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INFLUENCE OF FORCED COOLING OF THE FRICTIONAL ELEMENTS OF THE DISK BRAKE ON THE BRAKING EFFICIENCY

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Summary. The article presents the results of experimental research of influence of forced liquid-air cooling of frictional elements of the disk brake on efficiency of mechanical braking. That was evaluated by the experimental estimation of the friction coefficient and integral mean temperature of interacting surfaces under different modes of operation of the cooling system and mechanical braking.

Key words: braking efficiency, cooling of the frictional contact zone, disk brake, system of liquid-air cooling.

INTRODUCTION

The operation efficiency of the frictional brake systems of the rolling stock is the main factor of safety motion, on the reliability of which a number of emergency situations on railway depends. The increase of the speed motion of the trains suggests new, stricter requirements to the operation characteristics of frictional brakes, namely, disk brakes. The main obstacle in the increase of effectiveness of the disk brake is known to be the temperature which is generated in the contact zone of the block and disk while braking [2, 6, 7]. In connection with this, forced heat energy rejection which is generated while interacting with brake elements is one of the ways of increasing effectiveness in the use of mechanical braking devices [3].

The paper presents the results of experimental research on the effectiveness of the forced heat energy system from the area of contact of frictional elements of the disk brake in the rolling stock.

EXPERIMENTAL UNIT

Experimental research of the braking process was made with the help of the laboratory stand which was worked out by the department of hoisting-and-conveying machinery of the Volodymyr Dahl East-Ukrainian National University [9]. The stand is intended for testing different designs of brake devices and checking their outlet parameters. The diagram of the experimental unit is shown in Fig. 1.

The stand gives the possibility to accumulate kinetic energy with the help of rotating disks, to fix the rotation frequency, the number of switches and the durability of the drive operation as well as to register the following outlet parameters of the brake and the drive: the braking moment, force thrust, the time of disconnection of the brake and the drive acceleration, the time of switching and braking, the temperature of interacting surfaces, the turning angle of brake posts.

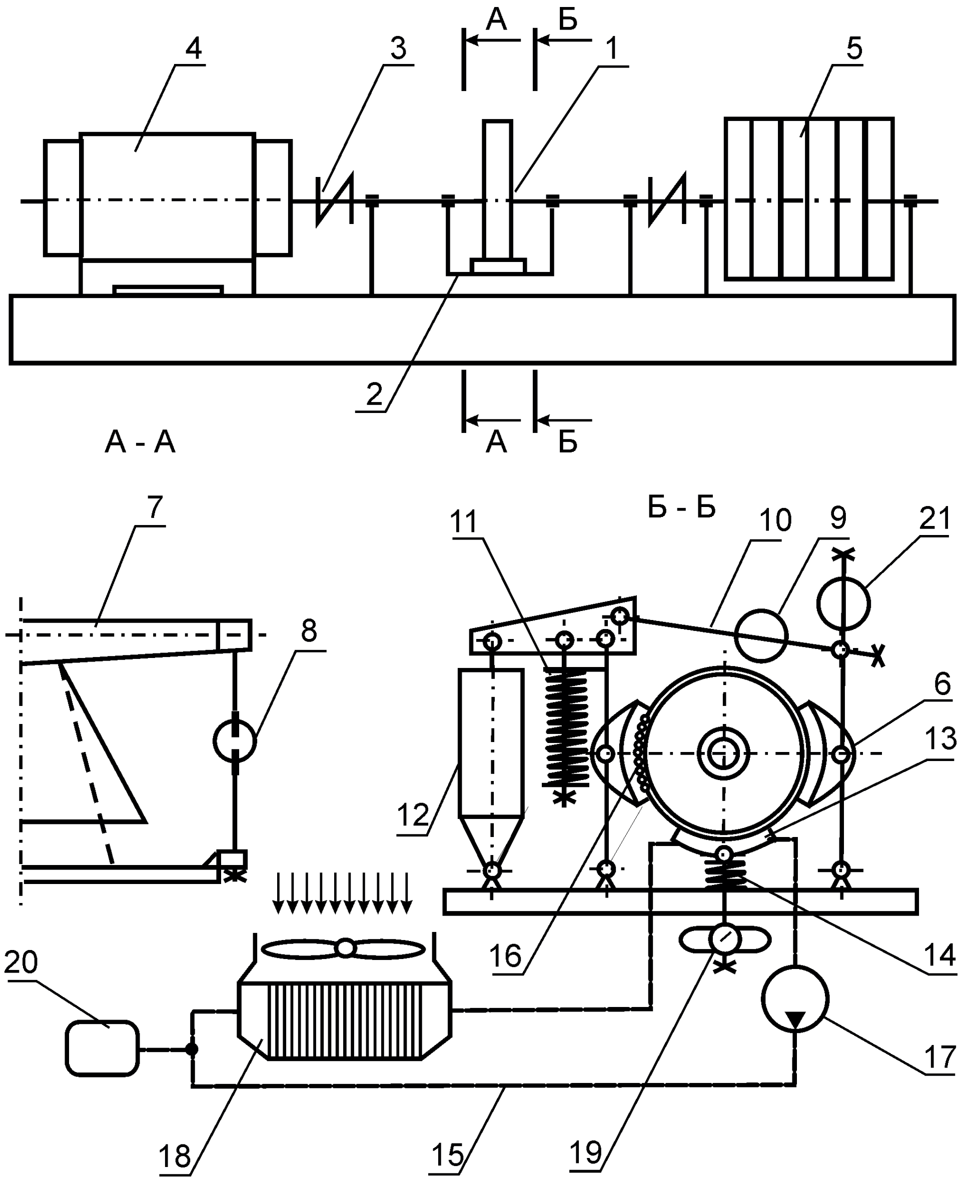

Fig. 1. Principle diagram of the experimental stand

The stand works in the following way. The brake 1 is set up on the flexible frame 2 with the help of the elastic coupling 3. The engine shaft 4 is connected with rotating mass 5 which consists of the disks and allows for changing the moment of inertia from 8 to 60 kg·m^2 due to the attachment of the disks of flywheel mass to the shaft or disconnection from it. The frame 2 and rotating mass 5 are carried by the rolling bearings which are fastened on the posts.

A closed two-shoe brake constitutes the base of the stand ТКТГ-200. The brake locking takes place due to the forces of the compressed spring. The breaking is accomplished by an electrohydraulic pusher ТГМ-25 (corresponding positions 11 and 12 in Fig. 1).

The brake moment (the friction coefficient is defined by its value) was measured with the help of dynamometrical rings 8 (Fig. 1, A-A), which are symmetrically placed on both sides of the brake, on which the resistance strain gauges were stuck with glue. Dynamometrical rings are connected with the bed base and a rocker 7 of the flexible frame 2.

Traction force that is proportional to the pressing force of the blocks to the brake pulley was measured with the help of the transducer 9. It was made in the form of dynamometrical ring with bonded strain gauges and set up on the brake traction 10 (Fig. 1, Б-Б). Thoriation of the dynamometrical rings took place each time before the experiments and after them.

Mesh force of the frictional material of the brake blocks and brake pulley was measured by the strain gauge 21 set up on the axis of the block rotation of the brake device with self-acceleration.

The temperature of the friction surfaces was measured by seven thermocouples set up in the body of the brake block along its vertical axis.

To fulfill this task it was necessary to make the following changes in the design of the stand: a heat-remover 13 was set up, it presents the vessel whose dimensions are stipulated by the calculated quantity of heat which is to be taken from the working zone. The vessel joins the heat exchanger 18 with the help of the pipe-lines 15, the circulation of the cooling liquid was controlled by the hydraulic pump 17. A cooling locomotive section 2TE116 was used as a heat-exchanger (effective area of heat-exchange makes $\approx$ 52 m^2) and it was cooled with the help of the axis fan ВОК – 4,0. The pressing of the heat-remover to the frictional disk (in this case to the brake pulley with the diameter of 200 mm) was realized by the spring 14 and checked by the dynamometer 19. A surge tank 20 was used for the compensation of the cooling liquid. A more detailed description of the cooling system and its functioning is given in the works [4, 5, 8].

The influence of the cooling system on the effectiveness of braking was evaluated by experimental determination of the friction coefficient and the temperature in the contact zone of the brake working elements under its different operation modes.

RESULTS OF EXPERIMENTAL RESEARCH

The data obtained in the process of experiments dealing with estimation of the friction coefficient between frictional surfaces of the brake block and pulley and integral mean temperature of the given surfaces are given in Fig. 2 and 3. In Fig. 2 the coefficient changes of friction-slip in the process of braking are shown (t – the time in the process of braking), Fig. 3 shows mean-volume temperatures contacting in the process of braking of frictional surfaces. Experimental values of the received quantities are marked in separate points and the theoretical values obtained in accordance with the calculation procedure are marked in full line. The procedure is worked out by the authors [5].

All the experimental values are tested with the help of Styudent criteria [1].

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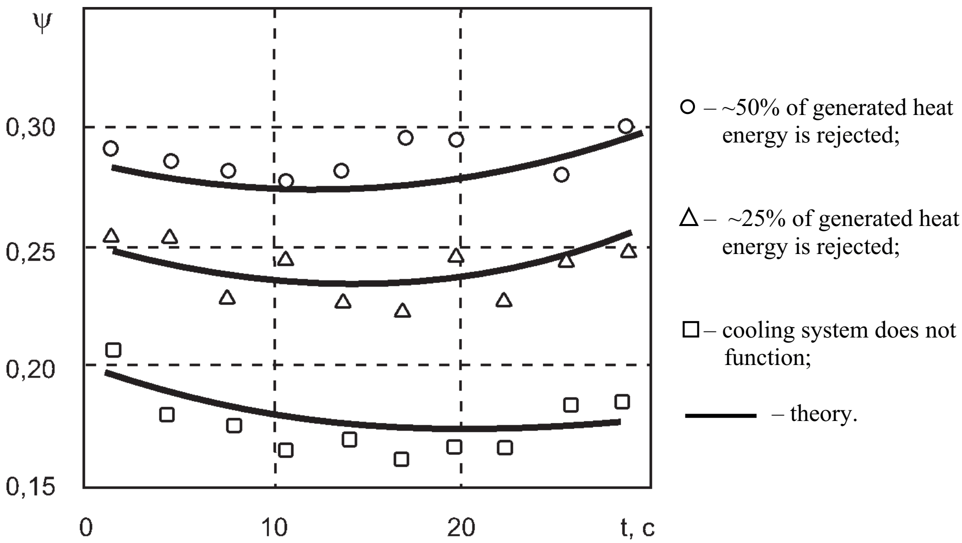

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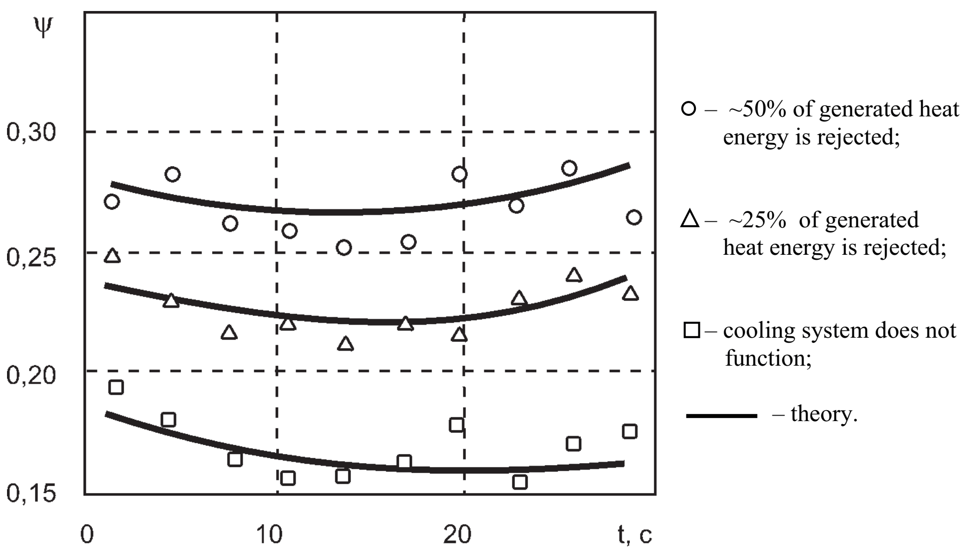
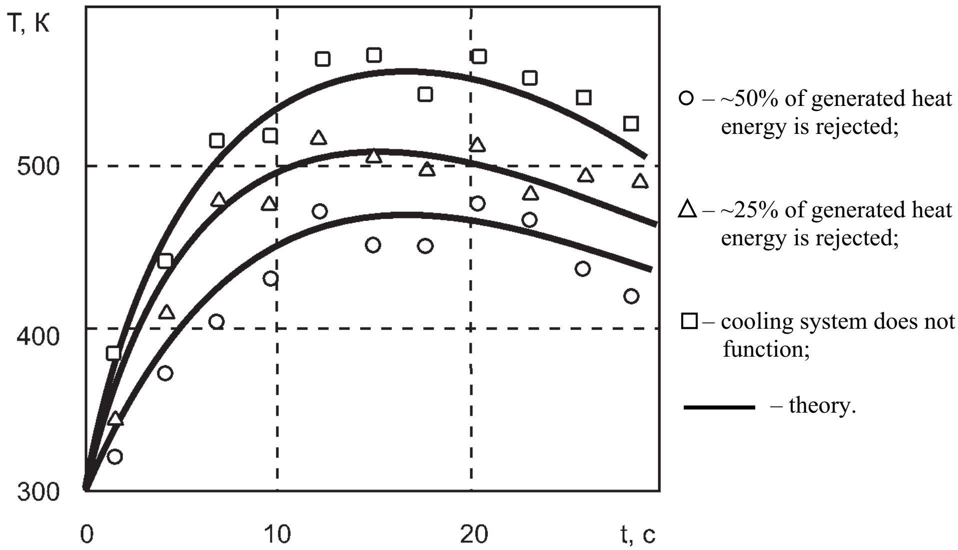


Fig. 2. Friction coefficient of frictional interacting surfaces in the process of braking; the pressing force of one brake block makes:
(a) – 1500 N; (b) – 1000 N

a)



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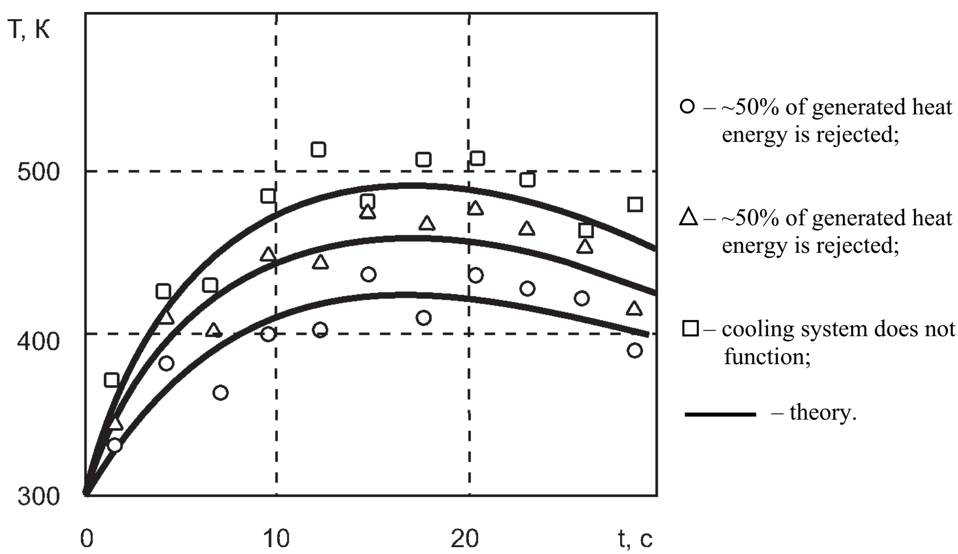

Fig. 3. Average temperature of frictional interacting surfaces in the process of braking; the pressing force of one brake block makes: (a) – 1500 N; (b) – 1000 N

CONCLUSION

The analysis of experimental data gives the possibility to make conclusion of positive influence of the offered method of active cooling of the frictional brake on the effectiveness of braking.

The friction coefficient while using forced liquid-air cooling is about 30% higher than without its use (in the case of rejecting about 50% generated heat and pressing force of the brake block of 1500 N). Mean temperature of interacting surfaces is lower by 15% in the comparison with the case when the cooling system is absent.

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ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ ВЛИЯНИЯ ПРИНУДИТЕЛЬНОГО ОХЛАЖДЕНИЯ ФРИКЦИОННЫХ ЭЛЕМЕНТОВ ДИСКОВОГО ТОРМОЗА НА ЭФФЕКТИВНОСТЬ ТОРМОЖЕНИЯ

Аннотация. В работе представлены результаты экспериментальных исследований влияния принудительного жидкостно-воздушного охлаждения фрикционных элементов дискового тормоза на эффективность механического торможения, что оценивалось путем экспериментального определения коэффициента трения и среднеинтегральной температуры взаимодействующих поверхностей при различных режимах работы системы охлаждения и механического торможения.

Ключевые слова: эффективность торможения, охлаждение зоны фрикционного контакта, дисковый тормоз, система жидкостно-воздушного охлаждения.