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Control Methods of Operational Properties of Lubricants

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Abstract. Some results of thermal-oxidation and temperature stability testing of motor oils are presented. The catalytic influence of metals on oxidizing processes in lubricants with use of steel 45 was determined. The parameters for identification of oils by groups of operational properties and quantity indicators of the influence of metals on oxidizing processes of lubricants are offered.

1. Introduction

The most urgent problem of modern mechanical engineering is rational application of the lubricants determining durability and non-failure operation of machines. Requirements to lubricants are increasing because it is necessary to provide wear resistance of materials of pair friction in a wide range of loadings, speeds and temperatures.

High temperatures in a combination with active action of oxygen and catalytic action of metal surfaces result in destruction of additives both a base basis and in intensive oxidation of oils with formation of insoluble oxidation products which drop out in a deposit. As a result of oil oxidation, its physical and chemical and operational properties change, viscosity and corrosion activity increases, anti-wear properties worsen.

The temperature has the basic influence on the lifetime of lubricants and causes oxidation and destruction of their base basis and additives. The parameter of thermal-oxidation stability is entered for estimation of anti-oxidizing properties of lubricants which is regulated by specifications and standards on their manufacture on acid number and the sludge formation period [1-3].

A standard method of four-ball lubricant determination of temperature stability with the use of the machine of friction [4] and measurement of the specific size of carbonization lubricants do not provide obtaining objective information.

These methods do not allow investigating lubricant destruction, its intensity and boundary conditions. Therefore, search and substantiation of new methods for research of lubricant temperature stability is a topical problem, solution of this problem will make possible to choose lubricants, to monitor and predict their condition while in service.

The aim of this research is to determine the temperature stability and thermal-oxidation stability of lubricants and substantiation of the criteria for temperature stability and quantity indicators of influence of metals on oxidizing processes of lubricants.

2. Materials and Methods. Experimental Procedure

To study motor oils of a various base basis we have been chosen: mineral Mobil 10W-40 SJ/CH and M-10-$Г_{2к}$; in part synthetic Zic 5000 10W-40 SH/CG-4; synthetic Pentosynth 5W-40 SH/CF.

The tests of motor oils for temperature stability were carried out in a range of temperatures from 140 up to 300 °C in a glass beaker on the device for determination of temperature stability [4]. The tested oil of 50 g was tested within 6 hours, and each subsequent test of the oil test was performed at temperature by 20 °C above the previous one. The temperature of the test was maintained automatically. The method of direct photometric measurement is one of the standard methods for diagnostics of lubricant oils. After testing of each sample the photometer, viscometer and electronic scales were used to determine the factor of absorption of the light flux, viscosity and volatility, respectively. Photometric measurement of oils was carried out for a layer thickness of 2 mm [5].

Thermal-oxidation stability testing of motor oils was carried out for samples of commodity oilM-10-$Г_{2к}$ weighing 100 g. Heating was carried out in a glass beaker, where the oil was mixed up using a glass mixer with a frequency of 300 rev/min. The temperature was set discretely with 10 degree step. Each sample was tested in an interval of temperatures from 150 ºC up to 180 ºC. After each test, auxiliary devices: a photometer, viscometer and electronic scales to determine the corresponding parameters of optical properties, viscosity and volatility were used. Testing of lubricant oils was carried out up to the value of the light flux absorption equal to 0.7–0.8 units or until the change in the relative viscosity was no more than by 25 %. Comparative evaluation of the changes in the properties of the marketable lubricating oil and the oil and steel was conducted for the factor of the catalytic action [5].

3. Results

Results of the test of the thermal-oxidation stability of oils.

Catalytic and inhibitor influence of metals on oxidation of lubricants was estimated using the obtained experimental dependences. Figure 1 shows graphic dependence of the factor of the light flux absorption on time and temperatures.

At temperatures of 180 °C and 170 °C, insignificant reduction of time of serviceability (curves $1^{/}$and $2^{/}$) of the lubricant oil, as a result of the catalytic actions of the steel 45 sample can be observed. It should be noted that at high temperatures, metal does not have essential influence on the processes a lubricant oxidation, in this case the most adverse factor being the temperature loading destroying additives and the basis of the mineral motor oil. This means that temperatures 180 °C and 170 °C are critical for the given mark of the motor oil.

At temperature 160 °C (curves 3 and $3^{/}$), we can observe an inhibitor action of steel 45 caused by formation of protective chemisorption layers on the sample surface which perform a protective function and interfering increase of speed of chemical transformations in oil. At temperature 150 °C (curves 4 and $4^{/}$), a reverse tendency is observed. Hence, at lower temperatures, chemical reactions of formation of a blanket on the surface of the solid body proceed very slowly, therefore, metal provides catalytic action on the lubricant. At high temperatures, these processes are accelerated, which is characterized by a dark blanket on the sample surface.

The obtained graphic dependences of the factor of the light flux absorption K_a on time and temperatures are described by the polynom of the following kind:

$$K_a = At^3 + Bt^2 + Ct + D, \quad (1)$$

where A and B are the factors describing intensity of formation of oxidation products; C is the factor dependent on the base basis of the lubricant and quality of additives; D is the factor describing the initial optical properties of oil; t is time of the test.

Influence of temperature and steel 45 on change of viscosity during thermal-oxidation stability tests o is expressed by the factor of the relative viscosity K_μ, and the determined relation is [5]:

$$K_\mu = \mu_0 / \mu_{ini} \quad (2)$$

where μ_o is viscosity of the tested oil, cS; μ_{ini} is initial viscosity (commodity oil), cS.

The dependence of the relative viscosity on time and temperature of test $K_\mu = f$ (t) is shown in figure 2. The viscosity of the lubricant in many respects depends on modes of operation and on the degree of its contamination by insoluble products of oxidation, and also on its dispersing-stabilizing properties.

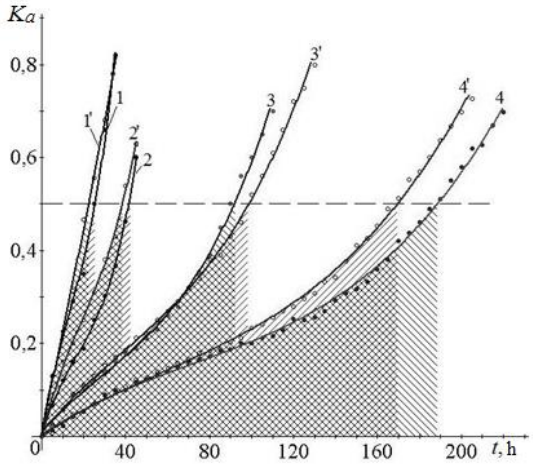

Figure 1. Dependence of light flux absorption factor K_a on temperature and time of the motor oil test M10-Г$_2$к: 1-4 - commodity oil at temperatures 180°C, 170°C, 160°C, 150°C; 1$^/$–4$^/$, respectively, for steel 45.

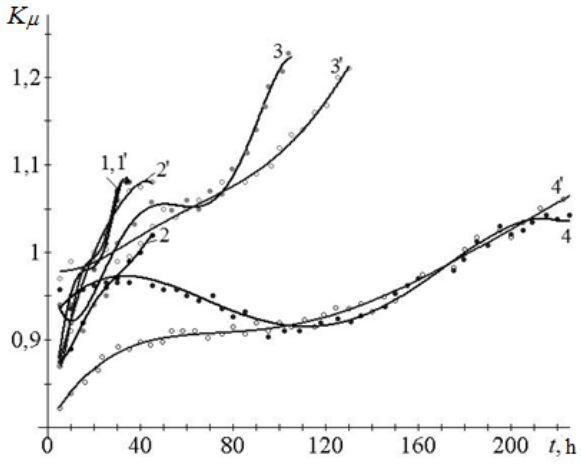

Figure 2. Dependence of the viscosity relative factor on time and temperatures of mineral motor oil testing M10-Г$_2$к (see figure 1).

As can be seen in the functional dependence, as the thermostatting time increases, viscosity grows for each of temperatures. At high temperatures (curves 1, 1$^/$–2, 2$^/$) an intensive increase in viscosity is observed that specifies high speed of formation of insoluble oxidation products. On the other hand, high temperature models aggressive operation conditions of the machine or an assembly, and consequently, high temperature of oil in micro volume.

A similar tendency of the increase in viscosity is shown at long testing time at temperatures of 160°C and 150 °C (curves 3, 3$^/$ and 4, 4$^/$), that is typical of mineral motor oils and reflects destructions of viscous additives which are found in the basis of the mineral oil.

Dependences of volatility on time and temperatures of the test (Fig. 3) characterize the presence of distillate fractions in oil.

High volatility molecules of a lubricant is observed at temperatures 180°C and 170°C, which is caused by high speed oxidizing processes and evaporation of easy fractions. At the subsequent temperatures more flat dependences (curves 3, 3$^/$ and 4, 4$^/$) describe gradual process of distillate fractions evaporation of lubricant oil.

Influence of metals on thermal-oxidation stability of lubricants is determined by the factor of the catalytic actions K_c in the expression:

$$K_C = S_{Ka} / S_{Ka.c}, \quad (3)$$

where S_{Ka} is the area limited by the curve of the dependence of the factor of the light flux absorption K_a on time in testing the commodity lubricant without catalyst; $S_{Ka.c}$ is the area limited by the curve of the dependence of the factor of the light flux absorption K_a on time in testing the commodity lubricant, with catalyst.

A quantity indicator of the catalytic action of steel on the oxidizing processes proceeding in the lubricant is determined under the Equation (3). It is established, that at the value $K_c > 1$, the process of motor oil oxidation M-10-G$_{2к}$ is accelerated, and at the value $K_c < 1$ slows down.

Hence, at the accelerated process of oxidation, as a result of the shipped metal in the tested oil, steel 45 is the catalyst of oxidation, that is the additional factor promoting acceleration of the ageing processes of a lubricant at the value of factor K_c<1 - inhibitor oxidations.

4. Results of the testing the temperature stability of oils

Influence of temperature on oil optical properties change was estimated by the factor of the light flux absorption K_a (figure 4). The dependences of the light flux absorption factor on temperature have two characteristic sections of various intensity for mineral (curve 1), partially synthetic (curve 2) and pure synthetic (curve 3) oils are established. It means that the oils of different bases have distinctions in structure and concentration of the destruction product and their influence on optical properties. The second section is characterized by stabilization of factor K_a confirming the end of the destruction process.

The destruction of the mineral partially synthetic and pure synthetic oil occurs in the first section and can be described by the equations of the second order

$$K_a = \alpha_1' T^2 + \alpha_2' T + b', \tag{4}$$

where α'_1 and α'_2 are the factors describing the intensity of formation of destruction products; b' is the factor dependent on the basis.

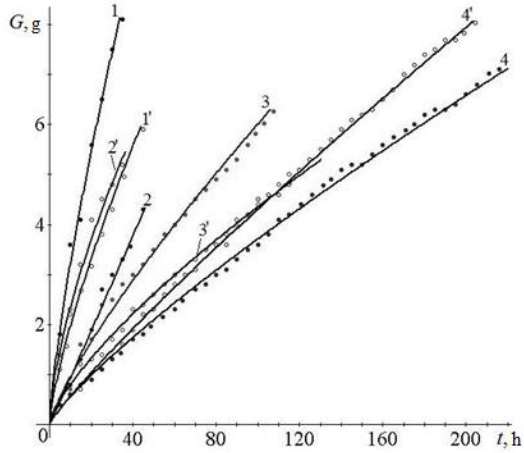

Figure 3. Dependence of volatility from time and temperature of test (see figure 1).

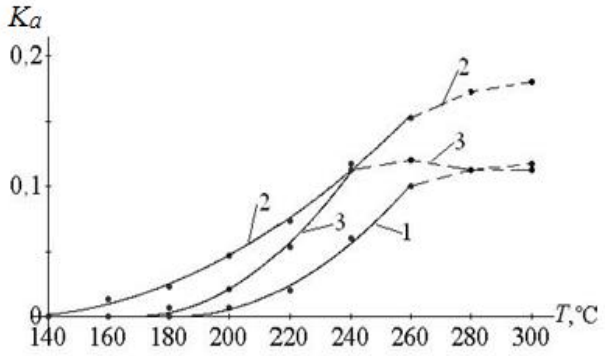

Figure 4. Dependence of the factor of light absorption flux K_a on temperature T in testing oils: mineral Mobil 10W-40 SJ/CH (1); in part synthetic Zic 5000 10W-40 CG-4/SH (2); synthetic Pentosynth 5W-40 SH/CF (3).

The factors of the destruction process are the values of temperatures at the beginning of destruction and its end, so, for mineral oil (curve 1) they are 185 °C and 260 °C, respectively, for partially synthetic oil (curve 2), they are 140 °C and 260 °C, and for pure synthetic oil (curve 3), they are 170°C and 240 °C.

The speed of the destruction as a quantity indicator of the destruction process for oils of various bases is determined and described by the derivatives of the first order Equations (5)

$$V_{Ka} = 2 \cdot \alpha T + c \tag{5}$$

where α is the factor describing a corner inclination of dependence $V_{Ka}=f(T)$; c is the factor describing destruction resistibility of oils; T is temperature of test, [°C].

With increase in temperature of test from 200 °C, reduction of viscosity that testifies about destruction a basis of oils is observed.

We suggest, that in destruction process with the increase in temperature optical properties of oil, speed of destruction process change, therefore, the offered complex criterion of temperature stability can be determined by the expression

$$K = V_{Ka} \cdot (T_2 - T_1), \quad (6)$$

where V_{Ka} is the destruction speed of the oil, 1/°C; T_1 is the temperature when destruction started, °C; T_2 8 is limiting temperature of the destruction, °C.

The more the temperature stability of the lubricant, the less is the value of factor K. The value of factor K is used to provide the operational properties:

at K<0,15, oils belong to group SL;
0,15 ≤K<0,3, oils belong to group SJ;
0,3 ≤K<0,5, oils belong to group SH;
0,5 ≤K<0,8, oils belong to group SG;
K≥ 0,8, oils belong to group SF.

The given criterion allows identification of oils by the groups of operational properties.

5. Conclusion

Methods for determining the temperature stability and thermal-oxidation stability of lubricants allow us to determine a new factor for estimation of destruction processes and oxidation of commodity lubricants which extends information on their quality, helps to make the right choice of the design stage of machines and units and to improve the system of classification and identification of oils by the groups of operational properties.

An integrated criterion of the catalytic action of metals on oxidizing processes of the lubricant is offered. It has been identified that at high temperatures, chemical adsorption of surface-active substances of the additives alloying the base oil occurs, and the processes of blanket formation proceed intensively. Thus, the superficial energy of the solid material influence the processes of self-organizing tribology systems, and the lubricant, one of the constructive elements of units and machines, is currently used.

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