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Results of the Study of Anti-Wear Properties of the Exhaust Motor Oil

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Abstract

The results of the testы of exhaust partially synthetic and synthetic motor oils are presented the criterion for evaluation of anti-wear properties of oils was justified, a method for determining of the state of the filtration system was proposed, mechanochemical processes occurring in the frictional contact area. The article also specifies the main indicators that determine the anti-wear properties of the motor oil, such as the length of the plastic and elastic-plastic deformation, electrical aging products, motor oils and strength of the protective film boundary at a sliding friction.

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Keywords: motor oil; anti-wear properties; electrical conductivity coefficient of friction contact; the diameter of the wear sca; plastic, elastic plastic and elastic deformation.

The resource of engine oils in internal combustion engines installed by manufacturers on the basis of motor testing and is regulated by the car mileage or running hours. Such a system replacement of oil does not encourage use of diagnostic tools control. The most severe for mechanical assemblies is boundary lubrication regime. Under these conditions, the ability of the lubricant layer to carry the load in the contact surfaces depends on the frictional interaction of the lubricant with operating mechanisms parts (physical adsorption, chemisorption) [1-5].

The main factor, which in the conditions of boundary lubrication greatest influence on the coefficient of friction is the temperature in the contact surfaces of the parts [6-8].

Anti-wear and extreme pressure properties of the oil are important indicators of its quality and selection criteria in the selection, because they are responsible for the life and reliability of friction units. Motor oil should be seen as

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a constructive element of the engine that is included in a complex tribological system, so control of the tribological properties are almost always carried out by testing in a real full-size engines [9-14].

The purpose of research. Determine the anti-wear properties of used motor oil and establish a criterion for their connection with the experimental concentration of impurities.

Research methods. The sample of used oil photometrically scanned to determine the total concentration of the products of aging, and then centrifuged and again photometrically scanned to determine the soluble products. The difference between the coefficients of absorption of the light flux before and after centrifugation determines the amount of insoluble aging products.

Used motor oils have been tested in the three-ball friction machine with the scheme of "ball-cylinder" friction, and each of the three balls interact on an individual track, and through one of the balls passed a constant current (100 mA) from a stabilized 3V power supply [15-18] . It is possible to determine the duration of the plastic, the elastic-plastic and elastic deformation of the elastic and frictional contact conductivity, which depends on the processes of formation of wear scar and boundary layers. The friction parameters were: load of 13 N, the sliding speed of 0.68 m/s, test temperature 80 º C.

Results and discussion. Partially synthetic and synthetic motor oils are fused during maintenance of cars in the service locations subjected to research. Samples of oil after thorough mixing, exposed to direct photometry at a thickness of the photo- metric layer of 0.15 mm [19,20]. The part of used oil samples centrifuged (8000 rev / min) and re-photometrically scanned. It is possible to determine the concentration of total, soluble and insoluble products of aging. The light absorption stream factor used oils was from 0.17 to 0.61 units. This confirms the imperfection of the existing oil change system of mileage and points to the reserves in more efficient use motor oils, as well as the need to introduce in the state enterprises motor oils control during the operation of equipment.

The research results are summarized in Table, which shows that after centrifugation used oil the light absorption stream factor Ka = 0.014 decreased to 0.29, that is 2-fold compared to the original oil. The proportion of insoluble products varies from 0.067 to 0.594. In this case, the proportion of insoluble products in the used oil characterizes the state of the filtration system. In the case where the proportion of insoluble products differ slightly from the light absorption stream factor Ka of original oil, the condition of the filtration system is unsatisfactory.

From among the partially synthetic oils should be mentioned oil number 2 and 4 and synthetic - 4 and 5, which are contaminated with insoluble products in consequence of the low productivity of filters. Therefore, the use of the photometer and centrifuge allows to evaluate condition of the oil filter.

Table 1. Results of tests used motor oil

Number of samples	The concentration of impurities			The diameter of wear scar, mm (U)	The total duration of deformation, min	The conductivity coefficient , K_c	The reduced density of insoluble impurities, $Di = Ka.i/S$	Coefficient characterizing the mechano-chemical processes, $Km.ch = td\ K_c$	The reduced density of total impurities, $Dt = Ka.t/S$
	total, $Ka.t$	soluble, $Ka.s$	insolubl e, $Ka.i$						
	Partially synthetic motor oil								
1	0,173	0,106	0,067	0,34	18,8	0,3	0,74	5,6	1,9
2	0,406	0,043	0,363	0,38	23,1	0,55	3,21	12,7	3,6
3	0,516	0,294	0,22	0,4	50	0,25	12,5	12,5	4,1
4	0,594	0,274	0,32	0,26	7,5	0,2	1,5	1,5	11,2
	Synthetic motor oil								
1	0,18	0,1	0,08	0,3	18,7	0,4	1,13	7,5	2,53
2	0,3	0,09	0,21	0,28	13,8	0,4	3,39	5,5	4,8
3	0,34	0,15	0,19	0,28	9,4	0,6	3,06	5,6	5,5
4	0,4	0,014	0,386	0,32	13,1	0,65	4,83	8,5	5,0
5	0,61	0,016	0,594	0,62	110	1,0	1,97	110	2,0

Dependencies anti-wear properties of used motor oil on the concentration of total (*Ka.t*) and insoluble products (*Ka.i*) are presented in Figure 1. For partially synthetic oils (curve 1, Fig. 1a) is characterized by decrease in anti-wear properties with increasing factor (*Ka.t*) to a value of 0.5, and then the anti-wear properties are increased.

For synthetic used oils (curve 2, Fig.1b) anti-wear properties are stable up to the value of factor *Ka.t* = 0.35, and then they deteriorate. Effect of insoluble aging products (*Ka.i*) on the part of anti-wear properties of synthetic oils (curve 1, Fig. 1b) has no clear dependence, and for synthetic they are stable up to the value *Ka.i* = 0.4, and then decreases.

When you wear the main influence on the anti-wear properties of used oils should have aging products formed during engine operation. It is therefore proposed *P* index defined as the ratio of concentration aging products to the area of the wear spots (Fig. 2), called the aging index of the density of products on frictional contact.

To partially synthetic of used oils (curve 1, Fig. 2) with growth factor *Ka.t* reduced density common products *Pc* to increase frictional contact, and for synthetic oils (curve 2 in Fig. 2 a) is set as the increasing and decreasing sections. For synthetic of used oils there is a maximum value of the index at a value of *Ka.t* = 0.35 units.

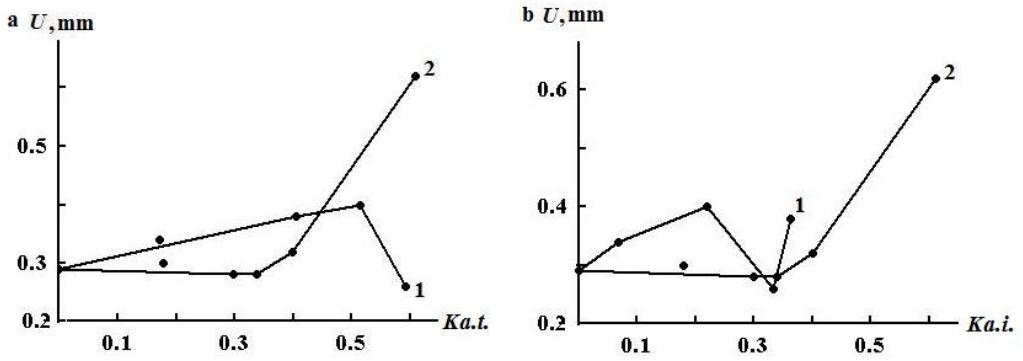

Fig.1. (a) dependence of diameter wear scar and the concentration of total; (b) the insoluble product:
1 - synthetic partially used oil; 2 - synthetic used oils.

The reduced density of the insoluble products of aging of used oils *Pi* (Fig. 2 b) frictional contact is subject to fluctuations, and dependence *Pi* = *f* (*Ka.t*) has a maximum at *Ka.t* = 0.4 for partially synthetic and synthetic oils.

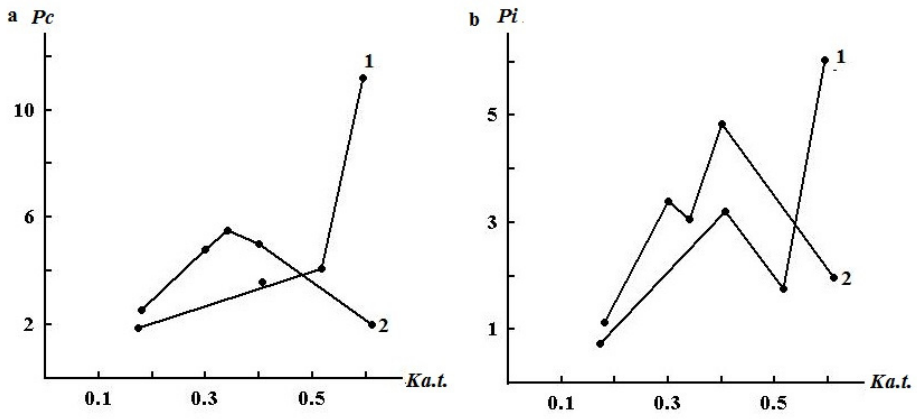

Fig. 2. (a) dependence of the reduced common density *Pc* ; (b) insoluble *Pi* products of aging
to frictional contact by the light absorption stream factor *Ka.t.*

Processes occurring on the frictional contact evaluated on current value, depending on the type of deformation of the microscopic irregularities, oil propensity to form protective boundary layers separating the friction surface by acid number.

Diagrams of record current flowing through frictional contact are shown in Figure 3 for the partially synthetic of used oils. The diagram shows areas where the current is a predetermined (100 mA), thus there is a metal contact of friction surfaces by plastic deformation. During this period, the formation of the actual contact area. The areas where the current decreases to a certain value, characterize the duration of the elastic-plastic deformation. Reducing the current intensity depend on the formation at the friction surfaces of chemical compounds with the metal products of aging. The site describes the the duration of current stabilization of elastic deformation and the ratio between the rates of formation and destruction of the protective layer on the friction surfaces.

When evaluating used oil antiwear properties friction load on the machine was set in stages. After heating to 80 ° C oil was applied load 3 N and after 5 minutes of the test was added 10 N. This excluded effect of hardening the friction surface and provides a more stable results.

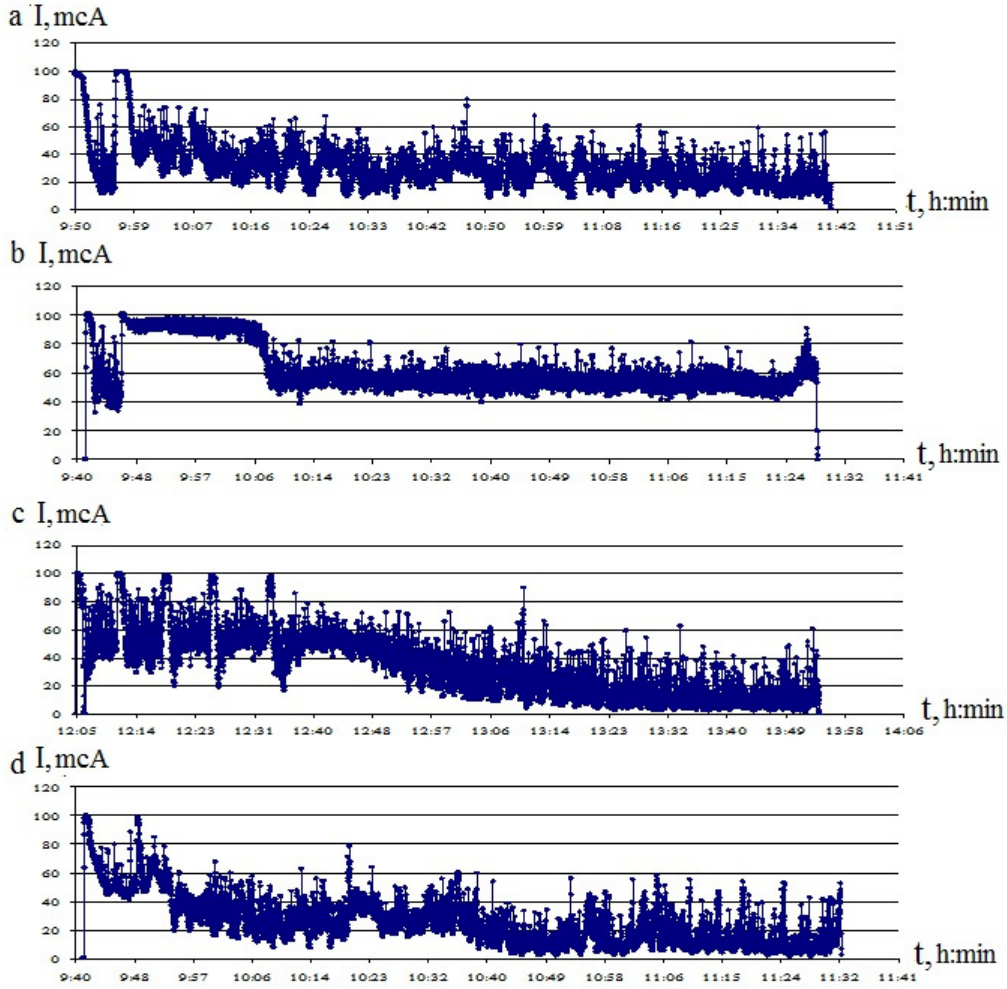

Fig.3. Dependence of the current flowing through the frictional contact between the light absorption stream factor *Ka.t* and testing time of used partially synthetic motor oils. (sample number 1-4, see Table).

Diagrams of current flowing through frictional contact constructed in order to increase the light absorption stream factor, which characterizes the total concentration of oil aging products. From the diagrams can be seen that the length of the plastic and elastic-plastic deformation is different, and it determines the diameter of the wear scar. The value of the current stabilization and oscillation amplitude is also dependent on the light absorption stream factor and expressed conductivity coefficient K_c frictional contact, defined ratio current of the flowing through the contact to the given current (100 mA).

Analogous diagrams obtained when testing used synthetic oils (Fig. 4). With an increase in the light absorption stream factor amplitude of the oscillations of the current in the areas of its stabilization decreases, and when the coefficient $Ka.t = 0.61$ (Sample 5), the current is almost equal to the specified $Kc \approx 1$ and wear is maximum. In this regard, it can be assumed that the value of the coefficient Kc in the area stabilizing effect on the wear of the friction pair.

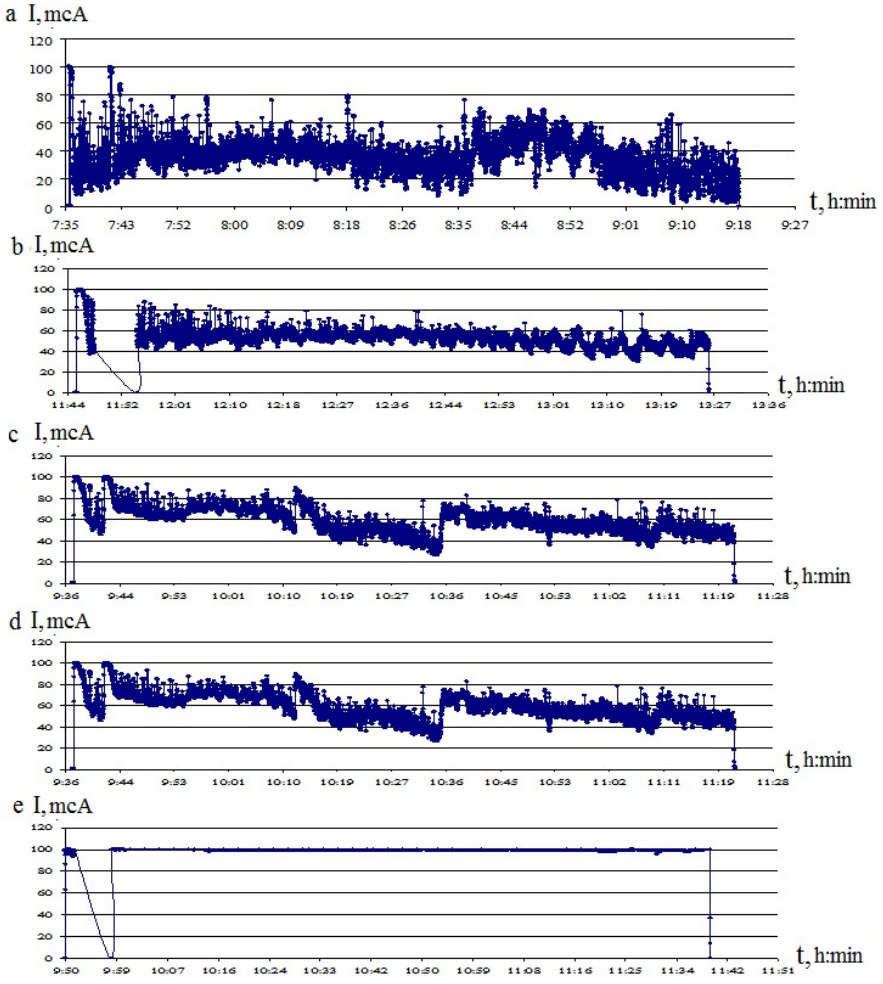

Fig. 4. Dependence of the current flowing through the frictional contact of the light absorption stream factor *Ka.t* and the test of time used motor oil (sample number 1-5, see Table).

Communication between the wear amount and the total duration of elastic plastic and plastic deformation is shown in Fig. 5, which shows that the wear increases with increasing total deformation time and described by a polynomial

$$U=at_d^2+bt_d+c, \quad (1)$$

where *a, b* and *c*- factors characterizing the impact of oil aging products on the amount of deformation.

The magnitude of wear affect mechano-chemical processes occurring on the frictional contact, the intensity of which depends on the concentration of active additives, oil aging products in their composition and chemical activity, so they determined the amount of current stabilization and amplitude of its oscillations. These processes are characterized by the tendency of oil to the formation of complex compounds on the friction surfaces and the adhesive strength of the basis of materials of the friction pair. In this regard, there is provided a coefficient characterizing the mechanochemical processes *Km.ch.* defined by the product:

$$Km.ch. = t_d \cdot K_c \quad (2)$$

where *td*- time total deformation; *Kc* - conductivity coefficient of friction contact.

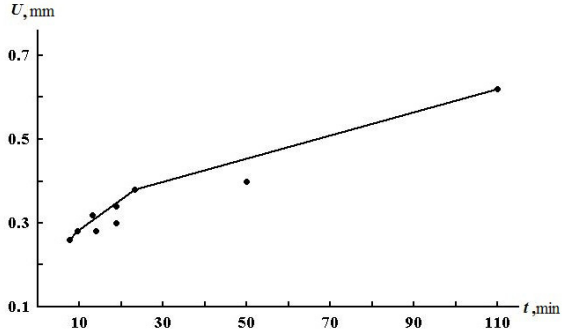

Fig. 5. Dependence of wear scar diameter on the length of the plastic and elastic-plastic deformation during the test used motor oils.

The physical meaning of this coefficient is that it characterizes the anti-wear properties of used motor oil as it affects the deformation that determines the formation of the actual contact area, and the ability of anti aging products on the friction surfaces to form protective films for steady wear.

A clear dependence between parameters of the coefficient *Km.ch* and the light absorption stream factor *Ka.t.* is not observed due to differences in the concentrations of active additive, common, soluble and insoluble products of aging, as in partially synthetic and synthetic waste oils, as well as their electrical conductivity and the ability to form protective boundary layers.

However, the intensity of mechanochemical processes in frictional contact determines the wear of friction pair, as evidenced by the dependence presented in Fig.6. With the increase in coefficient wear *Km.ch.* increases according to a linear

$$U = a\ Km.ch. + b, \quad (3)$$

where *a* - coefficient characterizing the wear rate; *b* - coefficient characterizing wear when tested commercial oil.

On the basis of the tests used motor oil it is shown that the use of a photometer, centrifuges, and the friction of the machine allows you to organize the state control over the oil in the engine operation and to maximize the efficiency of their use, which is aimed at reducing operating costs.

It was found that the length of the plastic and elastic-plastic deformation is one of the main indicators that determine the anti-wear properties of engine used oil.

Results of the study found that the value of the light absorption stream factor for partially synthetic and synthetic used oil should be in the range of 0.4 to 0.45. At which the working oil to be replaced.

Application electrometric method for testing lubricants to determine the parameters of mechano-chemical processes occurring in the frictional contact, the electrical motor oil aging products and the strength of the protective boundary layers in sliding.

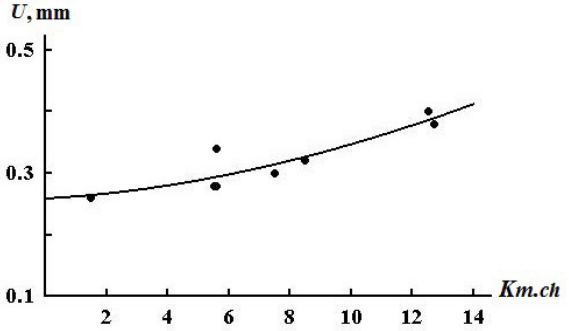

Fig. 6. Dependence of wear scar diameter on the coefficient characterizing the mechano-chemical processes in the test used motor oils.

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