Proceedings of 24th International Scientific Conference. Transport Means 2020.

Experimental Study of Temperature Stabilization Process in Tribological Contact of Brake Friction Pairs Under the Impact of Forced Cooling

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Abstract

The article covers the experimental study, which aims to establish the dependence of friction coefficient and temperature in the contact «brake disc – pad» on the cooled air supply factor to the friction contact during the braking process. Experimental studies of braking were performed using a laboratory brake stand designed to test variations of brake devices and control their initial parameters. The development of method to increase the brake system efficiency is based on the task of improving the productivity of the disc brake by efficient use of compressed air, drained from the brake cylinder, and cooling the brake lining and the working surface of the disc, moving friction wear products from the contact. The task of increasing the interaction efficiency of the disc brake friction elements by controlling the temperature in contact during braking of the locomotive is achieved by cooled air supply to contact zone.
KEY WORDS: *friction interaction, braking, experimental study, cooling*

1. Introduction

Based on the analysis of theoretical and experimental studies of frictional contact, it was found that the control of the mechanical component is not enough to achieve stable high coupling qualities of tribological units [1, 2]. The question of the effect of temperature on the stabilization of the coefficient of friction is not fully researched. It was found that when the temperature in the metal contact reaches 200 to 400°C, the strength properties of the surface layers change. Therefore, it is proposed to control the clutch of the tribological system «disc-pad» and «wheel-block-rack» by controlling the locally-mechanical and temperature components depending on the frictional contact conditions.

Experimental studies to determine the effect of stabilization of temperature processes on the output parameters of the brake were carried out on a laboratory stand [3-5]. The stand is designed to test various schemes of brakes and control their output parameters.

The stand allows to vary the moment of inertia with the help of rotating disks, rotational speed, duration of the drive and record the output parameters of the brake and drive, such as braking torque, traction, opening time of the brake and acceleration of the drive, response and braking times of the brake, speed of rotation of the drive, temperature of rubbing surfaces.

2. Experimental Study of Temperature Stabilization Process in Tribological Contact of Brake Friction Pairs Under the Impact of Forced Cooling

The stand as shown in Figs. 1 and 2 allows to accumulate kinetic energy by means of rotating disks, to fix frequency of rotation, number of inclusions, duration of work of the drive and to register such initial parameters of a brake and the drive: brake moment, efforts in draft, angle of rotation of brake racks.

The maximum error of thermocouple measurements is equal to 4°C for temperature values in the range from 0 to 400°C. In this case, strain gauges of the type PC – 30–400 were used with parameters: R: 400 ± 9 Ohms; S: 2.18 ± 0.01; P: 0.08 ± 0.07; σ: 0.5%; I: 15…30 mA. The dynamometer rings were calibrated each time before and after the series of examinations.

Acceleration time of the brake drive and speed are registered by means of the tach generator of a direct current.

The brake actuation time was measured from the moment the power was turned off from the brake actuator until the first contact of the pads with the brake pulley.

The braking time is measured from the end of the registration of the operation time to the moment of complete stop of the brake pulley, which is controlled by the voltage at the output of the tach generator. The number of inclusions is measured by a means installed in the computer.

Calibration characteristics were used to determine the actual values of the forces on the strain gauges. Thermocouples were calibrated in an oil bath using a thermometer and a digital measuring device DT-838T from Suns (its conversion error is not more than 1% of the measured value). The magnitude of the pressing force of the heat-removing element to the brake pulley was determined by the deviation of the arrow of the micrometer indicator (GOST 577 - 68, the division of 10^{-5} m, the limit of the main error allowed, $\pm 20 \cdot 10^{-6}$ m) of the exemplary dynamometer (measurement range: 0.1…1 kN, threshold response not more than 0.02% of the maximum allowable measured value) followed by enumeration on the calibration characteristics.

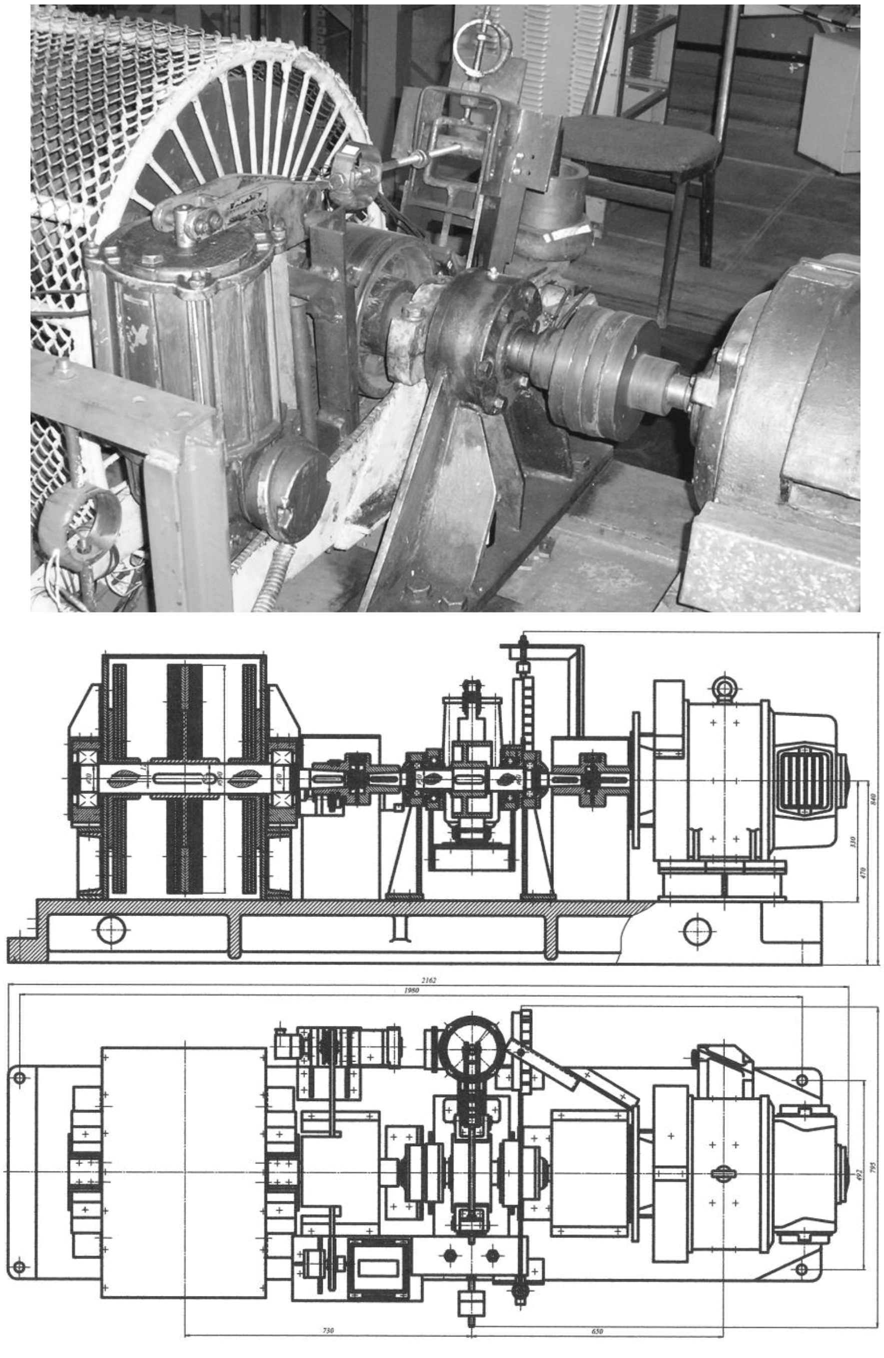


Fig. 1 The laboratory stand for studying brakes and controlling their output parameters

A PC/AT computer with an SDI-ADC14-32F ADC board compliant with the ISO 2000 certification standard and a measuring module that allows to record temperature, dynamic and static loads were used to know and process the initial data obtained during the experiment. Appropriate software was used to control the ADC.

To achieve the same conditions during each individual experiment, the working friction surfaces were carefully treated with alcohol both before and after the exam. In all experiments, the same pair of brake pads and heat-removing element were used. The purity of the treatment of these surfaces corresponded to the seventh class according to GOST 2789-73.

During the exams, the following external factors varied in these ranges:

- the force of pressing the brake pad to the pulley, consistently took values: 1500 and 2000 N;
- the initial value of the angular velocity of rotation of the brake pulley was: 1595 rpm (corresponding to the linear speed, respectively: 60 km/h. The magnitude of the linear deceleration during braking is about 1 m/s^2);

- the cooled air temperature varied: from -20°C to 20°C (which according to the theoretical estimate will correspond to the case when the brake cooling system will remove up to 25% of thermal energy generated during braking, respectively, for the above conditions conducting examinations and using in mathematical modeling of the process of complex heat transfer the calculation scheme adapted to the conditions of the experimental stand.

The cooling system was switched on before the start of the process of braking and recording of the studied values (if used in experiments) and operated with a fixed capacity. The nominal contact area of the brake pulley with the heat-removing element was 0.0055 m^2. External conditions during the experimental studies corresponded to the following: ambient temperature: 21°C, atmospheric pressure: 755 mm Hg, humidity: 65%.

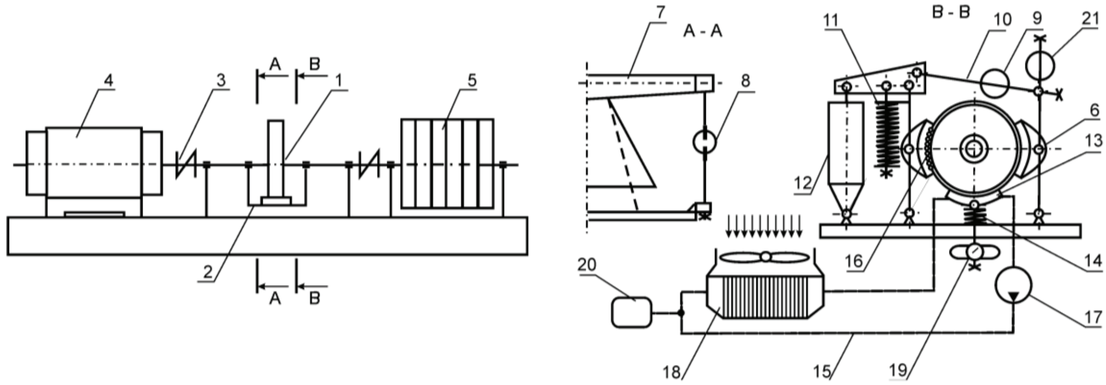


Fig. 2 Schematic diagram

The design of the stand is supplemented by a compressor and a cooled air supply unit (Fig. 3) [6-8]. By means of the compressor air supply in a pipe in which there is a temperature division into cold and hot air which are taken away from various apertures is carried out. The cooled air is supplied to the area of friction contact.

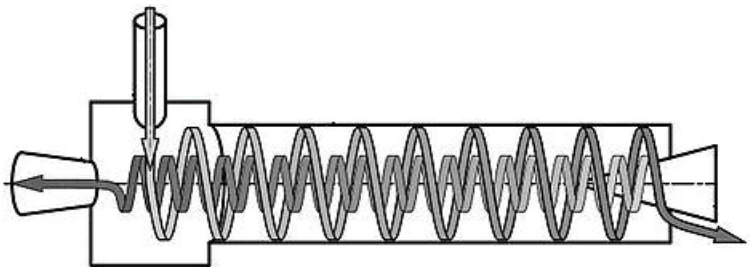


Fig. 3 Cooled air supply unit schematic diagram

Pre-compressed air is supplied to the nozzle, where it expands, cools and acquires high speed and kinetic energy. Since air enters the pipe tangentially, it forms a free vortex in the cross section of the pipe, the angular velocity of which is large at the axis and small at the periphery of the pipe. The excess kinetic energy of the inner layers is transferred (by friction) to the outer ones, increasing their temperature. This process occurs so quickly that the inner layers, having given off the energy to the peripheral and cooled even more, do not have time to receive an equivalent return of heat from them, i.e., thermal equilibrium does not occur in the field of air separation.

Being close to the central opening of the diaphragm, cold air exits through it to the right free end of the pipe, called cold. The heated peripheral layers move to the left towards the throttle valve and through it exit the hot end of the pipe. The quantities of hot and cold air received, and therefore the temperature of both, are controlled by the degree of opening of the valve.

The task of the research is to experimentally show the dependence of the coefficient of friction and temperature in the contact «brake disc - pad» on the factor of cooling air supply to the friction contact during the braking process.

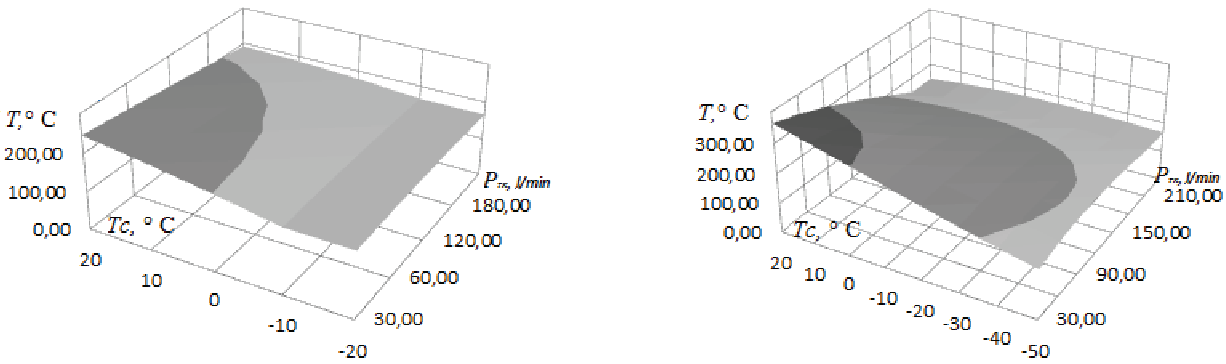
All experimental values obtained in parallel experiments were checked for the absence of errors according to the planning of the experiment methodology [9, 10]. To process the results of experiments, the normality of the distribution of random errors is checked, which is characterized by the following conditions:

1) measurement errors can take a continuous series of values;
2) with a large number of observations of the error of one value, but different signs, are equally common;
3) the frequency of errors decreases with increasing values.

However, the large number of measurements that occur in practice corresponds to the normal distribution law. At the same time, it is established that measurements on the definition of the size of temperature, a braking moment, coupling force, follow normal law of distribution of errors. The results of the experiments are presented in Fig. 4.

With the increasing temperature in the area of interaction of the friction pair there is a change in the coefficient of friction, which affects the quality of braking. The high temperature in the friction contact leads to a change in the strength characteristics of the surface layer.

The obtained dependences of the friction surface temperature in the process of single braking on time at different air temperatures and cooling productivity show the efficiency of temperature stabilization in the friction contact up to 25%.



a b

Fig. 4 Dependence of contact temperature on productivity and temperature of forced local cooling; the clamping force of one brake pad is: a – 1500 N, b – 2000 N

3. Conclusions

Experimental study of temperature stabilization process in tribological contact of brake friction pairs under the impact of forced cooling was held with a set of laboratory equipment that was improved (a bench stand for the studying influence of local cooling of a model disk-pad tribological contact), suitable experiment methods were developed. Based on the results of the experiments, substantiated parameters for controlling the brake friction contact were developed, as well as methods and devices for their implementation.

Acknowledgement

The study was carried out as part of the technical task of the research work DN-01-20 «Theory and practice of a systematic approach to creating a new rolling stock of railways with multifunctional control of thermomechanical loading «wheel-block-rail» to improve safety, energy and resource conservation» (state registration № 0120U102220).

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