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ANALYSIS OF THE INFLUENCE OF TRIBOLOGICAL TESTING MODES ON THE WEAR OF A STEEL PAIR WITHOUT LUBRICATION

***Abstract**: The results of computer calculation of the wear intensity of contact surfaces of steel bodies under various combinations of speed and load are presented in the article. Calculated values of rate and depth of wear of contact surfaces, contact forces and friction forces were obtained on the basis of a multifactorial experiment, according to the design of which a number of tests were carried out. It has been determined that the speed of movement of a body on a stationary surface significantly affects the intensity of wear rate, and the force acting on the moving body significantly affects the wear depth of the contact surface.*

***Key words**: friction force, wear rate, wear depth, contact surfaces, force.*

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1. Introduction

Understanding the relationship between friction and wear of contact surfaces is essential for improving the performance and service life of moving machine components [1].

Wear is the loss of material from contact surfaces as a result of mechanical action, such as when two materials come into contact and move relative to each other [2]. The mechanisms of friction and wear can be analyzed during tribological testing [3-4]. The relationship between friction and wear depends on many factors, the main ones being the properties of material, the size of microroughness of contact surfaces, the presence of lubricants, the applied force and the movement speed [5-10]. In real conditions, the wear process of contact surfaces is simultaneously influenced by all of the above factors, therefore a multifactorial experiment allows us to evaluate the influence of each factor on the nature and intensity of wear.

The practical value of the study is the results of forced tests, confirming the significant influence of changes in testing modes on the rate and depth of wear of contact surfaces of steel bodies moving without lubrication.

2. Materials and methods

Tribological tests were implemented using the Comsol Multiphysics program. On an infinite steel plate, a steel body moved along the X-axis at different speeds. The solid models were made of the same steel with the following properties: density – 7850 kg/m^3, Young's modulus – 210 GPa and Poisson's ratio – 0.3. The experimental conditions are shown in the Fig. 1.

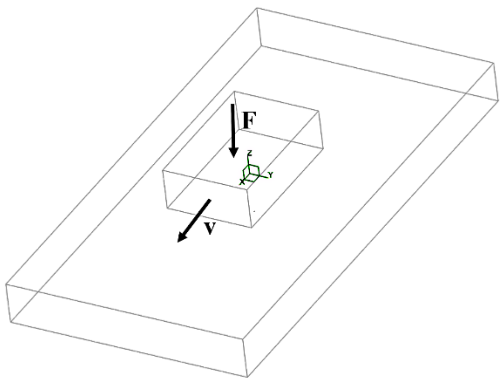

Figure 1. Experimental conditions.

To identify the influence of testing modes on the wear intensity of contact surfaces of bodies, 9 tests were carried out. The factors affecting the wear process were the body's speed of 0.5, 2, and 5 m/s and the force acting on the moving body of 0.5, 2, and 5 kN. The experimental design is presented in the Table 1.

Table 1. The experimental design.

Test number	Movement speed, m/s	Applied force, kN
1	0.5	0.5
2	0.5	2
3	0.5	5
4	2	0.5
5	2	2
6	2	5
7	5	0.5
8	5	2
9	5	5

The friction calculation was carried out using the Coulomb friction model. The coefficient of sliding friction was set to 0.6, since the contact of steel bodies occurred without the use of lubricant. The value of sliding resistance of the surfaces of bodies, caused by cohesion, was taken to be zero. The generalized Archard wear model is applied in the calculation to predict wear based on loads calculated at each point in the contact zone of surfaces. The time of movement of the body along the plate in each test was taken as 10 s.

A mesh consisting of prismatic, triangular and square elements was generated on the body models. The size of finite elements varied in the range of 0.00504-0.028 mm, which made it possible to obtain more accurate results of modeling the process of tribological wear tests on the contact surfaces of a steel-to-steel pair.

3. Results and discussion

Calculation of the value of wear and friction force on the contact surfaces of steel bodies was determined over the entire time range of the tribological experiment tests. The dependencies of effective wear rate on friction force, along the corresponding coordinate axes, are shown in the Fig. 2.

Under minimum tribological test conditions, the wear rate of contact surface of the moving body varies in the range of 0.04-0.28 μm/s. In the direction of the body's movement (X-axis), the friction force, with a maximum value of 280 kPa, acts in the opposite direction to the action of the driving force. The friction force acting along the Y-axis is 2.3 times smaller in value than the friction force acting along the X-axis. The friction force acting along the Z-axis has virtually no significant effect on the resistance of the movement body. Negative values of the friction force (Z component) are characterized by its action in the direction of the driving force.

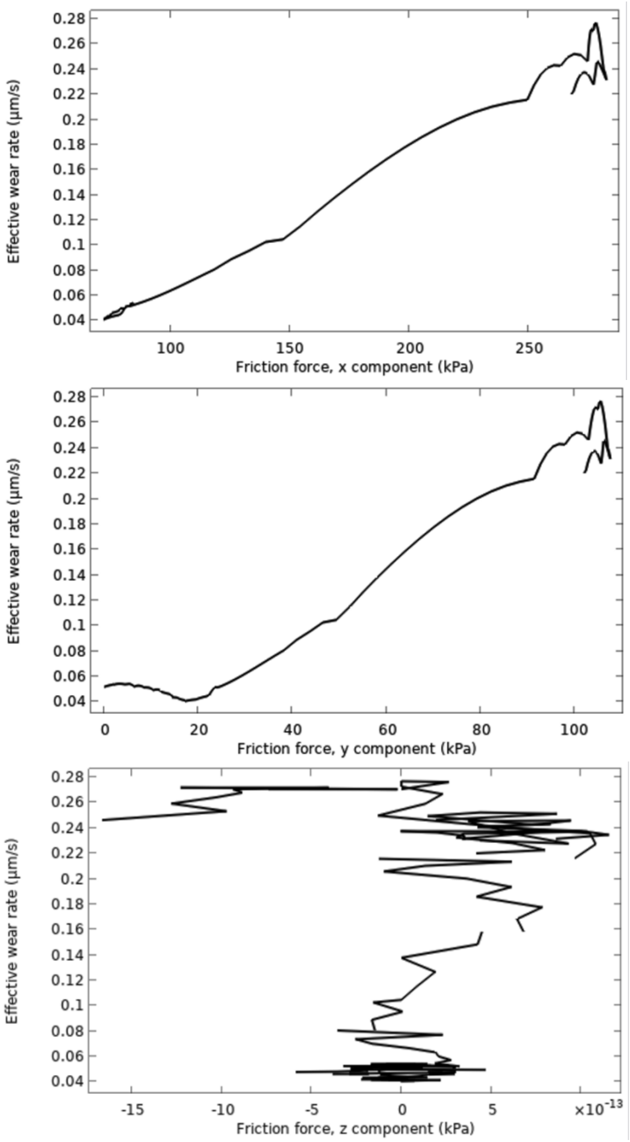

Figure 2. The dependencies of effective wear rate on friction force along the corresponding coordinate axes (test No. 1).

The Table 2 presents the maximum calculated values of contact forces, wear depth and effective wear rate of the contact surfaces of bodies after 10 s of each test.

Comparing the calculated values of contact forces of the steel-to-steel pair after all tests, it was found that the highest value of contact force is 1.16×10^6 N/mm^2. This value is determined for the third test of the experiment. Thus, it can be concluded that low speed of body movement with the application of maximum force to it causes high contact forces on the mating area.

The values of wear parameters, in the form of depth and rate, increase with the increase of force on the moving body and its speed, respectively. Moreover, at the tenth second of the first test, the rate and depth of wear are greater than in the second and third tests.

Table 2. Maximum calculated values of contact forces, wear depth and effective wear rate of the contact surfaces of the steel-to-steel pair at the tenth second of each test.

Test number	Contact forces, N/mm^2	Wear depth, µm	Effective wear rate, µm/s
1	4.69×10^5	0.6	0.69
2	4.63×10^5	2.08	0.19
3	1.16×10^6	5.19	0.48
4	1.08×10^5	1.9	0.19
5	4.33×10^5	7.6	0.75
6	1.08×10^6	19	1.87
7	1.07×10^5	4.65	0.46
8	4.27×10^5	18.6	1.85
9	1.07×10^6	46.5	4.63

4. Conclusion

The results of case study allow us to predict the wear intensity of contact surfaces of the steel-to-steel pair under various tribological test conditions. The nature of change in friction forces relative to the X, Y and Z axes and the values of wear rate of contact surfaces were determined. The greatest values of friction forces are identified in the direction opposite to the body's movement, the least values are in the direction of normal pressure force. Negative values of the sliding friction force characterize the direction of friction force in the direction of the body's movement. The wear rate is largely influenced by the movement speed of the body, and the wear depth is influenced by the value of force applied to the moving body.

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