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Refinement of Internal-Combustion Engine Oil Properties Via Magnetic Flux

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Abstract. To verify the influence of magnetic flux on the characteristics of SAE 10W-30 gasoline engine oil when the engine oil is exposed to different magnetic fluxes 0, 6, 9, and 13 Volt. The following oil characteristics were measured: viscosity at 40 and 100 °C, and total acid number (TAN) mg KOH/g. The research was carried out in a completely randomized design with three replications for each treatment under the 5% probability level to compare the means of the treatments. The results of the experiment showed that there were significant differences in the studied properties when the engine oil was exposed to the above magnetic fluxes and, inversely, especially the magnetic flux of 13 Volt, which led to a decrease in the viscosity of the oils at 40 °C to 67.704 cSt and 14.1 cSt at 100 °C, in addition to a decrease in the total acid number to 2.1 mgKOH/g. The results of this study promise the possibility of the magnetic flux affecting changes in the properties of gasoline engine oil, which may contribute to improving the performance of engine oils during operation.

Keywords. Engine lubrication oil, Viscosity, TAN, Sustainability, Magnetization, Oil condition.

1. Introduction

Engine oils perform multiple functions, including cooling, sealing, cleaning, and preventing engine corrosion, and these engine oils are manufactured from base oils and additives to perform the above functions [1]. Chemical additives have many benefits, such as improving the performance of engine oils during service [2]. Engine oil oxidation causes increased acidity, viscosity, gums, and sludge formation, and the depletion of chemical additives during service leads to engine oil deterioration [3]. Additives contribute to the resistance to oxidative stress that produces increased engine oil acidity, and oxidation occurs due to the interaction of air with oil [4] and contaminants such as glycol that react with engine oil and oxidize engine oil [5, 6]. However, using petroleum-derived oil base and refining additives in lubricants is linked to adverse effects on human health and the environment [7]. Searching for an alternative or reducing dependence on engine oil additives is challenging to protect the environment and humans from pollution. Reducing pollution is one of the Sustainable Development Goals adopted by the United Nations in its Vision 2030 [8].

Magnetization has been employed in experiments regarding internal combustion engines to enhance engine efficiency and eliminate emissions that negatively impact the environment. The results showed that the magnetization of fuel decreases the release of exhaust gases, such as carbon monoxide (CO) and hydrocarbons (HC), by dispersing clusters of hydrocarbons into smaller particles, enhances the efficiency of combustion and reduces the amount of unburned fuel [9, 10, 11]. However, few studies examined the effect of a magnetic flux on oil properties when the oil passes through a magnetic flux. An experiment examined the effects of an external magnetic field at a low temperature of 5°C on four kinds of crude oils; the results showed that oil viscosity was reduced because the magnetic field affects the microscopic clustering of particles suspended in the oil [12].
The research aims to determine the effect of magnetic flux on the characteristics of SAE 10W-30 gasoline engine oil when the engine oil is exposed to magnetic flux (0, 6, 9, and 13 Volts) by measuring the following oil characteristics: viscosity at 40 and 100 ^{O}C, and total acid number TAN.

2. Materials and Methods

The experiment was conducted in the workshop of the Agricultural Machinery Department/Al-Mussaib Technical Institute/Al-Furat Al-Awsat Technical University using a fixed four-stroke gasoline engine manufactured by the Japanese Corolla Company, type (A-FE4), with 30 working hours for each treatment. Table (1) shows the technical specifications of the engine. The engine was fitted out with Iraqi oil from the local market, which the Iraqi Oil Production Company manufactured, type SAE 10W-30.

Table 1. Engine specifications.

Manufacturer	Toyota
Engine type	A-FE4
Displacement	1.6 L
Configuration	4 Cylinder – in line
Bore × Stroke	81 × 77 mm
Fuel system	E.F.I
Fuel type	Gasoline
Compression ratio	1 - 9.5
Cooling system	Water-cooled
Valve train	DOHC – 16 Valve

The engine's lubricating oil goes through a magnetization system that treats it with four levels of magnetic flux: 0, 6, 9, and 13 volts. The engine was run until it became thermally stable, and the required readings were taken. Samples of oils were taken after exposure to the above magnetic flux levels to conduct laboratory analyses, including viscosity at 40 and 100 C, and total acid number (TAN). Laboratory analyses of oils were conducted at the Ministry of Science and Technology/Department of Materials Research/Petroleum and Petrochemical Research Centre. The analysis of variance (ANOVA) modelling with an alpha value of 0.05 was used to determine whether or not there were significant differences among the data [13].

2.1. Test System

A particular system was created to magnetize the oil to be tested, as in Figure (1). The system was connected to the engine, which contains several parts, represented by the supply source (9), the voltage reducer device (10), the current measuring device (11) in the system, and the magnetization chamber (4). The magnet system was installed in the engine's lubrication system.

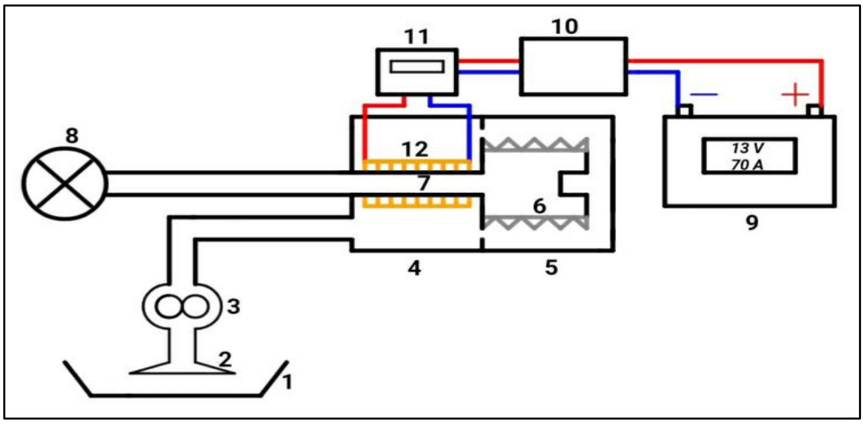

Figure 1. Schematic of the magnetization system. 1- Oil sump. 2- Oil filter. 3- Oil pump. 4- Magnetization chamber. 5- Oil filter. 6- filtration element. 7- A metal tube with open ends. 8- Engine parts. 9- DC battery (power supply). 10- Voltage reducing device. 11- A device for measuring the intensity of electrical current. 12- Magnetization file.

The power source used for the magnetization system is a DC lead-acid battery (9) with a voltage of 13 volts and a current of 70 amps/hour.
A voltage reducer device (10), shown in Figure (1), was used (DC-DC Step Down Buck Converter) to regulate the intensity of the electrical current from 40 to 1.2 volts with a power of 300 W to adjust the electrical current traveling through the magnetization chamber to the required test intensities of 6, 9, and 13 volts.
A DC Voltmeter device (11) in Figure (1) was connected to indicate the value of the electrical current supplied to the magnetization chamber for each treatment during the experiment.
A special chamber was manufactured to magnetize the engine oil (4) in the diagram above and is located between the oil filter and the engine. The magnetization chamber consists of a magnetization coil (12), which is a copper wire with a diameter of (0.24 mm) and several turns (600) around an open-ended metal tube (7) made of iron, with a length of (59 mm), an internal diameter of (23 mm), and a thickness of (2 mm). The file was placed inside a metal casing made of iron, diameter (66 mm) and thickness (1 mm). The calculating of the magnetic flux density was done according to the COMSOL Multiphysics, using Ampere's law to calculate the magnetic flux density, which states the following: Calculate the magnetic flux density B [14].

$$B = \mu_0 \, \mu_r \, H$$

Where: H = magnetic flex intensity, B = magnetic flex density (tesla), μ_r = relative permeability of martial, μ_0 = Absolute permeability of air or vacuum.

2.2. Practical Test

The engine is started as it begins pumping the oil coming from the oil sump (1), as shown in the magnetization system in Figure (1), through the oil pump (3). The oil first enters the magnetization chamber (4) so that the oil is magnetized and goes to the oil purifier (5). The engine oil then passes through the purification element (6) and returns a second time through the metal tube (7) to go to the engine parts (8), after which oil returns to the oil sump, and then the process is repeated. The coil is operated by supplying it with a current from the battery, as the coil is supplied with three values of DC 6, 9, and 13 volts to test the oil on three voltages for magnetic flux.
The distribution of the intensity of the magnetic flux applied to the oil was calculated using the Comsol simulation program, and the simulation results were as follows:

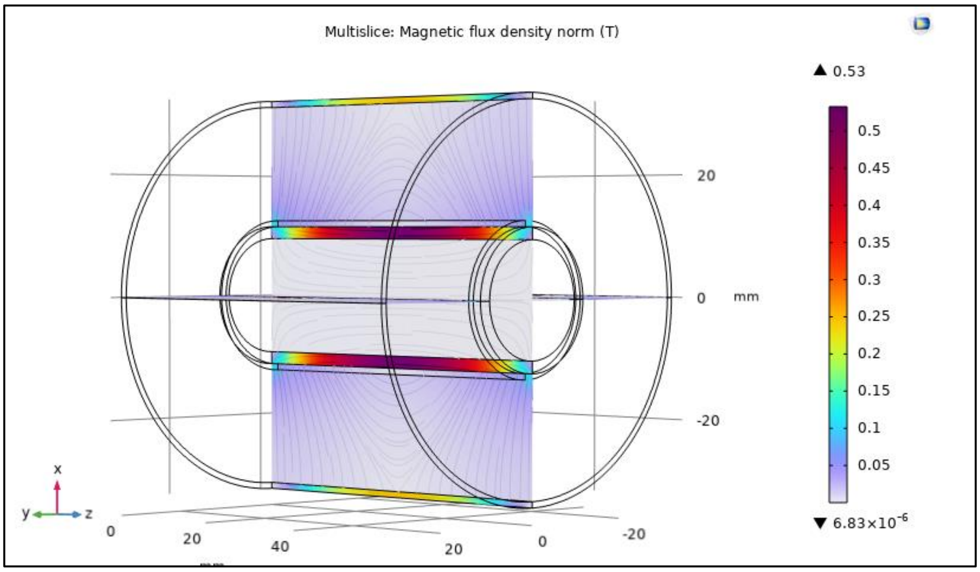

Figure 2. Magnetic flux (13 volts) by COMSOL.

The results of simulating the magnetic flux using the COMSOL program show the distribution of the magnetic flux of the magnetization chamber, as shown in Figure 2. The highest magnetic flux, shown in red for current intensity, was 13 Volt and 0.53 Tesla, and the lowest intensity, shown in grey, was 6×10^{-6} Tesla.

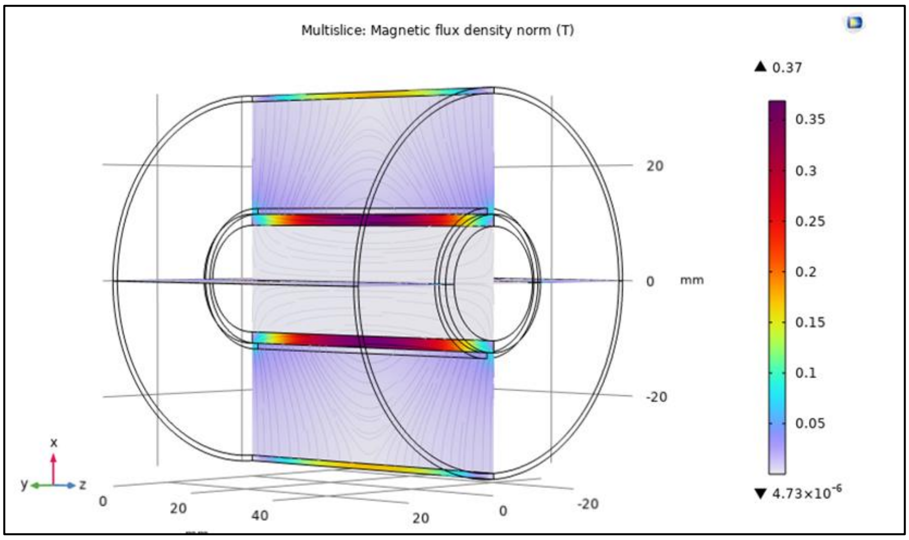

Figure 3. Magnetic flux (9 volt) by COMSOL.

At a current intensity of 9 Volts, the results showed that the highest magnetic flux, represented in red, was 0.37 Tesla, and the lowest magnetic flux, represented in grey, was 4 x 10^{-6} Tesla, as in Figure 3.

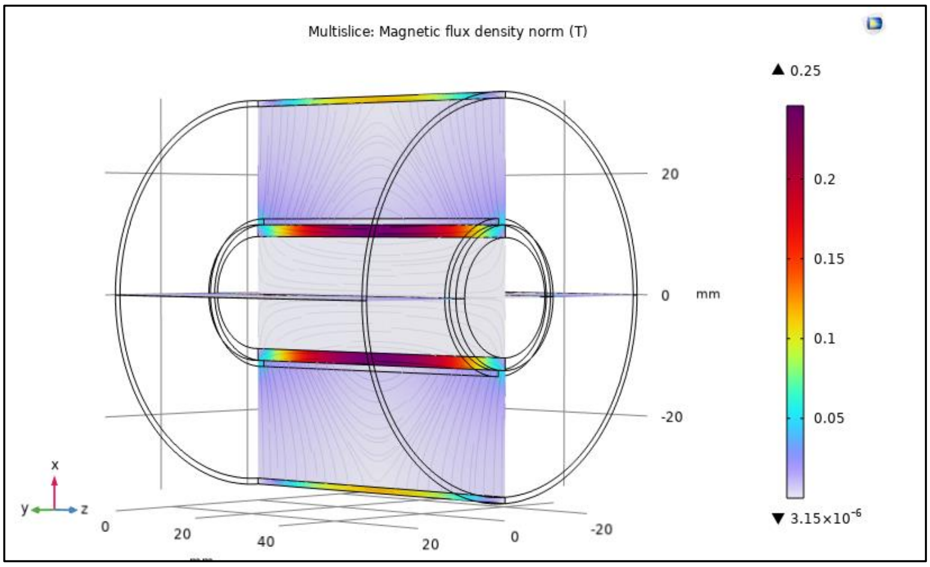

Figure 4. Magnetic flux (6 volts) by COMSOL.

At a current intensity of 6 volts inside the magnetization chamber, the highest magnetic flux density, represented by the red colour, was 0.25 Tesla, and the lowest magnetic flux density, represented by the light grey colour at the centre of the magnetization chamber, was 3×10^{-6} Tesla (Figure 4).

3. Results and Dissection

A magnetization system for generating various strengths of magnetic flux for engine oil was used to obtain data on gasoline engine oil viscosity at 40 and 100°C, flash point, and total acid number TAN. Magnetic flux strengths of 0, 6, 9, and 13 volts were used. The data was analysed statistically in a completely randomized design with a probability level of 5%.

3.1. . Viscosity

Figure 5 illustrates how the magnetic field's strength affects the oils' viscosity. The statistical analysis confirmed significant variations in the treatment when the flux intensity changed from 0 to 6, then to 9, and finally to 13 volts, at a probability level of 0.05. This indicates that the flux intensity impacts the oil viscosity as it changes from one intensity to another. When the magnetic flux was 0 volts, the highest viscosity rate was 40 degrees Celsius (Figure 5-a), reaching 73.8 centistokes. Subsequently, at 6 volts, the viscosity was 70.4 centistokes; at 9 volts, it decreased to 68.6 centistokes. Finally, at 13 volts, the viscosity dropped to 67.7 centistokes, marking the lowest rate; thus, the viscosity decreased ratios were 4.8%, 2.6%, and 1.3%, respectively, for the oil. A significant difference was noted due to the impact of magnetic flux on the oil viscosity of 100°C. The magnetic flux yielded the highest viscosity rate of 15.26 centistokes at 0 volts, 6 volts with 15.16 centistokes, and 9 volts with 14.66 centistokes. Meanwhile, the 13 volt produced the lowest viscosity rate of 14.06 centistokes (Figure 5-b). An augmentation in magnetic flux resulted in a reduction in viscosity measurements [12].

3.2. Total Acid Number TAN

Figure 6 illustrates the effect of magnetic flux on the Total Acid Number (TAN). The impact of magnetic flux varied significantly at a 5% significance level on the Total Acid Number. Precisely, a magnetic flux of 0 recorded the highest TAN rate of 2.86 mgKOH/g, while the TAN rate decreased with an increase in the voltages from 6 to 9 volts, reaching 2.53 and 2.26 mgKOH/g, respectively. In comparison, the lowest TAN rate is 2.03 mgKOH/g at 13 Volt. Moreover, the magnetic flux at 13 Volt reduced the Total Acid Number more effectively than other voltage values. Increasing the magnetic flux decreased the Total Acid Number, which may improve the engine oil's lifetime when used rather than being dependent on chemical additives. The oil's acidity exhibited a similar pattern to the oil's viscosity, with both decreasing as the magnetic flux increased. This correlation may be attributed to the fact that there is a direct relationship between oil viscosity and oil acidity [3].

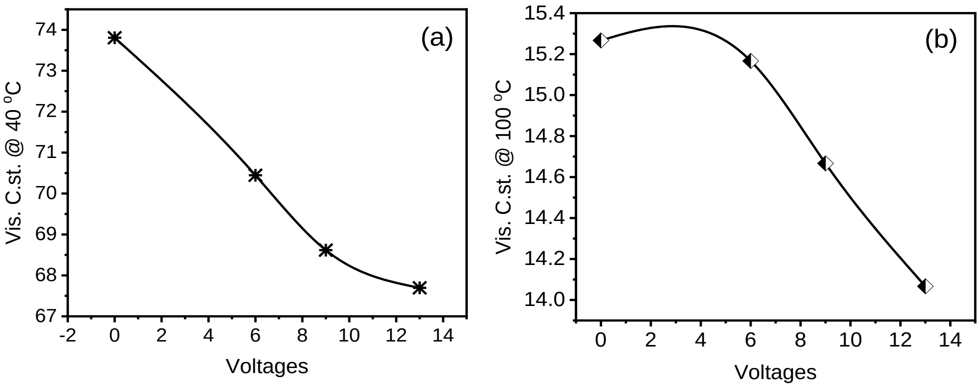

Figure 5. (a) Mean of viscosity@ 40 ℃ and (b) mean of viscosity@ 100 ℃ of SAE 10W-30 with four levels of magnetic flux.

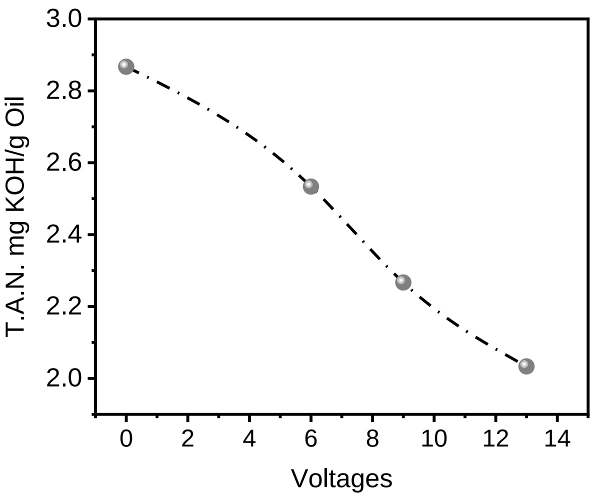

Figure 6. Mean of total acid number of SAE 10W-30 with four levels of magnetic flux.

Conclusion

- The magnetic flux differed in its effect on viscosity at 40 and 100 °C, and the total acid number of SAE10W-30 gasoline engine oil due to the low rates of the above characteristics and at a probability level of 5%.
- The effect of the magnetic flux of 13 volts was more than the other three flux rates in reducing the rates of the four characteristics studied.
- There was a difference between the magnetic flux rates used in their effect on viscosity at 40 and 100 °C, and the total acid number of the SAE10W-30 gasoline engine oil where both the viscosity decreased at 40 and 100 °C, and the total acid number with increasing the magnetic flux.

The study revealed that applying magnetic flux can enhance the characteristics of gasoline engine oil. This enhancement can potentially prolong engine oil's lifespan and decrease the need for chemical additives in lubricating oil. These findings align with the United Nations' sustainability goals for 2030.

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