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A COMPARATIVE STUDY ON THE TRIBOLOGICAL BEHAVIOR OF NEW AND USED 10W-40 ENGINE OIL APPLIED IN GASOLINE AND DIESEL ENGINES

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Abstract: This study presents a comparative analysis of the tribological behaviour of new and used SAE 10W-40 engine oil, collected from gasoline and diesel passenger car engines and tested under cold-start conditions. The investigation examined the influence of oil aging and engine type on viscosity, friction, and wear. Block-on-disc experiments were performed using aluminium (EN AW-6060) against hardened steel (EN 25CrMo4) following ASTM G77 procedures. The results showed that used oils exhibited lower coefficients of friction and smaller wear scars compared to new oil. The diesel-derived sample achieved the best performance, with the lowest steady-state friction and wear volume, likely due to degradation products and fuel residues that enhanced boundary lubrication. Although used oils displayed improved short-term tribological behaviour, their long-term performance in actual engines is limited by oxidation, contamination, and corrosiveness. These findings provide insights into lubricant degradation and may support the optimization of oil-change intervals and the development of improved multigrade oils.

Keywords: Tribology, engine oil, Cold-start conditions, Wear scar analysis, Gasoline and diesel engines

1. INTRODUCTION

The application of aluminium in internal combustion engine construction has become increasingly widespread, particularly in the manufacture of sliding bearings, pistons, and connecting rods. This material offers several advantages, including low specific weight, high corrosion resistance, favorable thermal conductivity, recyclability, and a measurable contribution to improved fuel economy. Nevertheless, its relatively limited wear

resistance and certain mechanical constraints necessitate careful consideration of surface protection, with engine oil quality playing a decisive role in ensuring reliability and durability [1].

The performance of engine oil exerts a profound and multifaceted influence on the wear behaviour of aluminium surfaces. Wear represents one of the principal mechanisms of material degradation in engine blocks, and its progression is governed by several factors: the presence of hard particles and chemical

contaminants in cooling and lubricating fluids promotes abrasive and corrosive wear; exposure to high-temperature gases contributes to erosive wear; frictional interaction between the cylinder wall and piston rings may induce adhesive wear even under lubricated conditions; and material fatigue further accelerates deterioration. High-quality engine oils mitigate these effects by reducing friction, maintaining optimal viscosity, and incorporating additive packages designed to protect aluminium components against wear and corrosion [2,3].

The SAE 10W-40 multigrade engine oil is among the most commonly applied lubricants in passenger car engines, primarily due to its capacity to maintain reliable performance across a wide range of operating temperatures. The “10W” designation reflects its ability to ensure adequate fluidity and lubrication during cold starts, whereas the “40” grade denotes sufficient viscosity retention at elevated thermal and mechanical loads. Such versatility enables 10W-40 oils to provide both start-up protection and long-term durability under diverse service conditions. Their formulations typically combine refined base oils with advanced additive packages, which collectively enhance viscosity stability, reduce friction and wear, and safeguard components from corrosion and deposit formation. Furthermore, recent studies have demonstrated that the incorporation of graphene–cellulose nanocomposites into 10W-40 oil can further improve its thermophysical and tribological performance, yielding a lower coefficient of friction and superior wear resistance, thereby extending the protective capabilities of this lubricant [4].

During service, engine oil inevitably undergoes degradation as a consequence of prolonged exposure to elevated temperatures, mechanical stresses, and by-products of fuel combustion. These processes manifest through visible changes such as darkening of the oil, loss of transparency, and the development of an unpleasant odour, which are commonly recognized as the first signs of oil aging and

contamination. Among the resulting alterations, variations in kinematic viscosity are of particular importance. A reduction in viscosity leads to decreased oil pressure and insufficient film strength, thereby increasing friction and accelerating the wear of critical engine components such as piston rings and bearings. Conversely, an excessive rise in viscosity compromises oil circulation and impedes the stable formation of a lubricating film at tribological contact surfaces [5–7].

Recycling of used engine oils is an essential strategy for sustainable resource utilization, environmental protection, and the mitigation of ecological hazards arising from toxic compounds contained in spent lubricants. The recycling of SAE 10W-40 engine oil poses particular challenges due to its complex chemical composition and the accumulation of contaminants during engine operation. Additive packages and chemical constituents undergo significant transformations under thermal and mechanical stress, generating harmful by-products that require advanced refining or re-refining technologies. Recent industrial advances, such as the development of Quartz EV3R 10W-40 by Total Energies, have demonstrated the feasibility of producing high-performance lubricants entirely from re-refined base oils, achieving up to a 46% reduction in wear and a 20% improvement in piston cleanliness compared to conventional oils [8]. Complementary academic studies have also provided promising results: Jurny et al. reported that solvent extraction using N-methyl-2-pyrrolidone enabled the recovery of approximately 10 L of reusable base oil from 25 L of used lubricant, thereby significantly reducing dependence on virgin crude oil for base stock production [9].

In this study, a comparative tribological analysis was carried out on new and used SAE 10W-40 engine oil after operation in gasoline and diesel passenger car engines. The investigation was performed under cold-start conditions, with the objective of assessing how oil aging and engine type influence viscosity changes, frictional response, and wear

protection. By examining both new and used oils, the study highlights the degradation mechanisms of 10W-40 under distinct combustion regimes and start-up stresses, thereby providing valuable insight into lubricant performance in real-world applications.

2. MATERIALS AND METHOD

This study investigated the tribological performance of SAE 10W-40 multigrade engine oil in both new and used conditions. New oil was tested as a reference to establish its baseline tribological properties, while used oil samples were collected after extended operation in gasoline and diesel passenger car engines. In service, the oil undergoes significant physicochemical changes, including variations in viscosity, darkening of colour, and accumulation of combustion by-products, all of which can directly influence its lubricating efficiency. The 10W-40 grade was selected because of its widespread application in passenger cars, providing adequate lubrication at low temperatures ("10W") while maintaining sufficient viscosity at elevated thermal and mechanical loads ("40").

Experimental testing was carried out using a TPD-95 block-on-disc tribometer, equipped with computer-controlled precision to ensure stable and repeatable operating conditions, in accordance with the ASTM G77 standard. In this configuration, an aluminium block (EN AW-6060 alloy) was pressed against a rotating hardened steel disc (EN 25CrMo4, 60–64 HRC, ground finish, Ø 35 mm), effectively replicating sliding contact conditions representative of real engine components. The aluminium blocks were prepared following a standardized surface treatment: sequential grinding at 500 rpm for 1 minute per side using progressively finer silicon carbide abrasive papers (P600, P1200, and P2000). This preparation ensured uniform surface conditions across all samples, which is essential for experimental reliability.

The tribological tests were performed under identical operating parameters: a normal load of 20 daN, a sliding speed of 0.5 m/s, and a total

sliding duration of 600 seconds. Continuous lubrication during testing was provided by a reservoir system (30 ml capacity), ensuring a stable supply of oil at the contact interface. Under these conditions, three sets of experiments were defined: new 10W-40 oil, used 10W-40 oil collected from a gasoline engine, and used 10W-40 oil collected from a diesel engine.

The volume of worn material was calculated analytically using the following expression:

$$V = \left(\frac{306.25}{2} \cdot 2 \arcsin\left(\frac{b}{35}\right) - \frac{\sqrt{306.25 - \frac{b^2}{4}} \cdot b}{2} \right) \cdot 6.35 \quad (1)$$

where b is the width of the wear mark (mm), 306.25 is the square of the disc radius, and 6.35 mm represents the block width. This equation accounts for the geometry of the block-on-disc contact and enables accurate estimation of volumetric wear based on the measured scar dimensions.

3. RESULTS AND DISCUSION

Figure 1 shows the variation of the coefficient of friction (μ) as a function of sliding distance for new SAE 10W-40 oil, as well as for used oil collected from diesel and gasoline engines.

At the beginning of the test, all samples exhibited relatively high friction values due to the absence of a fully established lubricating film. For the new 10W-40 oil (AL-10W-40-N), the coefficient of friction started at approximately 0.05–0.055 and gradually decreased to a stable level of around 0.02 after about 100 m of sliding. This behaviour reflects the running-in process, during which the oil film progressively formed and stabilized the contact conditions.

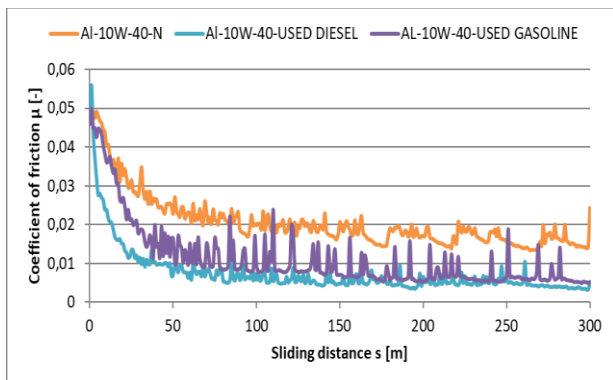


Figure 1. Coefficient of friction versus sliding distance for new and used SAE 10W-40 engine oils

In contrast, the used oil samples demonstrated improved frictional behaviour. The oil collected from the diesel engine (AL-10W-40-USED DIESEL) exhibited the lowest steady-state friction, stabilizing below 0.01 after the initial running-in stage. This may be attributed to chemical and physical changes in the oil during operation, including the presence of degradation products and fuel residues, which could enhance boundary lubrication properties under the given test conditions.

The used gasoline engine oil (AL-10W-40-USED GASOLINE) showed intermediate behaviour. While the initial friction values were comparable to those of the new oil, the coefficient of friction decreased more rapidly and reached values close to those of the used diesel oil. However, the curve exhibited more pronounced fluctuations, which may indicate less stable lubricating film formation, possibly due to differences in contamination mechanisms between gasoline and diesel combustion.

Table 1 presents the average wear scar width and the corresponding calculated wear volume for aluminium samples lubricated with new and used SAE 10W-40 engine oils. The values represent the mean of multiple measurements for each test group, ensuring statistical reliability.

The results indicate a consistent trend of reduced wear in the presence of used engine oils compared to new oil. The new 10W-40 oil produced the largest average wear scar (2.643 mm) and the highest wear volume (0.559 mm³), reflecting the oil's baseline tribological

behaviour in the absence of degradation products. In contrast, the used oils exhibited smaller wear scars and correspondingly lower wear volumes, with 2.300 mm (0.368 mm³) for the gasoline engine sample and 2.000 mm (0.242 mm³) for the diesel engine sample.

Table 1. Average wear scar width and wear volume of aluminium samples lubricated with SAE 10W-40 engine oils

Sample	Wear scar width, b (mm)	Wear volume (mm ³)
AL-10W-40-N (New Oil)	2.643	0.559
AL-10W-40-USED GASOLINE	2.300	0.368
AL-10W-40-USED DIESEL	2.000	0.242

The reduced wear observed with used oils can be attributed to chemical and physical transformations occurring during engine operation. Degradation products, fuel residues, and oxidized compounds may act as additional boundary lubricants, temporarily improving the oil's ability to form protective films on aluminium surfaces. Among the tested samples, the diesel-derived oil showed the lowest wear scar and wear volume, which is consistent with its lower steady-state coefficient of friction (Figure 1), suggesting more stable boundary film formation under the applied test conditions.

Nevertheless, it must be emphasized that although used oils may demonstrate improved short-term tribological behaviour in laboratory block-on-disc testing, their long-term protective performance in actual engine operation is adversely affected by oxidation, contamination, and increased corrosiveness. This dual effect highlights the necessity of carefully balancing lubricant degradation and protective efficiency when evaluating oil performance in real applications.

4. CONCLUSION

This study investigated the tribological behaviour of new and used SAE 10W-40 engine oil, with samples obtained from both gasoline

and diesel passenger car engines and tested under cold-start conditions. The findings highlight the influence of oil degradation and engine type on viscosity, frictional behaviour, and wear protection.

The results demonstrated that used oils exhibited lower coefficients of friction and reduced wear scar dimensions compared to new oil. The diesel-derived oil, in particular, achieved the lowest steady-state friction values and the smallest wear volume, suggesting the formation of a more stable boundary film. This behaviour is most likely associated with the presence of degradation products and fuel-derived compounds that temporarily enhance lubrication under boundary contact conditions.

However, despite these short-term improvements observed in laboratory testing, it must be emphasized that prolonged use of aged oils in engines is not beneficial. Chemical degradation, contamination, and increased corrosiveness compromise the long-term protective performance of lubricants. The insights gained from this comparative study contribute to a deeper understanding of oil degradation mechanisms and may support the optimization of oil-change intervals, lubricant formulation strategies, and improved protection of aluminium-based engine components.

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