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STATIC COEFFICIENT OF ROLLING FRICTION AT HIGH TEMPERATURE

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Abstract: New design of tribometer for measuring of static coefficient of rolling on the inclined plane at high temperature is presented in this paper. Results of experimental measurements in conditions of high temperatures while varying normal loads and radius of contact elements, shows that it is possible to use presented design in order to show complex influence of temperature. In this paper it is presented as idea, construction project and as final design of the new tribometer device.

Keywords: static coefficient of rolling friction, high temperatures, tribometer.

1. INTRODUCTION

Knowing the value of friction coefficient is very important for design engineers which develop machines with moving parts. However, adoption of predefined friction coefficient values is often burdened with numerous dilemmas and problems. The problems mostly pertain to finding values in tables and knowing conditions under which those values were measured, since data differ depending on laboratory of origin, testing equipment, method of measurement and other numerous parameters. Blau [1] treated the problem of friction and its measurement, discussing some of the most popular, standardized methods for the measurement of static and dynamic friction coefficients, as well as their application.

Based on relative velocity of bodies in contact, two types of friction can be recognized: friction of motionless bodies and friction of moving bodies [2,3]. Friction that occurs at motionless bodies is static friction and it depends on many parameters such as:

normal load, temperature of environment, surface roughness, materials in contact, etc. [4]. Scientists noted that one of the influential parameters is surface roughness, which directly influence on values of static coefficient of friction [1,4]. A subject of large number of investigations were these parameters, but not research regarding influence of high temperatures. Only a small number of investigations which deals with influence of higher temperatures on static friction characteristics of materials were conducted [5-8]. Their general conclusion is that the static friction coefficient increases with temperature, which is partly due to increased plasticity in majority of contact pair materials at higher temperatures. In a large number of investigations experiments of static friction coefficient were performed using equipment of various design and contact geometry [9-12].

Smaller number of investigations in this field was a result of large number of physical and technical problems that occur during development of tribometer for measuring the

coefficient of static friction at higher temperatures. These problems occur because it is necessary to acquire small values of normal load and friction force. Other problems are related to influence of temperatures on measurement equipment.

Authors of this paper will present new design for measuring the static friction at higher temperatures and low contact pressures.

2. THEORETICAL BACKGROUND

The initial idea was to make apparatus for measuring of static friction at higher temperatures on which the influence of higher temperatures will be very low. Also, authors took in consideration accuracy, and tried to design equipment with smaller relative error.

Suggested design uses method for measuring static coefficient of friction on an inclined plane, Fig. 1.
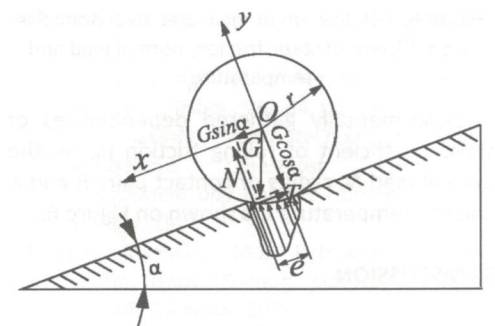
Figure 1. Equilibrium of body on an inclined plane

As shown on Figure 1, when there is case of rolling, it is possible to calculate coefficient of static rolling friction:

$$\frac{e}{r} = \tan\alpha = \mu_R \quad (1)$$

where: α – angle of inclined plane, μ_R – static rolling friction coefficient, e – coordinate which defines position of resulting reaction, and r – radius of rolling body.

Having all this in mind authors presented new design of tribometer, Fig. 2. All measurements conducted with this design will be performed mechanically with reading accuracy of 1 minute. It is necessary to mention that measuring system is separated

from the zone with high temperature, however, contact pairs, heater and thermo couple are very close to contact zone.
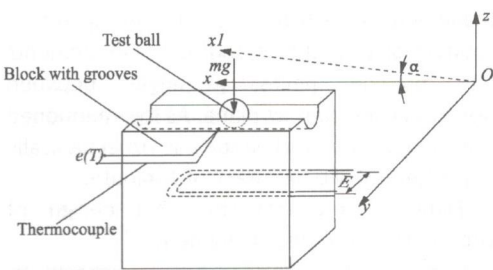
Figure 2. Schematic diagram of tribometer

Implementing this idea into practise will ensure that influence of temperatures on measuring system and all of his components are very low.

3. TRIBOMETER DESIGN

Based on initial idea, Fig. 2, 3-D model of tribometer was created using AutoDesk Inventor software package, Fig. 3.
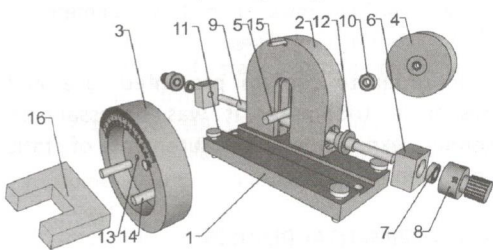
Figure 3. Exploded view of tribometer with specific elements

Specially designed screws (element 11), positioned on base plate (element 1), is used for levelling adjustment of tribometer, and on vertical base plate (element 2) was placed nut (element 12) and starting position indicator (element 15). 3-D model shows that spindle (element 9) with feed rate of 1 mm is in contact with nut (element 12) and nonius (element 8) which has function of presenting the measured value with precision of 1 minute. On vertical base plate there is an opening with function to enable movement of spindle (element 5) with help of two bearings (element 10). Bearings are connected with disks (elements 3 and 4) where is placed engraved measuring scale, with two

connection elements (element 14). Experimental sample will be put on element 16. Rotating of mentioned nonius will ensure movement of vertical base plate and with that rotating of elements 3 and 4. These elements will provide necessary angle between horizontal and contact plane. As it is mentioned, the angle of inclination is mechanically implemented with accuracy of 1 minute.

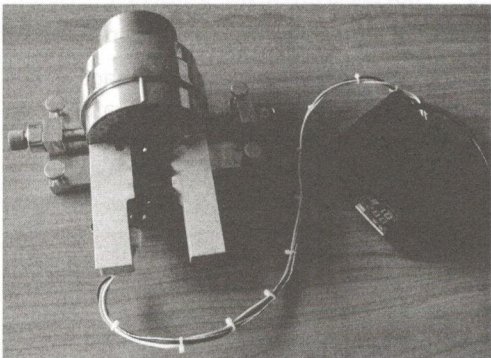Figure 4 presents the final design of tribometer with specific elements.

Figure 4. Photo image of the final tribometer design

In order to confirm presented idea and design of tribometer it was necessary to conduct experimental measurements of static coefficient of friction.

4. EXPERIMENTAL RESULTS

The main goal of these experiments is to define influence of the temperature on static coefficient of rolling friction of balls during rolling on different radius over grooves. Material used in this experiment for contact pairs, Fig. 5, (balls and block) is ASTM A-295/52100 bearing steal 62-66HRC.
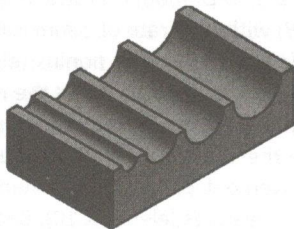

Figure 5. 3-D model of block with grooves used in experiments

The surface roughness of balls used in this experiment was $Ra = 0.002$ µm and surface roughness different radius groove profiles $Ra = 0.8 - 1$ µm. Groove profiles of block were made with different radius $R_1 = 2.5$, $R_2 = 5$, $R_3 = 6.5$, $R_4 = 8$.
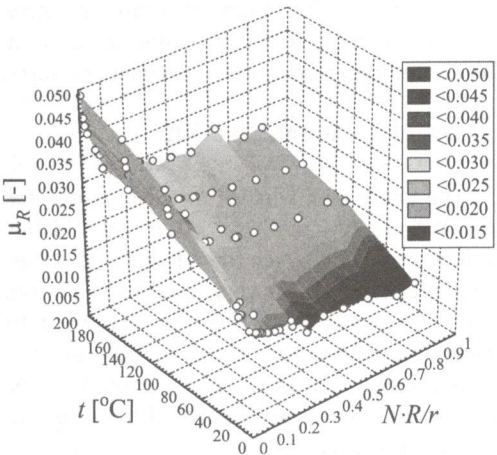

Figure 6. 3-D diagram of measured dependencies of coefficient of static friction, normal load and temperature

Experimentally gathered dependencies of static coefficient of rolling friction μ_R on the normal load N, radius of contact pairs R and r, and the temperature t is shown on Figure 6.

5. DISCUSSION

Experimental results shows that it is possible to use new design of tribometer for measuring of static coefficient of rolling friction on the inclined plane with high temperature and it can be concluded that coefficient of friction grows with increase of temperature.

Temperature in contact area influence on large number of factors regarding rolling friction since it decrease the hardness of materials in contact and it also removes water between two contact elements. With this new design of tribometer it is possible to carry out experiments with variation of large number of parameters in order to study its effects. Since measurement error of the new design of tribometer is very low (measurement angle of one minute) this design is very efficient.

6. CONCLUSION

This new design can provide efficient measurement of static coefficient of rolling friction with heating to the temperatures of 200 °C. Design can help researchers to better understand influence of specific parameters such as temperature on static coefficient of rolling friction, or with small changes in design of presented tribometer, influence on static coefficient of sliding friction.

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