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STUDY ON THE DYNAMIC VISCOSITY VARIATIONS OF DIFFERENT TYPES OF ENGINE OILS

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Abstract: This article investigates the impact of degradation on the viscosity of used engine oils, which plays a crucial role in engine lubrication and performance. The research focuses on the dynamic viscosity variations of different types of engine oils, including diesel, gasoline, and LPG oils, both new and used. By analyzing viscosity changes across various temperature ranges, the study highlights how contaminants, especially water and fuel, influence oil performance. The experimental setup involved measuring dynamic viscosity at temperatures ranging from 100°C to 25°C using a Brookfield viscometer. Results indicate that contamination generally increases oil viscosity, which can hinder lubrication efficiency and exacerbate engine wear.
Keywords: used engine oil, viscosity, lubricant, internal combustion engine

1. INTRODUCTION

Internal combustion engines have superior durability performance due to advancements in lubrication as well as oil manufacturing technology. A natural consequence of this evolution is the increase in the mechanical and thermal stresses of the engine and transmission subassemblies and the degradation of the working environment of the lubricants (especially those working in the engine) as a result of the use of ethylated fuels, with a higher sulfur content [1].

All the devices, devices and machines that serve to lubricate the thermal engine are called the lubrication system. The main type of friction encountered in the heat engine is sliding friction, which can be found in all forms: dry, liquid (viscous and limit), semi-dry and semi-liquid. The main role of engine lubrication is to remove the direct contact between the surfaces of the parts in relative motion, thus reducing the mechanical work of friction, heating and wear of the parts [2]. The oil also has the roles of cooling the engine components, removing impurities as well as chemically neutralizing the active compounds resulting from fuel combustion. The oil can fulfill these tasks only if it is circulated through a suitable system and in a suitable quantity to all the critical points of the engine and corresponds in terms of its properties to the prescriptions imposed by the engine manufacturer [3].

The viscosity of engine oil is a key parameter that directly influences these functions. Viscosity determines the oil's ability to flow and provide adequate lubrication under various operating conditions, impacting fuel efficiency, wear rates, and overall engine performance.

As engine oil ages due to thermal stress, oxidation, and contamination, its viscosity can change, potentially compromising its performance [4]. Different oil formulations respond differently to these stressors, leading to varying patterns of viscosity change. For instance, exhaust particles, originating from the fuel combustion, can disrupt the molecular structure of the lubricant, resulting in viscosity decrease [5]. This paper focuses on understanding how the viscosity of engine oil varies depending on both its type and its degradation level over time, by experimentally determining the variation of the dynamic viscosity of some engine oil samples.

2. THEORETICAL CONSIDERATIONS REGARDING VISCOSITY

Viscosity represents the characteristic of the oil to resist flow, it determines the internal friction, defining the flow and the hydrodynamic capacity of the lubrication regime. It depends on the temperature parameter, so in operating temperature ranges, between 30°C and 150°C, the viscosity level changes a lot [6].

In the nominal case, the friction goes out of the fluid zone because there is a high temperature so the viscosity is reduced. In the case of a cold start, the viscosity is higher ensuring proper lubrication, but as an inconvenience it leads to an increase in the mechanical work required to start the engine [7].

Viscosity can be classified into [1]:

- dynamic viscosity;
- kinematic viscosity.

The kinematic viscosity [υ] is the ratio between the dynamic viscosity η and the oil density ρ.

$$\upsilon = \frac{\eta}{\rho} \quad (2.1)$$

It is found in ordinary oils at positive temperatures and can be determined in the capillary viscometer. In the CGS technical system the unit of measurement is "stokes" [St] named after George Gabriel Stokes. Sometimes the subdivision "centistokes" [cSt] is also used [1].

$$1\text{St} = 100\text{cSt} = 1\text{cm}^2 \cdot \text{s}^{-1} = 0{,}0001\text{m}^2 \cdot \text{s}^{-1} \quad (2.2)$$

and:

$$1\text{cSt} = 1\text{mm}^2 \cdot \text{s}^{-1} \quad (2.3)$$

In the International SI System, the unit of measurement is: [m^2·s^(-1)].

Dynamic viscosity [η] is a fluid's resistance to deformation or flow. It usually varies little with pressure and much with temperature. It is found in negative temperature oils and thick oils (multigrade) and is performed in the rotary viscometer. In the technical system it is evaluated in centipoise [cP]. The reason is that at 20°C water has a viscosity of 1.0020 cP [1].

$$10\text{P} = 1\text{kg} \cdot \text{m}^{-1} \cdot \text{s}^{-1} = 1\text{Pa} \cdot \text{s} \quad (2.4)$$

and:

$$1\text{cP} = 0{,}001\text{Pa} \cdot \text{s} = 1\text{mPa} \cdot \text{s} \quad (2.5)$$

In the International System the unit of measurement is the Pascal-second:

$$[\text{Pa} \cdot \text{s}] = 1\text{kg} \cdot \text{m}^{-1} \cdot \text{s}^{-1} \quad (2.6)$$

In the CGS (centimeter-gram-second) system, the unit of measurement is the "poisse" [P] which comes from the name of the physicist Jean Louis Marie Poiseuille [1].

$$1\text{P} = 1\text{g} \cdot \text{cm}^{-1} \cdot \text{s}^{-1} \quad (2.7)$$

Viscosity index is the rate at which viscosity changes between two temperatures. If the oil heats up, then the viscosity decreases due to the viscosity index also decreasing. Under the conditions of a heating oil, the drop in viscosity is less if the VI value is higher. So if it has little change over a range of temperatures, this is a plus [8]. The viscosity index (VI) scale ranges from 0 to 100, where 0 is the least good and 100 is the best. Viscosity index can be a useful way to assess oil quality. This can provide useful information regarding a lubricant's formula, quality and type of base oils [1].

Regarding the stability of the viscosity of oils with temperature, the viscosity index, IV, is used, thus being able to characterize the oils. The determinative mode is made following a comparison of the behavior of the oil that was tested against the behavior of two reference oils [8].

Oil viscosity affects the ability to lubricate parts, relating to speed, temperature and coefficient of friction.

3. ENGINE OIL DEGRADATION

With pronounced wear of the segments, some higher gas leaks occur, the temperature can reach 450°C in spark ignition engines and between 500-700°C in compression ignition engines. The oil film has a temperature of 150-160°C and high specific pressures, so the crankshaft spindles and bearings work under difficult conditions. In the oil pan, the oil temperature under the respective operating conditions does not drop below 80-100°C [1].

In this context, the oil has to perform certain functions for a long period of time [109]:

- To properly seal the combustion chamber, eliminating or reducing gas leaks to the crankcase to a minimum;
- To produce the removal of heat, arising from the release of fuel combustion but also due to the friction between the parts;
- To form a stable unctuous film on the areas of the parts that are in contact, eliminating a metal contact at the stage of microasperities, such as surface sticking, and at the same time reducing the degree of surface wear;
- Neutralization of acids that occur during oil oxidation and fuel combustion;
- Realization of the cooling of the surfaces of the parts;
- Prevention of the corrosion process acting on the parts;
- Prevention of the formation calamine deposits;
- Avoiding settling by maintaining the deposits resulting from aging and wear in a stable emulsion form, followed by the evacuation of the respective deposits from the friction zone.

For these functions to be successfully performed by the base oils, it must be mixed with additives which are active chemical compounds.

Oil degradation is the process of changing the physico-chemical characteristics of the oil, during the period of storage and operation of the mechanisms [1].

Figure 1 presents the factors that lead to oil degradation.

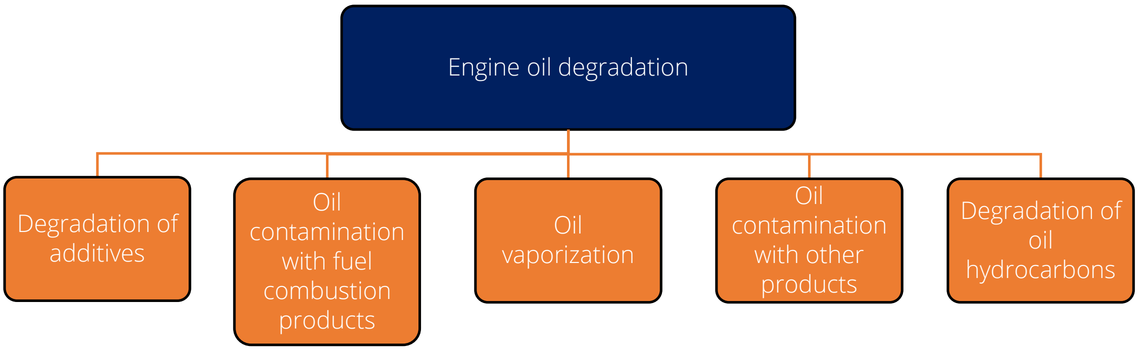

Figure 1. Factors that lead to oil degradation

As a result of the polymerization, oxidation and thermal decomposition of the hydrocarbons in the oil, organic acids, asphaltenes, carbenes, gums and carboids are formed, which lead to an increase in the viscosity of the oil, raise the level of corrosion and deposits on the surfaces of the parts. Degradation of additives occurs as a result of the contamination of the oil with other products such as: water that is absorbed from the humid air, water that is in the engine cooling system, powders, products formed as a result of the wear of the parts and the unvaporized fuel from the combustion chamber of the engine. Vaporization causes the volume of the oil pool to decrease and its functional composition changes [11]. The combustion chamber releases the burnt gases that enter the oil sump. These gases contain sulfur and nitrogen oxides, carbon particles, partial fuel oxidation products and water. Corrosion of parts occurs due to the acids H_2SO_4 and H_nNO_x formed from sulfur and nitrogen oxides together with water. The wear of the parts is made of carbon particles, and deposits occur through the products of partial oxidation [12].

Clogging of filters of lubrication systems, the appearance of deposits and intensive wear are formed due to wear products and powders. Water has a negative effect, producing the phenomenon of hydrolysis in which various additives break down in the presence of water, which causes corrosion of the parts. At the same time, the water emulsifies the oil and leads to clogging of the filters of the lubrication system. Over time additives lose their properties, having reduced effectiveness due to chemical reactions and their physical reduction following oil filtration [13]. The more severe the service conditions, the more pronounced the degradation of the oils. Thus, degraded oils are changed after a period established by the manufacturing companies. When changing, the actual condition of the oil at the time of the change is not taken into account, but is guided by its performance level and the operating conditions of the cars [1].

4. EXPERIMENTAL STUDIES ON THE VISCOSITY VARIATION OF ENGINE OILS

In the experimental part that was carried out, the comparisons that are brought to oils, new and used, but also of a diversified range such as diesel oil, gasoline oil and LPG oil, were observed, referring to the variations of their dynamic viscosity [cP] with temperature depending on the degree of oil degradation.

The equipment used consists of a Brookfield DV-E viscometer, with the help of which the values of dynamic viscosities [cP] were determined at various temperatures. A thermometer was used to know the temperature level of the oil, which was heated on an electric hot plate (figure 2). The temperature ranges within which the experimental data were taken is from 100°C decreasing towards 25°C, which is the ambient temperature.

In the first step, the electric stove was turned on, and the first sample of used engine oil (diesel oil) was placed in a Berzelius beaker, and then the oil was

Figure 2. Experimental stand

heated to 100°C, watching the temperature rise through the thermometer placed in the oil.

Thus, from the temperature of 100°C, the measurements were started, at decreasing temperatures, from 5 to 5°C until the ambient temperature of 25°C was reached. Measurements were made by placing the Berzelius beaker on the hot plate on the viscometer which was turned on and set. In the first oil sample, during the measurements, the hot plate after its use was stopped (figure 3). The experimental data were noted in a table.

Figure 3. Measurements and data collection

Figure 4. New oil sample (Castrol Edge 5W30)

The other oil samples were also tested in this approach. Three used oil samples were used: diesel, gasoline and LPG; and two samples of new oil: diesel and gasoline (figure 4).

Thus, based on the data extracted and written in the table, a comparison was made between the three used oil samples, determining the dynamic viscosity variations [cP], comparison between used diesel, gasoline and new diesel and gasoline oils, and a third comparison between new gasoline oil and new diesel oil but also new gasoline-LPG oil and used LPG oil. The comparisons made were designed in the form of graphs created with the help of the Excel program.

5. RESULTS

Following the experiment, based on the data in the table, representative graphs were made for the determined measurements. The table with measurements can be seen below:

Table 1. Experimental data

Temperature [°C]	Dynamic viscosity [cP]				
	Used engine oil (diesel)	Used engine oil (gasoline)	Used engine oil (LPG)	New engine oil (diesel)	New engine oil (gasoline)
100	33.7	32.9	28.5	32	27.2
95	34.6	33.7	28.9	32	28
90	36.1	34.5	29.7	33.8	29.6
85	37.7	35.3	30,1	34.4	30.4
80	40,1	36.7	31.3	36	33.2
75	42.3	39.3	33.7	37.6	35.2
70	46.5	41.7	35.7	40	37.2
65	50.5	44.9	38.5	42.4	39.9
60	56.6	49.7	41.7	45.6	43.2
55	61.7	56.2	47.3	48	48.6
50	69.8	62.7	53.2	55.2	55.6
45	81.9	71.9	62.1	64.8	64.6
40	94.1	85.6	65.2	77.6	73.6
35	112.3	102.3	68.1	92	84.4
30	135.2	108.5	73.4	111.2	104.9
25	196.8	118.2	108.9	133.6	126.4

Five graphs were made that follow the variation of the viscosity of engine oils. These will be displayed below.

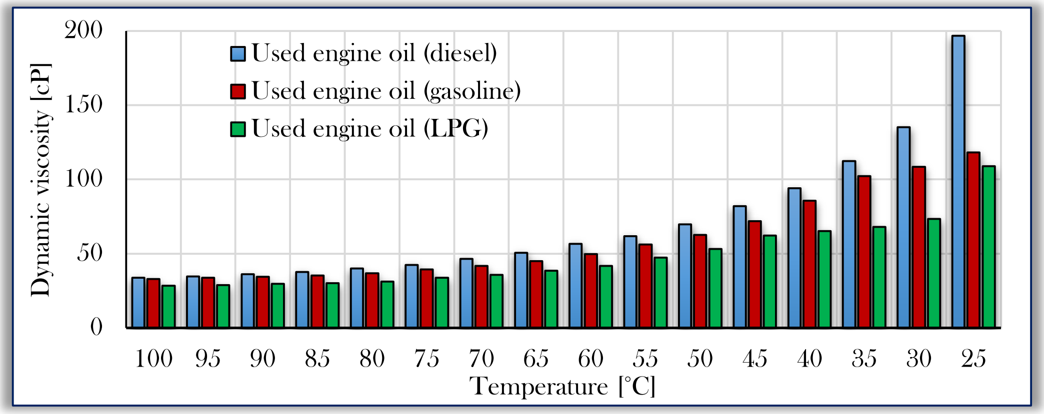

Figure 5. Comparison of the dynamic viscosity of the used engine oils depending on temperature variation

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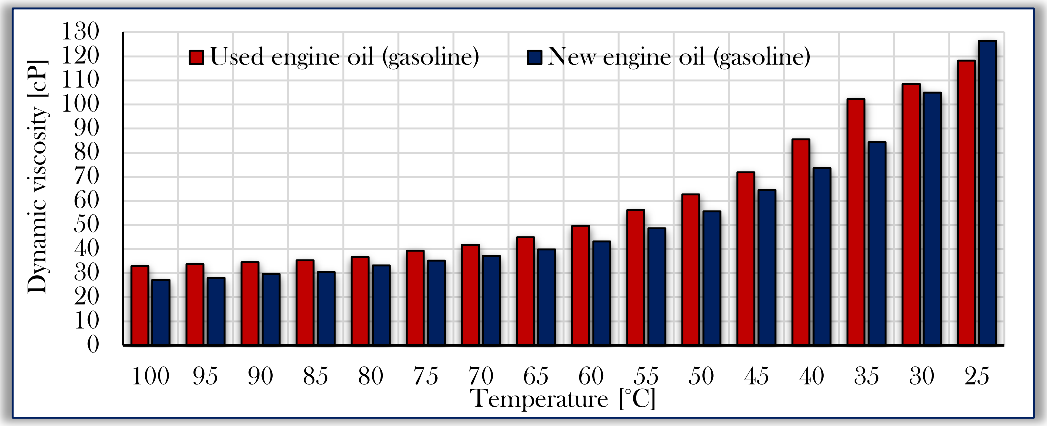

Figure 6. Comparison of the dynamic viscosity of used and new gasoline oil depending on temperature variation

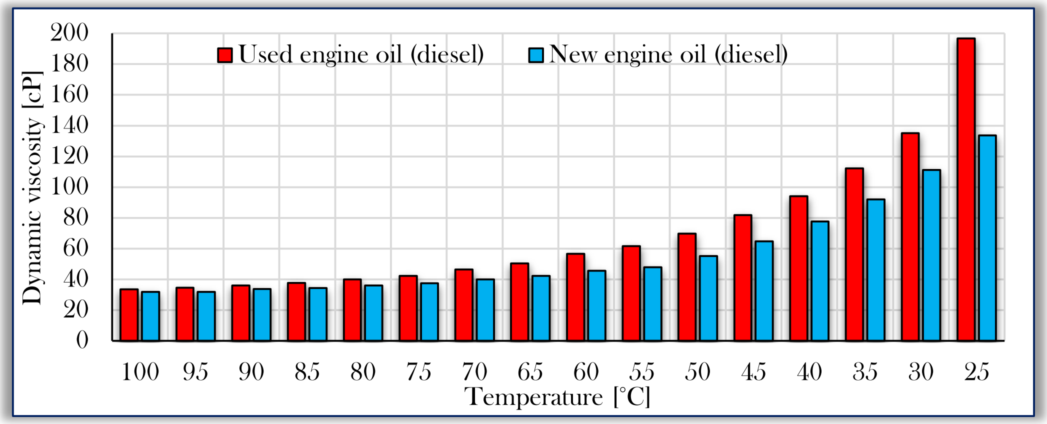

Figure 7. Comparison of the dynamic viscosity of used and new diesel oil depending on temperature variation

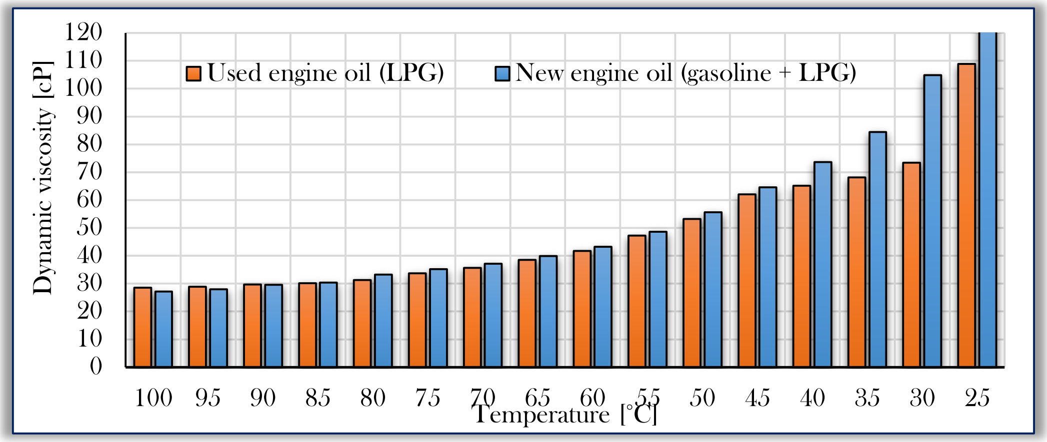

Figure 8. Comparison of the dynamic viscosity of used LPG oil and new gasoline-LPG oil depending on temperature variation

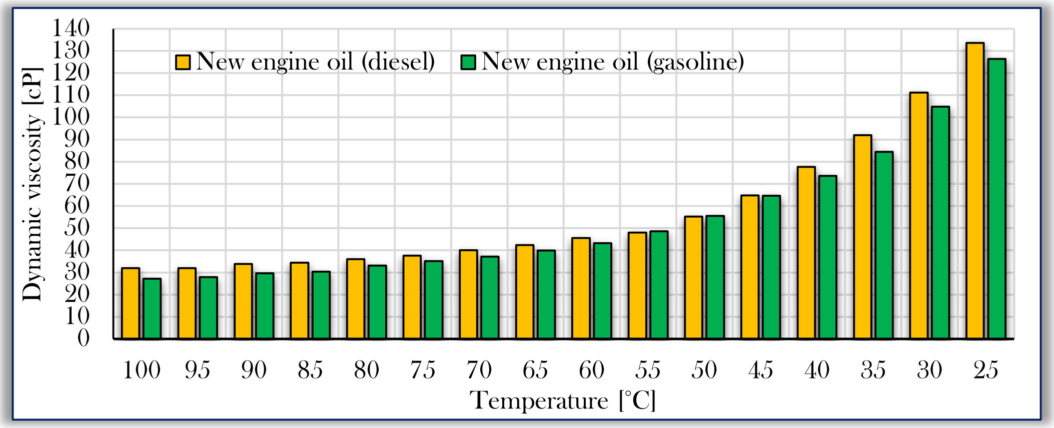

Figure 9. Comparison of the dynamic viscosity of new engine oils (diesel and gasoline) depending on temperature variation

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6. CONCLUSIONS

The impact of fuel contamination on engine oil performance is frequently underestimated compared to other common contaminants like soot and water. However, this study demonstrates that fuel, typically introduced into engine oil through internal injector leakage, can significantly alter the oil's properties. Specifically, fuel contamination reduces oil viscosity, thereby diminishing its ability to provide proper lubrication and potentially accelerating wear in engine components.

The interaction between soot and fuel contamination presents a complex dynamic, especially in diesel engines where soot particles are more prevalent. As expected, the ageing process – driven by oxidation and the accumulation of carbon black (CB) particles – resulted in an increase in oil viscosity. Conversely, diesel fuel contamination slightly reduced viscosity due to fuel dilution. Interestingly, when both CB particles and diesel were present, their opposing effects on viscosity balanced out, resulting in no notable change, particularly at elevated temperatures.

At higher operating temperatures, differences in oil viscosity caused by various contaminants, including CB and diesel fuel, are less pronounced. This suggests that under thermal stress, the combined influence of contaminants on viscosity diminishes, making temperature a dominant factor. These findings are crucial for optimizing oil maintenance strategies in real-world engine conditions, where mixed contamination and high temperatures are common.

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