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Issue Article

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CALCULATION OF SLIDING FRICTION FORCE AND DEFORMATION GRADIENT DURING CONTACT INTERACTIONS OF VARIOUS MATERIALS

Abstract: *The results of friction testing of samples made of various materials are presented in the article. The characteristics of the change in the value of friction force along the contact length and deformation gradient from the friction force of flat surfaces of the samples are graphically displayed.*
Key words: *contact length, friction force, deformation gradient, sample.*
Language: *English*

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1. Introduction

Friction as a physical phenomenon occurs when two or more bodies come into contact and leads to resistance to the movement of one body over another body [1]. The friction force that occurs during the contact of a moving body relative to a stationary body can be represented by a dimensionless coefficient of friction or a vector quantity [2-4]. The values of quantitative indicators of the intensity of the friction process depend on the type of contact materials, the surface quality, the speed of movement of bodies, the use or absence of lubrication between the contact surfaces [5-6], etc. With an increase in the friction force on the contact surfaces of bodies, significant mechanical and thermal deformations occur, which lead to abrasive wear and a decrease in the operational properties of working surfaces. Thus, numerical calculations in tribology are important for assessing the durability of parts made of metallic and non-metallic materials. The purpose of this article is to determine the nature of changes in the intensity of deformation and the friction force depending on the length of movement of the contact pairs [7-10].

2. Materials and methods

The process of contact interaction of flat samples made of various materials during movement was studied to calculate the friction force and the deformation gradient. Sample *1* was a plate on which sample *2* moved in the form of a rectangular bar. A total of 7 contact pairs of samples were tested. The following materials were accepted as sample materials: ice, steel, copper, cast iron, metal, stone, rubber, hard soil, aluminum and bronze. The coefficients of sliding friction and the physical and mechanical properties of accepted materials are presented in the Tables 1 and 2.

Table 1. The values of the sliding friction coefficients set for 7 tests.

Test number	Sample *1*	Sample *2*	Coefficient of sliding friction
1	ice	ice	0.028
2	steel	steel	0.2
3	cast iron	copper	0.27
4	stone	metal	0.45
5	hard soil	rubber	0.5
6	aluminum	aluminum	0.94
7	bronze	bronze	0.99

Table 2. Physical and mechanical properties of materials.

Material	Young's modulus, GPa	Poisson's ratio	Density, kg/m^3
ice	3	0.35	900
steel	200	0.3	7800
copper	110	0.34	8900
cast iron	124	0.25	7000
metal	200	0.3	7800
stone	50	0.26	2500
rubber	0.1	0.45	1200
hard soil	180	0.27	3000
aluminum	70	0.34	2700
bronze	75	0.34	8000

The contact interaction of the sample surfaces was carried out in the absence of a liquid layer between them. The contact length of the sample surfaces is assumed to be 4 m. The gravity of sample *2* in all cases was 3 kN, and the applied force to move sample *2* was assumed to be 1.5 kN.

3. Results and discussion

Some of the calculation results were presented graphically in the Fig. 1. Graphs *a* – *c* show the dependence of the friction force on the length of movement of a copper sample on a cast iron sample, a metal sample on a stone sample, and a rubber sample on a sample made of hard soil. The graphs *d* – *f* show the dependence of the deformation gradient on the friction force of similar contact pairs of samples.

The friction force varies in the range from 113 to 168 N/m^2 when two metal samples (such as copper and cast iron) come into contact. At the same time, during the movement of sample *2* along sample *1*, two stages of increasing and decreasing the friction force are observed. The first peak value of the friction force is marked at the beginning of the sample movement. The maximum value of the friction force is calculated when the sample passes 2/3 of the contact length. This is followed by a sharp decrease in the value of the friction force, which is determined at a length of 1 m until the end of the movement of sample *2*.

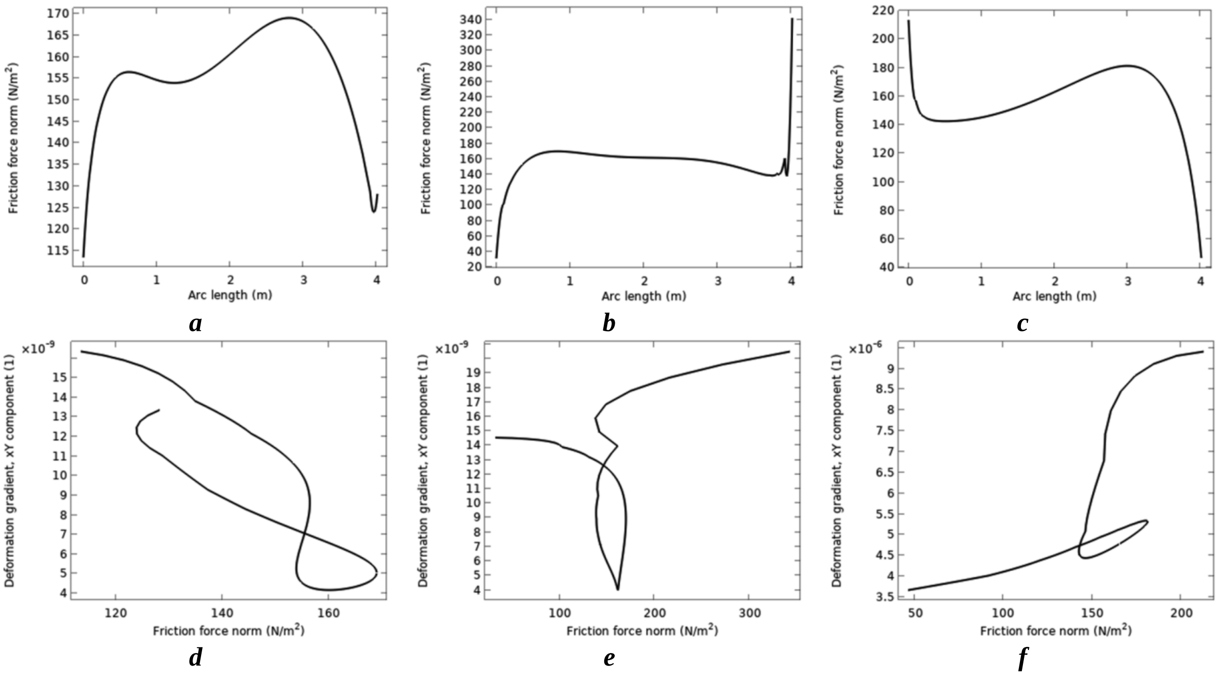

Figure 1. The calculation results are presented graphically: *a* – dependence of the friction force of a copper sample on a cast iron sample on the length of the contact movement; *b* – dependence of the friction force of a metal sample on a stone sample on the length of the contact movement; *c* – dependence of the friction force of a rubber sample on a sample made of hard soil on the length of the contact movement; *d* – dependence of the deformation gradient on the friction force (contact movement of copper on cast iron); *e* – dependence of the deformation gradient on the friction force (contact movement of metal on stone); *f* – dependence of the deformation gradient on the friction force (contact movement of rubber on hard soil).

When metal and stone samples come into contact, the friction force varies in the range from 30 to 340 N/m^2. At the same time, during the movement of sample *2* along sample *1*, two sharp jumps of the increase in the value of the friction force and one stage between them of a slow decrease in the value of the friction force are observed. The minimum value of the friction force is marked at the beginning of the movement of sample *2*, the maximum value of the friction force is marked at the end of the movement of sample.

When non-metallic materials (such as rubber and hard soil) come into contact, the friction force varies from 48 to 216 N/m^2. At the same time, the nature of the change in the friction force along the contact length has two sharp jumps of the decrease in the value of the friction force and one stage between them of a slow increase in the friction force. The maximum value of the friction force was determined at the beginning of the movement of sample *2*, the minimum value of the friction force was noted at the end of the movement of sample.

The greatest value of the deformation gradient on the contact surfaces is determined when a rubber sample moves along a sample made of hard soil. The greatest intensity of the deformation gradient for these samples is observed at the peak value of the friction force. However, for metal samples (copper and cast iron), the highest intensity of the deformation gradient is calculated at the lowest value of the friction force.

For the remaining tested contact pairs of samples, the nature of changes in the friction force and the deformation gradient is almost similar (with an increase or decrease in the calculated values by 10-12%) to the dependences of the copper-cast iron contact pair.

4. Conclusion

Thus, based on the calculation results obtained, the following conclusions can be drawn:

1. All the considered metal contact pairs have almost the same nature of the change in the friction force and the deformation gradient.

2. The greatest and lowest friction force is observed when metal and stone samples come into contact. At the same time, at the end of the movement of a metal sample, the friction force can reach 340 N/m^2, which is twice as much as the friction force at the contact of copper and cast iron samples.

3. The greatest intensity of the deformation gradient was determined at the contact surfaces of rubber and hard soil at the moment of sample movement. As the sample passes through the path, the values of the friction force and the deformation gradient decrease.

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