IOP Conference Series: Materials Science and Engineering

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To cite this article: B I Kovalsky *et al* 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **537** 062074

IOP Conf. Series: Materials Science and Engineering **537** (2019) 062074 doi:10.1088/1757-899X/537/6/062074

Research of engine and transmission oils for thermo-oxidative stability with cyclic temperature changes

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Abstract. The results of testing motor and transmission oils for thermal-oxidative stability, including optical density and coefficient of thermal-oxidative stability, are presented. According to the results of the study, the temperature range of application of the oils was determined. The method of testing engine and transmission oils with cyclic temperature changes is presented, which allows comparing oils of the same purpose by the number of cycles of raising and lowering the test temperature, as well as identifying them for compliance with the classification according to performance properties groups.

1. Introduction

Thermal-oxidative stability is a performance indicator of motor oils, since the products formed during oxidation affect the corrosion, anti-wear and viscosity properties. Researchers pay much attention to this indicator.

The oxidation resistance of lubricating oils is enhanced by doping them with antioxidant additives. However, the activity of additives during long-term operation of internal combustion engines falls, so it is important to have instrumentation to assess the current value of the thermal-oxidative stability of oils over the entire period of use.

In qualification tests, four methods are used to determine the thermal-oxidative stability on the device DK -2 NAMI, gear installation, on the induction period of precipitation [1] and the method Papok [2]. Thermal-oxidative stability is assessed by viscosity change, sediment content, deposits on the details of the test facility. However, all the parameters of oxidation depend on the test temperature, therefore, a number of researchers have studied the dependence of oxidative processes on the test temperature [3-9].

Analysis of methods and means of controlling the thermal-oxidative stability of lubricants showed that to obtain complete information on the oxidation mechanism, it is necessary to apply an integrated approach that takes into account changes in temperature and test time, as well as the composition of products formed during oxidation, which will establish the temperature range of efficiency and process evaluation criteria oxidation.

2. Method and results of research

The purpose of this research is to determine the temperature range of application of lubricants and their comparison by resistance to oxidation.

Mobil Super 3000 5W-40 SJ / SL / CF, Chevron Supreme 10W-40 SJ / CF, Bizol 0W-40 SJ / CF synthetic oil and transmission mineral oils Bizol 80W-90 GL-4 and synthetic Bizol Hypoid 75W-90 GL-4, GL-5 are selected for the study. The study method of thermo-oxidative stability was used. A distinctive feature of the technique is the testing of motor oils with cyclical changes in the test temperature, which allows them to be compared in terms of the number of endured cycles [10-12].

The research method involved the use of the following means of testing and control: a device for temperature control of oils, a photometer for direct photometry of oxidized oils with a thickness of a photometric layer of 2 mm and electronic scales. The technical characteristics of the devices are given in the monographs [13-15].

Motor oils were tested in the temperature range from 150 to 180 °C and from 180 to 150 °C through 10 °C, transmission oils were tested in the temperature range from 120 to 150 °C and from 150 to 120 °C. The first range is called the temperature increase cycle of the test, and the second - the temperature decrease cycle. The test time at each selected temperature was 8 hours. After each test, weighed and a sample of oxidized oil was taken to determine the optical density and absorption coefficient of the light flux.

Figure 1 shows the dependences of the absorption coefficient of the light flux on the test temperature in cycles of its increase from 150 to 180 °C and lowering cycles from 180 to 150 °C. Mobil Super Syn 0W-40 SJ / SL / CF oil (figure 1 (a) withstood two cycles of temperature increase from 150 to 180 °C and two cycles of temperature decrease from 180 to 150 °C for a total of 112 hours. It is established that in the first cycle of the temperature increase cycle of the test, the oil provides the greatest resistance to oxidation. In the fourth cycle of lowering the test temperature, auto-oxidation was detected, at which a more intensive increase in the coefficient K_a was observed than in the third cycle of temperature increase. On the basis of the data obtained, the temperature of 180 °C for the studied oil is high and it cannot belong to the SJ / SL performance properties group.

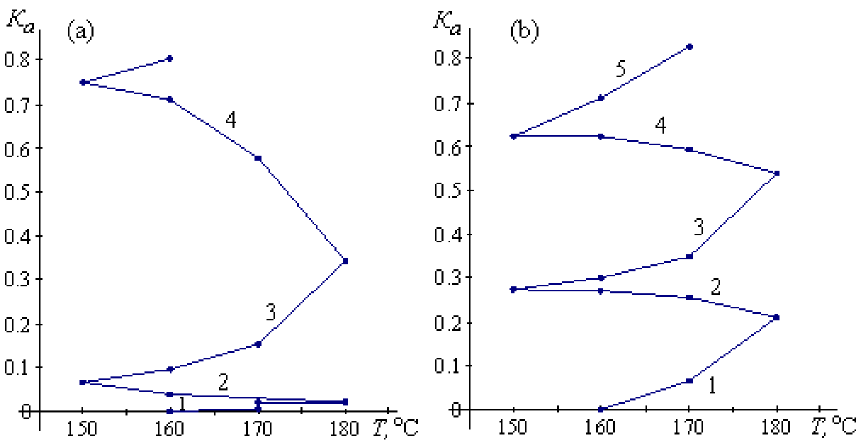

Figure 1. The dependence of the absorption coefficient of the light flux on temperature tests with cyclic change from 150 to 180 C of synthetic motor oils: a - Mobil Super Syn 0W-40 SJ/SL/CF; b - Mobil Super 3000 5W-40 SJ/SL/CF (odd numbers - temperature increase cycles; even numbers - temperature decrease cycles).

The temperature range of application of this oil is determined from 140 to 170 °C, and 170 °C is the limiting temperature.

Mobil Super 3000 5W-40 SJ / SL / CF synthetic oil withstood three cycles of increasing the test temperature and two lowering cycles, for a total of 128 hours. It has been established that at 180 °C the oxidation rate for this oil is high, therefore the temperature range of its application is in the range from 150 to 170 °C.

When studying these oils, the absorption coefficient of the luminous flux was used as an indicator for evaluating the oxidation processes. Consider the option of using as indicators for assessing the processes occurring in motor oils with cyclical temperature changes of the test using optical density *D* and the P_{tos} thermal-oxidative stability coefficient, which takes into account oxidation and evaporation.

Figure 2 shows the dependences of optical density (a) and thermal-oxidative stability coefficient (b) on the temperature test of Chevron Supreme 10W-40 SJ / CF partially synthetic engine oil in the temperature range from 150 to 180 °C and from 180 to 150 °C and thermo-oxidative stability coefficient.

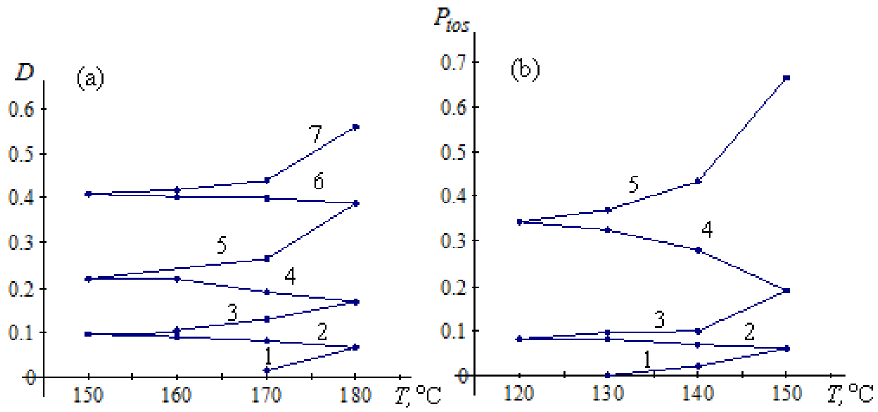

Figure 2. Dependences of optical density (a) and thermal-oxidative stability coefficient (b) on the test temperature with cyclic change from 150 to 180 C of Chevron Supreme 10W-40 SJ / CF synthetic engine oil: odd numbers - temperature increase cycles; even numbers - lowering cycles.

The test time at each temperature was 8 hours. According to the data, the test oil passed 176 hours of testing, with an optical density of 0.563, and a coefficient of thermo-oxidative stability of 0.796, the number of cycles of temperature increase was 4 cycles and 3 cycles of lowering the test temperature. It was established that at a temperature of 180 °C the greatest changes in optical density and coefficient of thermal-oxidative stability occur. The dependences (figure 2) show that the oxidation processes begin after 160 °C, and the greatest change in optical density occurs in the fifth cycle of the temperature increase of the test during the formation of secondary products more opaque.

Figure 3 shows the dependence of optical density and thermal-oxidative stability coefficient on the temperature test of a synthetic engine oil Bizol 0W-40 SJ / CF.

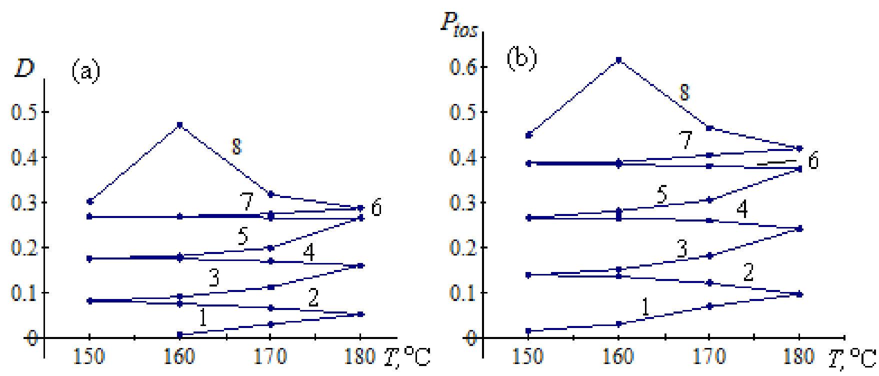

Figure 3. Dependences of optical density (a) and thermo-oxidative stability coefficient (b) on the test temperature with cyclic change from 150 to 180 C of synthetic engine oil Bizol 0W-40 SJ / CF: odd digits - temperature increase cycles; even numbers - lowering cycles.

This oil has withstood 20 hours of testing, four cycles of increasing the temperature of the test from 150 to 180 °C and four cycles of lowering the temperature from 180 to 150 °C. It has been established

IOP Conf. Series: Materials Science and Engineering **537** (2019) 062074 doi:10.1088/1757-899X/537/6/062074

that in the sixth and seventh cycles, oxidation processes are significantly slowed down, which was not observed in partially synthetic engine oil. Oxidation processes begin at a temperature of 160 °C, and the greatest increase in optical density and coefficient of thermal oxidative stability is established at a temperature of 180 °C. In addition, an abnormal increase in optical density is established at a temperature of 160 °C in the eighth cycle of temperature decrease, which can be explained by auto-oxidation processes. Below are the results of the study of transmission oils on thermal-oxidative stability with cyclical temperature changes.

Figure 4 shows the dependences of optical density and thermal-oxidative stability coefficient on the temperature test of Bizol 80W-90 GL-4 mineral transmission oil. The oil with stood 128 hours, three cycles of increasing the test temperature from 120 to 150 °C and two cycles of lowering the temperature from 150 to 120 °C, while the optical density was 0.62, and the coefficient of thermal-oxidative stability was 0.667. It was established that the oxidation processes began at a temperature of 140 °C, and in the fourth cycle of lowering the temperature, the formation of optically opaque oxidation products began, which caused a significant increase in optical strength (curve 4). Oil evaporability occurs at a temperature of 130 °C (curve 1, figure 4 (b). The mineral oil classification corresponds to GL-4, i.e. temperature of 140 °C, which is the limit.

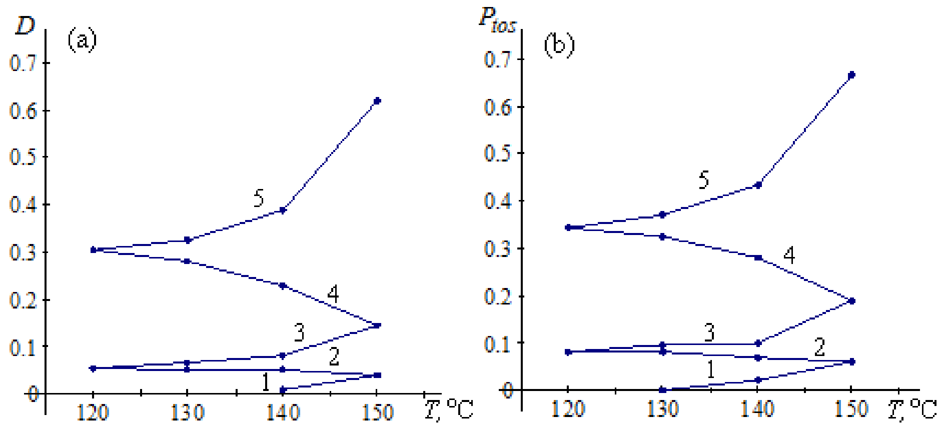

Figure 4. Dependences of optical density (a) and thermal-oxidative stability coefficient (b) on the temperature test of Bizol 80W-90 GL-4 mineral transmission oil: odd numbers - temperature increase cycles; even numbers - lowering cycles.

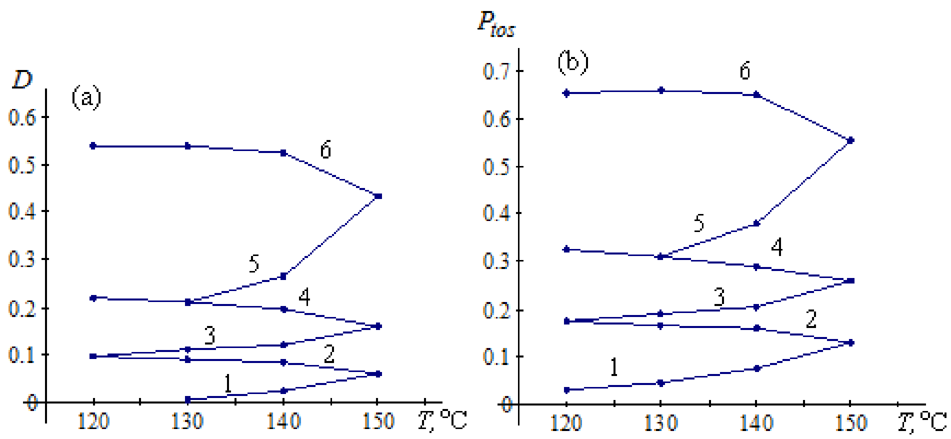

Figure 5. Dependences of optical density (a) and thermo-oxidative stability coefficient (b) on the temperature of the test of Bizol Hypoid 75W-90 GL-4, GL-5 partially synthetic transmission oil: odd numbers - temperature increase cycles; even numbers - cycles of lowering the test temperature.

Figure 5 presents the dependences of optical density and thermal-oxidative stability coefficient on the temperature of the test of partially synthetic Bizol 75W-90 GL-4, GL-5 transmission oil. This oil withstood 152 hours of testing, three cycles of temperature increase from 120 to 150 °C and three cycles of temperature decrease from 150 to 120 °C.

The oxidation processes began at a temperature of 130 °C, and evaporation was below 120 °C (curve 1, figure 5 (b). Unlike mineral oil in partially synthetic oil there is no cycle of lowering the temperature, in which there is a sharp increase in optical density. The disadvantages of a partially synthetic oil include a low evaporation temperature, after 152 hours of evaporation, the optical density of the oil under study was 0.543, and the coefficient of thermo-oxidative stability is 0.663, that is, the synthetic oil life is longer.

3. Conclusions

Based on the above studies, it was shown that the test method for lubricating oils during cyclic measurement of the test temperature allows to establish the temperature scope of the test oil, compare oils of a single purpose by the number of cycles of increase and decrease of the test temperature, and identify them for compliance with the classification according to performance properties.

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