deviations under the action of angular loads on it (**Fig. 6**). It is also possible to use a double pipe, i.e. pipes of a larger diameter into which a pipe of a smaller diameter is installed. In the interlayer between the pipes, a material with energy-absorbing properties is placed, for example, aluminum foam, which is currently widely used in mechanical engineering (**Fig. 7**). This will help to reduce the load on both the rod and the safety element under operational loads. It is important to say that there are varieties of energy-absorbing materials that have temperature-resistant properties, which allows to safely carry out welding work when carrying out repair and maintenance of the brake cylinder.

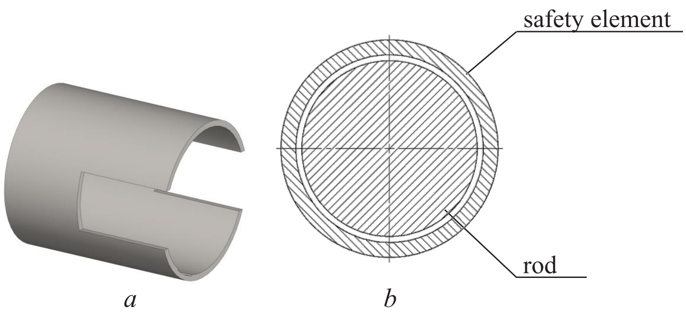

Fig. 6. Safety element: *a* – spatial model; *b* – cross section

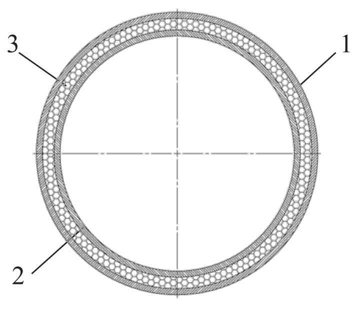

Fig. 7. Safety element of perspective design:
1 – outer pipe; 2 – inner pipe; 3 – energy absorbing material

The determination of the optimal parameters of the pipe is made according to the allowable moment of resistance.

Taking into account the fact that:

$$[\sigma] = \frac{P_1}{A} + \frac{P_2 \cdot l}{W}. \tag{4}$$

The moment of resistance will be:

$$W = \frac{P_2 \cdot l}{[\sigma] - \frac{P_1}{A}}. \tag{5}$$

Permissible stresses in the brake cylinder are given in **Table 1** and taken in accordance with **Table 1** 2.1 of DSTU 7598:2014. Freight wagons. General requirements for calculations and design of new and modernized 1520 mm gauge cars (non-self-propelled). An analogue of this standard is EN 12663-2. Railway applications – structural requirements of railway vehicle bodies – Part 2: Freight wagons.

Taking into account the data specified in **Table 1**, let's accept [σ] = 145 MPa.

Table 1

Permissible stresses for brake equipment parts (MPa)

Type of deformation	Carbon steel grades		Low alloy steel, grade 09G2S	Steel casting grades	
	St. 3, 15, 20	St. 5, 30		20GL	20GFL
Bending	145	160	200	145	160

It is important to say that when using analogues of the specified standard, it is necessary to take into account the corresponding voltages given in them. Due to the fact that these values may differ somewhat, the authors presented the data that were taken into account in the calculations (**Table 1**).

According to GOST R54157-2010. Pipes steel for a metalwork. Specifications» determined the optimal diameter of the safety element – a pipe having a diameter of 114 mm (**Fig. 8**) and a moment of resistance to the cross section of 48.52 cm^3 (**Table 2**).

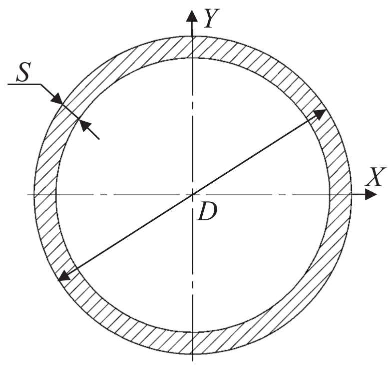

Fig. 8. Round pipe profile shape

Table 2

Dimensions, static characteristics and weight of 1 m of pipe

Pipe size, mm		Cross-sectional area F, cm^2	Static characteristics for the x and y axes		Weight of 1 m pipe M, kg
Diameter D	Wall thickness S		Moment of inertia of section I_{xy}, cm^4	Moment of resistance of section W_{xy}, cm^3	
114.0	5.5	18.75	276.58	48.52	14.72

There are analogues of the specified standard, however, the dimensions of the profiles given in them may differ slightly compared to the given standard.

In order to determine the strength of the brake cylinder, its spatial model was built in the SolidWorks software package [18–20]. The strength calculation was performed using the finite element method in the SolidWorks Simulation software package [21–23]. The Mises criterion was used as a calculation criterion [24–26].

The safety element is fixed to the cover by welding. To ensure the reliability of the interaction of the safety element with the cover of the brake cylinder, the calculation of the welding joint was made. Since the cover in the area of interaction with the safety element has a rounded geometry, the calculation is made as for elements from round pipes.

According to the document «Steel structures. Updated version (SNiP II-23-81), 2011» calculation of butt joints of elements from pipes for central tension-compression (I load scheme) should be performed according to the formula:

$$\frac{N}{\pi \cdot D_m \cdot t} \leq R_{wy} \cdot \gamma_{wc}, \tag{6}$$

where D_m – average diameter of a pipe with a smaller wall thickness; t – the smallest wall thickness of the connected pipes; R_{wy} – calculated resistance of the butt welding joint; γ_{wy} – coefficient that takes into account the operating conditions of the butt welding joint.

It must be said that when calculating a weld, it is possible to use other regulatory documents that regulate the requirements for ensuring its strength under appropriate load conditions.

In addition, the strength of the weld was checked under the action of a longitudinal force (load scheme II):

$$N \leq 0.85 \cdot \left(S_{wh} + S_{wt}\right), \tag{7}$$

$$N \leq 2 \cdot S_{wh}, \tag{8}$$

$$N \leq 2 \cdot S_{wt}, \tag{9}$$

where S_{wh}, S_{wt} – bearing properties of the heel and toe parts of the weld, respectively.

Wherein,

$$S_{wh} = \left(t_d \cdot l_{wah} \cdot R_{wy} \cdot \gamma_{wc} + k_f \cdot l_{wfh} \cdot R_{wd}\right) \cdot \gamma_{wc}, \tag{10}$$

where R_{wd} – value taken in accordance with the numerical values of R_{wf} or R_{wz}, i.e. less than two values are accepted in calculations: $0.7R_{wf}$ or R_w; R_{wf}; k_{wz} – calculated resistance of the fillet weld of the shear (conditional), respectively, for the weld metal and for the metal beyond the limits of fusion; t_d – thickness of the welded pipe wall; k_f – leg (height) of the fillet weld; l_{wah} and l_{wat} – total lengths of the joint sections, which are considered as butt welds, respectively, in the heel and toe parts of the joint; l_{wfh} and l_{wft} – total lengths o f the joint sections, which are considered as fillet welds, respectively, in the heel and toe parts of the joint.

3. Results and discussion

To determine the strength of the improved design of the brake cylinder, its calculation is made. The finite element model of the brake cylinder is shown in **Fig. 9**. When compiling a finite element model, tetrahedra are used. The optimal number of finite elements is determined by the graph-analytical method [27–29]. The number of grid elements is 45342, nodes – 14604. The maximum size of the grid element is 15.0 mm, the minimum is 3.0 mm. The minimum number of elements in the chain is 8, the ratio of increasing the size of the element is 1.6. The model is fastened by the sled. Construction material – steel grade 20 GL.

When compiling the design scheme, it is assumed that the air pressure P_a equal to 0.4 MPa acts on the brake cylinder. It is taken into account that the brake cylinder interacts with the air distributor conv. No. 483 in cargo mode [23]. It is also taken into account that the load from the rod of the brake cylinder P acts on the safety element. The load P is decomposed into two components – horizontal P_1 and vertical P_2 (**Fig. 10**).

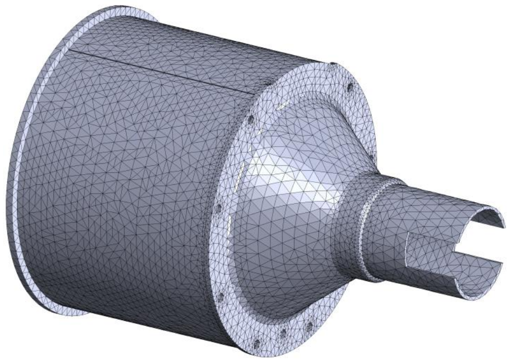

Fig. 9. Finite element model of the brake cylinder

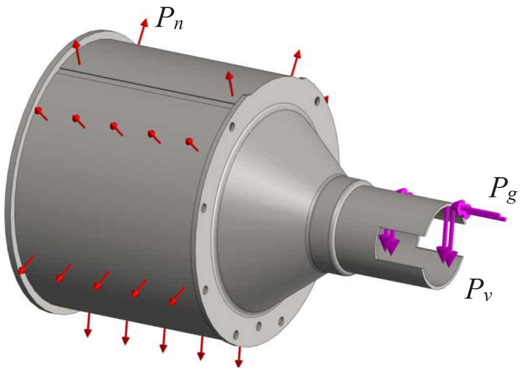

Fig. 10. Calculation scheme of the brake cylinder

The limitation of the existing calculation model (**Fig. 10**) is that the bolted connections between the components of the brake cylinder are not taken into account when performing strength calculations. Also, when making calculations, the welding joint between the safety element and the cover was not taken into account. That is, it is assumed that the model is monolithic.

The results of a robust calculation shows that the maximum equivalent stresses occur in the brake cylinder cover, namely in the areas of bolted connections and amount to 118.5 MPa (**Fig. 11**), and therefore do not exceed the allowable ones and are 18.3 % lower beyond them. The maximum displacements were recorded in the safety element and amounted to 1.4 mm (**Fig. 12**).

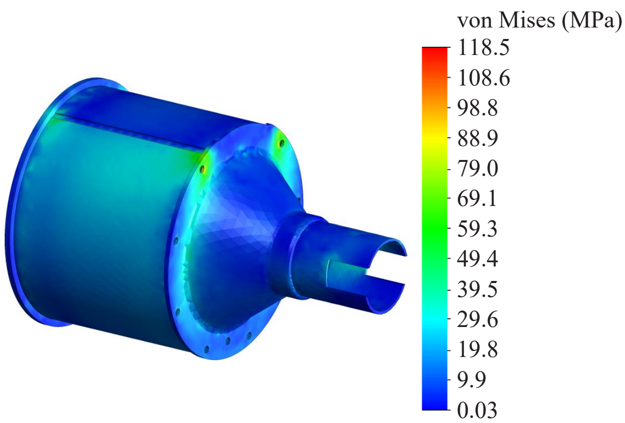

Fig. 11. Stress state of the brake cylinder

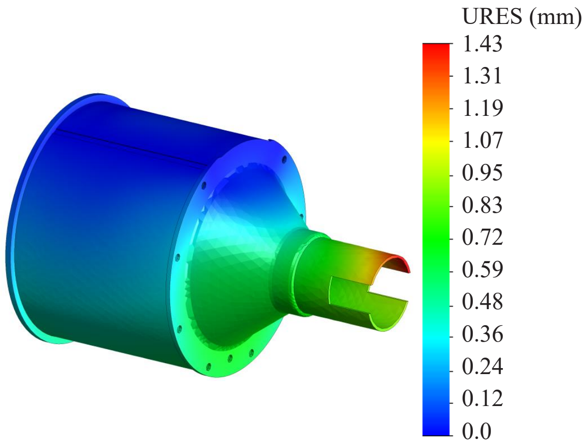

Fig. 12. Movement in the nodes of the brake cylinder

The calculations confirmed the feasibility of the decisions taken to improve.

To ensure the strength of the brake cylinder in the area of interaction of the safety element with the cover, the calculation of the welding joint between them was made.

When calculating according to overload scheme I, the following input characteristics were taken: $D_m = 114.0$ mm, $t = 5.5$ mm, R_{wy} was calculated in accordance with «Steel structures. Updated version (SNiP II-23-81), 2011» and amounted to $253.46 \cdot 10^{-3}$ MPa, $\gamma_{wc} = 0.75$.

When performing calculations according to the second load scheme, the following input data were taken: $t_d = 5.5$ mm, $l_{wah} = 1.03$ mm, $l_{wat} = 1.08$ mm, $k_f = 4.5$ mm (taking into account the thickness of the welded pipe and its welding conditions), $R_{wd} = 148.72 \cdot 10^{-3}$ kPa.

Based on the calculations made, it was found that the strength of the weld from the indicated types of deformations is ensured.

The advantage of this study compared to the known ones is that the increase in the efficiency of the brakes is achieved by improving the brake cylinder as their power device.

As a disadvantage of this study, there is a consideration of only one operating mode of the air distributor. In addition, the work does not prove the effectiveness of this solution on the brake cylinders of passenger cars.

The further direction of this study is to determine the resource of the improved design of the brake cylinder. It is also planned to determine the feasibility of using a double pipe with energy-absorbing material in the layer as a safety element (**Fig. 7**). An equally important stage of the study is the experimental load of the brake cylinder of an improved design. The issue of introducing new progressive materials into the design of rolling stock brake components [30, 31], including brake cylinders, requires attention.

The research will help ensure the reliability of the brake cylinder and increase the efficiency of the rolling stock brakes.

4. Conclusions

The load of the brake cylinder rod during its angular displacements is determined. In this case, the design scheme is considered in the form of a rod. Analytical dependencies are determined, which allow calculating the components of the load from the rod of the brake cylinder during its angular displacements. The condition for ensuring the strength of the brake cylinder rod is given.

The design of the brake cylinder has been improved in order to prevent angular movements of the rod. It is proposed to use a safety element in the form of a pipe, which is attached to the cover. This helps to limit the movement of the rod when leaving the housing. It has been established that the optimal diameter of the safety element is a pipe with an inner diameter of 114 mm and a section modulus of 48.52 cm^3.

The strength of the improved design of the brake cylinder is determined. The calculation is made by the method of finished elements. The results of a robust calculation showed that the maximum equivalent stresses occur in the brake cylinder cover – 118.5 MPa, and therefore do not exceed the allowable ones. The maximum displacements were recorded in the safety element and amounted to 1.4 mm.

The welding joint is calculated in the zone of interaction between the safety element and the cover. The performed calculations made it possible to conclude that the condition for the strength of the weld is provided.

The results of the research will contribute to improving the efficiency of the brakes, ensuring traffic safety, increasing the speed of the rolling stock, delivering goods, etc. Also, the conducted research will contribute to the creation of developments to improve the reliability of the rolling stock brakes.

Conflict of interests

The authors declare no conflicts of interest in relation to this article, as well as the published results of the study, including the financial aspects of conducting the study, obtaining and using its results, as well as any non-financial personal relationships.

References

[1] Wang, C., Lim, M. K., Zhang, X., Zhao, L., Lee, P. T.-W. (2020). Railway and road infrastructure in the Belt and Road Initiative countries: Estimating the impact of transport infrastructure on economic growth. Transportation Research Part A: Policy and Practice, 134, 288–307. doi: https://doi.org/10.1016/j.tra.2020.02.009

[2] Wangai, A. W., Rohacs, D., Boros, A. (2020). Supporting the Sustainable Development of Railway Transport in Developing Countries. Sustainability, 12 (9), 3572. doi: https://doi.org/10.3390/su12093572

[3] Bulich, D. I., Sapronova, S. Yu., Koshel, O. O., Tkachenko, V. P. (2019). Otsinka pokaznykiv nadiynosti nesuchykh konstruktsiy vantazhnykh vahoniv iz zalyshkovym resursom. Lohistychne upravlinnia ta bezpeka rukhu na transporti, 17–19. Available at: https://scholar.google.com.ua/citations?view_op=view_citation&hl=uk&user=RDqZWPMAAAAJ&citation_for_view=RDqZWPMAAAAJ:2osOgNQ5qMEC

[4] Sapronova, S., Bulich, D., Tkachenko, V. (2017). Continued service life of freight wagons. Visnyk Skhidnoukrainskoho Natsionalnoho universytetu imeni Volodymyra Dalia, 3 (233), 179–182. Available at: http://nbuv.gov.ua/UJRN/VSUNU_2017_3_35

[5] Galay, E. I., Galay, E. E. (2010). Tormoznye sistemy zheleznodorozhnogo transporta: Konstruktsiya tormoznogo oborudovaniya. Gomel’, 315.

[6] Voloshin, D., Afanasenko, I., Derevianchuk, Ya. (2018). The question of the hopper-car mechanical brake elements improving. Visnyk Ckhidnoukrainskoho natsionalnoho universytetu imeni Volodymyra Dalia, 2 (243), 54–59. Available at: https://journals.indexcopernicus.com/api/file/viewByFileId/474997.pdf

[7] Ravlyuk, V., Ravliuk, M., Hrebeniuk, V., Bondarenko, V. (2019). Research of the calculation scheme for the brake lever transmission and construction of the load model for the brake pads of freight cars. IOP Conference Series: Materials Science and Engineering, 708 (1), 012026. https://doi.org/10.1088/1757-899x/708/1/012026

[8] Osenin, Y., Mansur Al-Makhdi, D., Sergienko, O., Sosnov, I., Chesnokov, A. (2017). Providing stable friction properties of disc brakes for railway vehicles. Transport Problems, 12 (1), 63–71. doi: https://doi.org/10.20858/tp.2017.12.1.6

[9] Gorbunov, M., Domin, R., Kovtanec, M., Kravchenko, K. (2016). The multifunctional energy efficient method of cohesion control in the «wheel-braking pad-rail» system. Prace Naukowe Politechniki Warszawskiej, 114–126. Available at: https://snu.edu.ua/wp-content/uploads/2022/06/06_16_S_5.pdf

[10] Sinicyn, V., Kobishchanov, V. (2020). Braking system for bogie successive braking of freight cars. Bulletin of Bryansk State Technical University, 2020 (3), 21–28. doi: https://doi.org/10.30987/1999-8775-2020-3-21-28

[11] Vineesh, K. P., Vakkalagadda, M. R. K., Tripathi, A. K., Mishra, A., Racherla, V. (2016). Non-uniformity in braking in coaching and freight stock in Indian Railways and associated causes. Engineering Failure Analysis, 59, 493–508. doi: https://doi.org/10.1016/j.engfailanal.2015.11.023

[12] Zhang, Y., Zhang, M. (2018). The application status of unit brakes on metro vehicles in China. IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), 15 (3), 17–23. Available at: https://www.iosrjournals.org/iosr-jmce/papers/vol15-issue3/Version-3/C1503031723.pdf

[13] Gupta, V., Saini, K., Garg, A. K., Krishan, G., Parkash, O. (2016). Comparative Analysis of Disc Brake Model for Different Materials Investigated Under Tragic Situations. Asian Review of Mechanical Engineering (ARME), 5 (1), 18–23. Available at: https://www.trp.org.in/issues/comparative-analysis-of-disc-brake-model-for-different-materials-investigated-under-tragic-situations

[14] Asadchenko, V. R. (2004). Raschet pnevmaticheskikh tormozov zheleznodorozhnogo podvizhnogo sostava. Moscow, 120.

[15] Shvabiuk, V. I. (2016). Opir materialiv. Kyiv, 407.

[16] Kutsenko, A., Bondar, M., Chausov, M. (2019). Prykladna mekhanika (opir materialiv). Kyiv.

[17] Fomin, O., Lovska, A., Kovtun, O., Nerubatskyi, V. (2020). Defining patterns in the longitudinal load on a train equipped with the new conceptual couplers. Eastern-European Journal of Enterprise Technologies, 2 (7 (104)), 33–40. doi: https://doi.org/10.15587/1729-4061.2020.198660

[18] Fomin, O., Lovska, A., Khara, M., Nikolaienko, I., Lytvynenko, A., Sova, S. (2022). Adapting the load-bearing structure of a gondola car for transporting high-temperature cargoes. Eastern-European Journal of Enterprise Technologies, 2 (7 (116)), 6–13. doi: https://doi.org/10.15587/1729-4061.2022.253770

[19] Lovska, A., Fomin, O., Kučera, P., Píštěk, V. (2020). Calculation of Loads on Carrying Structures of Articulated Circular-Tube Wagons Equipped with New Draft Gear Concepts. Applied Sciences, 10 (21), 7441. doi: https://doi.org/10.3390/app10217441

[20] Fomin, O., Lovska, A. (2021). Determination of dynamic loading of bearing structures of freight wagons with actual dimensions. Eastern-European Journal of Enterprise Technologies, 2 (7 (110)), 6–14. doi: https://doi.org/10.15587/1729-4061.2021.220534

[21] Gallager, R. (1984). Metod konechnikh elementov. Osnovy. Moscow: Mir, 428.

[22] Alyamovskiy, A. A. (2010). COSMOSWorks. Osnovy rascheta konstruktsiy na prochnost’ v srede SolidWorks. Moscow, 784.

[23] Alyamovskiy, A. A. (2007). SolidWorks/COSMOSWorks 2006–2007. Inzhenerniy analiz metodom konechnykh elementov. Moscow, 784.

[24] Lovska, A., Fomin, O., Píštěk, V., Kučera, P. (2020). Dynamic Load and Strength Determination of Carrying Structure of Wagons Transported by Ferries. Journal of Marine Science and Engineering, 8 (11), 902. doi: https://doi.org/10.3390/jmse8110902

[25] Lovska, A., Fomin, O., Horban, A., Radkevych, V., Skok, P., Skliarenko, I. (2019). Investigation of the dynamic loading of a body of passenger cars during transportation by rail ferry. EUREKA: Physics and Engineering, 4, 91–100. doi: https://doi.org/10.21303/2461-4262.2019.00950

[26] Šťastniak, P., Moravčík, M., Smetanka, L. (2019). Investigation of strength conditions of the new wagon prototype type Zans. MATEC Web of Conferences, 254, 02037. doi: https://doi.org/10.1051/matecconf/201925402037

[27] Vatulia, G., Lobiak, A., Orel, Y. (2017). Simulation of performance of circular CFST columns under short-time and long-time load. MATEC Web of Conferences, 116, 02036. doi: https://doi.org/10.1051/matecconf/201711602036

[28] Fomin, O., Gorbunov, M., Gerlici, J., Vatulia, G., Lovska, A., Kravchenko, K. (2021). Research into the Strength of an Open Wagon with Double Sidewalls Filled with Aluminium Foam. Materials, 14 (12), 3420. doi: https://doi.org/10.3390/ma14123420

[29] Dudnyk, V., Sinenko, Y., Matsyk, M., Demchenko, Y., Zhyvotovskyi, R., Repilo, I. et. al. (2020). Development of a method for training artificial neural networks for intelligent decision support systems. Eastern-European Journal of Enterprise Technologies, 3 (2 (105)), 37–47. doi: https://doi.org/10.15587/1729-4061.2020.203301

[30] Cruceanu, C., Craciun, C. (2019). Aspects Regarding the Braking Capacity of Composite Brake Shoes for Railway Vehicles. Materiale Plastice, 56 (1), 18–21. doi: https://doi.org/10.37358/mp.19.1.5115

[31] Benbrinis, I., Redjel, B. (2018). Experimental characterization of friction wear and mechanical behavior of train wagon brake shoes made of carbon/carbon (C/C) composite material with an organic matrix. Synthèse: Revue des Sciences et de la Technologie, 37, 235–255. Available at: https://www.ajol.info/index.php/srst/article/view/182118

Received date 23.08.2022
Accepted date 14.10.2022
Published date 29.11.2022

How to cite: *Panchenko, S., Vatulia, G., Lovska, A., Ravlyuk, V., Elyazov, I., Huseynov, I. (2022). Influence of structural solutions of an improved brake cylinder of a freight car of railway transport on its load in operation. EUREKA: Physics and Engineering, 6, 45–55. doi: https://doi.org/10.21303/2461-4262.2022.002638*