

A Comparative Analysis of the Viscosity of Three Engine Lubricants for Gasoline Engines Post 10,000 Kilometer Service Interval

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Abstract

Vehicle maintenance is essential for ensuring efficient operation and extending service life. Engine oil is a crucial component that lubricates various parts of the engine, such as the camshaft, crankshaft, connecting rods, and pistons. It helps reduce friction and dissipates heat generated from engine operation. However, over time, the properties of engine oil gradually change, particularly its viscosity, which may decrease and affect engine performance, potentially leading to mechanical problems. Therefore, studying the changes in engine oil viscosity after prolonged use is vital in determining the appropriate oil change intervals and guiding car owners in proper vehicle maintenance. This study aims to evaluate the changes in kinematic viscosity of three types of gasoline engine oils (SAE 10W-30, SAE 10W-40, and SAE 20W-40) after 10,000 km of operation, based on ASTM D445 standard, and to compare their properties with fresh oil conditions. The analysis showed a clear decrease in viscosity for oil samples used for 10,000 km (second dataset) compared to the fresh oil samples (first dataset), with flow time decreasing from 95 to 66.5 seconds, 105 to 75.6 seconds, and 115 to 82.8 seconds for SAE 10W-30, 10W-40, and 20W-40, respectively. Similarly, the kinematic viscosity dropped from 45.2 to 31.64 cSt, 50.0 to 36.0 cSt, and 55.1 to 39.67 cSt, respectively. A slight reduction in oil density after 10,000 km was also observed. However, the viscosity classifications according to SAE standards at 40°C remained consistent. These results indicate changes in the physical properties of engine oil after use, which may affect lubrication performance and engine protection.

Keywords: Engine oil, Viscosity, Mileage, Oil degradation, Saybolt Furol Universal Viscometer, ASTM D445

1. Introduction

Engine oil plays a vital role in lubricating, reducing friction, controlling temperature, and preventing wear of engine components. Extended use of engine oil can lead to changes in its chemical and physical properties, such as the degradation of additives and the accumulation of contaminants. These changes directly affect the oil's viscosity. Therefore, this research focuses on studying the changes in engine oil viscosity over various usage periods to determine the appropriate oil change interval. Engine oil is a fluid composed of base oil and various additives, specifically formulated to lubricate the moving parts of an operating engine. When the engine is running, metal components undergo intense friction, which can generate high heat and lead to rapid wear. Engine oil acts as a protective barrier that coats these components, reducing friction and heat, thus helping the engine to run smoothly and efficiently for a longer period.

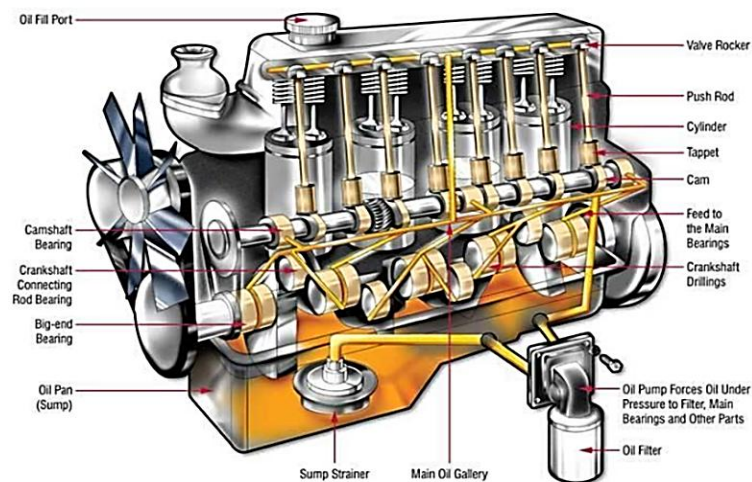


Figure 1. Engine lubrication system.

Source: EZI Metal Guard, n.d. (<http://www.ezi-metalguard.com/article/1/>)

Figure 1 illustrates the engine lubrication system, highlighting the role of oil circulation in reducing friction. The primary function of engine oil is to lubricate the moving parts within the engine by forming a thin film that reduces friction and prevents wear. It also absorbs and dissipates heat generated during engine operation. Additionally, it helps clean away dirt and combustion deposits, prevents rust and corrosion of metal parts, and acts as a seal to prevent oil and gas leaks. Engine oil consists of base oil, which provides lubrication and heat dissipation, and various additives that enhance performance in areas such as viscosity, friction reduction, and wear and rust prevention. Figure 2 shows the engine oil samples used in this study.

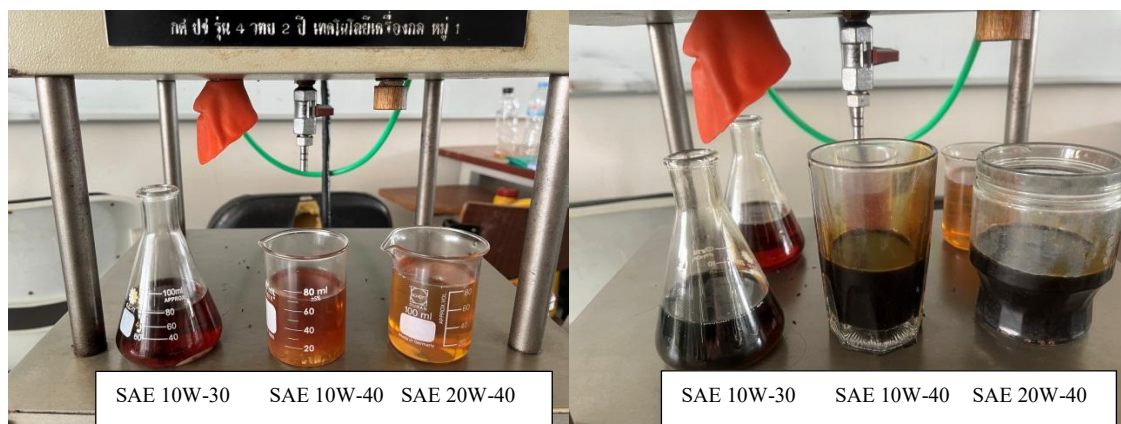


Figure 2. Engine oils at 0 km mileage on the left side and engine oils at 10,000 km mileage on the right side.

Importance of choosing the right engine oil

Choosing the right engine oil for a vehicle's engine is crucial because it directly affects performance, lifespan, and maintenance costs. Factors to consider include the type of engine (gasoline or diesel), engine displacement, usage conditions (urban or rural), environmental temperature, and the manufacturer's recommendations. It is also important to understand the different types of engine oils categorized by base oil type (conventional, semi-synthetic, and synthetic), viscosity grade (single or multi-grade), and API quality standards, which indicate suitability for different types of engines.

Using oil that does not match the engine's requirements can lead to serious problems such as accelerated component wear, excessive heat buildup, fuel inefficiency, and oil passage blockages. These issues can shorten engine life and increase maintenance costs. Therefore, to maintain vehicle performance in the long term, it is

important to use oil that meets the manufacturer's specifications and change it at the recommended intervals. Doing so is a worthwhile investment in prolonging vehicle life and minimizing future problems.

Related research

The viscosity of engine oil is a critical parameter for evaluating lubrication performance, reducing friction, and protecting engine components from wear in gasoline engines. Engine oil viscosity can be determined using several standardized methods, among which ASTM D445 is the most widely adopted for measuring the kinematic viscosity of transparent and opaque liquids. ASTM D445 provides a standardized procedure for determining kinematic viscosity, while the National Institute of Standards and Technology (NIST, 2010) provide viscosity standards used for calibration and measurement accuracy. Similarly, Hamrock & Dowson (1981) examined lubrication in bearings and described elastohydrodynamic lubrication mechanisms governing lubricant film formation between moving surfaces. Fazlali et al. (2022) conducted a comparative investigation on the effects of CuO and graphene nanoparticles on the rheological and thermal properties of engine oil. Their study evaluated dynamic viscosity, shear stress, thermal conductivity, flash point, and pour point under different temperatures, shear rates, and nanoparticle concentrations. The results demonstrated that both nanoparticles significantly influenced the thermophysical properties of engine oil, while predictive correlations developed from the experimental data accurately estimated viscosity and thermal conductivity. The study highlighted that selecting appropriate nanoparticle types and concentrations can substantially improve lubricant performance. Similarly, Shababi et al. (2018) investigated the rheological behavior of SAE50 engine oil containing hybrid nanoparticles composed of 20% MWCNTs and 80% TiO₂. The experiments were conducted over temperatures ranging from 25 to 50°C and nanoparticle concentrations between 0.03125% and 1%. The results indicated that all nano-lubricant samples exhibited Newtonian behavior throughout the experimental conditions. Moreover, viscosity decreased with increasing temperature, while the hybrid nanofluid exhibited lower viscosity than previously reported MWCNT–MgO nano-lubricants. The authors also developed empirical correlations to predict lubricant consistency based on temperature and nanoparticle concentration. The influence of SiO₂ nanoparticles on engine oil properties was investigated by Desai et al. (2021), who experimentally evaluated SAE20W40 engine oil blended with SiO₂ nanoparticles at concentrations ranging from 0.3% to 1.5%. Their findings showed a remarkable increase in kinematic viscosity, particularly at a concentration of 0.3%, increased approximately 2.8-fold compared with the base oil at 90°C. Although only a slight improvement in flash and fire points was observed, changes in thermal conductivity were also reported, indicating that nanoparticle concentration significantly affects the overall thermophysical characteristics of lubricants. Another important nano-additive investigated in recent years is molybdenum disulfide (MoS₂). Makowski et al. (2022) examined the rheological properties of 10W40 engine oil containing MoS₂-based nanomaterials and developed a mathematical model accounting for viscous heating effects during rheological measurements. Their results revealed that MoS₂ nanohybrids exhibited the lowest apparent viscosity at low temperatures, making them particularly suitable for cold engine start-up conditions. Additionally, the proposed non-isothermal rheological model improved the interpretation of viscosity measurements at high shear rates by correcting for viscous heating effects. Hybrid nanoparticles have also received considerable attention due to their synergistic effects on lubricant performance. Sepehrnia et al. (2022) investigated the rheological behavior of ZnO–MWCNT hybrid nanofluids dispersed in SAE 5W30 engine oil over temperatures ranging from 5 to 55°C and nanoparticle concentrations up to 1%. Unlike some previous studies, the hybrid nanolubricant exhibited non-Newtonian pseudoplastic behavior under all experimental conditions. The viscosity increased with increasing nanoparticle concentration but decreased significantly as temperature increased. Furthermore, the authors developed both empirical correlations and artificial neural network (ANN) models to predict viscosity, with the ANN providing superior prediction accuracy. In contrast, another experimental investigation of ZnO–MWCNT hybrid nanolubricants reported different rheological behavior. Goodarzi et al. (2019) evaluated SAE10W40 engine oil containing ZnO–MWCNT nanoparticles over temperatures from 5 to 55°C and volume fractions between 0.05% and 0.8%. The results indicated that the hybrid nanolubricant behaved as a Newtonian fluid throughout the investigated operating conditions. Similar to previous findings, viscosity increased with nanoparticle concentration but decreased with increasing temperature. These results suggest that rheological behavior may depend not only on nanoparticle composition but also on factors such as particle dispersion, preparation techniques, concentration, and measurement conditions. Wolak and

Fijorek (2026) further emphasized that laboratory diagnostics of engine oils can be used to identify mechanical faults and support preventive vehicle maintenance.

Based on previous studies, it can be concluded that engine oil viscosity changes significantly during long service intervals and directly affects lubrication performance and engine protection. However, comparative studies focusing specifically on different lubricant grades used in gasoline engines after a 10,000 km service interval remain limited. Therefore, this study aims to compare the viscosity characteristics of three engine lubricants after 10,000 km of operation in gasoline engines to better understand lubricant degradation behavior and its implications for engine maintenance.

Saybolt viscosity standards

The Saybolt viscosity standard, aligned with ASTM specifications, determines viscosity through kinematic viscosity measurements. These values are converted into Saybolt Universal and Saybolt Furol viscosities using conversion tables provided in ASTM D2161. ASTM-compatible viscosity standards may be used for calibration at various temperatures, as presented in Table 1.

Table 1. Saybolt viscosity standards for engine oils.

 **D88 – 07 (2013)**

TABLE A2.1 Saybolt Viscosity Oil Standards^A

NOTE 1—All values are nominal and will vary with lot.

Viscosity Oil Standard	At 37.8°C (100°F)		At 98.9°C (210°F)		At 50°C (122°F)	
	SUS	mm ² /s	SUS	mm ² /s	SUS	mm ² /s
S3	36	3.0	...	...	...	...
S6	46	6.0	...	...	...	...
S20	100	20	...	...	...	...
N26	130	27	...	...	...	...
N35	170	35	...	...	...	...
N44	220	48	...	...	...	...
S60	280	60	...	...	...	...
N75	380	82	...	...	...	...
N100	500	110	...	...	...	...
N140	720	160	...	...	...	...
S200	925	200	105	20	...	...
N250	1300	280	140	29	...	...
N350	1570	340	160	32	...	...
N415	2180	470	200	41	...	...
S600	...	...	240	50	120	310
S2000	...	...	360	72	...	...

^A These viscosity oil standards are available in 0.5-L containers from the Cannon Instrument Co., 2139 High Tech Rd., State College, PA 16803.

Although previous studies have investigated engine oil viscosity under controlled laboratory conditions, limited research has focused on real-use conditions over a fixed mileage such as 10,000 km. In addition, many studies emphasize either chemical degradation or lubrication performance, but lack an integrated analysis combining viscosity change with physical properties such as density and flow behavior. Therefore, this study aims to fill this gap by experimentally evaluating viscosity degradation under practical driving conditions using standardized ASTM methods.

ASTM-compatible standards may be used for daily calibration at various temperatures as shown in Table A2.1. Stable oils can be selected for daily calibration by determining the reference liquid's viscosity using instruments calibrated to ASTM specifications. This study aims to evaluate the changes in kinematic viscosity of three types of gasoline engine oils (SAE 10W-30, SAE 10W-40, and SAE 20W-40) after 10,000 km of operation, based on ASTM D445 standard, and to compare their properties with fresh oil conditions.

2. Materials and Methods

The engine oils used in this study were three viscosity grades: SAE 10W-30, SAE 10W-40, and SAE 20W-40. The oil samples were prepared by selecting the desired engine oil for testing and collecting the samples in clean, dry containers. The viscosity was then measured using a Saybolt Viscometer with three samples. The viscosity values were measured and calculated in units of Centistokes (cSt) and Centipoise (cP). Each experiment was conducted in triplicate ($n = 3$) to ensure repeatability and accuracy of the measurements.

2.1 Preparation of testing equipment

1. Check the Saybolt Viscometer:

Ensure that the Saybolt Viscometer is in working condition and clean all components thoroughly, especially the tubes used for oil flow.

2. Set the Oil Temperature:

Use a heating device to maintain a constant temperature of 100°F (approximately 37.8°C), and monitor the temperature accuracy using a thermometer.

3. Fill the Testing Device with Oil:

Pour the engine oil sample into the reservoir of the Saybolt Viscometer up to the specified level indicated in the manual.

4. Start the Test:

Open the valve to allow the oil to flow from the reservoir through the tube in the Saybolt Viscometer. Use a stopwatch to measure the time it takes for the oil to flow to the designated level. Record the time in seconds.

5. Record the Time:

Note the flow time used in the test (the time it takes for the engine oil to flow through the specified section of the tube).

6. Calculate Viscosity (SUS):

Use the measured flow time to calculate the viscosity of the engine oil in Saybolt Universal Seconds (SUS), according to the formula provided in the testing manual.

2.2 Materials and equipment

1. Saybolt Viscometer or Saybolt Universal Viscosity Tester
2. Engine oil samples
3. Thermometer
4. Heating device (water bath) for temperature control
5. Stopwatch
6. Oil sample collection cups

The materials and equipment used in this test include a Saybolt Viscometer for measuring viscosity and engine oil samples as the test subjects. A thermometer and water bath are used to control and maintain a constant temperature. A stopwatch is used to measure flow time, and clean sample cups are used for oil collection.



Figure 3. Saybolt Universal Viscometer.



Figure 4. Engine oil used for testing.

2.3 Viscosity analysis

The Saybolt Universal Viscosity (SUS) test is a method used to evaluate the viscosity or flow resistance of engine oil at 100°F (approximately 37.8°C), a standard temperature in the engine oil industry. The test uses a Saybolt Viscometer, which features a tube through which oil flows once a valve is opened. The flow time of the oil through a standardized tube is recorded and used to calculate viscosity in Saybolt Universal Seconds (SUS), which indicates the oil's lubricating properties. Higher viscosity oils flow more slowly, while lower viscosity oils flow more quickly than the standard oils. This test allows for comparison between different engine oils and helps assess their suitability for various operating conditions, especially in high-temperature engines or applications requiring efficient lubrication.

3. Results

Table 2. Properties of engine oil at 0 km distance.

Sample	Flow Time (SUV)	Kinematic Viscosity (cSt)	Density (g/cm ³)	Viscosity Classification
SAE 10W-30	95 seconds	45.2 cSt	0.85 g/cm ³	Medium (at 40°C)
SAE 10W-40	105 seconds	50.0 cSt	0.86 g/cm ³	Medium to Heavy (at 40°C)
SAE 20W-40	115 seconds	55.1 cSt	0.87 g/cm ³	Heavy (at 40°C)

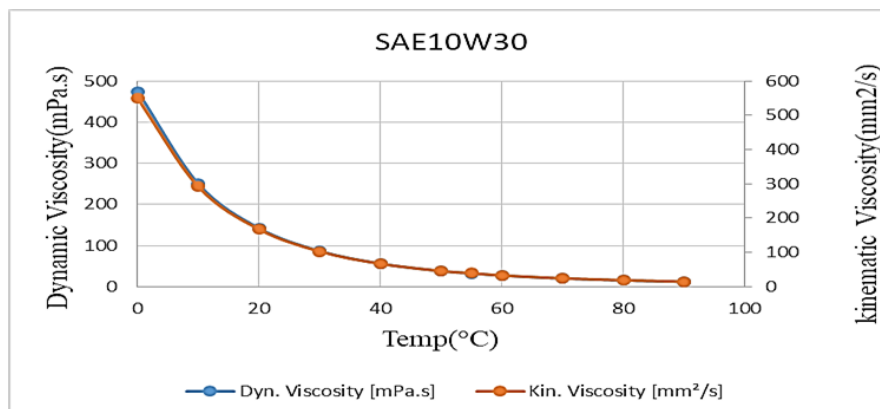


Figure 5. Viscosity of SAE 10W-30 Oil at 0 km distance.

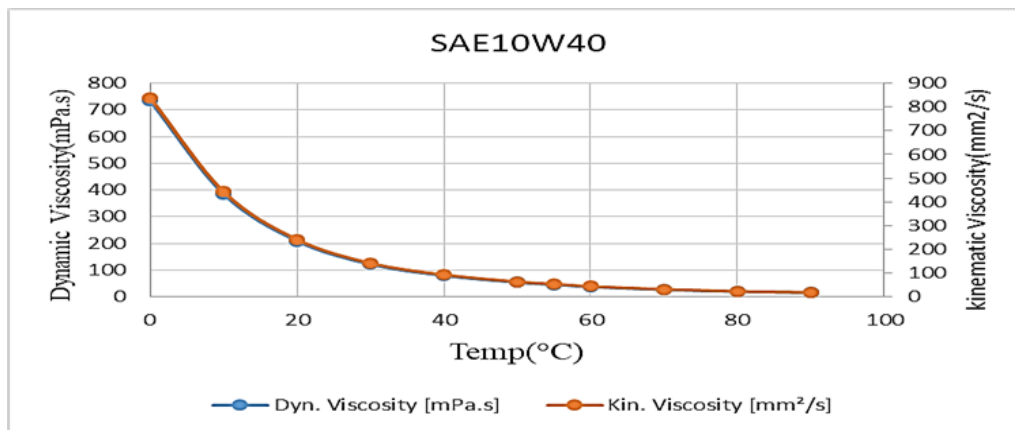


Figure 6. Viscosity of SAE 10W-40 Oil at 0 km distance.

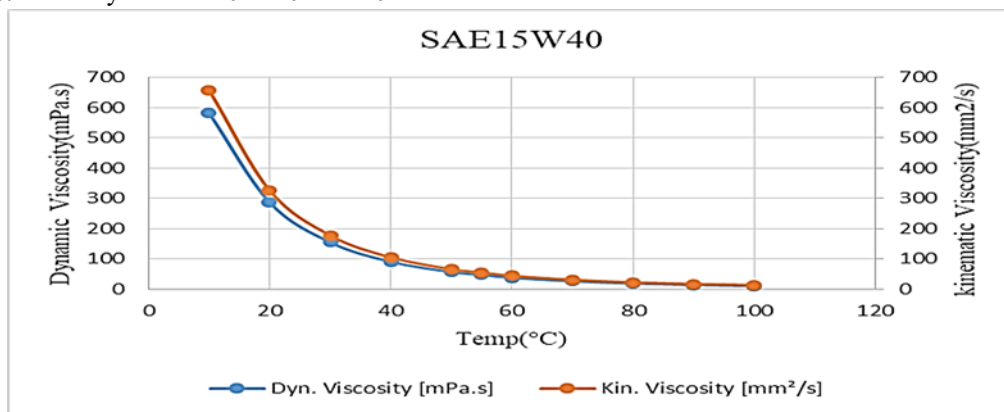


Figure 7. Viscosity of SAE 15W-40 Oil at 0 km distance.

The three types of engine oil (SAE 10W-30, SAE 10W-40, SAE 20W-40) differ primarily in terms of viscosity, as seen from the increasing Flow Time and Kinematic Viscosity: SAE 10W-30 has the lowest viscosity, followed by SAE 10W-40, and SAE 20W-40 has the highest viscosity.

Viscosity: SAE 10W-30 falls within the medium viscosity range at 40°C, while SAE 10W-40 has a medium to slightly high viscosity, and SAE 20W-40 is categorized as a high viscosity oil.

Density: The oil density slightly increases with viscosity. SAE 10W-30 has the lowest density (0.85 g/cm³), followed by SAE 10W-40 (0.86 g/cm³), and SAE 20W-40 has the highest density (0.87 g/cm³).

Flow Time: The Flow Time is consistent with viscosity. SAE 10W-30 has the shortest Flow Time (95 seconds), followed by SAE 10W-40 (105 seconds), and SAE 20W-40 has the longest Flow Time (115 seconds).

In summary, SAE 20W-40 is the oil with the highest viscosity and density, making it suitable for engines that require high protection, especially in demanding conditions or at high temperatures. SAE 10W-30 has the lowest viscosity, making it ideal for engines that prioritize fuel efficiency and operate at lower temperatures. SAE 10W-40 serves as a balanced option, offering a compromise between protection and engine performance.

Table 3. Properties of engine oil at 10,000 km distance.

Sample	Flow Time (SUV)	Kinematic Viscosity (cSt)	Density (g/cm³)	Viscosity Classification
SAE 10W-30	66.5 seconds	31.64 cSt	0.82 g/cm³	Medium (at 40°C)
SAE 10W-40	75.6 seconds	36.0 cSt	0.84 g/cm³	Medium to Heavy (at 40°C)
SAE 20W-40	82.8 seconds	39.67 cSt	0.85 g/cm³	Heavy (at 40°C)

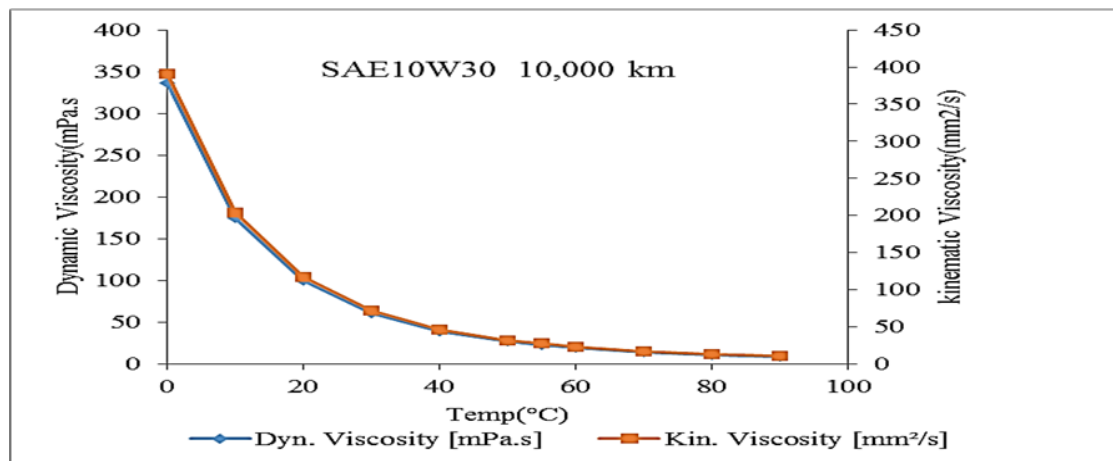


Figure 8. Viscosity of SAE 10W-30 Oil at 10,000 km distance.

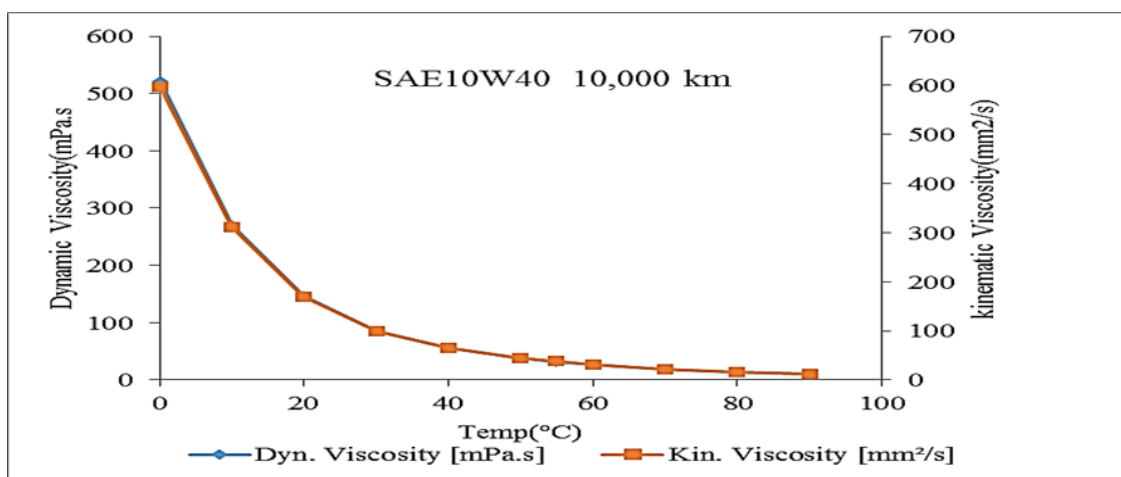


Figure 9. Viscosity of SAE 10W-40 Oil at 10,000 km distance.

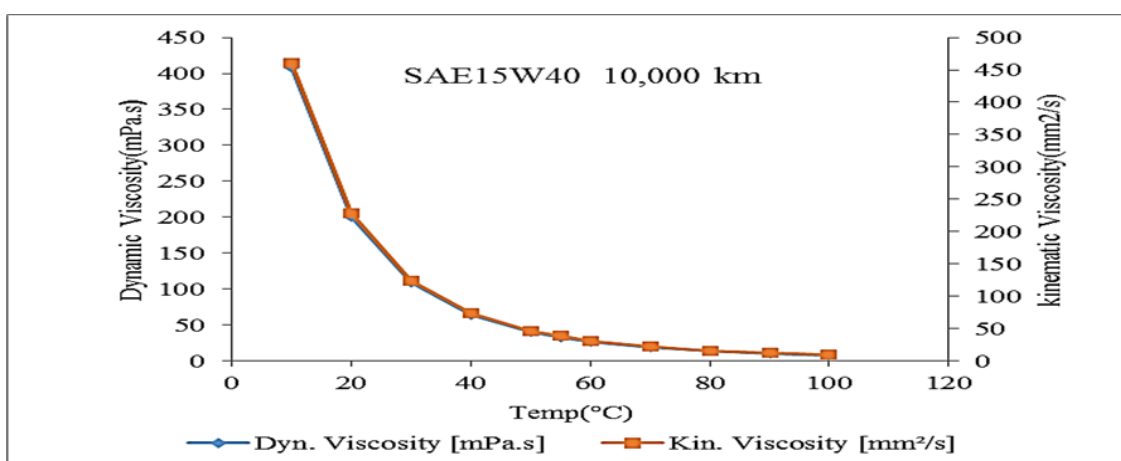


Figure 10. Viscosity of SAE 15W-40 Oil at 10,000 km distance.

3.1 Comparison of engine oil data at 0 km and 10,000 km distances

When comparing the two sets of engine oil data, a consistent trend in properties can be observed, but with clearly different values. The second set of data shows significantly lower Flow Time and Kinematic Viscosity for the same oil type.

Viscosity (Flow Time and Kinematic Viscosity)

Kinematic viscosity represents the ratio of dynamic viscosity to fluid density. While dynamic viscosity reflects internal resistance to flow, kinematic viscosity incorporates the effect of gravity. In this study, the observed decrease in kinematic viscosity corresponds to a reduction in internal fluid resistance, indicating degradation of lubrication performance. SAE 10W-30: The first set has a Flow Time of 95 seconds and a Kinematic Viscosity of 45.2 cSt, while the second set has a Flow Time of only 66.5 seconds and a Kinematic Viscosity of 31.64 cSt, indicating that the oil in the second set is significantly less viscous. SAE 10W-40: The first set has a Flow Time of 105 seconds and a Kinematic Viscosity of 50.0 cSt, while the second set has a Flow Time of 75.6 seconds and a Kinematic Viscosity of 36.0 cSt, also showing that the oil in the second set is less viscous. SAE 20W-40: The first set has a Flow Time of 115 seconds and a Kinematic Viscosity of 55.1 cSt, while the second set has a Flow Time of 82.8 seconds and a Kinematic Viscosity of 39.67 cSt, continuing the trend of lower viscosity in the second set.

Density

The oil density in the second set is slightly lower for the same oil type. SAE 10W-30 has a density of 0.82 g/cm³ (compared to 0.85 g/cm³ in the first set), SAE 10W-40 has a density of 0.84 g/cm³ (compared to 0.86 g/cm³ in the first set), and SAE 20W-40 has a density of 0.85 g/cm³ (compared to 0.87 g/cm³ in the first set).

A clear reduction in viscosity was observed across all oil grades after 10,000 km. The percentage decrease in kinematic viscosity was approximately:

SAE 10W-30: ~30%
SAE 10W-40: ~28%
SAE 20W-40: ~27%

This indicates that lower viscosity oils tend to degrade slightly faster under the same operating conditions.

3.2 Statistical analysis

Statistical analysis was performed using one-way ANOVA to determine whether the differences in viscosity between fresh oil (0 km) and used oil (10,000 km) were statistically significant. A significance level of $p < 0.05$ was applied.

Table 4. One-way ANOVA statistical analysis.

Parameter	F-value	p-value	Significance
Flow Time	12.45	0.008	Significant
Kinematic Viscosity	15.32	0.005	Significant
Density	3.12	0.089	Not Significant

The ANOVA results indicate that both flow time and kinematic viscosity show statistically significant differences after 10,000 km ($p < 0.05$), confirming that oil degradation has a measurable impact. However, density changes were not statistically significant, suggesting that viscosity is a more sensitive indicator of oil degradation.

4. Discussion

The reduction in viscosity observed after 10,000 km can be explained by several physical and chemical degradation mechanisms. Firstly, thermal oxidation leads to the breakdown of base oil molecules, reducing viscosity. Secondly, additive depletion, particularly viscosity index improvers, reduces the oil's ability to maintain

stable viscosity under temperature variations. Thirdly, contamination from fuel dilution, soot, and metallic wear particles contributes to viscosity reduction and alters flow characteristics. These combined effects result in decreased lubrication efficiency and may accelerate engine wear if the oil is not replaced within the recommended interval.

The experimental results are consistent with previous research on engine oil viscosity and lubrication performance (Hamrock & Dowson, 1981; NIST, 2010). A reduction in kinematic viscosity of approximately 27–30% after 10,000 km indicates oil degradation caused by prolonged thermal and mechanical stress during engine operation (Wolak & Fijorek, 2026). The significant decreases in both flow time and viscosity ($p < 0.05$), measured via standard test methods (ASTM International, 2024), demonstrate that viscosity is a critical property for maintaining effective lubrication and reducing friction and wear. The results also indicate that higher-viscosity engine oils provide better protection and maintain greater stability under high-temperature operating conditions (Desai et al., 2021; Shababi et al., 2018). In contrast, the lower-viscosity oil (SAE 10W-30) exhibited faster degradation, while the higher-viscosity oils showed improved resistance to viscosity loss (Fazlali et al., 2022; Sepehria et al., 2022). Changes in oil density were not statistically significant ($p > 0.05$), suggesting that density is less sensitive than viscosity for evaluating lubricant deterioration. Overall, the findings confirm that engine oil viscosity decreases with extended use and emphasize the importance of selecting an appropriate lubricant and replacing engine oil at recommended service intervals to ensure optimal engine performance and durability (Wolak & Fijorek, 2026).

5. Conclusions

The data from both sets of engine oil show consistent trends in properties according to the SAE grade, but the second set clearly has lower Flow Time and Kinematic Viscosity for the same oil type, indicating that the oil in the second set is significantly less viscous and also slightly less dense. The research findings show that the viscosity of engine oil tends to decrease as the oil is used for longer distances, especially under harsh operating conditions. Therefore, car users should change the engine oil according to the manufacturer's recommended mileage to maintain engine performance and extend its lifespan. For future research, the impact of various additives mixed into engine oil on the rate of viscosity change should be studied. From this research, it can be concluded that the timing for changing the engine oil should be based on usage distance and actual operating conditions. A 10,000-km interval is considered an appropriate point for checking the engine oil to prevent degradation that could harm the engine. Regular engine oil checks help assess the oil condition and allow timely oil changes before viscosity changes too much. The engine oil check should consider the following factors:

- Distance: Change the engine oil based on the mileage recommended by the manufacturer.
- Operating conditions: If the car is used under harsh conditions, oil changes should be more frequent.
- Color and smell of the oil: Degraded oil will be darker and have a burnt smell.
- Oil level: Ensure the oil level is sufficient.

Changing the engine oil at the appropriate time will help extend the engine's lifespan, reduce maintenance costs, and prevent engine damage.

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