MODEL ADHESION WEAR OF FRICTION SURFACE

МОДЕЛЬ АДГЕЗИОННОГО ИЗНОСА ПОВЕРХНОСТИ ТРЕНИЯ

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Abstract: *The article deals with forming the adhesive bond of bodies at the crystal lattice level. There is offered a mathematical model for determining the adhesion wear. There are carried out laboratory tests for model validation. There is found that the amount of adhesive wear is nonline-arly dependent on the surface roughness inclination angle.*
***KEYWORDS**: FRICTION, WEAR, ADHESION, MATEMATICS MODELING*

1. Introduction

Adhesion of steel surfaces is usually described in terms of the dispersion forces. Many existing adhesion models do not take into account the molecules adhesion within the solid body and the presence of irregularities on the parts surfaces. In the process of friction machine parts are exposed to adhesive wear. Moreover, in general, the amount of adhesive wear depends on the number of surface interacting cycles (n). Work [2] is dedicated to determining adhesive wear at individual surface contact (n = 1). Approaching the surfaces of two bodies at a distance forms adhesive bond FB3 (Fig. 1).

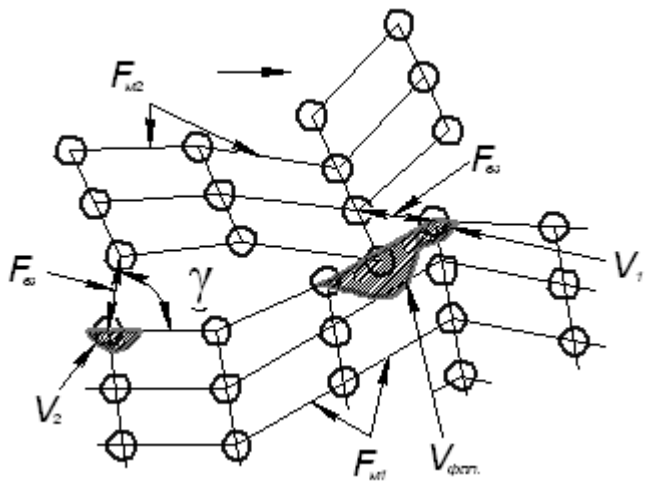


Fig. 1 Surfaces interaction during the adhesion at the nanoscale

There is also an intermolecular interaction in the volume of the forces themselves FM.. In-termolecular force and adhesion force can be determined by relationships proposed in work [1].

2. Results and Discussions

Let us assume that body 2 has the highest possible intermolecular force FM2=>max and ad-hesive wear of the body is not possible. Then, upon application of the shear load to body 2 there occurs adhesive wear of body 1, which visually represents the tension load on the surface.

Let us assume that the volume of the unit adhesive tear-out is determined by the intermo-lecular interaction force in the body FM. Then it is required to define vectors l, forming the vol-ume of tear-out. For a body having a crystal structure the vector direction can be determined by the shape of the unit cell, and the vector value is determined by the interplay of the two neigh-bouring molecules in the chosen direction. For example, steel, whose basic structure is austenite, the direction and the number of vectors that determine the amount of tear-out.

Thus, the vectors defining the scope of a single tear-out are located in three mutually per-pendicular planes, the angle between them is 45 degrees. The task of determining the scope of a single tear-out is reduced to determining the figure volume bounded by vectors l.

In order to build a mathematical model let us number the molecules on which vectors l are directed and assign the vector an index of the molecule to which it is directed. We note in par-ticular that vectors l1…l8 lie on the surface of the body, vectors l9…l13 are directed from the sur-face deep into the body. Let us construct a three-dimensional body model, built on top of 18 vec-tors in three-dimensional space. Assume that the body is an ellipsoid of revolution.

Approximately volume of the figure bounded by 13 vectors can be determined by the de-pendence

$$V = \frac{1}{12}[l_{10}(l_1 + l_9)(l_8 + l_2) + l_{13}(l_7 + k_9)(l_8 + l_6) + \\ + l_{12}(l_5 + l_9)(l_6 + l_4) + l_{11}(l_3 + l_9)(l_4 + l_2)]$$

From practice it is known that adhesion is carried out by digging to a depth significantly greater than the intermolecular distance of two neighbouring molecules. For this reason, we can-not say that the adhesive wear occurs to a depth greater than the intermolecular distance in the unit cell. Molecule located inside the body volume, communicates with a larger number of neighbouring molecules kk,, than a molecule located on the surface body and having a certain number of uncompensated bonds v1. Moreover, generally the number of possible neighbouring molecules k=kk+v1 is defined from the crystal lattice of the body.

The numerical value of the vectors l is by factors determining adhesion tension load. At the same time it should be noted that the actual surface profiles have irregularities such as roughness and subroughness. Thus, the adhesive bond FB3 is formed on surfaces disposed in relation to each other at a predetermined angle γ. The vector value l depends on the angle volume γ, because part of the body volume disposed closest to the top of asperity easier yields to tension load. Then the expression for l has the form

$$l_i = \left| \frac{v_1 F_{вз}}{k F_м G} tg\gamma \right|$$

where G - is shear modulus; k – is the possible number of neighbouring molecules; $k_k = k - v_1$ – is the actual number of neighbouring molecules.

It should be noted that the vectors directed deep into the body have the number of neigh-bouring molecules which is equal to the total number of possible molecules, $k = k_k$, then for vectors disposed on the surface

$$l_i = \left| \frac{F_{вз}}{F_м G} tg(F_{вз}, F_м) \right|,$$

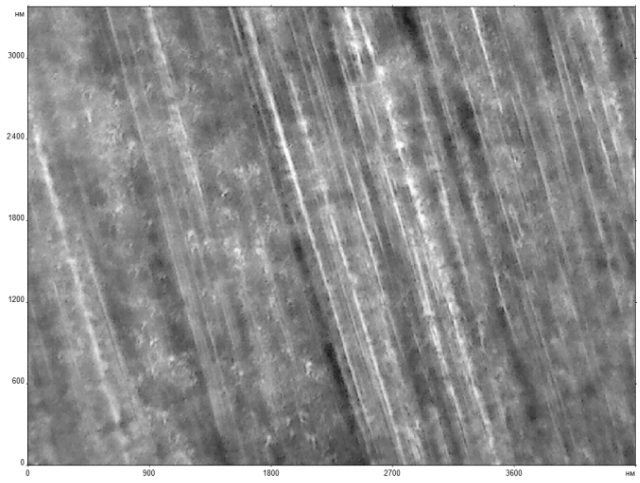
aimed deep into the body

$$l_i = \left| \frac{v_1 F_{вз}}{k F_м G} tg(F_{вз}, F_м) \right|.$$

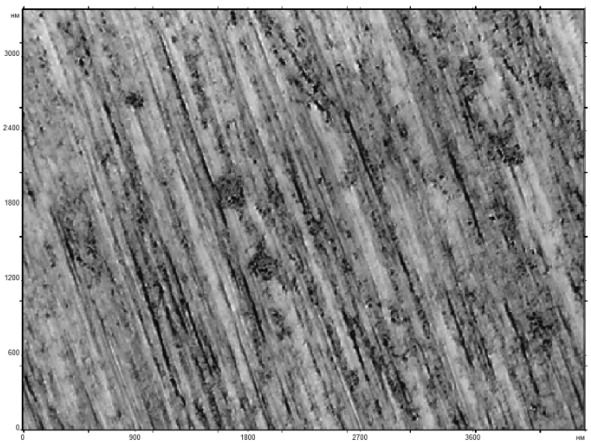
Formulas for calculating these parameters is given in works [1].

3. CONCLUSION

In order to test this theory, the experimental study of samples was conducted on the installation SAV10. Before the experiment samples of steel 1045 (*Ra* = 0.025) were purified by polar and non-polar solvent. In order to fix the surface before the test (2a) samples were examined under an optical microscope at a magnification 10000 fold.



a)



b)

Fig. 2. The surface of steel 45:
a) before forming the adhesive cut-away; b) after forming the adhesive tear-out.

Adhesive bond was considered formed when sample 2 is not detached from specimen 1 by gravity. Sample 2 was connected to a force sensor, sample 1 was rigidly secured to the mounting surface. By applying a force to the sensor sample 2 was displaced. Adhesive bond was considered broken at a time when there was a displacement of the sample relative to the other, then the surface of the samples was investigated under the microscope (Fig. 2b). The resulting dark spots were considered tear-out, formed as a result of adhesive wear.

The surface area and the wear-out depth were determined by 10 stains on 6 surface shots, after which the obtained values were averaged. The volume of tear-out is calculated as half of the ellipsoid volume

$$V = \frac{2}{3}\pi abc$$

where a, b, c - the ellipsoid axis.

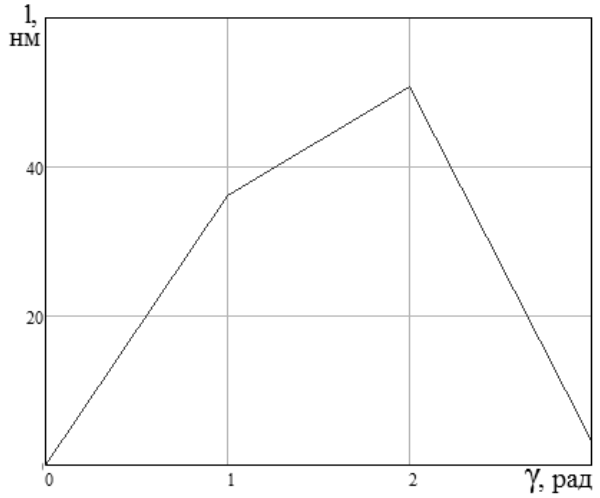
According to the above-mentioned relationships there was counted the volume of single tear-out based on the conditions that the tested steel has austenitic structure $k = 18$, the shear modulus of steel $G=79\cdot10^9$ Pa, the distance between the centres of the particles $r = 3.495$ *nm* [3], compensated distance $z_0=2.86$ Å [2], Hamaker's constant $A_{\mu}=45\cdot10^{-24}$ J [3].

The initial data, the results of calculations and experiments are given in Table 1.

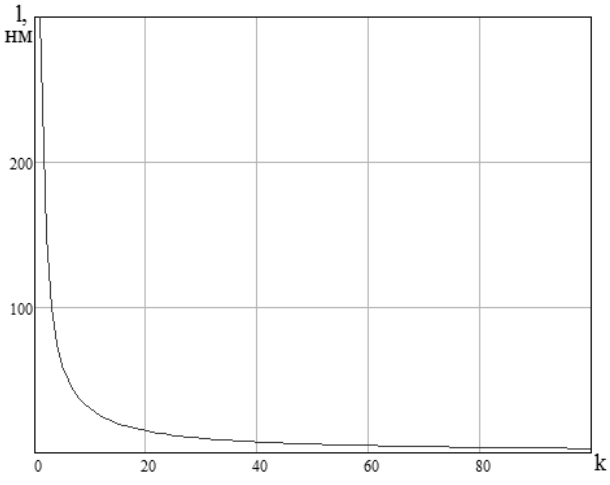
Table 1: Determination of adhesive tear-out volume

Calculated parameter	l_2	l_4	l_6	l_8	l_9	V, x10^5
Calculated, nm	59,651	59,94	59,65	59,94	16,57	1,241
Experiment, nm	54,43	66,30	54,43	66,30	16,65	1,258

Thus, there is a proximity of experimental and theoretical calculations. By theoretical expressions there were plotted the dependency graphs of the wear vector length *l* on the irregularities angle γ (Fig. 3a) and the number of possible neighbouring molecules *k* (Fig. 3b).



a)



b)

Fig. 3 Dependence of the wear vector length on:
a) the inclination angle of irregularities γ to the adhesive bond (if $k = k_k$);
b) number of possible neighbouring molecules k (for $\gamma = 68^0$).

As can be seen from Fig. 5, vector l increases, if angle $\gamma = 0^0 \ldots 115^0$ and decreases with angles $\gamma = 116^0 \ldots 180^0$. With the increasing number of possible neighbouring molecules wear is re-

duced, which means that the larger molecules the unit cell contains and the smaller the distance is between them, then it is less prone to adhesion. Using proposed in work [1, 4] model of adhesive wear there is calculated an equation for determining the scope of a single adhesive tear-out. In accordance with the model of adhesive wear volume depends nonlinearly on the profile inclination angle and the crystal structure of the steel. In future, using the methods suggested in the works, it is possible to obtain a general expression for the determination of a single adhesive tear of steel with any structure.

4. REFERENCES

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