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Experimental evaluation of 5W30 direct injection gasoline engine oils in Libyan market

Abdulwahed Shglabow[1], Zakaria Sihaib[2], Alkouni Ejlail[3]

Chemical engineering department, Higher Institute of Science and Technology in Zawia - Libya
1- shglabowabdulwahed@gmail.com, 2- zakariasihaib@yahoo.com, 3- Alkouni33@gmail.com

Abstract:
This study aims to evaluate the agreement between the physicochemical properties of nine fully synthetic SAE 5W30 direct injection gasoline engine oils (GDI) and the corresponding manufacturer declared data sheet, as well as the limits specified by standard specifications, aiming to identify potential cases of manufacturing defect or counterfeit products of international brands.
The samples analyzed include LIQUI MOLY, RAVENOL, Castrol MAGNATEC, Shell HELIX, mabanol, S-OIL SEVEN, VENOL, ZIC X9, and ALMOG Gamma.
Experimental analyses were performed in accordance with ASTM standards, covering kinematic viscosity at 40°C and 100°C, density, flash point, evaporation loss and viscosity index.
The results showed a generally high agreement between declared and experimental values, with minor deviations observed in kinematic viscosity at 40°C for some samples.
For Castrol, Shell, and S-OIL SEVEN, these oils demonstrated favorable physicochemical properties; however, further engine performance testing is required to confirm their resistance to deposits and LSPI.
Keywords: Engine, GDI, Lubricant oil, Viscosity Index, Flash point, Evaporation, Density.

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التقييم التجريبي لزيوت محركات البنزين ذات الحقن المباشر 5W30 المتوفرة في السوق الليبي

عبد الواحد شقلابو[1]، زكريا صهيب[2]، الكوني جليل[3]

قسم الهندسة الكيميائية – المعهد العالي للعلوم والتقنية بالزاوية – ليبيا

1- shglabowabdulwahed@gmail.com, 2- zakariasihaib@yahoo.com, 3- Alkouni33@gmail.com

الملخص:

تهدف هذه الدراسة إلى تقييم التوافق بين الخواص الفيزيائية والكيميائية لتسع عينات من زيوت محركات البنزين ذات الحقن المباشر 5W30 الاصطناعية بالكامل وبيانات الشركات المصنعة وحدود المواصفات القياسية.

تم فحص مدى مطابقة المعلومات المعلنة من قبل الشركات المصنعة لزيت مع نتائج الاختبارات المعملية للكشف عن احتمالية وجود غش صناعي وهو تقليد للعلامات التجارية العالمية.

شملت العينات: LIQUI MOLY, RAVENOL, Castrol MAGNATEC, Shell HELIX, mabanol, S-OIL SEVEN, VENOL, ZIC X9, ALMOG Gamma.

أُجريت الاختبارات وفق لمعايير الجمعية الأمريكية لاختبار المواد ASTM لقياس اللزوجة الحركية والكثافة ونقطة الوميض وفاقد التبخر وحساب مؤشر اللزوجة.

أظهرت النتائج توافقًا عالياً بين القيم المعلنة والقيم التجريبية، مع بعض التجاوزات في اللزوجة عند 40°م، و أيضا أوضحت النتائج أن بعض الزيوت مثل Castrol و Shell و S-OIL SEVEN تعطي أفضل أداء لتزييت المحرك، حيث أظهرت خصائص تدل على جودة عالية؛ ومع ذلك، يلزم إجراء المزيد من اختبارات أداء المحرك لتأكيد مقاومتها للترسبات و الاشتعال المسبق منخفض السرعة.

الكلمات المفتاحية: محرك السيارة ، الحقن المباشر للبنزين(GDI) ، زيت التزييت، مؤشر اللزوجة، نقطة الوميض، التبخر، الكثافة.

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Introduction:

Internal combustion engines have evolved significantly from primitive carburetors to modern direct injection (GDI) systems due to the need for greater fuel efficiency, reduced emissions, and increased power [1]. The need for specialized oils for modern engines (such as GDI and Turbo) is crucial, these oils are designed to withstand high temperatures without cracking, reduce emissions, and improve environmental cleanliness [2].

They also offer low phosphorus and sulfur content to protect catalysts, prevent LSPI (Low-Speed Pre-Induction), and have carefully selected chemical compositions to reduce this phenomenon [3].

Other advantages include lower fuel consumption, reduced viscosity to minimize rolling resistance, and extended engine life.

Additionally, they contain anti-wear and anti-sludge additives.

In parallel, engine oils have evolved from simple lubricants into complex technical components that play a vital role in engine protection and optimal performance [4].

Engine oils are made to lubricate the internal combustion engines, which power a wide range of engine and machines that help to enhance the economies globally [5]. Lubricants are essential to ensure mechanical integrity, as they minimize frictional losses, assist heat dissipation, and maintain sealing efficiency within the piston assembly. [6].

Typically, lubricating oils contain additives like dispersants and detergents, which help suspend contaminants within the fluid and clean the engine from sludge and varnish [7].

Oxidation and corrosion inhibitors are also common additives in lubricants to combat against chemical and thermal degradation of the oil as well as rust and corrosion of components [8].

Further, modern engine oils have taken on additional roles, such as supporting emissions reduction devices in engines that must meet strict emissions reduction regulations [9].

One of the most important properties of engine oil is its viscosity [10].

The ability of an oil to retain a high enough viscosity to maintain a lubricating film between moving components, while still having a

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viscosity low enough to flow around engine parts with minimal drag is vital to identifying its applications [11].

According to the SAE J300 classification system, engine oils are categorized based on their viscosity behavior across a range of temperatures. [12].

A combination of engine oil's kinematic viscosity, high temperature-high shear (HTHS) viscosity, and low temperature performance determines its viscosity grade [13]. Along with the SAE viscosity grades, organizations around the world have developed engine oil standards to set minimum performance benchmarks and meet original equipment manufacturer (OEM) requirements [14].

The most prominent standards are set by the American Petroleum Institute (API), International Lubricant Standardization and Approval Committee (ILSAC), and European Automobile Manufacturers Association (ACEA) [1]. Although these standards were developed based on the markets in their respective markets in North America and Europe, other countries like China and India have adopted and modified these standards to fit their own markets [2].

Materials and Methods:

The research material consists of nine trademarks of engine oil samples that were obtained from servicing workshops at ALMOHANDES Shop and all samples were fully synthetic engine oils with viscosity grade (5W-30). Each sample contained in a one-liter plastic bottle as it shown in Figure 1.

Figure 1. Nine trademarks of engine oil samples

All engine oil samples were tested at the industrial oil blending and filling plant laboratories of Zawiya Oil Refining Company.

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A- ASTM-D445-23 standard for kinematic viscosity at 40°C and 100°C, and viscosity index ASTM 2270 for viscosity index [1].
The time is measured for a fixed volume of liquid to flow under gravity through the capillary of a calibrated viscometer under a reproducible driving head and at a closely controlled and known temperature.
The kinematic viscosity (determined value) is the product of the measured flow time and the calibration constant of the viscometer.
Two such determinations are needed from which to calculate a kinematic viscosity result that is the average of two acceptable determined values.

B- ASTM-D 5800 – 03a for Evaporation Loss [4].
A measured quantity of sample is placed in an evaporation crucible or reaction flask that is then heated to 250°C with a constant flow of air drawn through it for 60 min.

C- ASTM-D92 for flash point [2].
Approximately 70 mL of test specimen is filled into a test cup.
The temperature of the test specimen is increased rapidly at first and then at a slower constant rate as the flash point is approached.
At specified intervals a test flame is passed across the cup.
The flash point is the lowest liquid temperature at which application of the test flame causes the vapors of the test specimen of the sample to ignite.
To determine the fire point, the test is continued until the application of the test flame causes the test specimen to ignite and sustain burning for a minimum of 5 s.

D- ASTM-D4052for density [3].

A small volume (approximately 0.7 mL) of liquid sample is introduced into an oscillating sample tube and the change in oscillating frequency caused by the change in the mass of the tube is used in conjunction with calibration data to determine the density of the sample at 15°C.

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Results and Discussion:

We will present the values of the parameters that were evaluated in the laboratory, the values of the parameters that were declared in the manufacturer's data sheet and the limits of the standard specifications so that it is easier for us to discuss these results.

A- Results of kinematic viscosity at 40°C test.

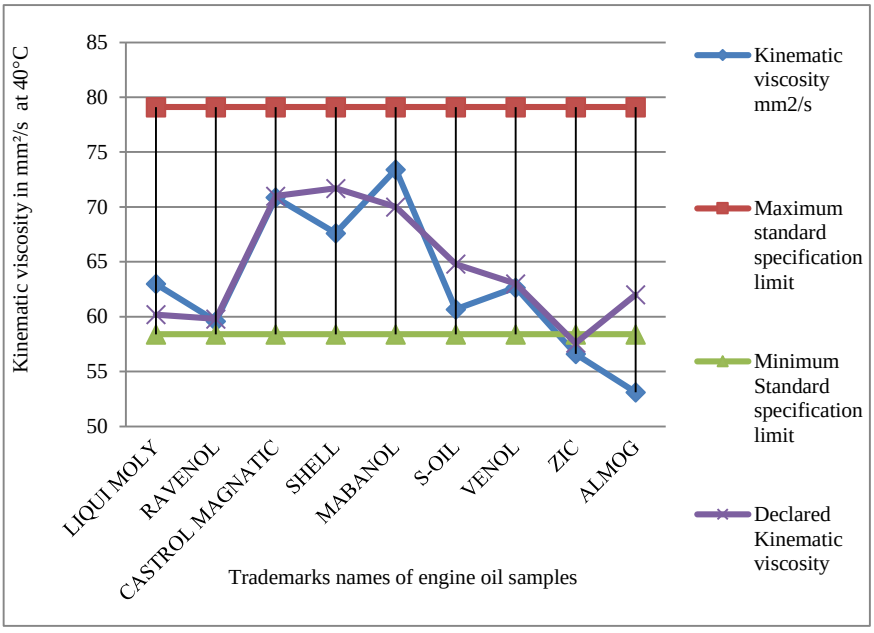

Figure 2. Results of kinematic viscosity at 40°C test

Based on available data in the figure 2 we could see that experimentally oils such as ZIC X9 and ALMOG Gamma have kinematic viscosity at 40°C (56.6 and 53.12 mm²/s, respectively) which is lower than the minimum limit in the standard specifications which is 58.4 mm²/s, this indicates its limited ability to provide good protection for the internal moving parts of the engine at low temperatures 40°C.

The rest of engine oil samples were within the limits of standard specifications between (58.4 and 79.1 mm²/s) [5] .

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B- Results of kinematic viscosity at 100°C test.

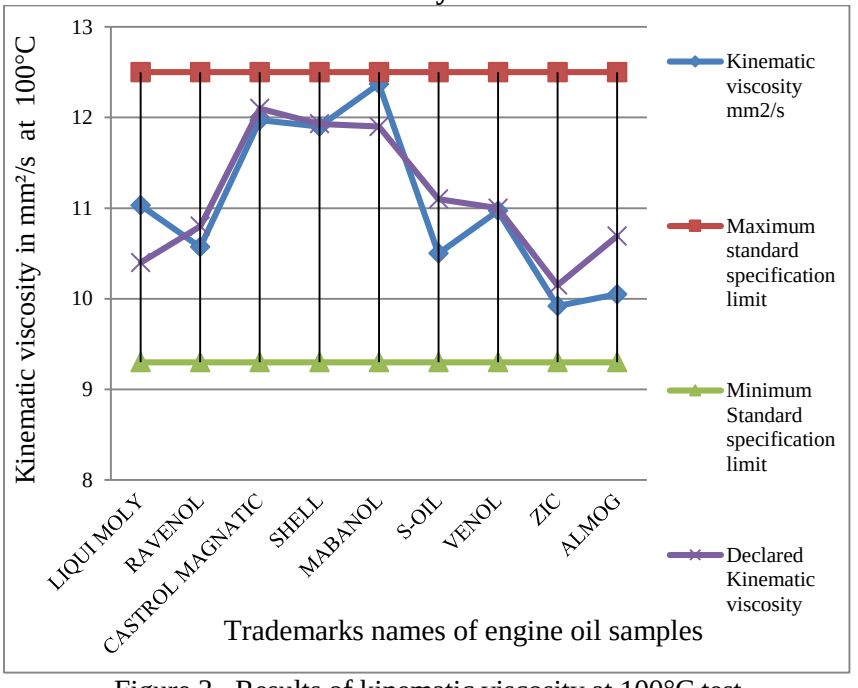

Figure 3. Results of kinematic viscosity at 100°C test

Based on available data in the figure 3 we could see that experimentally oils such as Shell HELIX and Castrol MAGNATEC exhibit the highest viscosity at 100°C (11.90 and 11.97 mm²/s, respectively), indicating their ability to provide strong protection at high temperatures.

Oils such as and ZIC X9 and ALMOG Gamma have the lowest viscosity at 100°C (9.92 and 10.05 mm²/s respectively), which may indicate better fuel efficiency but requires careful evaluation of its ability to protect under extreme conditions.

On the other hand, oil such mabanol has kinematic viscosity equal 12.37 mm²/s which close to the maximum limit in the standard specifications which is 12.5.

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C- Results of viscosity index test.

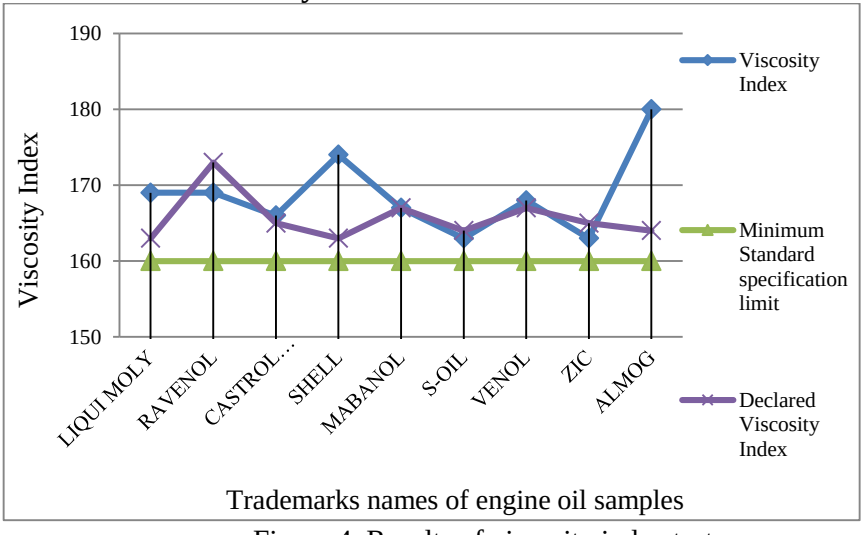

Figure 4. Results of viscosity index test

Based on available data in the figure 4 we could see that all the engine oil samples have value of viscosity index more than 160 and some of them the experimental results are too close to the value that declared in the manufacturer's data sheet.

D- Results of Evaporation Loss (Noack Volatility).

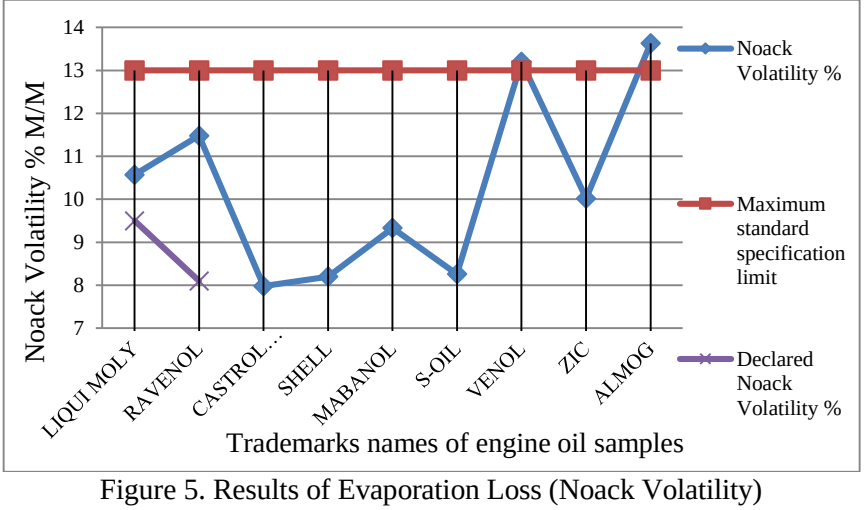

Figure 5. Results of Evaporation Loss (Noack Volatility)

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Based on available data in the figure 5 we could see that ALMOG Gamma and VENOL have the highest evaporation loss (13.63% and 13.2%, respectively) and the maximum limit in the standard specifications which is 13%.
This may lead to increased oil consumption.

E- Results of Flash point test.

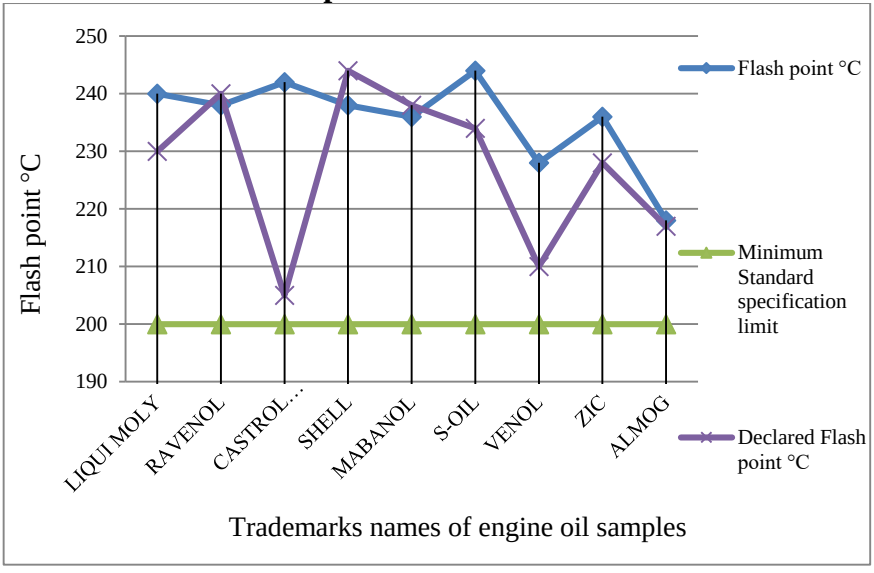

Figure 6. Results of Flash point test

Based on available data in the figure 6 we could see that experimentally S-OIL SEVEN and Castrol MAGNATEC have the highest flash points (244 and 242°C, respectively),
This indicates a good resistance to evaporation at high temperatures and contributing to maintaining oil levels and protecting the engine.
On the other hand, ALMOG Gamma engine oil has the lowest flash point (218°C) and this increase the evaporation at high temperatures and decrease the oil level in the engine.

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F- Results of Density test.

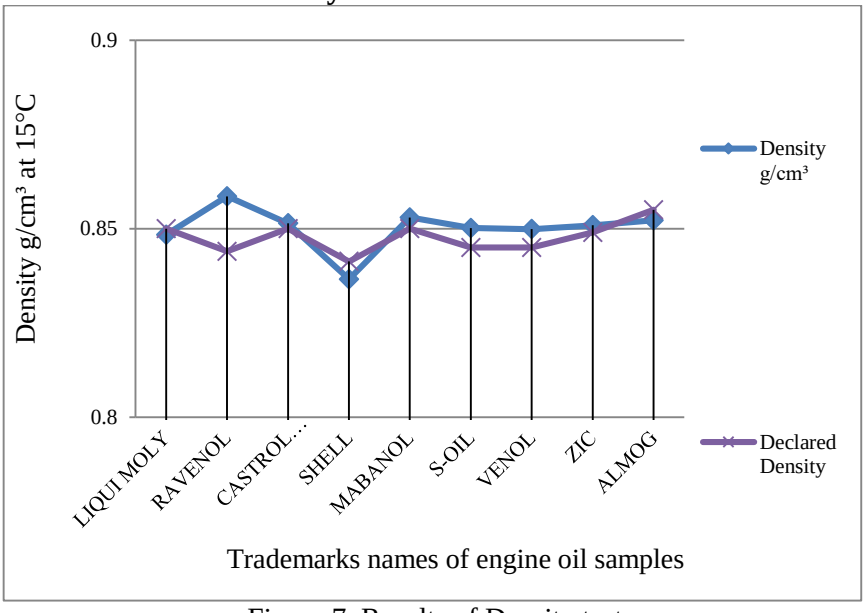

Figure 7. Results of Density test

Based on available data in the figure 7 we could see that the experimentally density ranges is from 0.8366 g/cm³ for Shell to 0.8586 g/cm³ for RAVENOL and these values are very close to what was declared by the manufacturers in the data sheet.
Density varies depending on the oil's chemical composition but does not directly affect performance as viscosity, flash point, and evaporation loss.

Conclusion and Recommendations:
Based on available data on the general characteristics of tested GDI engine oils:

* Performance of fully synthetic oils: Oils that demonstrate the best performance in indicators such as high flash point and low evaporation loss, such as Castrol MAGNATEC, Shell HELIX and S-OIL SEVEN, are likely to be fully synthetic or high quality, these oils demonstrated favorable physicochemical properties; however, further engine performance testing is required to confirm their

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resistance to deposits and LSPI, especially if they carry API SP and ILSAC GF-6A ratings.

* Performance of other tested GDI engine oils: Oils with high evaporation loss and low flash points (such as ALMOG Gamma and VENOL) may not provide the same level of long-term protection for modern GDI engines.

* Engine oils should be buying from an authorized distributor or agent of car engine oils, ensuring that these oils are original products and not counterfeit.

* We recommend that marketers and manufacturers of engine oils awareness consumers on choosing the appropriate engine oil according to the manufacturer's recommendations.

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