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Classification of motor oils by parameters of thermo-oxidative stability

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Abstract. The results of research of thermal-oxidative stability of motor oils of different underlying fundamentals. Proposed indicators for classification of engine oils, including a potential resource, the temperature of the beginning of the transformation process and the critical temperature. Based on the studies, it is shown that the application of the proposed method for the classification of motor oils allows you to get additional information about their quality, including indicators such as: potential resource, the temperature at which transformations in oil begin and the critical working temperature.

According to GOST 17479.1-85 [1] motor oils are divided into viscosity classes and groups according to their purpose and levels of operational properties. The main operational properties of motor oils include: detergent-dispersant, antioxidant, anti-wear, anti-corrosion and viscosity-temperature [2]. However, in [3, 4], when studying the thermo-oxidative stability of oils, which belong to the same group of operational properties, a significant difference was found in oxidation resistance in the temperature range from 160 to 180 °C. Therefore, the purpose of this research is to test a new method for the classification of motor oils based on their resistance to temperature influences.

For the study, all-season motor oils of various basic bases were selected: mineral Toyota Castle 10W-30 SL and Mobil 10W-40 SC/CC; partially synthetic Rosneft Maximum 10W-40 SL/CF and Zic 5000 10W-40 CG-4/SH; synthetic ALPHAS 5W-30 SN/CF.

The tests were carried out on the following control and testing means: a device for thermostating of oil; photometric device; electronic balance.

The research technique is as follows. A 100 g motor oil sample was poured into a glass beaker of a thermostat and tested at three temperatures of 160, 170 and 180 °C with stirring with a glass stirrer with a rotation speed of 300 rpm. within 8 hours. During the test, the temperature and speed of the stirrer were maintained automatically. After 8 hours of testing, the glass with the oxidized sample was weighed, the mass of the evaporated oil and the coefficient of evaporation were determined K_G.

$$K_G = \frac{m}{M},\qquad(1)$$

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

A portion of the oxidized sample is then taken for photometry and determination of the optical density D.

$$D = \lg \frac{F_0}{F} \qquad (2)$$

where F_0 - the luminous flux incident on the surface of the oil layer in the cuvette of the photometer; F - is the luminous flux passing through a layer of oxidized oil in the cell.

According to the data of D and K_G, the indicator of thermo-oxidative stability of K_{tos} is determined.

$$K_{tos} = D + K_G, \qquad (3)$$

Tests of engine oil continue until the indicator of thermo-oxidative stability of values equal to 0.75-0.8. This technology tests engine oil at other temperatures. Based on the obtained data on the index of thermo-oxidative stability, a graphical dependence of it on the time and temperature of the test is built, which determines the time to reach the K_{tos} value of 0.7, which characterizes the potential resource P of the studied oil at the set test temperatures. According to the potential resource, a graphical dependence of it on the test temperature is built, according to which its rate of change is determined, which characterizes the resistance of the studied oil to the temperature effect.

As an example, consider the technology for determining the critical temperature and potential resource of Toyota Castle 10W-30 SL mineral oil. Figure 1 shows the dependence of the thermo-oxidative stability index on the time and temperature of the test. It is shown that with decreasing test temperature, oxidation processes slow down. To assess the effect of temperature on the processes occurring in the oil, a potential resource indicator is proposed, which is determined by the time the K_{tos} indicator reaches a value of 0.7.
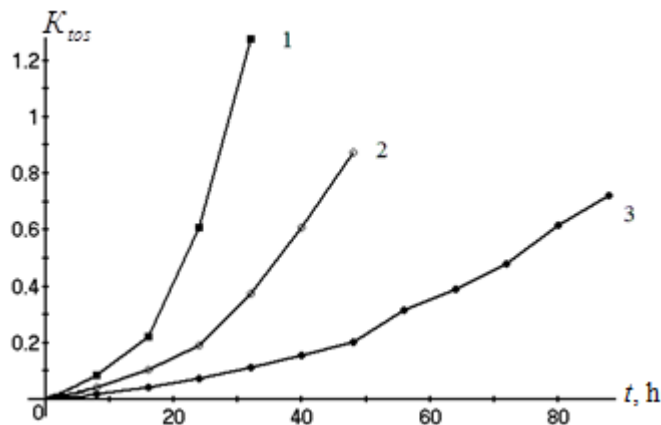

Figure 1. The dependences of the index of thermal oxidative stability on time and temperature of the mineral engine oil test Toyota Castle 10W-30 SL: 1- 180 ºC; 2-170 ºC; 3-160 ºC.

Figure 2 shows the dependence of the potential resource P on the temperature of thermostating of the studied oil. This dependence is described by a second order polynomial, and the regression equation has the form:

$$P = 0.1275 \cdot T^2 - 46.425 \cdot T + 4250.5 \qquad (4)$$

Having solved this equation, we determine the critical working temperature of the studied oil, which amounted to 182 ºC, at this temperature the time to reach the $K_{tos} = 0.7$ indicator will be 24.46 hours, and the time to reach the $K_{tos} = 0.7$ indicator at a temperature of 150 ºC will be 155.5 hours.

The regression equations for changing the potential resource from the test temperature of the remaining engine oils of various basic bases are summarized in the table 1.
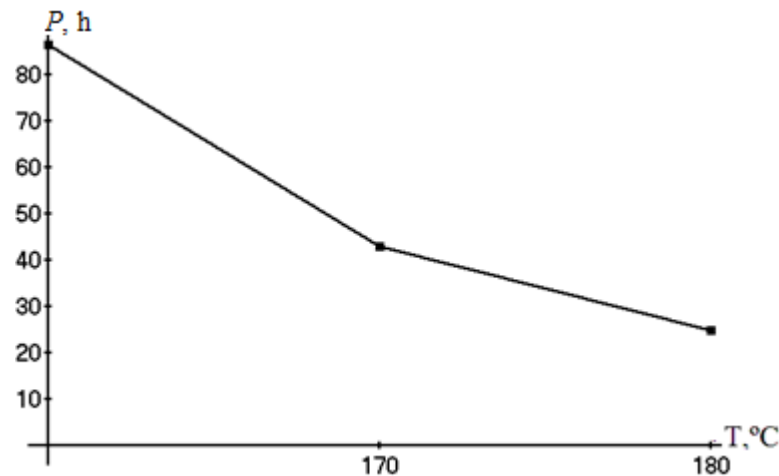
Figure 2. The dependence of the potential resource on the oxidation temperature (at $K_{tos} = 0.7$) of Toyota Castle 10W-30 SL mineral motor oil.

Table 1. The experimental data on changes in the potential resource from the test temperature at a value of the indicator of thermo-oxidative stability $K_{tos} = 0.7$.

Brand of oil	Equation of change of potential resource
Mineral oils:	
Toyota Castle 10W-30 SL,	$P = 0.12785 \cdot T^2 - 46.425 \cdot T + 4250.5$
Mobil 10W-40 SC/CC	$P = 0.0825 \cdot T^2 - 33.035 \cdot T + 3323.85$
Partially synthetic oils:	
Rosneft Maximum 10W-40 SL/CF,	$P = 0.31 \cdot T^2 - 110.3 \cdot T + 9841$
Zic 5000 10W-40 CG-4/SH	$P = 0.105 \cdot T^2 - 43.35 \cdot T + 4509$
Synthetic oil ALPAHS 5W-30 SN/CF	$P = 0.165 \cdot T^2 - 59.75 \cdot T + 5434$

Using the equations (table 1), one can determine the potential resource of the studied oils at lower and higher temperatures. These equations represent a parabola, the vertex of which corresponds to a critical temperature at which the resource is minimal, and the processes of oxidation and evaporation proceed at a high speed, causing anomalous phenomena [5-7]. Therefore, the critical temperature is an indicator that is recommended to be used to compare different oils and their classification.

By differentiating the equations (table 1), one can determine the average rate of change of the potential resource V_p for any to a critical temperature and use it to compare lubricating oils.

The thermo-oxidative stability index takes into account the oxidation and evaporation processes together, therefore, for the classification of motor oils of different base bases, it is important to know the temperature of the onset of the conversion processes in the oil during thermostating and the critical temperature at which anomalous phenomena occur, causing the microroughness of the friction surfaces to set [8]. To determine these temperatures, it is necessary to use the dependences (figure 1) and determine the time of change in the K_{tos} indicator when it reaches a value of 0.1 and its value for 8 hours of testing at different temperatures. These dependencies are presented in figure 3 *a* and *b*.
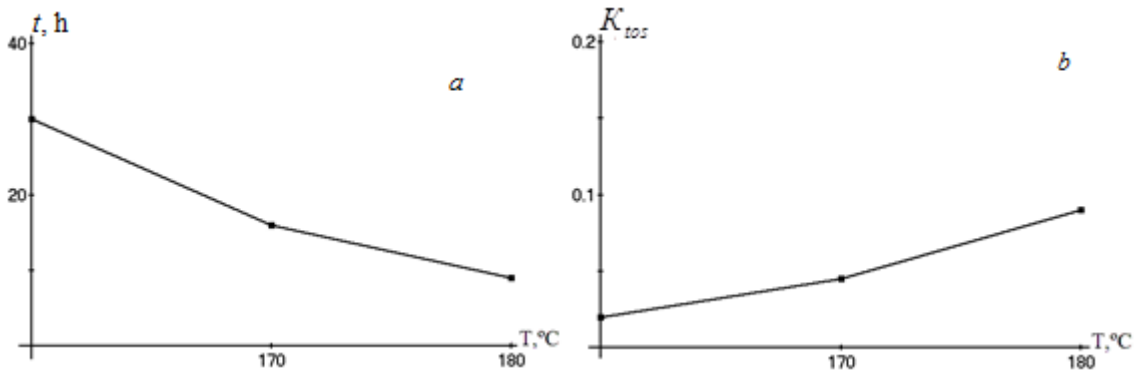
Figure 3. Dependences of the time of the change in the index of thermo-oxidative stability $K_{tos}= 0.1$ (*a*) and the K_{tos} indicator after 8 hours of testing (*b*) on the test temperature.

These dependences are described by a second-order polynomial, and the regression equations have the form for:

test time (figure 3*a*)

$$t = 0.035 \cdot T^2 - 12.95 \cdot T + 1206 \tag{5}$$

K_{tos} indicator (figure 3*b*)

$$K_{tos} = 1 \cdot 10^{-4} \cdot T^2 - 0.0305 \cdot T + 2.34 \tag{6}$$

Solving these equations, we determine the critical temperature of the test oil, which is 185 ºC and the temperature of the start of conversion in oil, which is 152 ºC.

In a similar way, we determine the potential resource, the temperature of the onset of conversion processes in oil, and the critical temperature for other oils. Indicators recommended for comparing various motor oils and suggestions for their classification are summarized in table 2.

Table 2. Experimental data on the study of motor oils of various basic bases.

Brand of oil	Potential resource P, h. (at $K_{tos} = 0.7$, $T = 170$ ºC	Transformation temperature in oil, ºC		Classification Compliance
		Beginning	Critical	
Mineral oils: Toyota Castle 10W-30 SL,	43	152	185	overpriced
Mobil 10W-40 SC/CC	93	170.7	203.0	understated
Partially synthetic oils: Rosneft Maximum 10W-40 SL/CF,	49	155.5	179.0	Complies with gasoline engines
Zic 5000 10W-40 CG-4/SH	174	172.2	201.0	understated
Synthetic oil ALPAHS 5W-30 SN/CF	45	161.0	186.1	overpriced

According to the data in table 2, the smallest potential resource was established at a test temperature of 170 ºC for Toyota Castle 10W-30 SL mineral motor oil - 43 hours, which is explained by the low temperature of the beginning of the transformation processes – 152 ºC. The classification of this oil

corresponds to the classification of partially synthetic oil Rosneft Maximum 10W-40 SL/CF, however, its potential resource is higher and amounted to 49 hours and the temperature of the onset of transformations is also above 155 °C, therefore the classification of mineral oil is overestimated.

A high potential resource was established for the Zic 5000 10W-40 CG-4/SH partially synthetic engine oil - 174 hours, which is confirmed by the high temperature of the onset of conversion processes in the 172.2 °C oil, therefore its classification is underestimated in comparison with the SL group. The classification of Mobil 10W-40 SC/CC mineral motor oil is similarly underestimated, in which the potential resource was 93 hours, and the temperature of the beginning of the transformation processes was 170.7 °C. Based on the results of research on motor oils, it can be argued that the oil classification system requires improvement.

Conducted experimental studies found:

Based on the studies, it is shown that the application of the proposed method for the classification of motor oils allows you to get additional information about their quality, including indicators such as: potential resource, the temperature at which transformations in oil begin and the critical working temperature.

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