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Experimental Study of the Influence of Friction Surfaces Cooling Parameters on the Efficiency of the Braking System of a Railway Vehicle Operation

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Abstract

The purpose of the study is to evaluate the effect of cooling frictional surfaces on the efficiency of the braking system by experimentally determining the coefficient of friction and the temperature of the interacting surfaces under different methods and regimes of cooling. Experimental research established that the mathematical model of the disc brake thermophysical characteristics, which takes into account the adaptive cooling system, ensures a satisfactory match of the results of calculations to experimental data; the discrepancy does not exceed 10-12%. Analysis of the experimental data obtained allows concluding that adaptive cooling of the brake friction surfaces has a positive effect on the braking efficiency. Thus, the coefficient of friction when using this system is 15-30% higher, depending on the performance and temperature of the cooling air, than without its use. The average integral temperature of surfaces in frictional interaction is lower by average of 20-30% compared to the case when adaptive cooling is not used.
KEY WORDS: *rail transport, braking, friction interaction, disc brake, energy efficiency, experimental study*

1. Introduction

The effectiveness of the braking equipment is one of the most important factors that determine the possibility of increasing trains' weight and speed, the throughput and carrying capacity of railways. The motion safety significantly depends on the properties and condition of the brake equipment of the rolling stock.

Considering constant increase in the speed of trains there are high requirements to brake devices. The application of known designs of the block and disk brakes is limited by permissible heating of the friction surfaces.

In order to increase braking effectiveness of the rolling stock, it is necessary to create sufficient braking power with the braking devices and ensure a stable grip of the wheels with rails. Analysis of the problems of existing brake equipment led to the choice of a promising direction of research on the braking effectiveness: control of the temperature of brake friction surfaces.

On the basis of the complex analysis of experimental and theoretical studies [1-6] it was determined that one of the most important problems of braking devices is maintaining the surface temperatures of their frictional pairs within certain limits. Exceeding the permissible temperatures of the friction surfaces leads to the loss of their wear and friction properties, destabilization of the operating parameters (dynamic coefficient of friction, mechanical and thermal deformations, wear, etc.) of brake devices.

In order to determine the most effective method of increasing the thermoregulation and energy dissipation capacity in braking systems, the system of intellectual decision support based on the software developed by the authors [7] was used. A survey of competent experts has allowed to identify the most promising methods for improving the braking friction system in order to increase the braking efficiency by controlling the temperature in the friction pairs.

As a result of the conducted expert research the estimation of innovative methods of the modern rolling stock braking system efficiency increasing has been evaluated. It has been established that the most promising method of increasing the braking efficiency is air supply with its temperature adjusted depending on the braking conditions.

In view of this, it is advisable, in order to meet the requirements for stabilizing the temperature of the friction brake pairs, to develop an adaptive control method for cooling the friction surfaces and to experimentally prove the expediency of using the advanced brake equipment to increase the energy dissipation capacity of the braking system friction elements; provide an assessment of effectiveness of the developed method for improving the railway vehicle brake equipment performance.

2. Experimental Study of the Influence of Friction Surfaces Cooling Parameters on the Efficiency of the Braking System of a Railway Vehicle Operation

The mathematical model of thermophysical characteristics of the rail brakes friction pairs considering adaptive cooling system [8, 9] describes the dependence in the contact temperature on the process parameters. With the increase in temperature in the friction pair elements field of interaction the next processes take place:

- significant increase in the pad wear intensity;
- significant change in friction coefficient affecting the braking performance.

The mathematical model of the thermophysical characteristics of the disc brakes allows to estimate the temperature of the friction surfaces of the brakes, taking into account adaptive cooling.

The disadvantage of compressed air supply to the frictional contact during braking as a method of improving the conditions of interaction in the friction system of the brake pad and disk is the low coefficient of convective heat transfer, which is caused by the insufficiently low temperature of the compressed air supplied to the contact area for its cooling. When braking, the temperature in the brake pad and disk contact severely increases, accordingly it is necessary to reduce it in order to avoid plastic deformations and danger of skidding.

The task of friction elements interaction efficiency increasing is achieved by the use of the Ranque-Hilsch Effect in the air supply system in the zone of friction contacts, while cooling the contact between the brake pad and disk, a cooled air from the vortex tube (Fig. 1) is supplied into the frictional contact. When temperature in the contact rises during braking, the coefficient of adhesion reduces while the probability of skidding increases. To prevent this phenomenon, compressed air is supplied to the brake disk and pad contact, which helps achieving maintaining the maximum value of the coefficient of friction (Fig. 2).

Fig. 1 The Vortex Tube

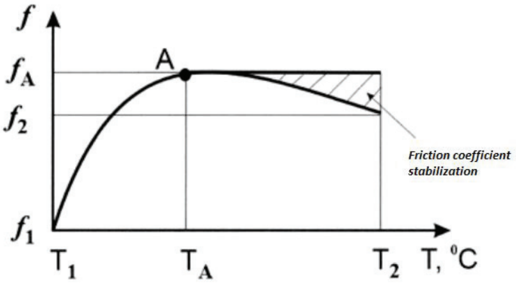

Fig. 2 Dependence of the friction coefficient on the temperature in contact

Thus, the application of the proposed method for improving the friction elements of the disc brakes interaction conditions will stabilize the brake disc and the pad adhesion ratio during braking.

Experimental study of the braking process was carried out with the help of a full-scale laboratory bench developed by the Department of lifting-transport vehicles of the Volodymyr Dahl East Ukrainian National University [10]. The stand is designed to test different designs of brake devices and control their output parameters.

The general view of the stand and its schematic diagram are shown in Figs. 3 and 4.

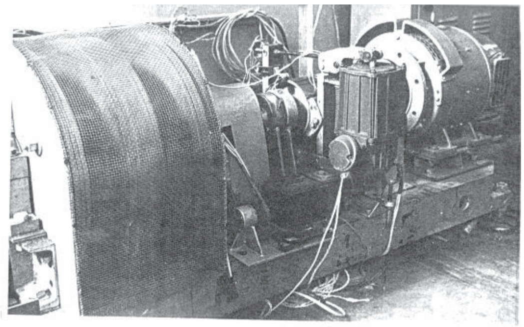

Fig. 3 The general view of the stand

The brake 1 (Fig. 4) is mounted on the rocking frame 2 and is connected by means of elastic couplings 3 to the drive motor 4 and a rotating mass 5 which consists of 18 disks and allows changing the moment of inertia from 2 to 60 kg • m^2 by attaching to the shaft or disconnecting the flywheel disks from it. The frame 2 and the rotating mass 5 are supported by rolling bearings reinforced on the struts. The stand allows to vary the moment of inertia with the help of rotating discs, the speed of rotation, the duration of the drive, and record such output parameters of the brake and drive as the braking torque, thrust force, the opening time of the brake and the drive, the response time of the brake, frequency of the drive rotation, temperature of friction surfaces.

The brake torque created by the brake is measured using the dynamometric rings 6 (Fig. 4, AA) connected by

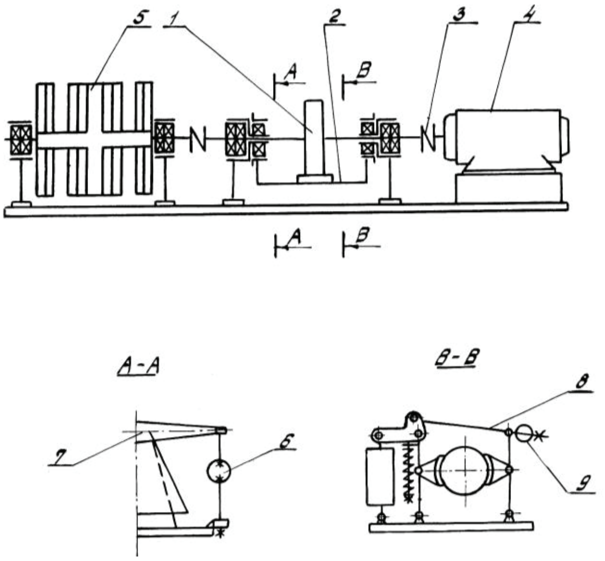

Fig. 4 Schematic structure of the stand

spherical hinges to the base. The rocker 7 is rigidly fixed to the rocking frame 2. The strain gauges are glued to the dynamometric rings, connected by a half-bridge circuit. The electrical signals from the strain gages are amplified by the amplifier 8ANCH-7M and registered by a light-beam daisy-chain oscillograph H-117 type.

The thrust force, which is proportional to the braking torque, is measured with the help of the sensor 9, made in the form of a dynamometric ring with glued strain gauges and a brake installed on the brake rod (Fig. 4, BB). Electrical signals from the datacenter are applied to the amplifier, and then to the recording device, which is an analog-to-digital converter type B7-35.

The opening and ramping times, trip and deceleration times are measured and recorded by the device for monitoring the output parameters of the brakes, which includes a pulse generator, a pulse counter and a set of sensors.

The opening time is counted from the moment the power is applied to the brake actuator until the pads go off, with the contact sensor installed on one of them, from the brake pulley. Acceleration time of the drive is counted from the moment the voltage is applied to the drive (M) until the nominal speed is reached. The frequency of rotation of the drive shaft is removed by a tachogenerator of direct current type TGP-5. The time of operation of the brake is measured from the moment the power is disconnected from the brake actuator to the moment of the first contact of the pads with the brake pulley, one of which has a contact sensor. The contact sensor when the brake disc surface touches the brake pulley disconnects the pulse generator from the pulse counter. The braking time is measured from the moment when the response time is recorded until the brake pulley stops completely, which is controlled by the voltage value at the output of the TGP-5 tachogenerator.

The speed of the drive (M) is measured by a TG-1 direct current tachogenerator type TMG-38. For visual observation of the rotational speed of the flywheel (MM), a TG-2 tachometer of the type D1-MM with a measuring instrument type TM and ZP is used. The shaft of rotating masses is connected with the shafts of tachogenerators by a belt transmission.

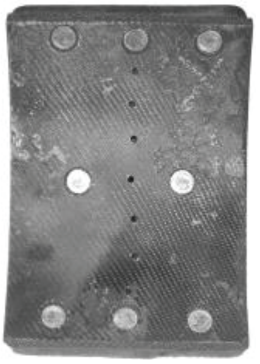

Fig. 5 Thermocouples placing on the working surface of the brake pad

Fig. 6 Measuring equipment. Pyrometer, anemometer

The temperature of the friction surfaces of the brake is measured with a thermocouple sensor (Fig. 5). A chromel-kopel thermocouple designed for heating up to 600°C was used. Structurally, the thermocouple is made in the form of a porcelain cylinder through which the thermocouple electrodes are passed through the holes. The thermocouple is installed in the body of the brake shoe and fixed with a screw. As a recording instrument a universal device type B7-35 was used.

The design of the stand is complemented by a compressor and a vortex tube, the construction of which is based on the Ranque-Hilsch Effect. The air is supplied into the pipe, in which there is a thermal separation into cold and hot air, which are diverted from different openings. The cooled air is supplied to the frictional contact area. To measure temperature and air velocity pyrometer and anemometer were used (Fig. 6).

The task of the study is to show experimentally the dependence of the coefficient of friction and temperature in the contact "brake disc-overlay" on the temperature and the productivity of the air supply to the frictional contact, to the friction track, the lining and the disk.

For example, the results of experiments with and without cooled air supply are presented in Figs. 7 and 8. Values obtained in parallel experiments were checked for errors using Student's criterion [11].

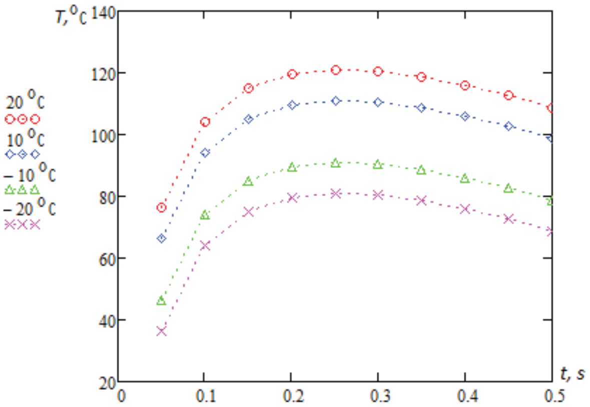

Fig. 7 Average temperature of friction surfaces during braking; the clamping force of one brake pad is 1500 N

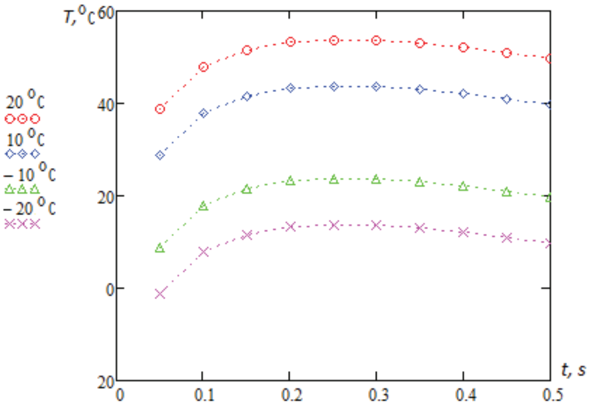

Fig. 8 Average temperature of friction surfaces during braking; the clamping force of one brake pad is 500 N

3. Conclusions

Experimental research established that the mathematical model of the disc brake thermophysical characteristics, which takes into account the adaptive cooling system, ensures a satisfactory match of the results of calculations to experimental data; the discrepancy does not exceed 10-12%. Analysis of the experimental data obtained allows concluding that adaptive cooling of the brake friction surfaces has a positive effect on the braking efficiency. Thus, the coefficient of friction when using this system is 15-30% higher, depending on the performance and temperature of the cooling air, than without its use. The average integral temperature of surfaces in frictional interaction is lower by average of 20-30% compared to the case when adaptive cooling is not used.

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References

1. **Gorbunov, M.I.; Prosvirova, O.V.; Kovtanets, M.V.; Kravchenko, K.O.** 2016. Analysis of multifunctional methods of control of the wheel-brake-friction system. Collection of scientific works of the State Economics and Technology University of Transport. Series: Transport Systems and Technologies (28): 35-43. (in Ukrainian).
2. **Gerlici, J.; Gorgunov, M.; Kravchenko, K.; Domin, R.; Kovtanets, M.; Lack, T.** 2017. Slipping and skidding occurrence probability decreasing by means of the friction controlling in the wheel-braking pad and wheel-rail contacts, Manufacturing Technology 17(2): 179-186.
3. **Hauser, V.; Nozhenko, O.; Kravchenko, K. and others** 2017. Impact of Three Axle Boxes Bogie to the Tram Behavior When Passing Curved Track, Procedia Engineering 192: 295-300.
4. **Hauser, V.; Nozhenko, O.S.; Kravchenko, K.O. and others.** 2017. Proposal of a mechanism for setting bogie wheelsets to radial position while riding along track curve, Manufacturing Technology 17(2): 186-192.
5. **Gerlici, J.; Gorbunov, M.; Nozhenko, O. and others** 2017. About creatiion of bogiie of the freiight car, Communications - Scientific Letters of the University of Zilina 19(2): 29-35.
6. **Gorbunov, M.; Pistek, V.; Kovtanets, M. and others.** 2017. Research to improve traction and dynamic quality of locomotives, Vibroengineering Procedia 13: 159 - 164.
7. **Gorbunov, M.M.; Kovtanets, M.V.; Kravchenko, K.O.; Prosvirova, O.V.** 2012. Certificate of registration of copyright for work No. 45058 Computer program "Decision-making in the tasks of railway transport using the method of expert assessments". (in Ukrainian).
8. **Prosvirova, O.V.; Kravchenko, K.O.; Kovtanets, M.V.** 2017. Computational and experimental study of the effect of adaptive cooling on the thermophysical characteristics of the disk brake. International scientific and practical conference "Modern techniques, innovations and experience of practical application in the field of technical sciences". (in Ukrainian).
9. **Gerlici, J.; Gorbunov, M.; Kravchenko, K.; Prosvirova, O.; Lack, T.; Hauser, V.** 2018. Assessment of Innovative Methods of the Rolling Stock Brake System Efficiency Increasing, Manufacturing Technology 18(1): 35-38.
10. **Boyko, G.A.; Budykov, L.Y.** 1988. Stand for diagnostics of crane brakes. Transport equipment. Moscow: TNIITETYAJMASH (6) P.88-39. (in Russian).
11. **Starchenko, V.M.** 2008. Scientific bases of increase of braking efficiency by improvement of conditions of interaction of wheels with brake blocks and rails. Lugansk, Volodymyr Dahl East Ukrainian National University 354 p. (in Ukrainian).