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RESEARCH

Influence of the Previous Preheating Temperature on the Static Coefficient of Friction with Lubrication

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A B S T R A C T

Experimental investigations static coefficient of friction in lubricated conditions and pre-heating of the sample pin at high temperatures is discussed in this paper. The static coefficient of friction was measured in the sliding steel copper pins per cylinder of polyvinylchloride. Pins are previously heated in a special chamber from room temperature to a temperature of 800 °C with a step of 50 °C. Tribological changes in the surface layer of the pins caused by pre-heating the pins at high temperatures and cooling systems have very significantly influenced the increase in the coefficient of static friction. The results indicate the possibility of improving the friction characteristics of metal materials based on their thermal treatment at elevated temperatures.

1. INTRODUCTION

Surface roughness and condition of the contact surface is of great interest and importance in many applications including fluid flow. Numerous theories are based on hypotheses and different observations, which occur from experimental data and explain the influence of different contact surfaces on the value of the coefficient of friction. In researches [1,2] the authors show that increasing the temperature of the body in contact has a significant impact on increasing the coefficient static of friction. Static friction is realized at the moment of macro tangential displacement of a moving body in relation to a motionless body [3,4]. The coefficient of static friction depends on a number of parameters, primarily the contact surface, normal load, atmosphere and temperature, surface absorption, surface finish and material of contact surfaces [5-9]. Experimental tests [10-15] are based on the observation of changes in the coefficient of static friction due to changes in temperature of the contact surfaces. In these studies, it is found that the influence of increased temperature leads to tribochemical changes on the surfaces of contact pairs. The changes are shown in the form of the appearance of oxides, borides, carbides and nitrides, which causes the change in the coefficient of static friction. It is observed that keeping the contact pairs at higher temperatures increases the oxide layer, which results in the increasing of the coefficient of static friction. When the surface contact between the contact pairs becomes completely based on the contact of iron oxide, it leads to stabilization of the coefficient of static friction due to appropriate chemical and thermal reactions [10]. According to [16] it is experimentally confirmed that the coefficient of static friction of tool steel has a lower value at temperatures around 800 °C. Experimental results indicate that the coefficient of static friction between the contact pair of nitrided tool steel and boroned steel is lower at higher temperatures compared to tool steel without surface nitriding. Reducing the coefficient of friction with increasing temperature can possibly be connected to the formation of a concentrated oxide layer, which is caused by oxidation at higher temperatures [16]. Vanadium (V) significantly reduces the coefficient of friction at higher temperatures due to the ability of forming lubricating oxides, V2O5 [16,17]. Experimental tests [18] show that the TiN coating has a higher coefficient of friction during the entire temperature range from 25 °C to 700 °C, compared to the VN coating. Researches show that the reason for the decreasing coefficient of static friction of VN coatings is the previously formed oxide layer which consists mainly of V2O5 oxide. The mentioned oxide has a low shear strength and very low melting point, which leads to lower coefficients of static friction at higher temperatures because of its crystallographic structure [19].

Experimental research of static coefficient of friction with the previous preheating contact element from ambient temperatures up to 800OC, in steps of 50^{0}C were carried out in this paper. The contact element is cooled after pre-heating to room temperature. We considered the contact pair that makes steel copper pin with the characteristics defined in DIN 8559 and pipe of polyvinylchloride (EN1452-2). Whereby the pair of contact during the measurement process in fluid flow - oil. The measurement procedure is identical to the measurements explained in the framework by reference [20].

2. EXPERIMENTAL INVESTIGATIONS

Experimental investigations were carried out with the previous thermal preparation the pin as one of the contact pairs. Pins are previously heated by the temperature from room temperature to 800 °C with a step of 50 °C. During the measurement process - sliding the pin per cylinder (pipe) is conducted in a fluid flow. Namely, tube is filled with fluid and sealed in order to create identical conditions of lubrication. The studies were conducted on tribometer for measuring the static coefficient of friction, which is described in details in [20]. The sample (pin) is heated to a certain temperature in a special chamber (Fig. 1), then cooled to room temperature. After cooling to room temperature, the sample is placed in cylinder filled with fluid (Fig. 2). Considered the contact pair that makes steel copper pin whose characteristics are defined in DIN 8559 and tube from polyvinyl chloride whose characteristics are defined in standard (EN1452-2). Figure 2 shows the levelled position of the contact pair in the middle of the fluid (oil) in which the tube is rigidly attached to the platform measuring device (tribometer).

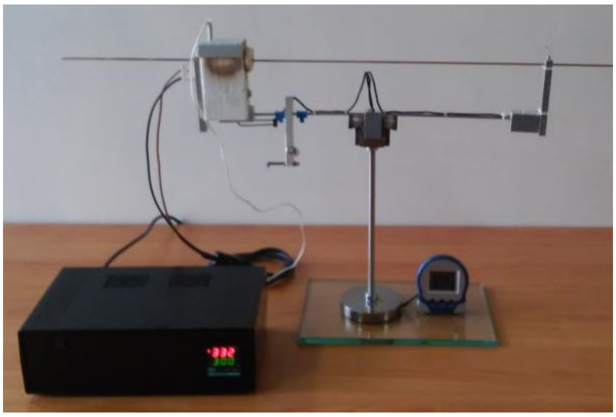

Fig. 1. The sample is heated in the chamber

Rotating the platform at a specific angle of the α, sliding occurs the pin per cylinder in the middle of the fluid (Fig. 3). The angle α at which the sample begins with a sliding scale is read with a tribometer. From the paper [20] it is known that the tgα is equal μ the static coefficient of friction.

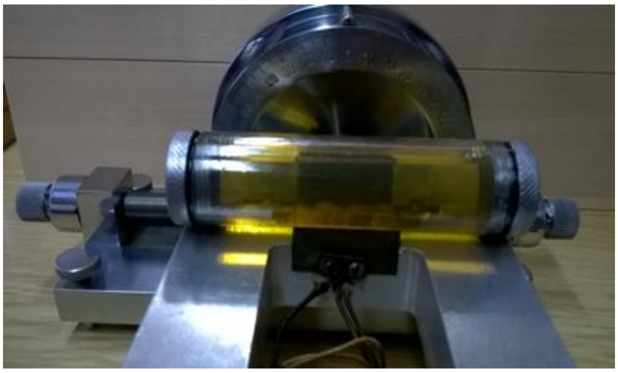

Fig. 2. The sample in levelled position.

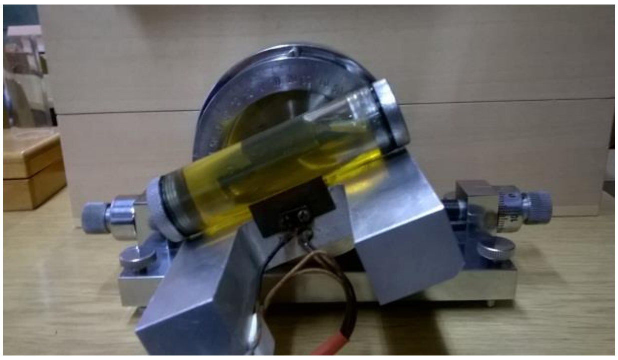

Fig. 3. Rotating the platform and begin sliding the pin.

Was performed a total of 17 experimental tests. Each of the experimental test was repeated 30 times, in order to reliably determine the mean value of the coefficient of friction. Obtained the mean value of the coefficient of static friction for certain values of the previous temperature heat treatment pins are given in Table 1.

Table 1. Calculated mean value of the coefficient of static friction μ_s depending on test temperatures.

Pretreatment temperature of specimen [°C]	μ_s [-]
23	0.24
50	0.33
100	0.44
150	0.39
200	0.31
250	0.60
300	0.46
350	0.39
400	0.52
450	0.45
500	0.45
550	0.53
600	0.55
650	0.54
700	0.55
750	0.61
800	0.66

3. ANALYSIS OF RESULTS

The experimental results are shown in the diagram in Fig. 4. From the diagram, it can clearly be seen growing trend static coefficient of friction with increasing temperature of the previous heat treatment pins. Oscillations trend shows increase in the coefficient of friction as a result of different levels of influence of certain temperature range.

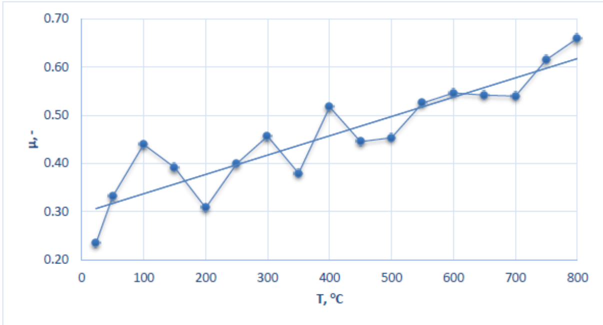

Fig. 4. Dependence of the static coefficient of friction μ_s from the previous preheating temperature T.

From the given diagram, it can be concluded that of the previous temperature heat treatment pins have a very significant impact on the value of the coefficient of static friction. The consequence of the increase in the coefficient of static friction is essentially related to structural changes in the surface layer and the oxide layer was formed as a result of the previous heat treatment.

In the first measurement at room temperature coefficient of static friction is μ_s=0.24. After the second and third measurements, heating the sample to 50 °C and 100 °C and cooling, the static coefficient of friction rises to μ_s= 0.44. The increase in the static coefficient of friction can be largely attributed to the formation of an oxidation layer on the surface of the sample. With further heating the sample to 150 °C and 200 ° C occurs decline in the static coefficient of friction to values μ_s=0.39 and μ_s=0.31. For further heating the samples to 800 °C temperature occur certain decline in and increase the static coefficient of friction which can be seen from the diagram in Fig. 4. Static coefficient of friction is an intricate process governed by a combination of factors, such as the real area of contact, the contact geometry, the surface roughness of the members in contact, the load, and the temperature. When a specimen over a cylindrical groove, a component of the force of friction related to slip arises and, therefore, surface films can manifest their influence. The temperature elevation affects all of the above listed factors, since it favours a decrease in the hardness of the metals in contact, changes in the con tact geometry due to thermal expansion, as well as removing water and contamination films. All of these effects can increase the static coefficient of rolling friction; therefore, they require serial tests with variable parameters to be carried out. The tribometer with the inclined plane can be efficient in these tests because of the simplicity and clarity of measurements.

4. CONCLUSION

The obtained results indicate a very significant impact of the previous heat treatment pins on the measured value of the coefficient of static friction. Previous thermal preparation of the pin as a contact element (pre-heating and cooling pins) causes structural changes and the creation of the oxide layer, which is characterized by higher coefficients of friction. According to the research results for a given temperature range, there was a nearly threefold increase in the value of the coefficient of static friction. This fact points to the possibility increase friction characteristics of metal materials based on heat treatment, which opens a wide space for research and optimization of friction gears in terms of improving their characteristics in real industrial systems.

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