The method of monitoring the indicators of thermo-oxidative stability of mixtures of motor oils

B I Kovalsky, V I Afanasov, V G Shram*, Yu N Bezborodov and O N Petrov
Siberian Federal University, 82 Svobodny Avenue, Building 6, Krasnoyarsk, 660041, Russia

*E-mail: Shram18rus@mail.ru

Abstract. The results of a study of mixtures of mineral motor oil M-10G2k with 5% by weight of Castrol 0W-30 SL/CF synthetic oil are presented. The redistribution of thermal energy is considered, which was investigated by the dependence of the increment of the absorption coefficients of the light flux and evaporation on the time and temperature of the test. The effect of the synthetic additive on the optical properties, volatility, coefficient of thermo-oxidative stability, kinematic viscosity when testing the mixture in the temperature range from 160 to 180 °C is established.

Partially synthetic engine oils with starting properties exceeding mineral oils are widely used in the operation of internal combustion engines. However, at present, there is no methodological basis for substantiating the ratio of the concentration of the components of the mixture. Therefore, the purpose of this study is to determine the effect of a synthetic additive not only on the starting properties of the oil, but also on their potential resource [1], [2], [3], [4], [5]. The mineral oils M-10G2k and their mixtures with 5% by weight of Castrol 0W-30 SL/CF synthetic oil were examined. Mixtures were studied at temperatures of 180, 170 and 160 °C. The following control and testing tools were used for research: a device for thermostating of oils, photometric devices, a low-volume viscometer, and electronic scales [6].

The research technique is as follows [7], [8]. A sample of the oil or a mixture of constant mass was subsequently thermostatically controlled at temperatures of 180, 170 and 160 °C with stirring by a mechanical stirrer with a rotation speed of 300 rpm. The temperature and speed of the mixer during the test were maintained automatically. The tests were terminated when the light absorption coefficient reached a value of 0.7–0.8. Moreover, after every eight hours of testing, the samples of thermostated oils (commodity and mixtures) were weighed, the mass of the evaporated oil was determined, a part of the sample (2 g) was taken for direct photometry and calculation of the absorption coefficient of the light flux $K_a$ at a photometric layer thickness of 2 mm.

$$K_a = \frac{300 - R}{300},$$

(1)

where 300 – photometer readings in the absence of oil in the cuvette, $\mu$A; $R$ – photometer readings with an oil-filled cuvette, $\mu$A.
A portion of the oxidized oil sample (9 g) was used to measure kinematic viscosity. After measuring the oil from the cuvette of the photometer and viscometer, they were poured into a glass of a temperature control device, which was reweighed, and the tests continued for the next eight hours.

Thermo-oxidative stability $K_{tos}$ of the studied mixtures was determined by the sum

$$K_{tos} = K_a + K_G,$$

where $K_G$ – evaporation coefficient.

$$K_G = \frac{m}{M},$$

where $m$ – mass of evaporated oil during the study, $g$; $M$ – mass of oil sample before testing, g.

The coefficient of thermo-oxidative stability characterizes the amount of thermal energy absorbed by the products of oxidation and evaporation.

Figure 1 shows the results of a study of mineral motor oil M-10G2k and its mixture with 5% by weight of Castrol 0W-30 SL/CF synthetic motor oil in the temperature range from 180\degree \text{C} and 160\degree \text{C}. According to the data for the test temperatures of 180\degree \text{C} and 160\degree \text{C}, the synthetic additive reduces the intensity of the oxidation processes, and for the test temperature of 170\degree \text{C} it accelerates them (curve 2\textsuperscript{'}). The volatility of oil mixtures decreases compared to M-10G2k oil for the entire range of studied temperatures (figure 2). Therefore, the synthetic additive Castrol 0W-30 SL/CF improves the motor properties of the oil M-10G2k.

Redistribution of thermal energy was studied by the dependence of the increment of the light flux absorption coefficients $\Delta K_a$ and evaporation $\Delta K_G$ on the time and temperature of the test 170\degree \text{C} (figure 3 a and b). This is confirmed by synchronous and non-synchronous changes in these indicators. A synthetic additive increases the increment of the coefficient $\Delta K_a$ (curve 2) and decreases the value of the increment $\Delta K_a$ (curve 2).

Kinematic viscosity was estimated by the coefficient of relative viscosity, determined by the ratio of the viscosity of the oxidized oil to the viscosity of the commodity (figure 3 c). According to the data, the synthetic additive increases the viscosity after 60 hours of testing by 16\%, and M-10G2k oils without additives by 22\%, i.e., the oxidation products formed in a mixture of oils differ in concentration from products formed in mineral oil.
The dependences of the coefficient of thermo-oxidative stability on the time and temperature of the test (figure 4) show that at test temperatures of 180 and 160 °C, a synthetic additive reduces this indicator, i.e. the processes of transformation into mixtures of oils proceed at lower values of thermal energy. At a temperature of 170 °C, transformation processes occur at higher values of thermal energy.

The homogeneity of the compositions of the oxidation products was investigated by the dependence of the coefficient of thermo-oxygenative stability on the absorption coefficient of the light flux (figure 5). It was found that the synthetic additive (curve 1', 2', 3') changes the slope of the dependence $K_{tos} = f(K_a)$, i.e. at one value of the coefficient of $K_a$, the value of the coefficient of $K_{tos}$ is less for a mixture of oils. The regression equation of dependence $K_{tos} = f(K_a)$ for oil M-10G2k has the form:

$$K_{tos} = 1.08 \cdot K_a,$$

for mixtures $K_{tos} = 1.04 \cdot K_a$.

The dependences of the coefficient of thermo-oxidative stability on the time and temperature of evaporation of the mineral motor oil M-10G2k (curve 1, 2, 3) and its mixture with 5% mass of synthetic Castrol 0W-30 SL/CF (curves 1', 2', 3'): 1, 1' - 180 °C; 2, 2' - 170 °C; 3, 3' - 160 °C.

The dependences of the coefficient of thermal oxidative stability on the absorption coefficient of the light flux and the test temperature of the mineral motor oil M-10G2k (curve 1-3) and its mixture with 5% by weight of synthetic Castrol 0W-30 SL/CF (curve 1', 2', 3'): 1, 1' - 180 °C; 2, 2' - 170 °C; 3, 3' - 160 °C.
The speed of the conversion process for oil M-10G2k is 1.08 units, and for a mixture of 1.04 units. Transformation processes begin when the coefficient $K_{\text{tot}} = 0$.

The relations between the absorption coefficients of the light flux and evaporation (figure 6) are expressed by the coefficient $K_E$ characterizing the proportion redistribution of thermal energy, either in the direction of accelerating the oxidation processes, or - evaporation. A synthetic additive increases the coefficient of $K_E$ by reducing the rate of evaporation at all test temperatures.

The effect of the synthetic additive was evaluated by the coefficient of catalytic effect, determined by the difference between the thermal oxidative stability coefficients obtained for the mineral oil M-10G2k and its mixture with 5% by weight of Castrol 0W-30 SL/CF synthetic oil (figure 7). It was found that the synthetic additive is an inhibitor at test temperatures of 180 and 160 °C and a catalyst at a temperature of 170 °C.

**Figure 6.** Dependence of the $K_E$ coefficient on the time and temperature of testing the mineral motor oil M-10G2k (curve 1, 2, 3) and its mixture with 5% synthetic Castrol 0W-30 SL/CF (curves 1', 2', 3'): 1, 1' - 180 °C, 2, 2' - 170 °C, 3, 3' - 160 °C.

**Figure 7.** Dependences of the catalytic effect coefficient of mixtures of mineral motor oil M-10G2k with 5% by weight of synthetic Castrol 0W-30 SL/CF on the test time: 1 - 180 °C; 2 - 170 °C; 3 - 160 °C.

Conducted experimental studies showed the following results:

- Based on the studies, it was found that the synthetic additive of Castrol 0W-30 SL/CF oil to the mineral motor oil M-10G2k is an inhibitor of oxidation processes at temperatures of 180 and 160 °C, reduces the evaporation of mixtures at test temperatures from 160 to 180 °C, and reduces the kinematic viscosity .
- In the production of partially synthetic motor oils, it is necessary to take into account not only the viscosity-temperature characteristics of oil mixtures, which provide an increase in starting properties during the winter period of operation of internal combustion engines, but also a potential resource taking into account the complexity of the operation of equipment.

References

[1] Wenzel S V 1979 *The use of lubricating oils in internal combustion engines* (Moscow: Chemistry)
[2] Foster N S and Amonnete J E 2001 Derocation of trace levels of water in oil by photo acoustic spectroscopy *Sensors and Actuators* 77 620-4
[3] Barnes M 2002 Fourier transform infrared spectroscopy *Practing oil analysis Magazine*
[4] Kondakov L A 1982 *Working fluids and seals of hydraulic systems* (Moscow: Mashinostroenie)
[5] Kowalsky B I, Shram V G and Lysyannikov A V 2018 Semigraphical Method of Motor Oils Thermal-Oxidative Stability Index Control *Proceedings of the 4th International
Conference on Industrial Engineering. Lecture Notes in Mechanical Engineering pp 873-80

[6] Lysyannikova N N, Kravtsova E G and Kovaleva M A 2018 Control Method of Thermo-oxidative Stability Factors of Synthetic Motor Oil Proceedings of the 4th International Conference on Industrial Engineering pp 1039-48

[7] Kowalski B I, Afanasov V I, Shram V G and Batov N S 2018 The method of monitoring the temperature parameters of the engine oil mixture News of universities. Applied chemistry and biotechnology 4 125-33

[8] Kowalsky B I, Petrov O N, Sokolnikov A N, Shram V G and Agrovichenko D V 2019 Testing results of the method for determining the thermal oxidative stability of lubricating oils News of universities. Applied chemistry and biotechnology 1 129-44