Determination of engine oil characteristics

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Abstract. The given introduced paper deals with determination of contamination, content of elements, change of composition and stability against the oxidation of motor oils. This work is aimed at chaining the individual properties of engine oil in dependence on the use of oil in traffic. Results show, that properties of engine oils do not depend only on the time of use but they also depend on other factors, such as state of the vehicle, the way of driving the vehicle, and the condition of maintenance.

1. Introduction

Motor oil or engine oil or engine lubricant is any of various substances comprising the base oils, enhanced with particularly antiwear additive plus detergents as well as dispersants and multi-grade oils viscosity index improvers. Motor oil is use for lubrication of internal combustion engines. The main function of motor oil is to reduce friction and wear of moving parts and to clean the engine from sludge (one of the functions of dispersants) and varnish (detergents). It also neutralizes acids that originate from fuel and from oxidation of the lubricant (detergents), improves sealing of piston rings, and cools the engine by carrying the heat away from moving parts [1, 2]. In addition to the basic constituents noted in the preceding paragraph, almost all lubricating oils contain corrosion and oxidation inhibitors. Motor oil may be composed of only a lubricant base stock in the case of non-detergent oil or a lubricant base stock plus additives to improve the oil detergency, extreme pressure performance, and ability to inhibit corrosion of engine parts. The composition of a typical engine oil is as follows: 78 % base oil, 10 % viscosity improvement additive (to improve flow), 3 % detergent (detergent substances which clean the engine), 5 % dispersant (for the suspension of dirt particles), 1 % wear protection and 3 % other components. The density of liquid lubricants with temperature decrease and with pressure increase. The viscosity is one of the most important properties of motor oils. The viscosity of a fluid is a measure of its resistance to deformation at a given rate [2, 3]. Oils with lower viscosity are liquid and thin. They have less internal flow resistance, downstream. Motor oils with a higher density have a higher viscosity and slower flow and a higher resistance [3, 4]. From the point of view of real operation, a change in viscosity with hanging temperature is considered, and the higher the temperature, the lower the viscosity. The viscosity index describes the change in viscosity in dependence on temperature [5, 6–8]. Engine oil is characterize by viscosity and quality.

According to these characteristics, the engine oils are classified into individual viscosity classes and performance classifications. The SAE (Society of Automotive Engineers, USA) classification [5] is use to indicate the viscosity properties of engine oil. In table 1, there is an overview of the SAE engine oil breakdown and viscosity type. The UAE uses six winter classes with the W letter along with the number...
and five summer classes with the number. The given number does not determine the relation to the physical quantity, it is the name of the class [9].

Table 1. Classification of engine oils [10].

| Viscosity classes | Dynamic viscosity (mPa s) |
|-------------------|--------------------------|
| SAE 0W            | 3 250 at 30 °C           |
| SAE 5W            | 3 500 at 25 °C           |
| SAE 10W           | 3 500 at 20 °C           |
| SAE 15W           | 3 500 at 15 °C           |
| SAE 20W           | 4 500 at 10 °C           |
| SAE 25W           | 6 000 at 5 °C            |
| SAE 20            | -                        |
| SAE 30            | -                        |
| SAE 40            | -                        |
| SAE 50            | -                        |
| SAE 60            | -                        |

2. Experiment

2.1. Samples
In experimental part, eight samples of engine oils were used – 4 of them were new and 4 of them were after performance.
Sample no. 1 – SAE 40 – new oil
Sample no. 2 – SAE 40 – used oil, 11 750 km
Sample no. 3 – SAE 20W 40 – new oil
Sample no. 4 – SAE 20W 40 – used oil, 6 000 km
Sample no. 5 – SAE 5W 40 – new oil
Sample no. 6 – SAE 5W 40 – used oil, 14 000 km
Sample no. 7 – SAE 15W 40 – new oil
Sample no. 8 – SAE 15W 40 – used oil, 24 500 km

2.2. Methods
Spot test
In this test, a drop of motor oil, applied to the chromatographic paper, will generate four concentric circles, which indicate engine condition. The centre spot indicates the presence of sediments such as dust, wear particles, carbon, insoluble and other contaminants. The second circle indicates the condition of the oil. If the engine and oil are in good condition, the second circle will appear lighter than centre spot. The boundary layer of the second circle indicates possible water content. The transparent yellow ring will form an outer circle when there is fuel in the oil [7].

EDX analysis
Energy-dispersive X-ray spectroscopy (EDX) is an analytical technique used for the elemental analysis or chemical characterization of a sample. It is based on an interaction of some source of X-ray excitation and a sample.

TG analysis
Thermogravimetric analysis or thermal gravimetric analysis (TGA) is a method of thermal analysis in which the mass of a sample is measured on the basis of the temperature changes over the time. This
measurement provides information about physical phenomena, such as phase transitions, absorption, adsorption and desorption, as well as chemical phenomena including chemisorption, thermal decomposition, and solid-gas reactions (e.g., oxidation or reduction).

3. Results and discussion

3.1. Spot test
Sample no. 1 (figure 1) represents the new oil and it is in good condition because the second circle is lighter than the centre spot. Sample no. 2 stands for used oil after performance of 11 750 km. Using the chromatographic paper, we can see that second circle is lighter than the centre spot. Sample shows the low impurity, there is not any water or any residues of fuel. Based on the mentioned condition, the oil exchange is not necessary.

![Figure 1. Sample no. 1 and no. 2.](image1)

Engine oil – sample no. 3 (figure 2) is new oil without any content of water and fuel. Sample no. 4 is used oil after performance of 6 000 km. The centre spot is black. The given oil exhibits insoluble impurities. In addition, there is the indication of water and fuel. Engine oil is not in good condition.

![Figure 2. Sample no. 3 and no. 4.](image2)

Sample no. 5 (figure 3) is new SAE 5W 40 oil. Sample no. 6 is used oil after performance of 14 000 km. The second circle has a light brown colour using the chromatography paper. Oil is without any content of fuel. Oil should be change in a short time.

![Figure 3. Sample no. 5 and no. 6.](image3)
Sample no. 7 (figure 4) is new SAE 15W 40 oil. Sample no. 8 represents the used oil after performance of 24 500 km. The centre spot is black. Engine oil exhibits the high impurity content. The second circle indicates that the oil is in poor condition, but there is not the presence of any fuel.

Figure 4. Sample no. 7 and no. 8.

3.2. EDX analysis
The sample no. 1 and no. 2 comprises calcium, sulphur and phosphor (table 2). These elements are in engine oil as detergents. Zinc is an antioxidant. The oil 2 contains copper, lead and iron from normal wear. The lead limit is 25 ppm, iron limits for engine oil is 50 ppm and copper limit is 30 ppm. In relation to the sample no. 2, there is also the presence of copper, lead and iron, which stand for common wear.

Table 2. EDX analysis of sample no. 1 and no. 2.

| Element | Sample no. 1 | Sample no. 2 |
|---------|-------------|-------------|
| Ca      | 2341 ± 11 ppm | 2529 ± 12 ppm |
| S       | 1768 ± 11 ppm | 2513 ± 14 ppm |
| P       | 562 ± 12 ppm  | 503 ± 13 ppm  |
| Au      | 19 ± 3 ppm    | -            |
| Zn      | 9 ± 1 ppm     | 12 ± 1 ppm   |
| Cu      | -            | 26 ± 2 ppm   |
| Pb      | -            | 21 ± 3 ppm   |
| Fe      | -            | 13 ± 2 ppm   |

In table 3, there is element content for sample no. 3 and no. 4. Sample no. 4 contains an increased value of iron and copper. Potassium in engine oil is from water, because potassium is use as an additive to the coolant. Zinc in oil is as antioxidant and molybdenum as a lubricant.

Table 3. EDX analysis of sample no. 3 and no. 4.

| Element | Sample no. 3 | Sample no. 4 |
|---------|-------------|-------------|
| S       | 3256 ± 16 ppm | 2573 ± 13 ppm |
| Ca      | 2878 ± 14 ppm | 1886 ± 10 ppm |
| Zn      | 779 ± 3 ppm   | 549 ± 3 ppm   |
| P       | 756 ± 10 ppm  | 484 ± 13 ppm  |
| Mo      | 24 ± 1 ppm    | 20 ± 1 ppm    |
| K       | -            | 212 ± 7 ppm   |
| Fe      | -            | 65 ± 2 ppm    |
| Cu      | -            | 43 ± 2 ppm    |
The element content for sample no. 5 and no. 6 is in table 4. We can see that in sample no. 6, there are calcium, sulphur and phosphorus. They represent the detergents in oil. Sample no. 6 contain low amount of iron from wear of individual construction components.

| Element | Sample no. 5 | Sample no. 6 |
|---------|--------------|--------------|
| Ca      | 2818 ± 13 ppm | 3035 ± 14 ppm |
| S       | 2239 ± 13 ppm | 3345 ± 17 ppm |
| P       | 934 ± 11 ppm  | 959 ± 11 ppm  |
| Zn      | 910 ± 3 ppm   | 974 ± 4 ppm   |
| Fe      | -             | 20 ± 2 ppm    |

In sample no. 7 and no. 8 sulphur, phosphor and calcium were observe (table 5). They represent the detergents in engine oil. Moreover, the presence of zinc stand for function of antioxidant in oil. The iron, copper and lead content in sample no. 8 is above the permissible level.

| Element | Sample no. 7 | Sample no. 8 |
|---------|--------------|--------------|
| S       | 4642 ± 20 ppm | 5046 ± 21 ppm |
| Ca      | 4513 ± 18 ppm | 2062 ± 11 ppm |
| Zn      | 713 ± 3 ppm   | 750 ± 3 ppm   |
| P       | 552 ± 14 ppm  | 478 ± 13 ppm  |
| Cu      | 26 ± 2 ppm    | 48 ± 2 ppm    |
| Fe      | -             | 418 ± 3 ppm   |
| Pb      | -             | 42 ± 3 ppm    |

3.3. TG analysis
TGA/DSC 2 STARE System of METTLER TOLEDO was used for study of oxidation stability of engine oil. The measurement of TG curves were carried out in oxygen atmosphere.TG curves of sample no. 1 and sample no. 2 are in figure 5. The onset temperature for new oil is 264.4 °C and for used oil (sample no. 2) is 242.9 °C.

![Figure 5. TG curves of sample no. 1 and no. 2.](image-url)
4. Conclusion
In engine SAE 40 oil – sample no. 2 (11 750 km), there is low impurity content, and it is also important to point of that there is not indication of any water or water residues of fuel. Therefore, the oil exchange is not necessary. In TG curve, there is the onset temperature on for used oil is lower than for new oil. Engine SAE 20W 40 oil – sample no. 4 (6 000 km) is contaminated by water, oxides and nitrate products along with increased content of iron particles. Oil has to be exchange as a short time. Engine SAE 5W 40 oil – sample no. 6 (14 000 km) has high content of impurities, but without any presence of water or fuel. Oil should be exchange in short time. Engine SAE 15W 40 oil – sample no. 8 (24 500 km) is contaminated by water, oxides and nitrate products. Moreover, also the high content of iron particles/dust. Oil exchange recommended in short time interval.

Engine oil lifetime depends on the time of use as well as it is related to the technical condition of the vehicle, operating conditions, maintenance and driving style.

5. References
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Acknowledgments
The work was supported by the project „Advancement and support of R&D for “Centre for diagnostics and quality testing of materials“ in the domains of the RIS3 SK specialization“, code NFP313010W442 and project KEGA 003TnUAD-4/2019.