

Control Method of Thermo-Oxidative Stability Factors of Synthetic Motor Oil

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Abstract The article presents the research results of effect of temperature on a number of thermo-oxidative stability factors, including optical density, volatility, thermo-oxidative stability index and potential resource. Method of research of lubricating oils for thermal-oxidative stability is described and includes the application of testing devices and control, such as a device for thermostating of the oils, photometer for direct electrophoretic oxidized oils and electronic scales. Dependences of optical density, potential resource, volatility, thermo-oxidative stability factors with time and testing temperature of synthetic motor oil, on the basis of which new factors of thermo-oxidative stability were proposed and including the temperatures of the onset of oxidation, volatility and temperature transformations in oil, and the critical temperatures of these processes. The article proposes a grapho-analytical model for definition of thermo-oxidative stability factors at all temperatures without research based on oil testing under two temperatures, which possible to reduce the labour inputs of the research more than two fold. The proposed control method of thermo-oxidative stability factors allows us to expand information on the quality of lubricants by determining the onset temperatures of oxidation, evaporation and temperature conversions in oil, as well as critical temperatures of this processes. It also allows to improve the classification system by the groups of operational properties.

Keywords Optical density, Volatility, Thermo-oxidative stability, Grapho-analytical model, Potential resource, Critical temperatures.

1. Introduction

Thermo-oxidative stability is an operational factor, which determines ageing resistance of lubricating oils. There are many control methods for this factor [1-18], part of which are standardized, however consumers are not provided with the full information about resilience of lubricating oils to temperature effects. For that reason, finding new methods of control and gauge for thermo-oxidative stability is a crucial task, which expands information about quality of oils and their informed choice for differently loaded equipment.

The purpose of researches to develop a control method for thermo-oxidative stability factors, which will allow expanding information about resilience of lubricating oils to the temperature effects in the wide range of temperature tests.

2. Methodology

Research method involved the use of the following test and control instruments: oil thermostating device, a photometer for direct photometry of oxidized oils at a thickness of a photometric layer of 2 mm and electronic scales. The technical characteristics of the devices are given in the monograph [19-21].

Multigradesynthetic oils ALPHA'S 5W-30 SN/GF and LUKoil Luxe 5W-30 SL/CF were chosen for the research.

According to the research method, a sample of oil with a mass of 100 ± 0.1 g was poured into a glass beaker of the thermostating device at atmospheric pressure while stirring with a glass stirrer with a rotation speed of 300 rpm. The temperature of thermostating was set discrete and was maintained automatically with an accuracy of ± 2 °C. The duration of the test was determined by the time when the optical density of the oxidized oil reached the value of 0.5 to 0.6 units. Each 8-hours of test, a glass beaker with an oxidized oil sample was weighed, the mass

of the evaporated oil was determined, part of the sample (2 g.) was selected for direct photometry and determination of the optical density D .

$$D = \log 300 / P \quad (1)$$

where 300 – photometer readings when cuvette is devoid of fuel, uA; and P – photometer readings when cuvette is filled with oil, uA;

Thermo-oxidative stability of synthetic oil was estimated from change in optical density D , volatility G and the coefficient of thermo-oxidative stability P_{tos}

$$P_{tos} = D + K_G \quad (2)$$

where K_G – volatility index

$$K_G = m / M \quad (3)$$

where m and M are the mass of evaporated oil during time t , and the mass of oil before the tests, g.

Thermo-oxidative stability coefficient P_{tos} takes into account effect of temperature on the change in optical density and evaporation, so it allows us to compare various oils according to this index.

3. The results of research

Fig. 1 shows variation of optical density with time and testing temperature of ALPHA'S 5W-30 SN/GF synthetic motor oil. It was found that as the temperature of the test was lowered from 190 °C to 160 °C, the oxidation time to the optical density $D=0.2$ increased from 23 hours to 157 hours, i.e. increased by 6.83 times.

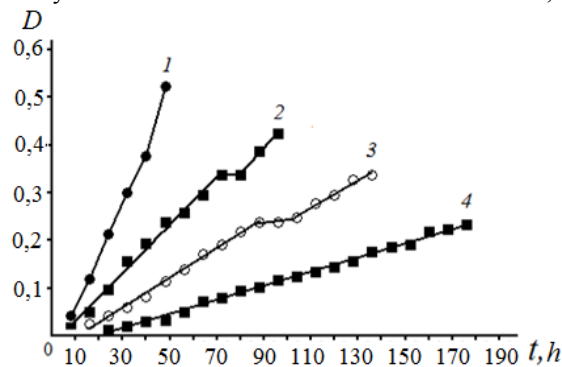


Fig. 1. Dependence of optical density on time and testing temperature of ALPHA'S 5W-30 SN/GF synthetic motor oil: 1 – 190 °C; 2 – 180 °C; 3 – 170 °C; 4 – 160 °C

Using dependence (Fig. 1), it is possible to determine potential resource P of the oil under study at each temperature (Fig. 2a). These dependences are described by a polynomial of the second degree and regression equations for oils have the following form

$$\text{ALPHA'S 5W-30 SN/GF} \quad P = 0.1975T^2 - 75.735T + 7294.25 \quad (4)$$

$$\text{LUKoil Luxe 5W-30 SL/CF} \quad P = 0.275T^2 - 105.35T + 10113 \quad (5)$$

Indexes of correlation are 0.998 and 1.

According to data in Fig. 2a, potential resource of LUKoil Luxe 5W-30 SL/CF synthetic oil exceeds ALPHA'S 5W-30 SN/GF potential resource at temperatures below 175 °C.

One of the important thermo-oxidative stability factors is the onset temperature of oxidation processes, which is determined by the dependence of the optical density on the test temperature during 24 hours (Fig. 2b). These dependences are described by a polynomial of the second degree and regression equations for oils have the following form

$$\text{ALPHA'S 5W-30 SN/GF} \quad D = (2.1 \times 10^{-4})T^2 - 0.06696T + 5.35 \quad (6)$$

$$\text{LUKoil Luxe 5W-30 SL/CF} \quad D = (9 \times 10^{-4})T^2 - 31T + 26.71 \quad (7)$$

Indexes of correlation are 0.997 and 1.

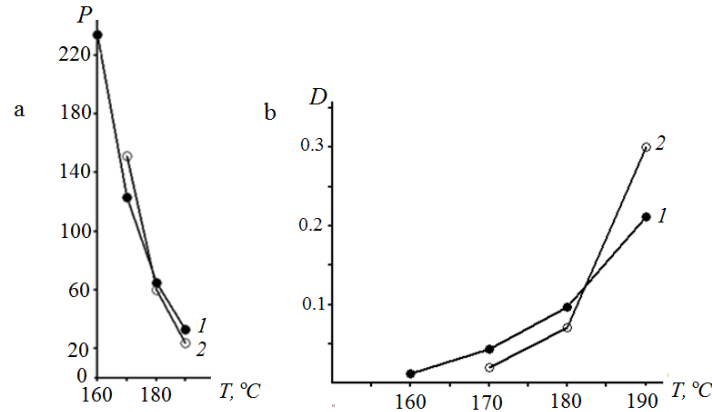


Fig. 2. (a) Dependence of synthetic motor oils potential resource on testing temperature: 1 –ALPHA'S 5W-30 SN/GF; 2 – LUKoil Luxe 5W-30 SL/CF (optical density $D=0.3$); (b) Dependence of the optical density on the testing temperature of synthetic motor oils: 1 – ALPHA'S 5W-30 SN/GF; 2 – LUKoil Luxe 5W-30 SL/CF (testing time – 24 hours)

Derivatives of equations 7 and 8 determine the average rates of change in optical density with testing temperature. If we equate them to zero, it is possible to determine the onset temperatures of oxidation processes. The results are 159.4°C for ALPHA'S 5W-30 SN/GF and 172.2°C for LUKoilLuxe 5W-30 SL/CF.

Another important thermo-oxidative stability factor is critical operability temperature of oils under study, which is determined by the time of optical density reaching the value of $D=0.05$ (Fig. 3).

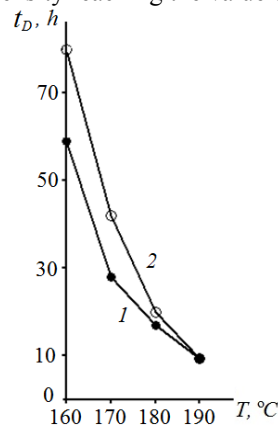


Fig. 3. Dependence of time by which optical density reaches the value of $D=0.05$ on testing temperature of synthetic motor oils: 1 – ALPHA'S 5W-30 SN/GF; 2 – LUKoil Luxe 5W-30 SL/CF

These dependences are described by a polynomial of the second degree and regression equations for oils have the following form

$$\text{ALPHA'S 5W-30 SN/GF} \quad t_D = 0.05875T^2 - 22.157T + 2099.3 \quad (8)$$

$$\text{LUKoil Luxe 5W-30 SL/CF} \quad t_D = 0.06875T^2 - 26.397T + 2543.3 \quad (9)$$

Indexes of correlation are 0.99 and 0.99.

Derivatives of equations 9 and 10 determine the rates of oxidation at each temperature. If we equate them to zero, it is possible to determine the critical temperature of oils under study. The results are 188.5°C for ALPHA'S 5W-30 SN/GF and 192°C for LUKoilLuxe 5W-30 SL/CF.

Fig. 4a demonstrates dependence of volatility on time and testing temperature of ALPHA'S 5W-30 SN/GF synthetic motor oil. It shows that with decreasing test temperature, the rate of evaporation processes decreases.

Seven grams of oil evaporate in 29 hours at a temperature of 190°C, and in 160 hours at 160 °C, i.e. with a decrease in temperature from 190 to 160 °C, evaporation time of seven grams increases by 5.52 times.

Fig. 4b shows dependence of synthetic motor oil volatility on testing temperature after eight hours of testing. These dependence are used to determine onset temperatures of evaporation processes. These dependences are described by a polynomial of the second degree, and regression equations for oils have the following form

$$\text{ALPHA'S 5W-30 SN/GF} \quad G = (5 \times 10^{-4})T^2 - 0.125T + 8.1 \quad (10)$$

$$\text{LUKoil Luxe 5W-30 SL/CF} \quad G = (5 \times 10^{-4})T^2 - 0.085T + 0.8 \quad (11)$$

Indexes of correlation are 0.999 and 1.

Derivatives of equations 11 and 12 determine the average rates of evaporation. If we equate them to zero, it is possible to determine the onset temperatures of oxidation processes for oils under study. The results are 125°C for ALPHA'S 5W-30 SN/GF and 160°C for LUKoil Luxe 5W-30 SL/CF.

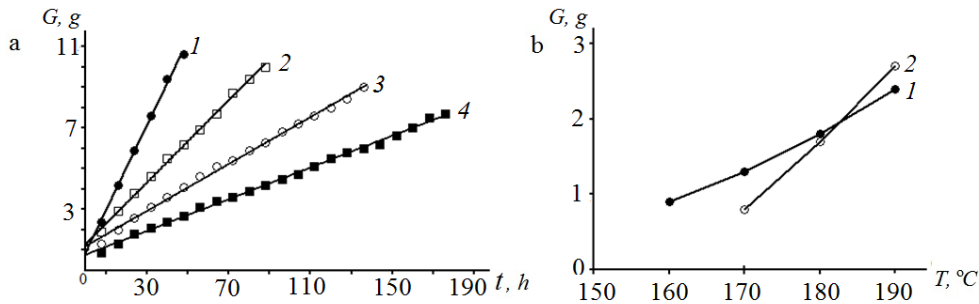


Fig. 4.(a)Dependence of volatility on time and testing temperature of synthetic motor oil ALPHA'S 5W-30 SN/GF: 1 – 190 °C; 2 –180 °C; 3 – 170 °C; 4 – 160 °C; (b) Dependence of volatility on testing temperature of synthetic motor oils: 1 – ALPHA'S 5W-30 SN/GF; 2 – LUKoil Luxe 5W-30 SL/CF (testing time – 8 hours)

Second important operational factor of motor oil efficiency is critical temperature, which is determined by the time of evaporation of two grams of motor oil under different testing temperatures (Fig. 5).Regression equations of these dependence are described by a polynomial of the second degree

$$\text{ALPHA'S 5W-30 SN/GF} \quad t_G = 0.0225T^2 - 8.705T + 846.75 \quad (12)$$

$$\text{LUKoil Luxe 5W-30 SL/CF} \quad t_G = 0.04875T^2 - 18.367T + 1736.3 \quad (13)$$

Indexes of correlation are 0.999 and 0.996.

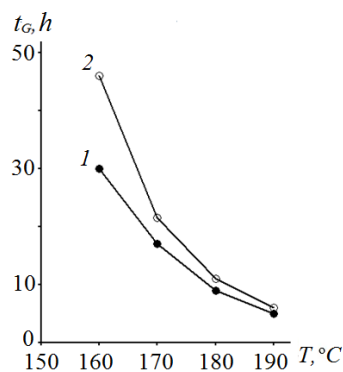


Fig. 5.Dependence of time required to evaporate two grams of synthetic oil on testing temperature: 1 – ALPHA'S 5W-30 SN/GF; 2 – LUKoil Luxe 5W-30 SL/CF

Derivatives of equations 13 and 14 determine the average rates of evaporation of two grams of oil from testing temperature. If we equate them to zero, it is possible to determine the onset temperatures of oxidation processes for oils under study. The results are 193.4°C for ALPHA'S 5W-30 SN/GF and 188.4°C for LUKoil Luxe 5W-30 SL/CF.

Fig.6a shows dependence of coefficient of thermo-oxidative stability P_{tos} on time and testing temperature of synthetic motor oil ALPHA'S 5W-30 SN/GF. These dependence are used to determine onset temperatures of oil conversion processes taking into account the processes of oxidation and evaporation, as well as the critical temperatures of their operability.

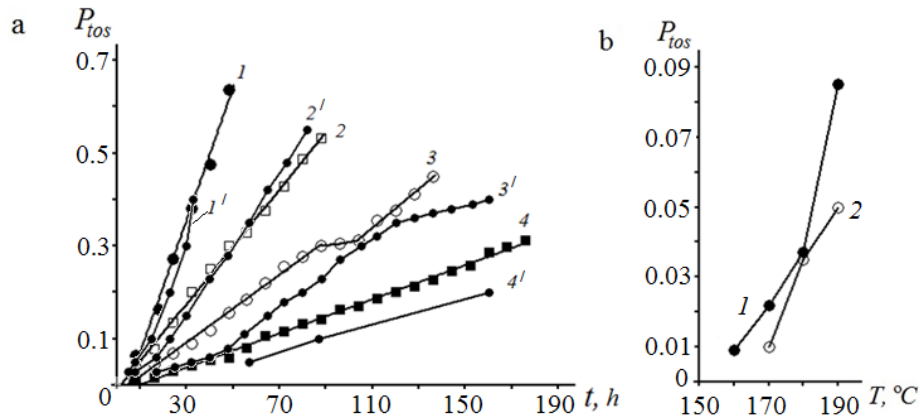


Fig. 6.(a)Dependence of thermo-oxidative index on time and testing temperature of synthetic motor oil ALPHA'S 5W-30 SN/GF: 1 – 190 °C; 2 –180 °C; 3 – 170 °C; 4 – 160 °C and LUKoil Luxe 5W-30 SL/CF : 1' – 190 °C; 2' –180 °C; 3' – 170 °C; 4' – 160 °C; (b) Dependence of synthetic motor oils thermo-oxidation stability index on the test temperature: 1 – ALPHA'S 5W-30 SN/GF; 2 – LUKoil Luxe 5W-30 SL/CF (testing time – 8 hours)

Fig. 6b shows the dependence of synthetic motor oils thermo-oxidation stability index on the test temperature after eight hours of testing. These dependences are described by a polynomial of the second degree, and regression equations for oils have the following form

$$\text{ALPHA'S 5W-30 SN/GF} \quad P_{tos} = (8 \times 10^{-5})T^2 - 0.028195T + 2.28175 \quad (14)$$

$$\text{LUKoil Luxe 5W-30 SL/CF} \quad P_{tos} = (5 \times 10^{-5})T^2 - 0.02T - 0.8 \quad (15)$$

Indexes of correlation are 0.985 and 1.

Derivatives of equations 15 and 16 determine the average rates of conversion processes in oils under study. If we equate them to zero, it is possible to determine the onset temperatures of conversion processes. The results are 161.1°C for ALPHA'S 5W-30 SN/GF and 166.6°C for LUKoil Luxe 5W-30 SL/CF.

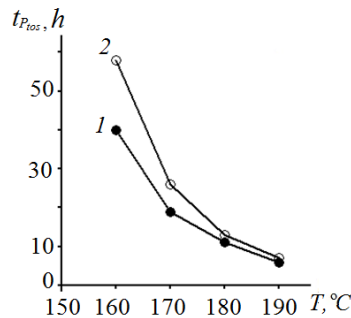


Fig. 7.Dependence of time required to achieve thermo-oxidation stability index $P_{tos}=0.05$ on testing temperature of synthetic motor oils: 1 – ALPHA'S 5W-30 SN/GF; 2 – LUKoil Luxe 5W-30 SL/CF

Fig. 7 shows dependences of time required to achieve thermo-oxidation stability index $P_{tos}=0.05$ on testing temperature of synthetic motor oils. These dependences are described by a polynomial of the second degree, and regression equations for oils have the following form

$$\text{ALPHA'S 5W-30 SN/GF} \quad t_{P_{tos}} = 0.04T^2 - 15.1T + 1431.5 \quad (16)$$

$$\text{LUKoil Luxe 5W-30 SL/CF} \quad t_{P_{tos}} = 0.065T^2 - 0.02T + 0.8 \quad (17)$$

Indexes of correlation are 0.992 and 0.995.

Derivatives of equations 17 and 18 determine the rate of change of conversion time in synthetic oils on the testing temperature when index P_{tos} achieves value of 0.05. If we equate them to zero, it is possible to determine the critical operability temperatures of synthetic motor oils under study. The results are 188.7°C for ALPHA'S 5W-30 SN/GF and 187.7°C for LUKoil Luxe 5W-30 SL/CF. Thus, resistance to temperature conversions with a temperature drop to 160 °C is higher in LUKoil Luxe 5W-30 SL/CF

4. Conclusion

The proposed control method of thermo-oxidative stability factors allows us to expand information on the quality of lubricants by determining the onset temperatures of oxidation, evaporation and temperature conversions in oil, as well as critical temperatures of these processes. It also allows to improve the classification system by the groups of operational properties. The proposed grapho-analytical method for determining the parameters of thermo-oxidative stability makes it possible to reduce the labour inputs of the research more than twofold by using the results of the study obtained at two testing temperatures.

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