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The Impact of Operating Mileage on the Properties of Libyan and Imported 10W-40 Engine Oils

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تأثير مسافة التشغيل على خصائص زيوت المحركات 10W-40 الليبية والمستوردة

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Abstract:
This study explores how the physical and chemical properties of various engine oils change when subjected to real driving conditions over different mileage intervals. Four commercial 10W-40 engine oils were examined, THURAYA, ALMONG, and MD (all locally produced in Libya), along with RAVENOL (an imported brand), to ensure consistency in comparison. Oil samples were collected after operating distances of 1,000 km, 2,500 km, and 4,000 km, with the vehicle maintained at a constant speed of 130 km/h. Fresh, unused oil samples were also analyzed and served as reference points. The evaluation focused on key performance indicators such as viscosity at 40 °C and 100 °C, flash point, and the concentration of essential metals including calcium, zinc, and phosphorus, measured using standard laboratory techniques. The findings revealed a clear deterioration in oil quality as mileage increased. Visually, the used oils showed noticeable darkening and loss of the transparent, glossy appearance defined by Libyan standards. Viscosity values declined steadily with distance, with THURAYA oil maintaining the best stability, while ALMONG oil exhibited the greatest reduction at both test temperatures. Elemental analysis showed variations in calcium, zinc, and phosphorus levels, indicating differences in additive depletion, evaporation of lighter oil fractions, and engine wear. Among the tested samples, RAVENOL oil contained the highest calcium concentration, suggesting superior anti-wear and detergent properties, whereas ALMONG oil recorded comparatively lower calcium content. The flash point values declined progressively with continued operation, ultimately falling outside the allowable limits defined by the Libyan standard, which indicates contamination and deterioration of the oil constituents. In general, the findings revealed that operating mileage has a noticeable effect on engine oil performance and highlight the necessity of routine oil condition monitoring, and timely replacement to preserve the engine efficiency, minimize wear, and prolong its operational lifespan.

Keywords: Engine Oils, Viscosity, Flash Point, SAE 10W-40, Additive Elements.

الملخص
تبحث هذه الدراسة في كيفية تغيّر الخصائص الفيزيائية والكيميائية لأنواع مختلفة من زيوت المحركات عند تعرضها لظروف التشغيل الفعلية على مسافات قيادة متفاوتة. تم اختبار أربعة أنواع من زيوت المحركات التجارية بدرجة لزوجة واحدة 10W-40 وهي: الثريا، المونغ، إم دي (جميعها محلية الصنع في ليبيا)، و رافينول (مستورد)، وذلك لضمان اتساق

المقارنة. تم جمع عينات الزيت بعد مسافات تشغيل بلغت 1000كم، 2500 كم، و4000 كم، مع الحفاظ على سرعة ثابتة للمركبة قدرها *130*كم/س .كما تم تحليل عينات الزيت الجديدة (غير المستخدمة) لاستخدامها كعينات مرجعية. ركّز التقييم على مؤشرات أداء رئيسية مثل اللزوجة عند درجتي حرارة 40°م و100°م، ونقطة الوميض، وتركيز بعض المعادن مثل الكالسيوم والزنك والفوسفور، وذلك باستخدام أجهزة مخبرية معيارية. أظهرت النتائج تدهوراً ملحوظاً في خصائص الزيوت مع زيادة المسافة المقطوعة. ومن خلال الفحص البصري، لوحظ تغيّر واضح في لون الزيوت المستعملة وفقدانها لمظهرها الشفاف واللامع الذي حددته المواصفة القياسية الليبية. كما انخفضت قيم اللزوجة تدريجياً مع زيادة المسافة، حيث أظهر زيت الثريا أقل انخفاض في اللزوجة، في حين سجّل زيت المونغ أعلى انخفاض عند درجتي الحرارة محل الدراسة. أما تحليل المعادن فقد أظهر تبايناً في محتوى الكالسيوم والزنك والفوسفور، مما يعكس سلوك المواد المضافة وتبخر الأجزاء الأخف من الزيت بالإضافة إلى تآكل أجزاء المحرك. وقد أظهر زيت رافينول أعلى تركيز لمادة الكالسيوم، مما يشير إلى أداء أفضل في مقاومة التآكل والتنظيف، بينما احتوى زيت المونغ على مستويات أقل نسبياً من الكالسيوم. كما انخفضت قيم نقطة الوميض مع استمرار الاستخدام، حتى تجاوزت الحدود المسموح بها في المواصفة الليبية، مما يدل على حدوث تلوث وتدهور في مكونات الزيت. بشكل عام، توضح النتائج أن المسافة التشغيلية تؤثر بشكل كبير على أداء زيوت المحركات، وتؤكد على أهمية المتابعة الدورية لحالة الزيت واستبداله في الوقت المناسب للمحافظة على كفاءة المحرك وتقليل التآكل وإطالة عمره التشغيلي.

الكلمات المفتاحية: زيوت المحركات، اللزوجة، نقطة الوميض، *SAE 10W-40*، العناصر المُضافة.

Introduction

With the continuous annual development of automotive engines in terms of design and operating mechanisms, mineral engine oils, primarily derived from crude oil, play a vital role in ensuring engine efficiency and extending service life. After crude oil extraction and transportation to refineries, it undergoes several refining processes aimed at removing impurities and achieving the appropriate viscosity for the base oil. In addition, engine oils contain various chemical additives that impart properties not available in base oils alone, such as the ability to operate over a wide temperature range and to maintain stable physicochemical characteristics throughout different service periods [1].

High-quality engine oils are characterized by strong resistance to oxidation during combustion processes within the engine and by their ability to maintain appropriate oil levels during operation, even under severe conditions. Moreover, effective engine oils exhibit rapid flow at low temperatures, ensuring complete lubrication of all engine components during cold starts and thereby protecting them from corrosion and wear [2]. Simultaneously, engine oils contribute to engine cooling during operation, as excessive engine temperatures may lead to mechanical failure or engine shutdown, resulting in significant economic losses [3].

Engine oils are required to meet specific physicochemical property criteria. Consequently, several organizations, such as the European Automobile Manufacturers' Association (ACEA) and the Society of Automotive Engineers (SAE), have established performance standards for lubricating oils based on engine manufacturers' requirements. These requirements vary depending on manufacturing technologies and engine operating conditions [4] [5].

Aisa (2017) [6] investigated the effect of vehicle mileage on the physicochemical properties of SAE 40 diesel engine oil produced at Baghdad refineries. The study examined properties such as density, viscosity, water content, additives, plasticizers, and ash content for mileages below 2500 km. The results showed that increasing mileage led to higher oil density and ash content, accompanied by a reduction in viscosity and water content.

A previous study conducted by Aburass et al. (2020) [7] examined the effect of mileage on selected properties of gasoline engine oils available in the Libyan market, including internationally manufactured oils such as CASTROL and RAVENOL, compared with the locally produced THURAYA oil. All oils belonged to the 20W-50 grade. However, the study did not include all local oil brands and did not address important parameters such as flash point and oil appearance before and after use. In another study, Ejledi and Hensheri (2024) [8] investigated the impact of mileage on engine oil properties, focusing on viscosity and foam formation for 5W-30 oil. They recommended that oil replacement decisions should not rely solely on nominal mileage but should also consider actual operating conditions, emphasizing the importance of periodic maintenance and oil replacement beyond 10,000 km to preserve engine lifespan.

Bufares et al. (2023) [9] conducted applied laboratory tests to compare a limited number of engine oil brands available in the Libyan market and assess their compliance with Libyan standard specifications under real operating conditions. The results indicated no significant change in the physical properties of the oils after use; however, the authors recommended supporting these findings with additional indicators, such as additive element concentration analysis, to achieve a more accurate assessment of oil quality. Hameed (2023) [10] performed an analytical study on the effect of vehicle mileage on the degradation of semi-synthetic SAE 10W-30 engine oil, comparing newer engines (model 2020) with older ones (model 2012). The study revealed more pronounced oil degradation in vehicles with high mileage (>100,000 km) compared to those with lower mileage (<25,000 km), indicating that extended oil usage in older vehicles leads to noticeable changes in oil properties, potentially reducing engine performance and increasing energy consumption.

Silini and Murjan (2024) [11] provided a comprehensive analysis of the behavior of THURAYA oil (10W-50) in gasoline engines over time, examining vehicles from different manufacturers such as CITROEN, HYUNDAI, ISUZU, and DAEWOO LANOS. The study highlighted the effects of time and increasing mileage on oil properties and their impact on overall engine performance. Additionally, Ateeya and Ahmed (2023) [12] evaluated the physicochemical properties of several SAE 20W-50 engine oils available in the Libyan market, including THURAYA, Gasoline F Zawia, Goldex Plus Super, and LUKOIL, with the aim of recycling and improving their properties. The study also presented a brief overview of used oil recycling stages using solvent mixtures, demonstrating that recycled oil can be reused in automotive engines after the addition of suitable performance-enhancing additives.

Objectives and Significance of the Study

Based on the findings of previous studies, this research paper aims to compare the physicochemical properties of locally produced SAE 10W-40 engine oils in Libya, manufactured by the Zawia Oil Refining Company and private producers, with an internationally manufactured oil of the same grade. The study focuses on evaluating the conformity of local oils with international counterparts in terms of physicochemical performance, quality and efficiency. This study differs from previous research in the type of oil investigated, as no prior studies, according to the authors' knowledge have examined SAE 10W-40 oil. Furthermore, a single FIAT engine was used throughout all laboratory experiments without replacement, minimizing the influence of variables such as engine type, size, operating pressure and speed. This approach ensures fair comparison, accuracy, and scientific reliability of the results.

The findings of this study are expected to contribute to the development of the local lubricants industry in Libya by providing accurate data on the quality and efficiency of locally produced oils, compared with international products. Such data may assist local manufacturers in improving production processes and product formulations to meet the requirements of automotive engines and industrial machinery.

Commonly Used Engine Oils in the Libyan Market

A wide variety of engine oils are used in Libya, differing in viscosity grades and performance levels, according to classifications and standards established by the American Petroleum Institute (API). These oils play a fundamental role in reducing friction and wear between engine components, enhancing operational efficiency, and extending engine lifetime. The Libyan market includes oils produced by European, American, and Russian companies, in addition to locally manufactured products. The selection of suitable engine oil depends on prevailing climatic conditions and vehicle operating characteristics, with particular emphasis on SAE viscosity grades such as 5W-20, 5W-30, 10W-40, and 20W-50, while ensuring compliance with standards related to oil performance under Libyan operating conditions.

The Libyan standard specification LNS 1058-1:2023 [13] defines the physicochemical requirements for SAE 10W-40 lubricating oil. According to this standard, the oil must exhibit a clear and bright appearance, with kinematic viscosity at 100 °C ranging from a minimum of 12.5 mm^2/s to a maximum of 16.3 mm^2/s. In addition, the minimum flash point (open cup) for SAE 10W-40 oil must not be less than 195 °C.

Experimental Work and Equipment Used

The investigated engine oils included commonly used locally produced brands, namely THURAYA, MD, and ALMOG. The performance of these oils was compared with that of a high quality internationally manufactured oil (RAVENOL) to evaluate their properties and conformity with the Libyan standard specifications. The oils were analyzed using a set of specialized laboratory instruments, including X-ray fluorescence (XRF), which was employed to determine the concentrations of metallic elements present in base oils and chemical additives, such as phosphorus (P), zinc (Zn), and calcium (Ca). This method is recognized for its high accuracy in measuring elemental concentrations at parts-per-million (ppm) levels. The instrument operates using helium gas to enhance measurement precision. In addition, SVM 3001 viscometer was used to determine the kinematic viscosity of the oils, while a Cleaved Open Cup apparatus was employed to measure their flash points. All experimental tests were conducted at the Oil Analysis Laboratory of the Zawia Oil Refining Company, in collaboration with the Petroleum Research Center of the National Oil Corporation.

Engine Specifications

The experimental tests were conducted using a four-cylinder FIAT gasoline engine with a 1.3 L capacity, manufactured in Italy in 2004. The engine is equipped with an indirect carburetor-based fuel delivery system. Its total lubricating oil capacity, including the oil filter, is 4 liters, and it is connected to a five-speed manual gearbox. For each tested oil, operating distances of 1000 km, 2500 km, and 4000 km were chosen to evaluate performance and degradation behaviour. Detailed technical specifications of the engine are provided in Table 1.

Table (1): Engine Specifications

Parameter	Specification
Engine Type	FIAT
Manufacturing Year	2004
Engine Power	13 Hp
Engine Mileage	15,061 km (nearly new)
Engine Condition	Excellent
Country of Manufacture	Italy
Transmission	Manual
Oil Sampling Distances	1000 km / 2500 km / 4000 km

Types of Engine Oils

SAE 10W-40 engine oil is the most widely used grade in the Libyan market due to its suitability for local climatic conditions, and compatibility with most commonly used vehicle engines. Table.2 presents the types of engine oils evaluated in this study.

Table (2): Engine oils used in the study

No.	Oil Brand	Viscosity Grade	API Classification	Country of Manufacture
1	THURAYA	10W-40	SL	Libya
2	MD Oil	10W-40	SN	Libya
3	ALMOG Oil	10W-40	SN	Libya
4	RAVENOL	10W-40	SN	Germany

Experimental Procedure

Prior to each test, the engine was operated briefly to warm the oil, facilitating complete drainage of the previously used oil. The oil filter was then replaced with a new one, and fresh oil was added to the engine. Subsequently, the vehicle odometer was reset to enable accurate data recording, and the engine was operated again under controlled test conditions for the distance shown in Table 3.

Table (3:) Operating Mileage

No.	Oil Brand	1st Mileage (km)	2nd Mileage (km)	3rd Mileage (km)
1	THURAYA	1000	2500	4000
2	MD Oil	1000	2500	4000
3	ALMOG Oil	1000	2500	4000
4	RAVENOL	1000	2500	4000

Experimental Instruments

After completing the operational tests and collecting oil samples, a series of physical and chemical analyses were conducted on the four engine oils at different operating distances. The following instruments were used.

- **X-ray Fluorescence Spectrometer (XRF)**

The X-ray fluorescence (XRF) instrument was employed to measure the concentrations of metallic elements present in base oils and chemical additives, such as phosphorus (P), zinc (Zn), and calcium (Ca). This technique is recognized as a highly accurate method for determining elemental concentrations at parts-per-million (ppm) levels. The instrument operates using helium gas to enhance measurement accuracy. Figure (1) illustrates the X-ray device used in this study.

Figure (1): X-ray fluorescence instrument (XRF)

- **Cleveland Open Cup Apparatus**

The Cleveland Open Cup (HFP 386) apparatus, shown in Figure (2), was used to determine the flash point temperature of flammable liquids. The test procedure involves placing a small quantity of the oil sample into the test cup, followed by gradual heating while continuously monitoring the temperature. At a specific temperature, a small flame or spark is introduced. The temperature at which the first visible flash occurs on the oil surface is recorded as the flash point.

Figure (2): Cleveland Open Cup apparatus

- **SVM 3001 Viscometer**

The SVM 3001 viscometer, manufactured by Anton Paar and shown in Figure (3), is an automated instrument used for measuring kinematic viscosity. It operates over a temperature range of −60 °C to +135 °C and a viscosity range of 0.2 to 30,000 mm²/s, in compliance with ASTM D7042 and ASTM D445 standards. The device provides accurate digital results within less than five minutes without the need for oil baths or fragile glass capillary tubes. Additionally, it does not require separate heating or cooling systems. Viscosity measurements are performed by injecting the oil sample into a connected measuring tube, offering high accuracy, rapid testing, ease of operation, and eliminating the need for traditional glassware replacement or extended waiting times.

Figure (3): Anton Paar SVM 3001 automated viscometer

Results

A series of tests were conducted on engine oil samples subjected to operational trials at different mileage intervals, with all tested oils having the same viscosity grade (SAE 10W-40). After each predefined operating distance, an oil sample was collected from each oil type to evaluate changes in its physicochemical properties. The results were then compared with reference samples taken prior to use. The evaluation focused on variations in viscosity, density, elemental composition, and flash point, using the laboratory instruments described earlier in this study.

Following sample collection and classification according to the distances traveled, a noticeable difference in oil color was observed between fresh and used samples for all tested oils. The results indicated that, after use, the oils lost the clear and bright appearance required by the Libyan standard specification. This change occurred after different operating distances under a constant vehicle speed of 130 km/h. Such visual changes reflect the degradation of the oils' physical and chemical properties due to continuous operation and service conditions, as illustrated in Figures (4–7).

Figure (4): RAVENOL oil samples

Figure (5): ALMOG oil samples

Figure (6): MD oil samples

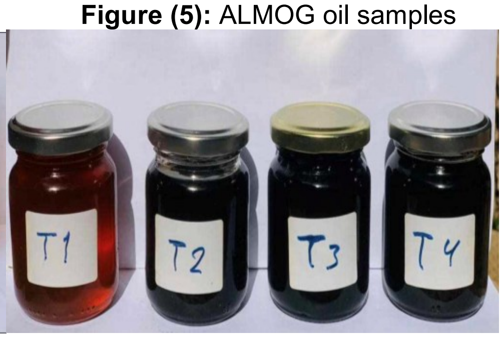

Figure (7): THURYA oil samples

The symbols R1, G1, D1, and T1 refer to the fresh (unused) oil samples of RAVENOL, ALMOG, MD, and THURAYA, respectively, prior to their addition to the engine, and were used as reference samples for analysis. The remaining symbols represent samples collected from the same oils after engine operation at distances of 1000 km, 2500 km, and 5000 km for each oil type investigated.

Discussion

Calcium is considered one of the most important additive elements in engine oils, functioning primarily as a detergent and anti-wear agent. It prevents the accumulation of acidic deposits, and forms as a protective layer on metal surfaces, thereby protecting the engine from corrosion and oxidation. However, with increasing operating distance and higher oil temperatures, partial evaporation of lighter oil components may occur while calcium remains in the oil, leading to its accumulation within the engine.

Such accumulation can contribute to increased friction, which in turn accelerates wear of internal engine components. Over time, this process may result in a reduction in both thermal and mechanical efficiency, increased fuel consumption, and abnormal rises in engine temperature, ultimately negatively affecting the overall vehicle performance.

Figure (8) shows that RAVENOL oil contains the highest calcium concentration among the oils examined. This observation may indicate that RAVENOL oil incorporates mineral additives that can maintain calcium levels over longer mileage, thereby reducing the adverse effects of wear within the engine. The sustained presence of calcium may also reflect a superior ability of the oil to resist corrosion. In contrast, although MD oil and THURAYA oil exhibit lower calcium concentrations than RAVENOL, they still provide a reasonable balance between engine protection and anti-wear performance. These oils may rely on alternative additive formulations that offer corrosion protection to a slightly lesser extent. Conversely, Figure (8) indicates that ALMOG oil contains the lowest calcium concentration, which may suggest a reduced capacity to mitigate wear or that its performance is more strongly influenced by operating conditions and driving style, potentially leading to higher wear rates of engine components.

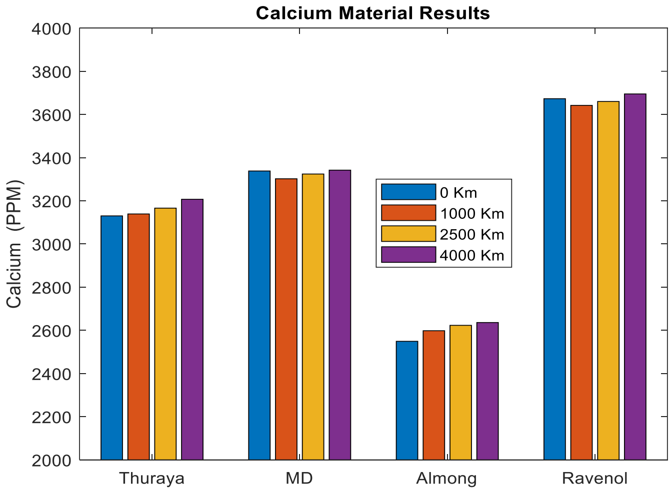

Figure (8): Calcium concentration test results

Figure (9) presents a comparison of zinc content in the oils studied, revealing noticeable differences among oil types as well as variations with increasing operating distance. An overall increase in zinc concentration was observed after each operating interval. This increase may be attributed to the natural wear of engine components, as certain engine parts are manufactured from zinc-containing alloys. As these components are subjected to friction and wear during operation, zinc particles may be released into the oil, resulting in elevated zinc concentrations.

Figure (10) illustrates the results of phosphorus analysis after different operating distances, compared with unused (fresh) oil samples. The results show a very slight increase in phosphorus content in MD, ALMOG, and RAVENOL oils. In contrast, a sudden and pronounced increase in phosphorus concentration was observed in THURAYA oil. This increase may be explained by the evaporation of lighter oil fractions during operation, leading to a higher concentration of mineral additives such as phosphorus in the remaining oil. Additionally, the accumulation of ash and solid contaminants may contribute to increased oil density and elevated concentrations of phosphorus and other metallic elements.

Figure (11) presents the viscosity values of all investigated oils at 100 °C, showing a clear decrease in viscosity with increasing operating distance. When comparing the initial (unused oils) viscosity values, the results indicate that both the locally produced oils and the imported oil exhibit very similar viscosity levels, and all of them fall within the limits defined by the Libyan standard. Furthermore, the results reveal that THURAYA oil experienced the lowest percentage reduction in viscosity, amounting to 6.2%, whereas ALMOG oil showed the highest viscosity reduction, reaching 16.3% after an operating distance of 4000 km.

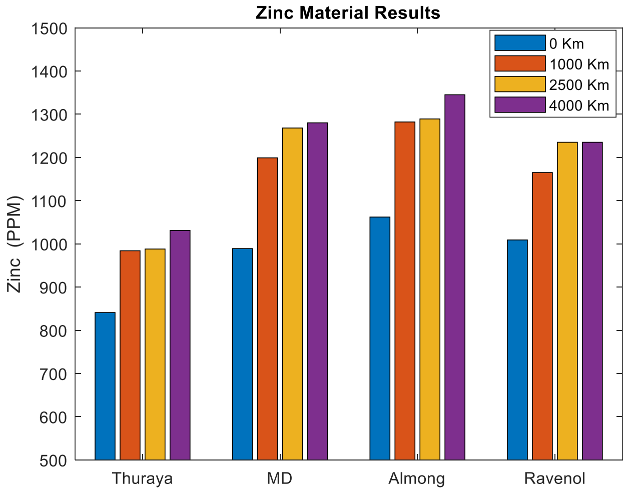

Figure (9): Zinc concentration test results

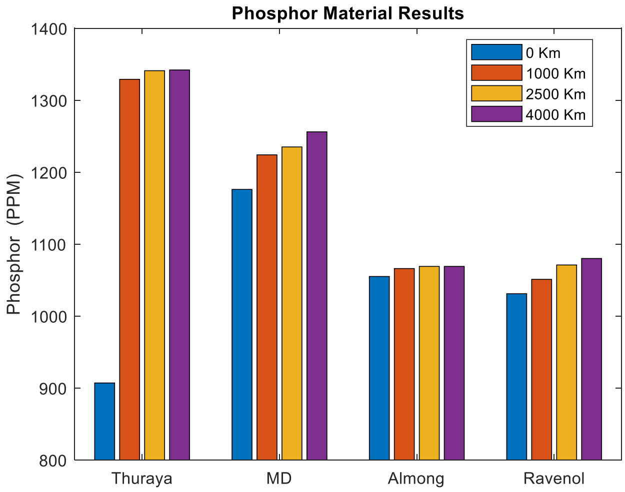

Figure (10): Phosphorus concentration test results

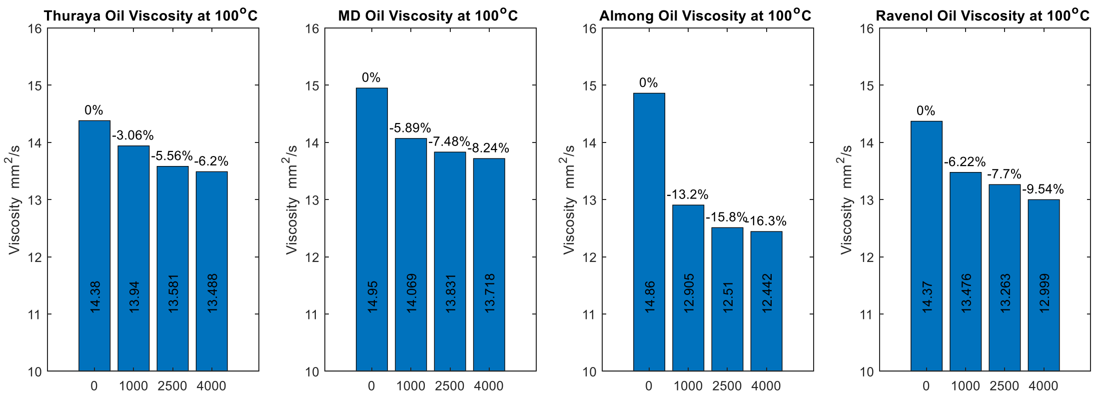

Figure (11): Viscosity test results at 100 °C

Figure (12) illustrates the viscosity values at 40 °C, where the results indicate that ALMOG oil and MD oil samples exhibited higher viscosity before use compared with THURAYA oil and RAVENOL oil. With increasing operating distance, a gradual decrease in viscosity was observed for all tested oils.

Notably, THURAYA oil recorded the lowest viscosity reduction of 7.78% after 4000 km relative to its initial value, while ALMOG oil exhibited the highest reduction, reaching 20.9% over the same distance.

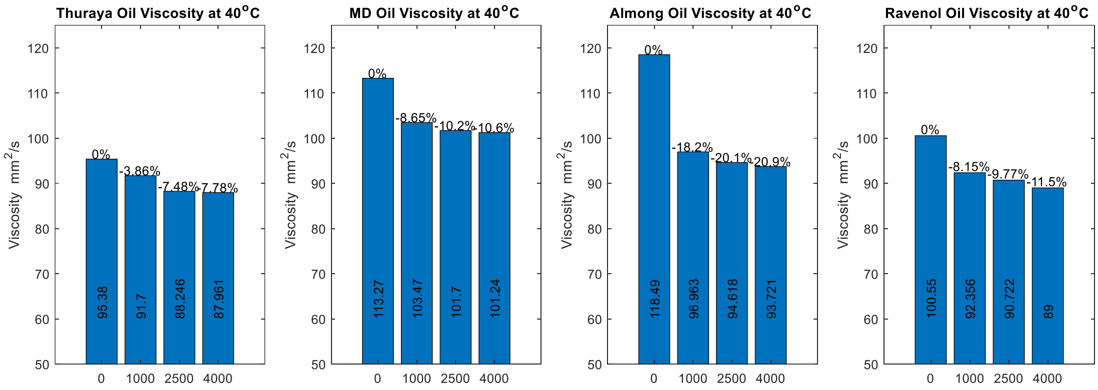

Figure (12): Viscosity test results at 40 °C

Figure (13) compares the flash point test results for the different oils evaluated in this study. The results for fresh, unused oil samples indicate that the flash point values of all oils were within the limits specified by the Libyan standard. However, these values gradually decreased with increasing operating distance, eventually falling outside the standard range. This trend indicates that flash point is strongly influenced by oil condition and service duration during engine operation, reflecting the physicochemical changes that occur in lubricating oils over time.

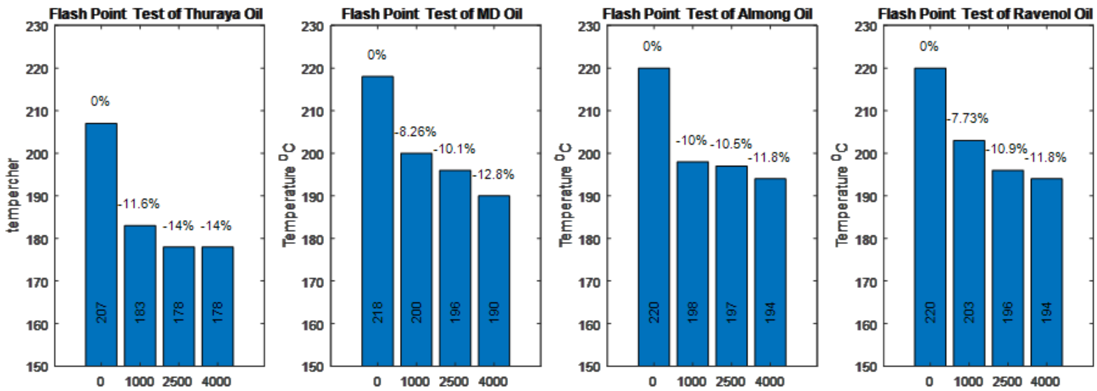

Figure (13): Flash point results

Conclusion

This study investigated the degradation characteristics of four SAE 10W-40 engine oils, comprising three locally produced brands (THURAYA, MD, and ALMOG) and one internationally manufactured brand (RAVENOL), under actual engine operating conditions over specified mileage intervals. To ensure comparability, all tests were conducted using the same engine and identical operating parameters, allowing a consistent evaluation of physicochemical property changes with increasing mileage.

The findings indicate that all tested oils exhibited progressive deterioration as mileage increased. Observable degradation included darkening of oil color, reductions in kinematic viscosity at both 40 °C and 100 °C, variations in additive element concentrations, and a continuous decline in flash point. These changes reflect the combined influence of thermal loading, mechanical shear, contamination, and additive consumption during operation.

Notable differences in viscosity retention were observed among the oils. THURAYA showed superior resistance to viscosity loss, whereas ALMOG experienced the most pronounced decline. Elemental analysis revealed differences in calcium, zinc, and phosphorus content, suggesting variations in additive formulations and durability. RAVENOL maintained the highest calcium levels, indicating enhanced detergent and anti-wear performance. Overall, the results demonstrate that significant oil degradation can occur at relatively low mileage, underscoring the importance of routine oil condition monitoring and timely replacement.

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