

EXPERIMENTAL DETERMINATION OF SLIDING FRICTION COEFFICIENTS FOR THE TRIBOLOGICAL PAIR RUBBER AGAINST CERAMIC

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Abstract: Materials selected for various applications must satisfy specific tribological characteristics, particularly regarding their static coefficient of sliding friction. One frequently utilized material combination is the tribological pair of rubber and ceramics—a representative example being the interaction between a rubber shoe sole and a ceramic floor surface. This study focuses on experimentally determining the static coefficient of sliding friction for this material pair. The results reveal that the static friction coefficient is strongly influenced by the type of ceramic, particularly its surface roughness, highlighting the critical role of surface properties in tribological performance.

Key words: static coefficient of sliding friction, experimental testing of sliding friction, tribological couple

1. INTRODUCTION

In different branches of industry there is a need to combine tribological pairs that have different behavior conditions. In some cases, tribological couples in different structures are expected to have a low static coefficient of friction (for example, sliding bearings) and in some cases, the static coefficient of sliding friction is required to be quite high (for example, the contact between the wheel tire and the surface). It is precisely for these reasons that various solutions are combined that can provide the necessary conditions for the quality functioning of an assembly or structure. The development and improvement of existing materials as well as the development of new materials leads to the possibility of making an increasing number of tribological pairs composed of different types of materials. The type of material of the triboelements, as well as the manufacturing method and operating conditions have a significant influence on the values of the static sliding friction coefficient of the tribo-elements. The surfaces of real bodies are not smooth, but rough [1], [2], [3].

Real bodies are not rigid, their surfaces are deformable and wear out. In mechanics, real bodies are viewed as rigid bodies with rough and deformable surfaces, which is the most common case of bodies used in practice. Their touch is a rough connection. Wear and tear is ignored. When two real bodies, under the influence of external forces, are in contact, then in the plane of contact there is a force that opposes the movement (sliding) of one body on the other. That force is the sliding friction force. Contact surfaces of real bodies form a friction pair, they can be dry or lubricated. The sliding friction of non-lubricated contact surfaces is called dry friction [4].

The function that represents one of the basic characteristics of tribo-mechanical systems can be expressed as the ratio of input and useful output quantities. Disturbances affect friction and wear processes. Losses in tribo-mechanical systems are extremely significant from the aspect of quality implementation of elementary functions. Tribological processes are very complex processes and they depend on a large number of factors. Friction, as a process of opposing the movement of the triboelements of the system, greatly affects the mechanical degree of useful effect, which is the most important parameter for assessing the ability of the tribo-mechanical system to preserve the transported energy. Wear, as a form of removal of material from the contact surfaces, affects changes in technical parameters and changes in the functioning of the tribomechanical system. Figure 1 shows the area of nominal and real contact [5].

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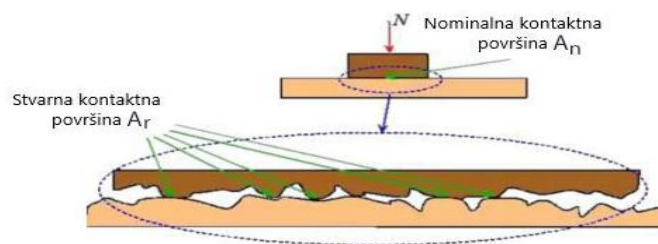


Figure 1 - Area of nominal and actual contact [5]

Sliding friction is the resistance to relative motion that occurs when one solid body slides over another. The force of friction is proportional to the normal force acting on the surfaces in contact, which can be represented by the following expression:

$$F_t = \mu N \quad (1)$$

where is:

F_t – force of friction

μ – coefficient of friction

N – normal reaction

According to this theory, the friction force does not depend on the size of the surfaces in contact and the speed of sliding, but only on the load, the degree of roughness and the nature of the material of the elements. However, recent tests have shown that this formula is not entirely satisfactory. Thus, the frictional force depends on the normal reaction, the degree of roughness, the size of the actual contact surface, the hardness of the material, etc.

2. DEVICE FOR MEASURING THE SLIDING FRICTION COEFFICIENT (TRIBOMETER)

The device used for measurement determines the sliding friction coefficient using the inclined plane method. It consists of a base, a measurement section, and a magazine containing samples for testing. The magazine holds a set of multiple substrate samples and several weights that slide on the substrate. The nominal load value is 1 N. The measurement range of the friction coefficient is from 0.05 to 1 and is read analogously on the device. The value of the sliding friction coefficient can be determined as the tangent of the angle at the moment when sliding begins in the contact tribological pair or can be directly read on the device's scale. The device also allows for the fabrication of contact pair elements from other materials not included in the set, which enhances its functionality in determining the friction coefficient for various types of materials and different surface roughness levels, both with and without lubrication. The device for determining the friction coefficient (tribometer) is shown in Figure 2.

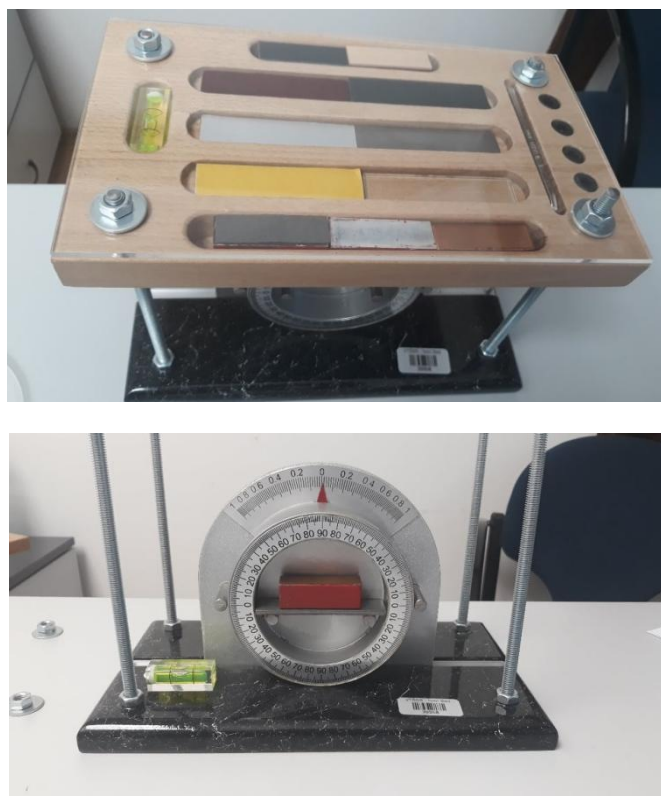


Figure 2 - Device for measuring the coefficient of sliding friction (tribometer)

Before experimental measurements, it is necessary to level the device by placing a spirit level on the base of the device and adjusting it using four screws. First, leveling is performed in one plane and then in the other. For practical reasons, it is recommended to perform leveling with the rolling disc positioned approximately in the middle of its left and right boundary positions.

After the device is prepared, the samples are selected and prepared. First, the initial contact tribological pair—a substrate made of the desired material—is placed so that it rests on both pins of the device. Then, the second contact tribological pair—a sample made of the desired material—is positioned on top of it. The starting measurement position is the contact of the second tribological pair with the first, constrained by the end wall of the rotating disc on the left or right inner side of the guide located in the indentation of the rolling disc.

Before conducting the procedure for measuring the friction coefficient, it is necessary to carefully prepare the samples by thoroughly cleaning them. Some samples (e.g., metal ones) may need to be wiped first with an oiled cloth and then with a dry cloth to remove any impurities. If the static sliding friction coefficient is to be measured under lubricated conditions, a thin layer of lubricant should be applied to the contact tribological pairs after cleaning. The appearance of the measuring device with the starting measurement position is shown in Figure 3.



Figure 3.- Starting measuring point

After preparing for the measurement, the inclined plane is rotated by gently moving the support of the rolling disc by a few degrees. The coefficient value is recorded at the moment when the upper contact tribological pair (weight) begins to slide. This value can be read either on the upper scale, ranging from 0 to 1, or by reading the angle on the circular scale and calculating its tangent, which represents the friction coefficient.

3. EXPERIMENTAL RESULTS

Experimental testing of the static sliding friction coefficient μ was conducted for the tribological pair of rubber and ceramic. For the purposes of the experiment, three ceramic samples of different colors and surface roughness were prepared. Rubber material was used as the weight, while three types of ceramic were used as the substrate. The appearance of the ceramic substrates is shown in Figure 4.



Figure 3 - Appearance of Ceramic Substrates

The results of the experimental testing of the static sliding friction coefficient μ , as well as the angle of substrate inclination $\tan \alpha$ at the onset of sliding (sliding angle), are presented in Table 1. By definition, the sliding friction coefficient is equal to the sliding angle, as indicated on the measuring device itself, $\mu = \tan \alpha$.

Table 1: Values of the Static Sliding Friction Coefficient for the Tribological Pair RUBBER-CERAMIC

Number of measurements	Ceramic base 1		Ceramic base 2		Ceramic base 3	
	μ	$\text{tg } \alpha [^\circ]$	μ	$\text{tg } \alpha [^\circ]$	μ	$\text{tg } \alpha [^\circ]$
1	0,4	21,8°	0,55	28,8°	0,30	16,7°
2	0,28	15,5°	0,46	24,7°	0,32	17,8°
3	0,32	17,8°	0,48	25,6°	0,34	18,8°
4	0,30	16,7°	0,50	26,6°	0,30	16,7°
5	0,32	17,8°	0,44	23,8°	0,26	14,6°
6	0,30	17,7°	0,46	24,7°	0,32	17,8°
7	0,36	19,8°	0,48	25,6°	0,24	13,5°
8	0,32	17,8°	0,42	22,8°	0,26	14,6°
9	0,34	18,8°	0,44	23,8°	0,24	13,5°
10	0,28	15,6°	0,42	22,8°	0,34	18,8°
11	0,30	16,7°	0,46	24,7°	0,36	19,8°
12	0,24	13,5°	0,40	21,8°	0,32	17,8°
13	0,26	14,6°	0,44	23,8°	0,30	16,7°
14	0,28	15,6°	0,46	24,7°	0,34	18,8°
15	0,34	18,8°	0,48	25,6°	0,38	20,8°
16	0,26	14,6°	0,40	21,8°	0,44	23,8°
17	0,32	17,8°	0,42	22,8°	0,34	18,8°
18	0,30	16,7°	0,38	20,8°	0,32	17,8°
19	0,26	14,6°	0,46	24,7°	0,32	17,8°
20	0,28	15,6°	0,44	23,8°	0,44	23,8°

Figure 4 illustrates the values of the static sliding friction coefficient for 20 measurements across all three types of ceramics. The figure shows that the highest value of the static sliding friction coefficient is for rubber and ceramic 2 (the middle ceramic substrate shown in Figure 2). This can be attributed to the fact that ceramic 2 has a significantly rougher surface compared to the other two samples.

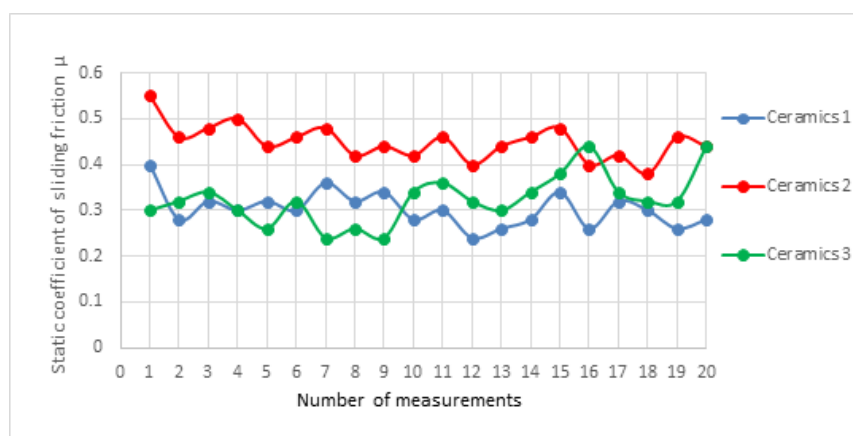


Figure 4 - Experimentally Determined Values of the Static Sliding Friction Coefficient for the Tribological Pair Rubber and 3 Types of Ceramic

Based on the measurement results shown in the table, it is possible to determine the average values of the static sliding friction coefficient. The results of the average static sliding friction coefficients are presented in Figure 5.

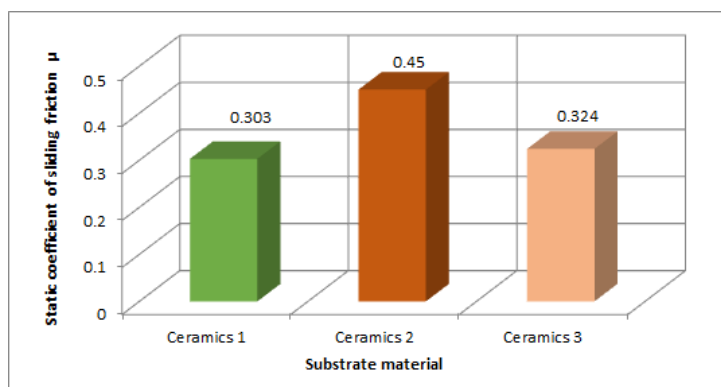


Figure 5 - Average Values of the Static Sliding Friction Coefficient for the Tribological Pair RUBBER-CERAMIC

4. CONCLUSION

As is well known, the values of the static sliding friction coefficient have a significant impact on the behavior of tribological pairs during operation. By using a tribometer and fabricating weights and substrates for extensive measurements, it is possible to determine the static sliding friction coefficient values for tribological pairs. The results presented in this study have shown that the same substrate materials with different surface characteristics can exhibit varying sliding friction coefficient values, with deviations exceeding 30%. When selecting an appropriate tribological pair, special attention should be paid to the specific requirements that the pair must meet, and a reliable prediction of behavior should be made prior to installation. This can certainly be achieved by using a device like this in conjunction with the expertise of professionals dealing with this field.

5. REFERENCES

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