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Investigation of the Effect of Mileage on the Physical and Chemical Properties on a Sample of Diesel Engine Oils Available in the Libyan Market

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Abstract:
Internal combustion engine oils play a significant and vital role in engine service life and extending its lifespan. The purpose of this study was to examine the effect of mileage on the physical and chemical properties of a sample of diesel engine oils available in the Libyan market. In this study, several laboratory experiments were conducted at the Libyan Oil Research Center and the Zawiya Oil and Gas Refinery on a sample of Italian-made IVECO Urania SAW 15W-40 diesel engine oil after using it for varying distances (0 km, 3,500 km, 5,000 km, and 10,000 km). In addition to measuring viscosity, which is considered one of the most important and reliable parameters for assessing the properties and lifespan of the used oil, this research also examined other equally important properties, namely density, pour point, flash point, and ash percentage. A used oil sample was taken from a four-cylinder diesel engine with an age of 120,000 km, belonging to a (Iveco Cursor) model. The results of this study showed that the effect of distance traveled on the studied properties was clear and noticeable. For example, the viscosity decrease reached 15.43% at 40°C and 11.7% at 100°C for a distance of 5,000 km compared to a distance of 0 km, and an increase in the average density by 0.114%. The rate of change in flash point was also clear from 226°C at 0 km to 228°C at 5,000 km. The ash content of the used oil increased by 13.27% compared to a distance of 0 km, and the pour point was less than -30°C.
Keywords: Viscosity, density, pour point, flash point, ash percentage.

دراسة تأثير المسافة المقطوعة على الخواص الفيزيائية والكيميائية لعينه من زيوت محركات الديزل الموجودة بالسوق الليبي

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ملخـــــــص البحـــــــــث
زيوت محركات الاحتراق الداخلي تلعب دوراً كبيراً ومهماً جداً في الفترة الزمنية لخدمة المحرك وإطالة عمره. الغرض من هذه الدراسة هو اختبار مدى تأثير المسافة المقطوعة على الخواص الفيزيائية والكيميائية لعينه من زيوت محركات الديزل الموجودة بالسوق الليبي. في هذه الدراسة أجريت عدد من التجارب المعملية بمركز بحوث النفط الليبي ومصفاة الزاوية لتكرير النفط والغاز على عينه من زيت محرك الديزل من نوع أفكو IVECO Urania SAW 15W−40 ، إيطالي الصنع، بعد استخدامها لقطع مسافات متفاوتة (0 كم , 3500 كم , 5000 كم , 10000كم). إلى جانب قياس خاصية اللزوجة (Viscosity) والتي تعتبر من أهم الخواص التي يمكن الاعتماد عليها لقياس خصائص وعمر الزيت المستخدم، تم في هذا البحث دراسة بعض الخواص الأخرى ذات أهمية لا تقل شأنا عن خاصية اللزوجة والمتمثلة في الكثافة(Density) ، درجة الانسكاب (pour point)، درجة الوميض (Flash point) ، ونسبة الرماد (pour point). لقد تم أخذ عينة الزيت المستخدم من محرك ديزل ذو أربع أسطوانات بعمر يصل الي 120000كم لسيارة نوع شاحنة (Iveco Cursor). وأظهرت نتائج هذه الدراسة أن تأثير المسافة المقطوعة على الخصائص المدروسة كان واضحاً

وملحوظاً. على سبيل المثال بلغ مقدار الانخفاض للزوجة 15.43% عند درجة حرارة 40 Cوبنسبة 11.7% عند درجة حرارة 100 Co لمسافة 5000 كم مقارنة بالمسافة 0 كم , وزيادة في معدل مقدار الكثافة (Density) بمقدار 0.114% . وكان معدل التغير في نقطة الوميض (Flash point) واضحاً أيضاً من C226عند 0 كم الي 228 Cعند 5000 كم . وارتفعت نسبة الرماد (Ash Content) بالزيت المستعمل الي 13.27% بالمقارنة عند المسافة 0 كم و وبلغت درجة الانسكاب اقل من – C)).30

الكلمات المفتاحية: اللزوجة، الكثافة، درجة الوميض، درجة الانسكاب، نسبة الرماد.

1. Introduction

The lubrication process in the internal combustion engine operating system plays a fundamental role in extending engine life, given that the engine operates under pressure and high temperatures. The oil acts as a cooling fluid for engine parts, enabling it to maximize its design efficiency and protect the engine's combustion chambers from collapse.

Engine oils are classified as mineral oils. They are derived or manufactured from crude oil. Therefore, the quality of the crude oil is very important in determining the properties of the oil. For these reasons, mineral oils are more widely used than synthetic oils. However, mineral oils may not have the properties required for car engines. Therefore, their properties are improved by adding chemicals. Additives can be classified as detergents, anti-rust and anti-corrosion agents, anti-oxidants, anti-friction agents, viscosity enhancers, antifreeze agents, and oil repellents [1-4]

Combustion oils are classified according to approved standards, including those of the Society of Automotive Engineers (SAE) and the American Petroleum Institute (API), which is responsible for granting licenses and certifications for the types of oils used [1, 2]. Based on the SAE classification, the viscosity of the oil is classified according to specific numbers and letters, such as (w-300, w-305, w-4010, w-5020, etc.). The numbers indicate the temperature, and the letters indicate the seasons of use, whether summer or winter [5-6].

Several factors contribute to negatively impacting oil consumption or changing its specifications and effectiveness in internal combustion engines, including the distance travelled. For this reason, it has become necessary to conduct studies to evaluate the chemical and physical properties of engine lubricants available in local markets by comparing them with local and international standard specifications, as well as comparing the specifications obtained from laboratory analyses with the specifications published on the websites of the companies that manufacture these selected samples.

Abdullah Azawi Issa (2017) [2] studied the effect of the distance traveled by vehicles, a 2013 Hyundai Korean bus, on the physical and chemical properties of SAE 40 engine oil produced at Baghdad refineries. The results of this study showed that the oil density increased with increasing distance travelled, reaching 90.2% at 2,500 km, and that the oil viscosity gradually decreased with increasing distance, reaching its highest value at 2,500 km. (Dr. Mohamed Abu Ras, Dr. Mohamed Al-Ruwaimi, M. Mohamed Farshik, 2020) [3] studied the extent of change in the specifications of a new gasoline engine oil (FIAT 1.2) after using it for different distances (3000 km, 4000 km, 5000 km), where three types of oils were used (Ravenol, Castrol, Altria). The results of the study on the samples of used oils showed that the greater the distance travelled, the greater the decrease in the viscosity of the oil, where the viscosity percentage at a temperature of 100 °C after travelling a distance of 5000 km decreased to 8.22% for Ravenol oil, 8.32% for Castrol oil, and 8.86% for Altria oil. Dr. Omar Sultan, Mr. Muhammad Qabbasa, Dr. Nadia Al-Sabani, 2020 [7] conducted an analytical study on the quality of 8 types of gasoline engine oils circulating in the Libyan markets, focusing on the SAE 20 W50 grade. The results of this study showed that the lowest quality oils in terms of viscosity were Idrivl02 and B-oil, while the best quality oils were Ravenol and Luk oil samples. The viscosity index of the Super-Gt oil sample did not match the technical specifications for viscosity index values. Mohsin Majeed (2014) [8] compared the effect of both physical and chemical properties of motorcycle lubricating oil after operating it for 5,000 km using natural gas and gasoline. The properties of the lubricating oil were tested according to standard ASTM methods. Their results showed that lubricating oil using natural gas as a fuel suffered less degradation in its properties than lubricating oil using gasoline as a fuel. Hiba Yassin Ahmed, 2021[9] studied the reality of the quality of internal combustion engine oils available in the local markets in Iraq and the extent of their compliance with standard specifications. He determined the kinematic viscosity, pour point, and flash point of 40 engine oil samples at 100°C. The analytical results showed that most of the oil samples studied conformed to the standard specifications.Dana Karim Hameed (2013) [10] studied the relationship between the number of miles traveled and its effect on engine oil degradation. The effects of new and old engines on key oil properties, including kinematic viscosity, flash point, and flash point, were investigated. The results of this study showed that the deterioration of oil properties in older engines is higher than in new engines. Rattan, J., and Parihar (2017) [11] studied enhancing the viscosity index (VI) of lubricating oils by adding VSI improvers. The results showed that the VSI process of blended oils made from lubricating oils has the potential to reach a maximum value. It was found that the occurrence of the maximum VSI depends on the lubricating oil used and the type and concentration of the VSI improver.

We note that most of these studies focused on the viscosity property of gasoline engines, considering this property one of the most important for assessing oil quality. In this research, the effect of mileage on the properties of a sample of one of the oils commonly used in the Libyan market, SAW 15W-40 IVECO Urania diesel oil, manufactured in Italy, will be examined to test the extent to which its properties and specifications change after being used for varying distances. The most important properties to be studied are viscosity, density, pour point, flash point, and ash percentage.

2- Experimental and Research Mechanism

In this study, an experiments was conducted on IVECO Urania SAW 15W-40 diesel oil for a (Iveco Cursor) engine with a service life of approximately (120,000 km). Experiments were conducted at the Zawiya Refinery and the Oil Research Center. The specifications of the protein engine are shown in Table (1).

Table (1) shows the specifications of the diesel engine used in the study.

Vehicle type	Engine capacity	Number of cylinders	Torque	Transmission
IVECO COURS 13	12.88 CC	6	480HP	Manual

2-1 Physical and chemical properties under study

The properties of each type of oil can be determined through its physical and chemical parameters, such as viscosity, density, flash point, flow rate, acid number, lubricity, and freezing point. Depending on the oil's application, attention is focused on one or more parameters, such as density, viscosity and its relationship to temperature changes, and auto-ignition point.

1- Density:

Density is the ratio of the mass of a substance measured in kilograms to its volume measured in cubic meter (kg/m^3). There is also the concept of relative density, symbolized by the symbol S, which is the ratio of the mass of a given volume of a substance to the mass of an equal.

In this study the density was measured by using the volumetric hydrometer method according to the standard specification.

Standrad Test Method for (ASTMD 1298) and Density-API-by Hydrometer Method.

2- Viscosity:

Viscosity, generally known as a liquid's resistance to flow, is a measure of the internal friction between oil molecules, or the resistance of oil molecules to separation under the influence of external forces.

Viscosity has two types: absolute dynamic viscosity, whose unit is poise and centipoises (g/cm.sec), and kinematic viscosity, which is the ratio of dynamic viscosity to the density of the liquid at the same temperature, whose unit is centistokes (cm^2/sec).

In this study, viscosity tests were conducted on a diesel oil sample at different temperatures (40°C, 100°C) in the oil laboratory at the Zawiya Oil Refinery and the Oil Research Center, using a Saybolt viscometer, according to ASTM D2270 standards [6]. the relationship V=C.t was used, where:
V: viscosity in centistokes (CSt)
t: Time in seconds (Sec)
C: Viscosity coefficient (a numerical figure that demonstrates the effect of temperature on viscosity).
Figure (1) shows the two viscosity measuring devices. In this process, the viscosity index (VI) of oil sample was calculated at two temperatures (40°C, 100°C) by measuring the time required for a specific volume of oil to flow under the influence of gravity through a capillary glass tube.

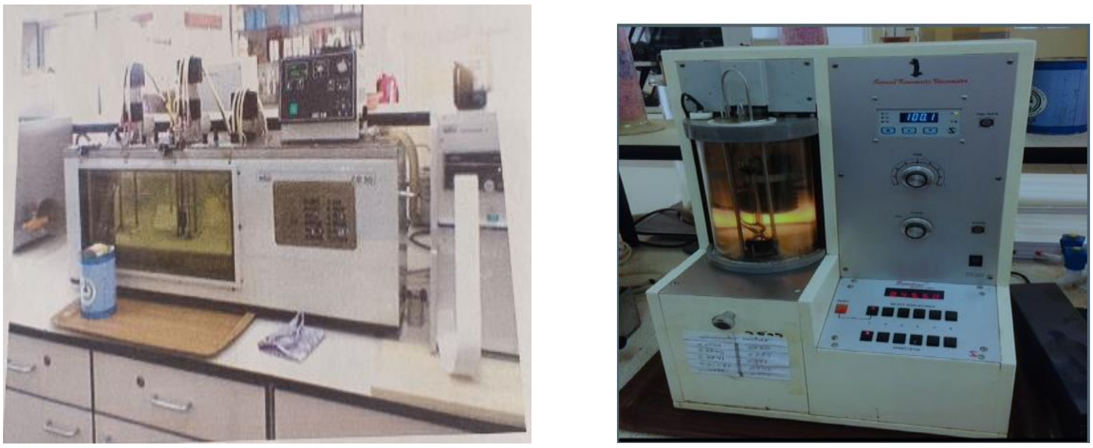


Figure 1: Viscosity measuring devices.

3- Viscosity Index (V.I)
Viscosity Index is the ability of the oil to maintain its fluidity at a certain range of temperatures. Viscosity Index is the main factor in engine oil specifications, and it is the relationship between viscosity and oil temperature. This factor serves as an indicator of the degree to which viscosity is affected by temperature. The higher the viscosity index the better the oil, as it is less affected by temperature changes. It is calculated based on knowledge of the kinematic viscosity. The viscosity index must not be less than 115 according to international specifications.

4- Water Content:
The amount of water in the oil is measured by the ASTN D-95 test method and by the vapor condensation method formed by the recovery method. The unit for measuring water content in oils is PPM.

5- Ash content:
Ash content is the non-volatile residue resulting from the incomplete combustion of petroleum derivatives. Ash content is measured using several methods. This study measured gray content according to ASTM 482 and used the Centrifuge Speed Pre-Selection method up to 4000 rpm with a drying oven.

6- Pour Point:
Pour point is the lowest temperature at which oil will pour when cooled under specific conditions. It is one of the most important requirements for engine and lubricating oils, especially in cold climates, and is related to the type of crude and wax present in it. It is an indicator of the oil's ability to flow at cold operating temperatures and is measured in degrees Celsius (Celsius). This is very important for engine oils and oils that operate at low and very low temperatures. In this study, the pour point of the

oil sample under study was determined according to the standard method [7] ASTM D97 and using the apparatus shown in Figure (2-A).

7- Flash Point:

Flash point is an indicator of the oil's ability to volatility. Flash point is the temperature at which an amount of up to 70 ml of oil flashes when exposed to an open flame. This point may range between (123 - 327) degrees Celsius. Figure (2-B) shows the device used to measure the degree of flashing.

Figure 2: Flash point and pour point measuring device

3- Results and discussion

In this study, a number of laboratory experiments were conducted at the Libyan Oil Research Center and the Zawiya Oil and Gas Refinery on a sample of Italian-made IVECO Urania SAW 15W-40 diesel engine oil. The oil was used for varying distances (0 km, 3,500 km, 5,000 km, 10,000 km) and at temperatures of 40 °C and 100 °C. The results of this study showed that the effect of distance traveled on the studied properties was clear and noticeable for the sample during different operating periods.

3-1 Effect of distance traveled on density

The results in Figure (3) indicate that the oil density is clearly affected by the distance traveled, as it was observed that the oil density increases with the increase in the distance traveled, where the percentage of change compared to the distance 0 km to the highest distance in the study was, respectively: 0.091%, 0.114%, 0.119%, due to temperatures, loads, water formation, combustion of components, sulfur compounds and solid parts. These factors contribute greatly to the increase in oil density and cannot be eliminated except by changing and replacing new oil.

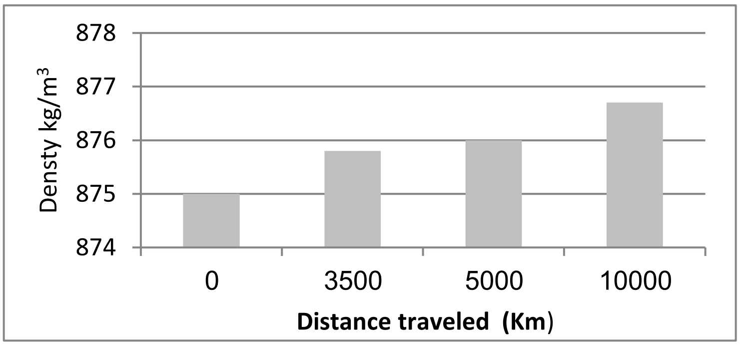


Figure 3: Relationship between oil density and distance traveled

3-2 Effect of distance traveled on viscosity

- **Oil viscosity at 40°C**

At 40°C, the results, as shown in Figure (4), showed a clear change in the viscosity rate, as the viscosity gradually decreases with increasing distance traveled and for long distances. This is due to the engine being exposed to various stresses resulting from high temperature, friction, corrosion and combustion products, the most important of which is the carbon content. This leads to a change in the color of the oil and a loss of viscosity properties. We note from the figure a decrease in the viscosity of the oil with increasing operating period compared to the distance of 0 km by percentages of 8.16%, 15.432% and 17.9%. This is consistent with numerous studies and evidence of the inverse relationship between temperature, distance, and viscosity, with the clear influence of the operating and maintenance conditions of the engine.

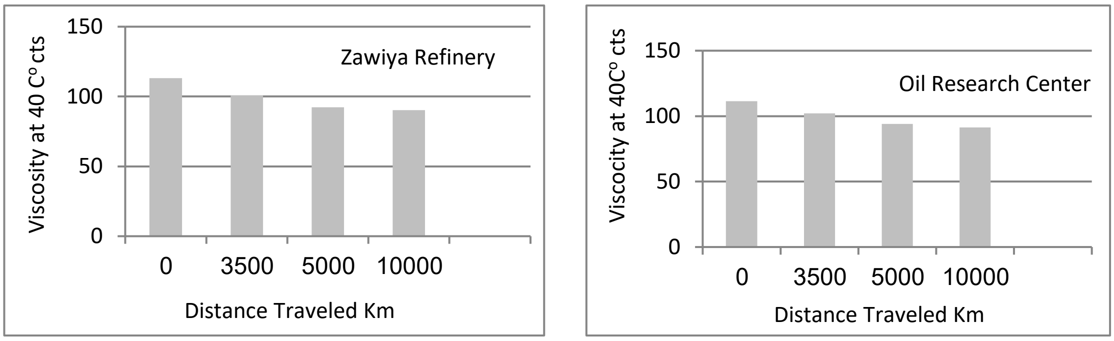
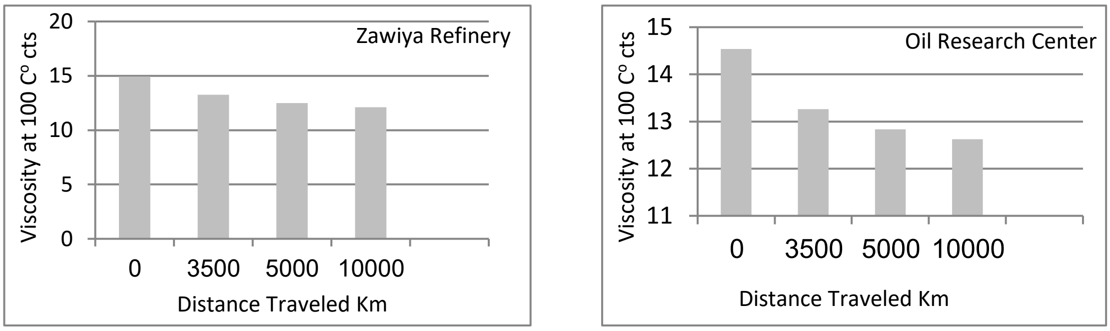


Figure 4: Relationship between oil viscosity and distance traveled at 40°C

- **Oil viscosity at 100°C**

At 100°C, the results as shown in Figure (5), show that the viscosity property gradually decreases with increasing distance traveled and over long distances due to the various stresses, friction, wear and combustion products that the engine is exposed to. We note from the figure that the viscosity of the oil decreases with increasing operating period compared to the distance of 0 km by rates of 8.7%, 11.7% and 13.15%. From the results shown in Figures 3 and 4, we find that the viscosity property is affected by the value of the distance traveled and the difference in temperature. This is consistent with many studies and proves the inverse relationship between temperature, distance and viscosity with the clear effect of the state of the operating and maintenance systems that the engine goes through.



5:Relationship between oil viscosity and distance traveled at 100°C

3-3 Effect of distance traveled on viscosity index

From Figure (6), we note that the viscosity index decreases with increasing distance traveled, and ranges between (127-134), but it indicates the stability of the oil viscosity despite the decrease. Therefore, the smaller the change in the viscosity index, the higher the quality of the oil used. This is consistent with several studies that indicate that a high viscosity index indicates little change in viscosity with temperature and distance traveled.

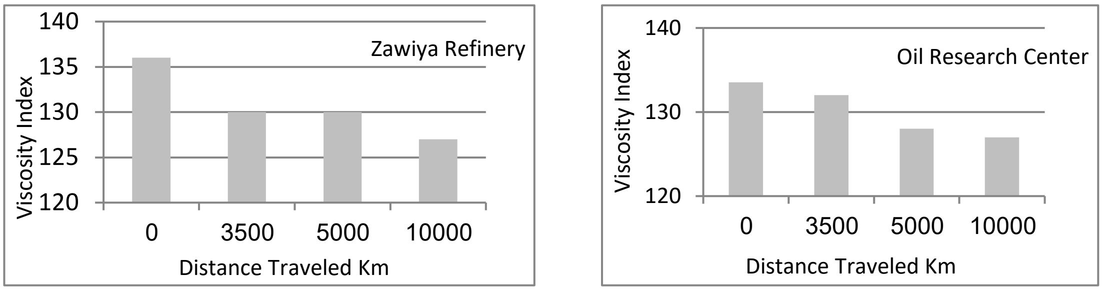


Figure 6: Relationship between viscosity index and distance traveled

3-4 The Effect of Distance Traveled on Flash Point

From Figure (7) we note that the flash point increases with the increase in the distance traveled, as the percentage of increase compared to the distance of zero km reached 0.17%, 0.88%, and 1.76% when conducting tests in the laboratories of the Oil Research Center, and at rates of 0.4%, 2.1%, and 3.8% when conducting tests in the laboratories of the Zawiya Refinery for distances of 3500 km, 5000 km, and 10000 km, respectively. This indicates the evaporation of lighter components and the retention of heavier components in the oil as a result of the high engine temperature and temperature changes during operation.

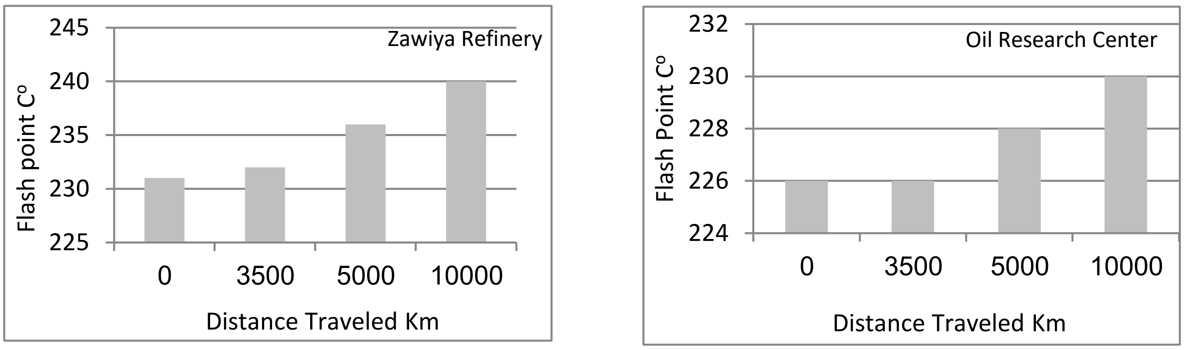


Figure 7: Relationship between flash point and distance traveled

3-5 The Effect of Distance Traveled on Ash Content wt%

We note from Figure (8) that the ash content increases with increasing distance traveled. The percentage increase compared to the distance of 0 km was 8.29%, 13.27% and 16.27% for distances of 3,500 km, 5,000 km, and 10,000 km, respectively. The ash content test indicates the condition of the combustion chamber, the wear and tear on the moving parts, the percentage of dirt, and the percentage of lead. Through the readings, we find the ash content within the permissible range.

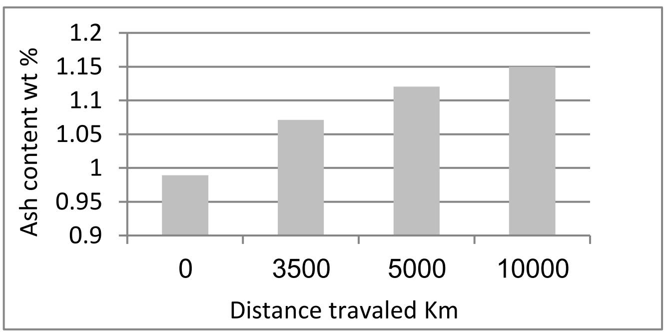


Figure 8: Relationship between ash content wt% and distance traveled.

3-6 The Effect of Distance Traveled on Elements (ppm)

From Figure (9), we note the percentage of change in minerals with oil operating distance. We conclude that the percentage of each mineral (calcium, zinc, and silicon) increases with increasing oil usage time due to operating conditions such as high temperature, friction, and corrosion. Meanwhile, the percentage of phosphorus decreases with distance traveled, according to the percentages shown in the figure, compared to new oil.

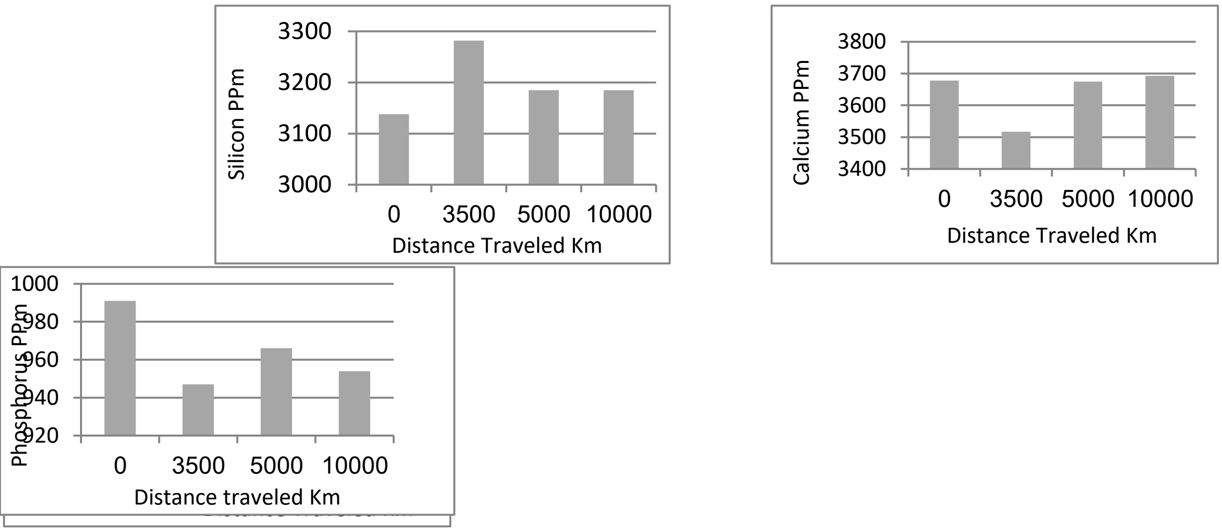


Figure 9: Effect of distance traveled on oil components.

Conclusion

In this study, the viscosity, density, flash point, and pour point tests were performed on a sample of IVECO Urania SAW 15W-40 diesel engine oil, manufactured in Italy, after using it for different distances (0 km, 3500 km, 5000 km, and 10000 km). The tests were conducted at the Libyan Oil Research Center and Zawiya Oil Refinery. The results obtained from this study showed that the physical and chemical properties are affected by the value of the distance traveled. It was found that oil density was clearly affected by the distance traveled. It was observed that oil density increased with increasing distance traveled. The percentage increase in density value compared to a distance of 0 km was 0.091%, 0.114%, and 0.119% for distances traveled of 3,500 km, 5,000 km, and 10,000 km, respectively. Regarding oil viscosity, the results of this study showed that oil viscosity declines with increasing distance traveled. The viscosity decreased by 15.43% at 40°C and by 11.7% at 100°C when the distance traveled was 5,000 km compared to 0 km. The viscosity decreased by 17.9% at 40°C and by 13.15% at 100°C when the distance traveled was 10,000 km compared to 0 km. The results also showed that the distance traveled also had a clear effect on the flash point, as the flash point increased with the increase in the distance traveled, with the percentage of increase compared to the distance of 0 km reaching 0.17%, 0.88%, and 1.76% for the distances traveled of 3500 km, 5000 km, and 10000 km, respectively. The ash content of the used oil increased to 16.27% at the distance traveled at 10,000 km, compared to the distance traveled at 0 km, and the pour point was less than -30°C.

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