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Effect of Multi-Walled Carbon Nanotubes (MWCNTs) on the Tribological and Thermal Performance of Lubricating Engine Oils

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Abstract: Lubricating oils play a vital role in reducing wear and friction among moving parts such as gears, shafts, and engines. The evaluation of these lubricants relies heavily on their tribological and thermal properties. The addition of nano additives to lubricant oils markedly improves their anti-wear performance, decreases friction, and enhances thermal characteristics. This research examines the tribological and thermal properties of 15W30 base oil mixed with different concentrations of multi-wall carbon nanotubes (MWCNTs) (0.5, 0.75, 1, and 1.25 wt.%). This study is pioneering in exploring the effects of using MWCNTs on the properties of lubricant oils. Tribological assessments were performed using a four-ball apparatus while additional properties such as, flash point, pour point, and thermal conductivity were measured and compared to the base oil. The findings indicated that the nano additives led to a reduction in wear scar diameter by 60%. Furthermore, enhancements in flash point 10%, thermal conductivity 67%, and pour point 28% were noted in comparison to the base oil. Finally, the use of CNTs significantly improved the overall performance of 5W30 engine oil.

Keywords: Tribological properties, thermal performance, lubricating oil, multi-wall carbon nanotubes (MWCNTs), nano additives enhancement

1. Introduction

Lubricants serve as a critical component in mechanical systems, ensuring reduced friction and wear, which ultimately extends the operational life of machinery. Beyond minimizing friction, lubricants also play a key role in dissipating heat and preventing corrosion under various operating conditions. To meet the growing demands of modern industries, especially in automotive and heavy machinery sectors, enhancing the performance of lubricants has become a significant area of research. This enhancement is achieved by improving their tribological properties, which govern wear and friction behavior, and rheological properties, which dictate their flow and thermal performance under different stress and temperature conditions. The characteristics of oils are significantly enhanced by the addition of various types of additives. Friction modifiers, such as molybdenum compounds and fatty acids, reduce the coefficient of friction by forming a thin, low-shear film on surfaces (Barlets et al, 2000; Spikes, 2015), while anti-wear agents like zinc dialkyldithiophosphate (ZDDP) create protective layers to prevent surface damage under extreme pressure (Spikes, 2004). Viscosity modifiers ensure consistent flow and film strength across a range of temperatures, making them crucial for multigrade oils, whereas antioxidants, including phenolic and aminic compounds, inhibit oxidation to extend oil life and reduce sludge formation (Soleimani, 2018). Detergents and dispersants prevent deposit buildup and suspend soot particles, maintaining engine

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cleanliness and efficiency (Loane et al, 1951; Honary & Ritcher, 2011), while corrosion inhibitors protect metal surfaces from chemical damage by forming a protective barrier (Kadhim et al., 2021). Recent advancements have introduced nano additives, such as graphene, carbon nanotubes, and metal oxides, which significantly enhance lubricants' tribological and rheological properties by reducing friction, improving wear resistance, and enhancing thermal stability (Gad et al, 2021; Kamel et al, 2021).

The combination of these additives allows modern lubricants to meet the stringent demands of automotive and industrial applications, delivering superior performance and durability. Nanoparticles, owing to their ultra-small size and unique surface characteristics, improve the tribological behavior of lubricants by multiple mechanisms. They can form a protective tribo-film on metal surfaces, fill micro-cracks or asperities, and act as rolling elements, thereby significantly reducing direct metal-to-metal contact. For instance, carbon-based nanoparticles, such as multi-wall carbon nanotubes (MWCNTs) and graphene nanosheets (GNSs), are widely recognized for their ability to reduce the coefficient of friction and enhance wear resistance (Rahman et al., 2022). These nanoparticles create a low-shear interface, improving load-bearing capacity and extending the service life of components under extreme mechanical stresses (Kamel et al., 2023).

The integration of nanoparticles into lubricants has opened new avenues for improving tribological performance. Nanoparticles possess unique characteristics, including high surface area and exceptional mechanical strength, allowing them to interact effectively with metal surfaces. For example, metal oxide nanoparticles like zinc oxide (ZnO) Vardhaman (2020) and titanium dioxide (TiO_2) Birleanu et al. (2022) have shown significant reductions in wear rates and friction coefficients due to their ability to form a robust tribo-film between interacting surfaces. Similarly, carbon-based nanoparticles, such as graphene nanosheets (GNSs) and multi-wall carbon nanotubes (MWCNTs), have emerged as highly effective tribological additives, capable of reducing friction and wear even under extreme load conditions. These nanoparticles work by filling micro-cracks and acting as rolling elements, which prevent direct metal-to-metal contact. Rheological properties, including viscosity, thermal stability, and flow characteristics, are critical for the performance and longevity of lubricants. Nanoparticles modify these properties by interacting with the lubricant base oil at the molecular level, enhancing its ability to maintain stable flow and viscosity under varying shear rates and temperatures. For example, the inclusion of metal oxide nanoparticles, such as titanium dioxide (TiO_2) and aluminium oxide (Al_2O_3), has been shown to improve the thermal conductivity and viscosity of lubricants (Mohamed et al., 2020).

The goal of this study is to determine the ideal weight percentage (wt.%) of MWCNTs, which might be added to commercial lubricating oil to enhance its functionality. After the MWCNT additions have been dispersed, the performance of the base oil has been assessed by measuring its rheological characteristics, such as pour and flash points and kinematic viscosity, and its tribological characteristics, such as wear and friction coefficients.

2. Materials

MWCNTs with a 97% purity level were bought from Nano Tech Co., Ltd. on October 6th, Giza, Egypt.The MWCNTs measured between 2 and 20 µm in length and 10 and 12 nm in diameter. The base oil was Mobil 5W-30, a popular grade of lubricant oil Mobil that is frequently used for lubricating pumps and engines. Table 1 lists base oil's primary characteristics.

Table 1. Properties and Specifications of base oil

Property	
Grade	*SAE 5W-30*
Kinematic Viscosity @ 100 C, mm2/s	*10.3*
Kinematic Viscosity @ 40 C, mm2/s,	*60.7*
Viscosity Index, ASTM D2270	*159*
Density @ 15.6 C, g/ml, ASTM D4052	*0.85*
Pour Point, °C, ASTM D97	*-39*
Flash Point, Cleveland Open Cup, °C, ASTM D92	*235*

3. Fabrication of Nanocomposites

The process involves mixing 5W30 car oil with different concentrations of multi wall carbon nanotubes (MWCNTs) (0.5, 0.75, 1, and 1.25 wt.%) and then dispersing the mixture using a sonication bath, where high-frequency sound waves (20-40 kHz) are applied for 30 minutes to break down any agglomerates of carbon nanotubes and ensure a stable, uniform dispersion throughout the oil, resulting in a homogeneous blend of 5W30 oil with carbon nanotubes.

4. Wear Test and Friction

After the mixing process, a wear and friction test is conducted using the Four-Ball Test Machine in accordance with the ASTM D2596 standard as shown in Figure 1. During the test, the temperature of the test lubricant is regulated at 25°C, and the top ball is rotated at 1200 r/min for 60 minutes under specific load conditions. This setup evaluates the lubrication performance of the 5W30 oil mixed with carbon nanotubes by measuring its ability to reduce wear and friction. The results help determine how well the oil mixture minimizes friction and wear, showcasing the enhancement of its tribological properties due to the inclusion of carbon nanotubes.

Figure 1. Four ball Machine test

5. Pour Point

The lowest temperature at which a liquid maintains its flow characteristics is known as its pour point Figure 2. This characteristic, which shows the temperature at which the oil may still flow efficiently, is crucial for lubricating oils. Test tubes containing virgin oil and oil with nanoparticles were placed in a test tube holder in order to measure the pour point. Following the samples' solidification, the test tubes were taken out, and the temperature at which the solidified samples started to melt and flow was measured using a thermometer. In accordance with ASTM D-97, the pour point was measured.

Figure 2. Pour point Tester

6. Flash Point

The tendency of a liquid to combine with air to generate a combustible mixture under particular circumstances is indicated by the flash point temperature (Fig 3). It is an essential characteristic for determining a material's flammability. The ASTM D-93 standard was used to determine the oil samples' flash point. This method involved heating the oil in a container and passing a little flame above the liquid's surface. The temperature at which the oil ignites is known as the flash point.

Figure 3. Flash point Tester

7. Thermal Conductivity

The KD2-Pro device (Fig.4) uses the transient hot-wire approach to evaluate the thermal conductivity of nano-oil samples. This technique involves heating a thin metal wire with an electric current and then monitoring the heat transfer to the surrounding fluid. The fluid's thermal conductivity can be ascertained by monitoring the wire's temperature change over time. This method offers important information about how well the oil transfers heat, which is essential for high-performance applications. It makes it possible to evaluate the improved thermal characteristics of nano-oils in comparison to traditional oils.

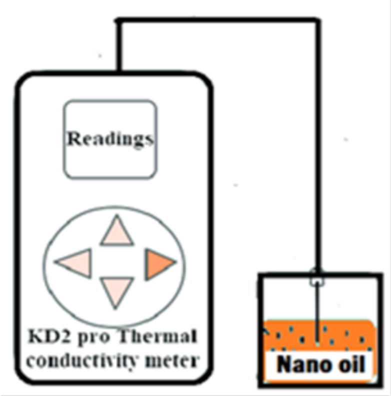

Figure 4. KD2-Pro thermal conductivity

8. Result and Discussions

8.1 Characterization of MWCNTs

The X-ray diffraction (XRD) pattern shown in Figure 5 highlights a distinct peak at 2θ=26.5∘, corresponding to the (002) plane. This prominent peak confirms the graphitic structure of the carbon, providing clear evidence that the material consists of multi-walled carbon nanotubes (MWCNTs). The Transmission Electron Microscopy (TEM) images of CNTs were used to investigate their structural characteristics and measure the dimensions of the nanoparticles. As illustrated in Figure 5, the average diameter of the CNTs is approximately 10 nm, with lengths ranging from 1 to 20 µm.

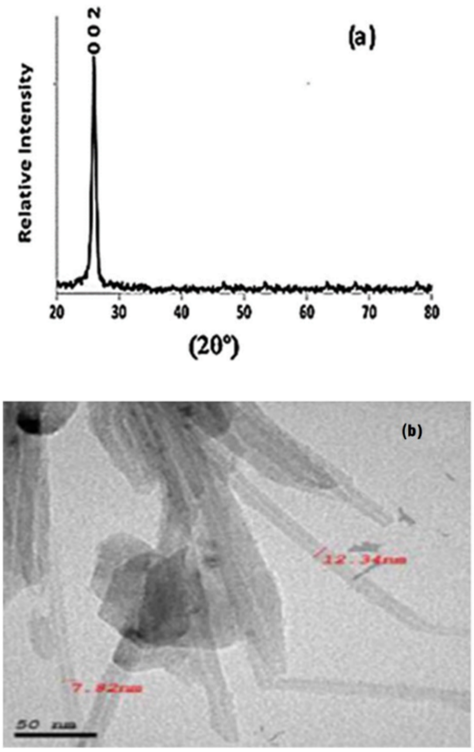

Figure 5. XRD patterns of (a) MWCNT TEM image of (b) MWCNTs

8.2 Tribological Tests

Tribological studies were conducted on oils blended with multi-walled carbon nanotubes (MWCNTs) at varying concentrations of 0.5, 0.75, 1, and 1.25 wt. %. As illustrated in Figure 6, the results revealed a significant enhancement in the oil's tribological performance with the addition of MWCNTs. Specifically, the wear scar diameter (WSD) was markedly enhanced by 87%, compared to base oil. The optimal concentration was identified as 1 wt.%, at which the wear properties reached their most favorable values. However, at concentrations exceeding 1 wt. %, the performance improvements began to plateau or slightly decline due to the agglomeration of nanotubes. These findings highlight the effectiveness of MWCNTs as an additive for enhancing the tribological characteristics of lubricating oils. The improvement in wear can be attributed to the unique capabilities of nano additives, which facilitate smoother sliding surfaces between asperities by acting as nano bearings, effectively reducing wear. Additionally, these additives exhibit self-repairing properties by filling holes and dimples on the material's surface, thereby restoring surface integrity. This self-mending action, as demonstrated in numerous studies [9, 10], enhances the performance and durability of lubricated systems, making nano additives a highly effective solution for improving tribological characteristics, even under challenging operating conditions.

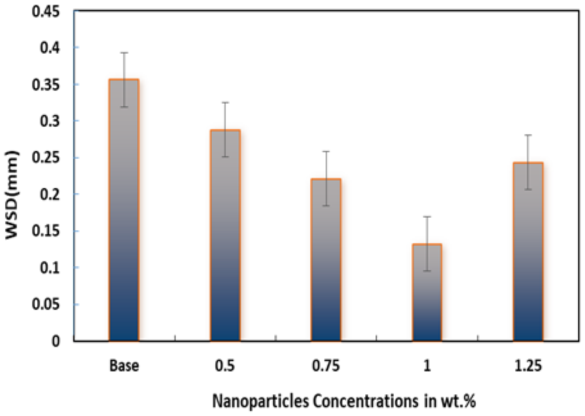

Figure 6. Wear Scare Diameter of base oil and oil with MWCNTs

8.3 Flash and Pour Point

The results indicated that the optimal concentration of MWCNTs was 1 wt. %. At this concentration, the oil exhibited the best balance of enhanced properties, including an improved flash point and a reduced pour point. As shown in Figure 7, the flash point increased by approximately 10%, indicating higher thermal stability and greater resistance to ignition. Similarly, the pour point improved by about 28%, as illustrated in Figure 8, demonstrating better low-temperature fluidity. These findings confirm that 1 wt. % of MWCNTs is the most effective concentration for optimizing both the thermal and operational performance of the oil.

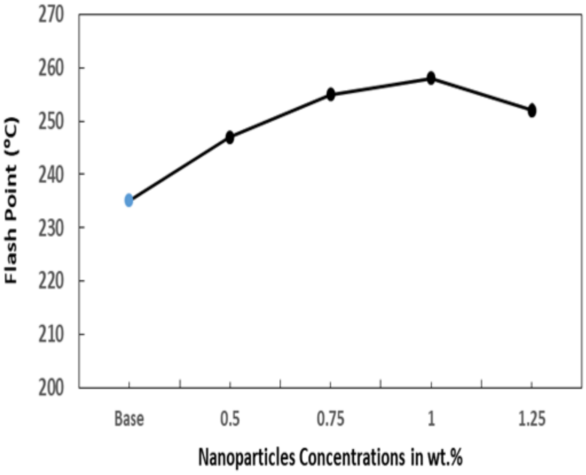

Figure 7. Flash point of Base oil and oil with MWCNTs

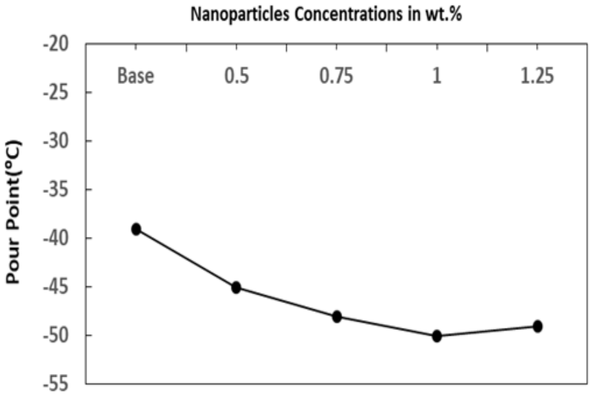

Figure 8. Pour point of base oil and oil with MWCNTs

8.4 Thermal Conductivity

The addition of MWCNTs considerably increased the oil's thermal conductivity, according to the findings of the thermal conductivity tests. The oil's thermal conductivity improved as the MWCNTs concentration rose, indicating that the nanotubes successfully boosted heat transfer. Significantly, when the carbon content rose, the thermal conductivity improved at 1 wt.%, which also happened to be the ideal concentration for other characteristics including pour point and flash point. This pattern highlights how more carbon content improves lubricating lubricants' thermal performance.

9. Conclusions

The study concludes that incorporating multi-walled carbon nanotubes (MWCNTs) into lubricating oils significantly enhances their tribological and thermal properties, with an optimal concentration identified at 1 wt.%. At this concentration, the oil exhibited the best balance of enhanced characteristics, including a 60% reduction in wear scar diameter, a 10% increase in flash point reflecting greater thermal stability, and a 28% improvement in pour point indicating superior low-temperature fluidity. The improvements are attributed to the unique capabilities of MWCNTs, which act as nano bearings to reduce wear and friction while demonstrating self-repairing properties by filling surface defects and restoring integrity. Additionally, thermal conductivity increased with higher MWCNT concentrations, where heat transfer efficiency was maximized. Beyond this concentration, performance gains plateaued or slightly declined due to nanotube agglomeration. These findings highlight the effectiveness of MWCNTs as an additive for improving the performance and durability of lubricating oils under various operating conditions.

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Conflict of Interest

The authors declare no conflicts of interest

References

Bartels, T., Bock, W., Braun, J., Busch, C., Buss, W., Dresel, W., ... & Omeis, J. (2000). Lubricants and lubrication. Ullmann's Encyclopedia of Industrial Chemistry. https://doi.org/10.1002/14356007.a15_423

Birleanu, C., Pustan, M., Cioaza, M., Molea, A., Popa, F., & Contiu, G. (2022). Effect of TiO2 nanoparticles on the tribological properties of lubricating oil: an experimental investigation. Scientific Reports, 12(1), 5201. https://doi.org/10.1038/s41598-022-09245-2

Gad, M. S., Kamel, B. M., & Badruddin, I. A. (2021). Improving the diesel engine performance, emissions and combustion characteristics using biodiesel with carbon nanomaterials. Fuel, 288, 119665. https://doi.org/10.1016/j.fuel.2020.119665

Honary, L., & Richter, E. (2011). Biobased lubricants and greases: technology and products. John Wiley & Sons.

Kadhim, A., Al-Amiery, A. A., Alazawi, R., Al-Ghezi, M. K. S., & Abass, R. H. (2021). Corrosion inhibitors. A review. International Journal of Corrosion and Scale Inhibition, 10(1), 54-67.

Kamel, B. M., El-Kashif, E., Hoziefa, W., Shiba, M. S., & Elshalakany, A. B. (2021). The effect of MWCNTs/GNs hybrid addition on the tribological and rheological properties of lubricating engine oil. Journal of Dispersion Science and Technology, 42(12), 1811-1819. https://doi.org/10.1080/01932691.2020.1789470

Kamel, B. M., Arafa, E. L., & Mohamed, A. (2023). Tribological and rheological properties of the lubricant containing hybrid graphene nanosheets (GNs)/titanium dioxide (TiO2) nanoparticles as an additive on calcium grease.

Journal of Dispersion Science and Technology, 44(14), 2675-2682. https://doi.org/10.1080/01932691.2022.2122491

Mohamed, A., Tirth, V., & Kamel, B. M. (2020). Tribological characterization and rheology of hybrid calcium grease with graphene nanosheets and multi-walled carbon nanotubes as additives. Journal of Materials Research and Technology, 9(3), 6178-6185. https://doi.org/10.1016/j.jmrt.2020.04.020

Rahman, M. M., Islam, M., Roy, R., Younis, H., AlNahyan, M., & Younes, H. (2022). Carbon nanomaterial-based lubricants: review of recent developments. Lubricants, 10(11), 281. https://doi.org/10.3390/lubricants10110281

Soleimani, M., Dehabadi, L., Wilson, L. D., & Tabil, L. G. (2018). Antioxidants classification and applications in lubricants. In Lubrication-tribology, lubricants and additives. IntechOpen. https://doi.org/10.5772/intechopen.72621

Spikes, H. (2004). The history and mechanisms of ZDDP. Tribology letters, 17(3), 469-489. https://doi.org/10.1023/B:TRIL.0000044495.26882.b5

Spikes, H. (2015). Friction modifier additives. Tribology letters, 60(1), 5. https://doi.org/10.1007/s11249-015-0589-z

Vardhaman, B. A., Amarnath, M., Ramkumar, J., & Mondal, K. (2020). Enhanced tribological performances of zinc oxide/MWCNTs hybrid nanomaterials as the effective lubricant additive in engine oil. Materials Chemistry and Physics, 253, 123447. https://doi.org/10.1016/j.matchemphys.2020.123447