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Results of the Experimental Evaluation of the Effect of Surface Roughness and the Load on the Mechano-Chemical Processes at the Boundary Sliding Friction

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Abstract

The article presents experimental data on the influence of the roughness and the load on the mechano-chemical processes at the boundary sliding friction. It was found that the use of electrometric method for assessment of the mechano-chemical processes occurring in the frictional contact area allows one to determine the duration of plastic and elastic-plastic deformation and the electrical conductivity, and the product of these indicators was suggested to be taken as a criterion for anti-wear properties of lubricants allowing to estimate their propensity to form protective boundary layers.

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Keywords: boundary friction; surface roughness; the diameter of the wear scar; mechano-chemical process; electrical conductivity; plastic and elastic-plastic deformation.

There are two mechanisms at a sliding friction, carry in contribution into the friction force (coefficient of friction): adhesion phenomena on the contact and deformation processes [1-4]. Contribution adhesive constituent becomes insignificant at friction by scabrous surface due to the decrease in the actual contact area, and the role of the deformation component increases [5,6]. Due to the absence of the general classification of the mechanism of formation and separation of the study of wear particles research in the field of wear are limited to establishing the factors his accelerating or retarding.

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In the works of V.E. Panina degradation of the surface layer of the friction material is considered from the standpoint of structural levels of plastic deformation and physical mesomechanics [7,8], the basis of which is to describe the deformation of the surface layer as a motion macro and mesovolume material to the scheme " shear +

rotate" [9-15]. This scheme allows the deformation of the material and the formation of discrete sizes of wear particles present as a result of the formation of the surface layer structure of the fragments, which turn relative to each other it causes early occurrence of microcracks and local discontinuity and ends separating material fragments from the surface of the wear particles.

A major role in the fight against wear acquire chemical reactions that result in the friction surfaces to create a protective film. At the boundary friction, there are two opportunities for the protective films on the metal surface: they are generated by friction due to the activity of the lubricant, or formed during the processing of parts [16].

P.A. Rebinder indicated that the adsorption layer becomes chemical compounds with metal advisable character to not occurs friction mechanical disruption of the base material and it reduces to a continuous process of forming a film of a novel chemical compound and its wear [17]. To create a chemical compound on the friction surfaces of the lubricant containing additive is introduced phosphorus, sulfur and chlorine, however, the physicochemical characteristics of these compounds under the influence of friction and surface roughness and the load on formation of insufficiently studied.

The purpose of research. Determine the quantitative parameters of the effect of surface roughness and the load on the formation of the protective boundary layers in sliding.

The method of the study. In the as lubricant mineral engine oil used Lukoil standard 10W-40 SF / CC. Tests were conducted on three balls friction machine with the scheme of "ball-cylinder" friction [18]. The difference of this machine from the fourball in the fact that each of the balls interact with the cylinder on an individual track friction, and through one of the balls in friction passed a constant current (100 mA) from a stabilized source of 3V to study mechano-chemical processes occurring in the frictional contact [19, 20]. In the as probationary samples were used balls ø 9,5 mm from the bearing № 204 and the upper wing of the ball bearing № 7208 with a diameter of 80mm. Parameters friction : 13H load, sliding speed of 0,68 m / s, test temperature 80 ± 0,1ºC. The current flowing through the frictional contact was set in a static position of the ball and the cylinder thermostat TR101 and recorded through a transducer signal is fed to a computer for recording.

Results and discussion. The roughness of the surface of the cylinder set by means polishing abrasive sandpaper different grits: M250 GOST 6456-82, 14A M40 M76 GOST 6456-82 и P 1200 EcoWet FinCand. Dependencies wear scar diameter are presented in fig. 1 as a bar graph. It is shown that with increasing roughness increases the wear by reducing the actual contact area.

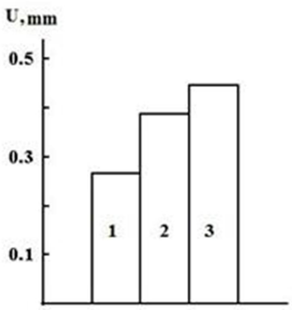

Fig.1. The histogram depending on the diameter of the wear scar grit abrasive sandpaper : 1 – P1200; 2 - 14A M40 M76; 3 - 14A12H M250.

The current flowing through the frictional contact (Fig. 2) from a stabilized power supply also depends on the surface roughness because the rate of formation of protective boundary layers decreases with increasing roughness. Analysis chart changes current on the frictional contact reduce determine the duration of plastic and elastic-plastic deformation and the influence of this parameter on the wear value. The analysis results are summarized in table. 1.

Table 1. Test Results Lukoil mineral engine oil 10W-40 SF / CC, depending on the surface roughness

Crocus cloth	Diameter spot wear, mm	The total duration of the deformation, min.	Coefficient conductivity, K_c	The criterion of anti-wear properties
P1200	0,267	16,7	0,10	1,7
14A M40 M76	0,387	37,5	0,20	7,5
14A12H M250	0,447	13,8	0,85	11,7

According to the presented data (Table 1) conductivity coefficient friction of contact increases with increasing surface roughness, and The total duration of the deformation of plastic and elastic-plastic deformation of the smallest at the maximum roughness, and largest during processing cage crocus cloth with an average grain size. Thus there is an optimum surface roughness when forming a contact area for the maximum duration.

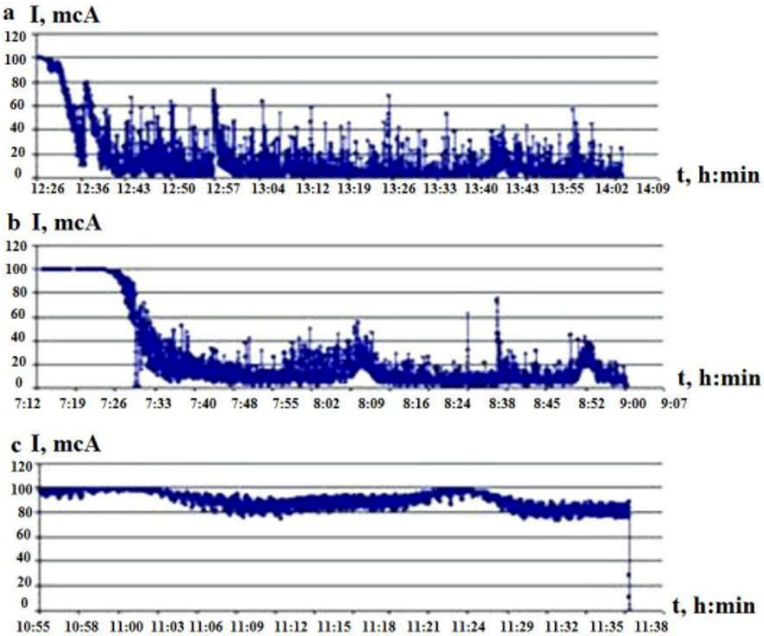

Fig.2. Graph current flowing through the frictional contact of test time and grit abrasive sandpaper:
(a) P1200; (b) 14A M40 M76; (c) 14A12H M250.

As a result studies proposed criterion anti-wear properties of lubricants K_a , defined by the expression

$$K_a = t_g \cdot K_C \tag{1}$$

where t_g - the duration of the plastic and elastic-plastic deformation; K_C - conductivity coefficient.

$$K_C = I / I_3 \tag{2}$$

where I and I_3- current flowing through frictional contact and the predetermined current value 100 mcA.

The criterion of anti-wear properties K_a has a linear dependence on the spot wear diameter (Fig.3). Regression equation depending U = f (K_a) has the form

$$U = 0,0184K_a + 0,24 \tag{3}$$

The correlation coefficient is 0,99.

The applicability of the proposed K_a criterion the tested study influence of loading on the formation of the protective boundary layers on the current flowing through the frictional contact. The study results are summarized in Table 2. According to Table 2 increasing load the duration of the deformation of plastic and elastic-plastic deformation increases, and the average value for the load conductivity coefficient of 23 to 43 H stabilized.

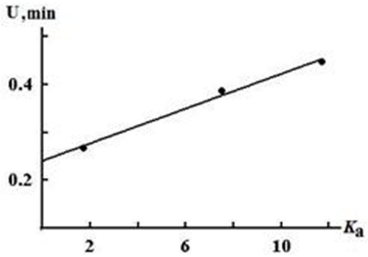

Fig.3. The Dependence of spot wear diameter of the criterion anti-wear properties mineral motor oil Lukoil standard 10W-40 SF / CC.

Table 2. Results of the study on the influence load on the anti-wear properties of mineral oil Lukoil standard 10W-40 SF / CC

Diameter spot wear, mm	Load, H	The total duration of the deformation, min	Coefficient conductivity, K_c	Contact pressure H/mm^2	The criterion of anti-wear properties
0,273	13	12,5	0,2	222,2	2,5
0,287	23	17,9	0,15	355,5	2,7
0,30	33	42,5	0,15	466,8	6,4
0,313	43	48,0	0,15	559,2	7,2

On the Fig. 4 shows the dependence of the Diameter spot wear on the load. It should be noted that the load was applied in steps. First, within 5 minutes the applied load 3H then added load of 10 H. This procedure excluded the hardening of the friction surface.

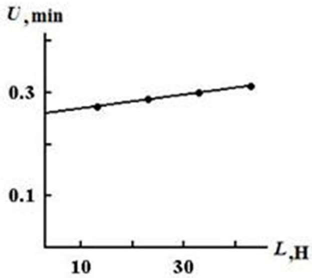

Fig. 4. The dependence of spot wear diameter of the load during the test mineral motor oil Lukoil standard 10W-40 SF / CC.

In the diagrams of current flowing through the frictional contact (Fig. 5) can to see moments the apps of additional load, wherein current increased to a maximum value (100 mA), and then decreased to the minimum value. The total deformation was calculated for each load, and sum up. On the chart it is clear that with the increase in load especially from 33 to 43 H oscillations current decrease , that is, the formation of the protective boundary layers more stably, however additional load is applied and within 2 min. the is torn pellicle, when the she is re-formed, the current drops to a minimum value.

With increasing load was increased pressure in contact (Fig. 6) and the bearing capacity of the boundary layer. Regression equation depending P= f (L) has the form

$$P = 11{,}364L + 70 \tag{4}$$

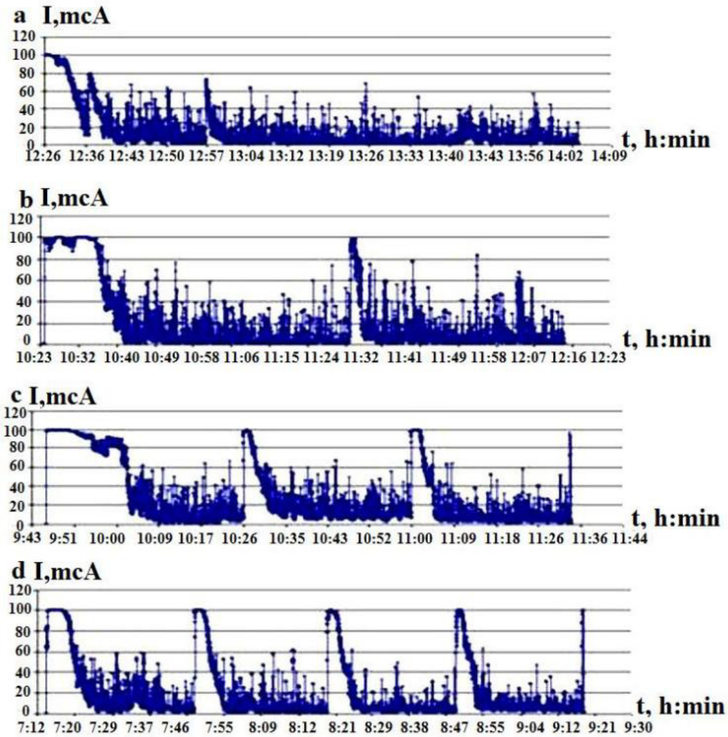

Fig.5 Diagram of changing the current flowing through the frictional contact of the time and load when tested mineral motor oil Lukoil 10W-40 SF / CC: (a)13 H; (b) 23 H; (c) 33 H; (d) 43 H.

With the change of the load 13 to 43 H pressure in the contact is increased from 222 to 559 H / mm^2, and spot wear diameter increased by only 15% from 0.273 to 0.313 mm. Analysis charts showed that an increase in the protective boundary layers are destroyed instantly and formed in approximately two minutes.

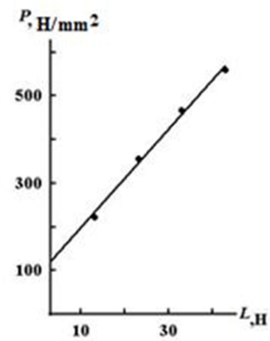

Fig.6. The dependence pressure on the frictional contact of the load during the test mineral motor oil Lukoil standard 10W-40 SF / CC.

The dependence of spot wear diameter from criterion anti-wear properties lubricant (Fig. 7) in the range of loads between 13 and 43 H is linear . The regression equation according to U = f (K_a) has the form:

$$U = 6,5 \cdot 10^{-3} K_a + 0,26 \qquad (5)$$

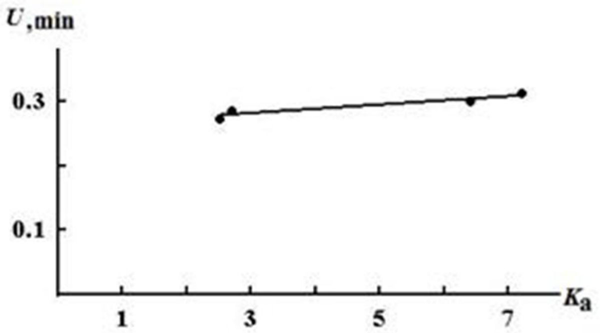

Fig. 7 dependence of spot wear diameter from anti-wear properties criterion mineral motor oil Lukoil standard 10W-40 SF / CC.

Based on the studies proved that the use of electrometric method for assessing the mechanochemical processes occurring on the frictional contact allows you to determine the duration of plastic and elastic-plastic deformation and electrical conductivity, the product of these indicators suggested as a criterion anti-wear properties of lubricants, which allows to evaluate their tendency to form protective boundary layers.

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