Thermal Properties of Engine Oils through the Integration of Graphene Nanoparticles: A Greener Approach for Sustainable Mechanical Systems

G. Kadirgama[1], *Muhammad* A. M. A. Lee[1], *D.* Ramasamy[1*], *K.* Kadirgama[1,2,3*], *M.* Samykano[1], and *T.* Yusaf[4]

[1]Faculty of Mechanical & Automotive Engineering Technology, Universiti Malaysia Pahang, Pekan 26600, Pahang, Malaysia
[2]Almaaqal University, College of Engineering, Department of Civil Engineering, Basra, 61003, Iraq
[3]Automotive Excellence Center, Universiti Malaysia Pahang, 26600 Pekan
[4]School of Engineering and Technology, Central Queensland University, Brisbane, QLD 4008, Australia

Abstract. Tribology is a high demand mechanical system with friction and wear. Mechanical systems lose efficiency as a result. One answer for this issue is to utilize an oil that can limit contact and wear, bringing about improved effectiveness. The advancement of effective lubricating added substances for tribological properties improvement and improved thermal conductivity has gotten huge modern and scholarly consideration. By and large, nano-sized particles scattered in lubricants, referred to as nano-based lubricant, are utilized in mechanical structures to lessen heat and forces of frictions. Moreover, new guidelines will empower the utilization of greener lubrication advancements in oils. To resolve this issue, lubricants should satisfy guidelines while able to give exceptional oil characteristics. As another green material, this research will investigate the dissolving of Graphene nanoparticles in lubricants. The objective of this study is to perceive what Graphene added 10W40 motor oil means for the thermal properties and tribological characteristics. Graphene, which was added to 10W40 lubricant, was used to study the best design. Graphene nanoparticles were distributed in baseline engine oil in a two-step process. In the preparation of Graphene-based motor oil with a low volume mixture in the scope of 0.01% to 0.07% was used. Thermal conductivity and viscosity are estimated for all volume mixtures. Testing uncovered that Graphene added 10W40 motor oil were steady all through the review, with very little deposits in the following 30 days. The thermal conductivity of Graphene in SAE 40 motor oil expanded as the volume mixture is added.

* Corresponding author: deva@umpsa.edu.my; kumaran@umpsa.edu.my

1 Introduction

Since its inception, nanotechnology has further developed sliding surfaces by utilizing nanoparticles as added substances in lubricants. The added substances in the engine oil can improve or reduce the properties of the base oil. The not entirely settled by the attributes of the nanoparticles, like shape, size, and volume portion [1]. Numerous analysts announced superior consistency changes in nanoparticle-functionalized engine oil. They looked into how lubricant viscosity changed when the concentration of nanoparticle additives increased and the temperature increased. [2]. They found critical connections between viscous properties, temperature, and nanoparticle mixing. Expanding temperatures, diminished visvous consistency while expanding molecule volume mixture expanded in nano lubricant. As per these examinations, expanding the temperature and nanoparticle size, or diminishing the nanofluid fixation, decreases the viscosity of the nanofluid [3].

The main advantages of nano lubricants over conventional additives are their temperature resistance and limited tribological reactions [4]. Different types of nanoparticles, such as organic or inorganic nanoparticles, can be used. Polymers, liposomes, exosomes and protein-based nanoparticles, are instances of natural biobased nanoparticles, though inorganic nanoparticles incorporate silica nanoparticles, metal nanoparticles, carbon nanotubes and quantum specks[5]. Specialists are keen on natural inorganic, or half breed, nanoparticles in light of the fact that they can consolidate valuable compound such as, optical, and mechanical properties while improving the different advantages of nano lubrications. The scattering of nanoparticles, for example, Graphene or the latest examination natural nanoparticle utilizing coal fly debris crossover with different inorganic nanoparticles like copper, silica, and alumina has aroused the curiosity of scientists and scholastics as of late, as it prompts contact and frictions [6].

However, the use of Graphene as a nanomaterial dispersant in any base fluid, particularly lubricants, is not well documented in the literature. Graphene is non-toxic, biodegradable, and has a large surface area in addition to high strength [7]. With a focus on biodegradable, renewable, sustainable, and carbon-neutral polymer materials, graphene emerges as an affordable and sustainable material with oil soluble, optical transparency, and mechanical performing improvements. [8]. Investigation of Graphene nanoparticle crossovers (hybrids) is as yet inconsistent, however it has expanded essentially since the multifunctional report on the advantage of Graphene [9].

The thermal conductivity of a fluid is a vital property that influences how well it moves heat. Nano particle added engine oil with improved thermal properties will make the lubricant perform well. Analysts attempted to work on the low thermal conductivity of standard lubricants, by adding liquids by scattering nanoparticles all through the base liquid, generally motor oil [10].

The focus of this paper is to assess the thermal characteristics of Graphene nano lubricants for use in cylinder liner and oil rings of pistons in tribology uses.

2 Methodology

2.1 Preparation of nano lubricant

10W40 was picked as a base liquid for the nano added engine oil. Dispersing the particles into the base fluid, nano lubricants with volume mixtures from 0.01 to 0.07% by weight and optimal composition ratios were prepared in this stage. The process flow and steps for producing graphene nano lubricants are depicted in Figure 1.

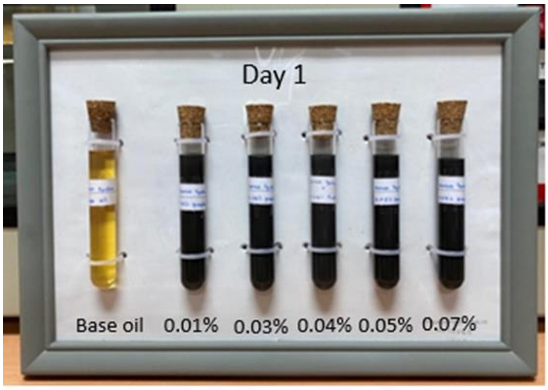

Fig. 1. Day 1 observation of Graphene + 10W40 Engine Oil.

$$\emptyset = \frac{\left[\frac{Wp}{\rho p}\right]}{\left[\frac{Wp}{\rho p}+\frac{Wbf}{\rho bf}\right]} \qquad (1)$$

Graphene nano lubricant was prepared with volume fractions of 0.01, 0.03, 0.04, 0.05, and 0.07% in 200 ml of SAE 40 base oil. Where, Wp represents the weight of the nanoparticles (grammes), (p represents the density of the nanoparticles (g/cm3), (bf represents the density of the base fluid in g/cm3, and Wbf represents the weight of the base fluid (grammes). Then, a magnetic stirrer was utilised to mix nanoparticles with the base fluid. The nano lubricant was mixed for 30 minutes. Each nano lubricant solution was then left in an ultrasonic bath for approximately 2 hours. This was a crucial step in increasing the nano lubricant's stability.

2.2 Stability examination for nano lubricant

The sedimentation technique and visual receptiveness investigation are utilized. As the molecule size of the supernatant molecule stays steady inside the arrangement, for stability investigation, nanoparticle suspensions is researched. A few researchers have adjusted sedimentation methods in their examinations of floating particles [11]. A stationary sample with 8 ml of nano lubricant is laid down in a test tube. The sample is monitored and compared it to images from the initiation day. Then, pictures of nano lubricant sedimentation over time were took among the first day and 30 days later. During this time, pictures of the shifts in sedimentation performances and parting levels are summarized.

Using a UV–Visualisation method. A straightforward, fast, and cheap method for large measuring and characterizing the stability situations of colloidal dispersion. The manner is based on the combination of fluids and is useful for analysing various types of fluid particle distribution, but unsuitable for analysing nanoparticle dispersion at high volume concentrations. In this experiment, the device operated at a constant wavelength of 1200 nm for every nano lubricant sample measurement. In this analysis, a Pelkin Elmer UV–vis spectrophotometer with a wavelength range of 190 to 3300 nm (model number TGA 4000) was utilised. For a single sample of nano lubricant, the equipment has consistently operated at a wavelength of 1200 nm.

The test samples are placed within the spaces using a transparent plastic cuvette. The spectrophotometer provides six sample slots for measurement, one for the 10W40 reference fluid and five for nano lubricant samples. Before every measurement, apparatus was fastidiously cleaned with refined water to forestall cross-tainting with the past example. The

UV-vis spectrophotometer is utilized to gauge the light pillar's decline after reflection from a surface or transmission through the specimen. The dissipating and retention of not set in stone by contrasting the Graphene particles added lubricant results. When coordinated at the example test, the absorbance of the light will demonstrate the presence of nanoparticles in the base liquid. To put it another way, because the solution contains fewer nanoparticles, it is anticipated that the base fluid's densely packed nanoparticles will have a lower absorbance value [12].

For the sedimentation observation, pictures were taken after a certain amount of time had passed and the nanoparticles had settled to the bottom of the test tube without being disturbed. This test can last anywhere from days to months. Researchers have come up with different test times for different combinations of nanoparticles and lubricants. So, it's important to say that the main idea behind choosing the test time is to look at how samples of lubricant behave in unusual ways when they spread out. During the observation period, all the samples were kept in test tubes and left alone. They were checked every so often to see if anything looked different. At week 1, the samples were well mixed, and no nanoparticles had settled to the bottom of the test tube. After 4 weeks, the top layer of the solution is the supernatant.

3 Results of the Thermophysical Analysis

3.1 Stability analysis of Graphene nano lubricant

Figure 2 shows the range of patterns for different amounts of Graphene nano lubricant in different volumes. From 0.01% to 0.07%, it can be seen as the peak absorbance. UV spectrometer works well on liquids and mixtures, however, the data will be incorrect if the sample contains darker solutions and is composed of solid particles suspended in liquid. So, it shows that a concentration of 0.05% is the best for keeping Graphene stable, and future experiments will only focus on this concentration.

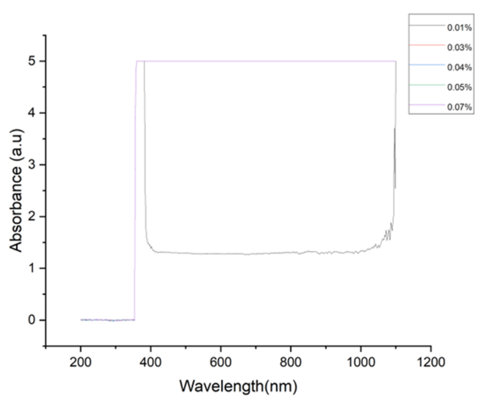

Fig. 2. Absorbance of each concentration of nano lubricant.

3.2 Thermal conductivity

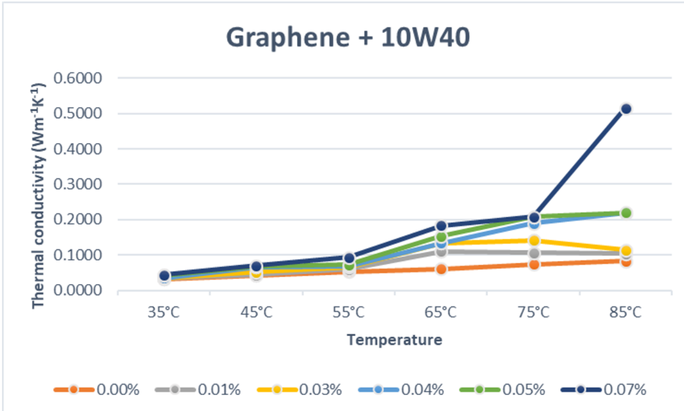

Fig. 3. Overall thermal conductivity.

Referring to thermal conductivity increases as volume concentration increases, as shown in Figure 3 and the same trend can be observed for base oil (10W40). The maximum achievable thermal conductivity is 0.5163 W (m.K) at 0.07% volume concentration and 85°C temperature. According to all measurements, the thermal conductivity value fluctuates as the temperature rises. As depicted in Figure 3, the combination of Graphene and 10W40 engine oil as the thermal conductivity amount exhibits a consistent growth pattern for the nano lubricant. This proves that the 0.07% has the best performance in the system.

4 Conclusion

Nanofluid high-thermal-conductive materials improve engine lubrication thermal properties at 0.07% concentrations. This work examined the thermophysical properties of nano lubricants, evaluated graphene as an engine oil additive improve their performance in stability and thermal conductivity. Nano lubricants revealed graphene's thermal conductivity, and lubricant flow behaviour. These findings demonstrate nano lubricants' thermophysical properties can improve lubrication systems. Graphene as an engine oil additive may reduce friction, wear, and tribological behaviour.

This work improves understanding of nano lubricants, investigates Graphene as an engine oil additive, and optimises lubricant performance. This work may improve lubrication systems for a variety of applications, benefiting industries and extending machinery and engine lifespans. More work is needed to fully utilise nano lubricants, graphene additives, and lubricant design and application.

The authors would like to thank MOHE in FRGS grant FRGS/1/2022/TK10/UMP/02/35 and also UMPSA in assisting the research in funding RDU223307 for this work.

References

[1] A. Ashraf, W. K. Shafi, M. I. Ul Haq, and A. Raina, "Dispersion stability of nano additives in lubricating oils – an overview of mechanisms, theories and methodologies," *Tribology - Materials, Surfaces & Interfaces,* vol. **16**, no. 1, pp. 34-56, 2022/01/02 (2022).

[2] N. W. b. A. Rahman and M. A. b. A. Aziz, "The effects of additives on anti-wear properties of lubricating grease formulated from waste engine oil," *Egyptian Journal of Petroleum,* vol. **31**, no. 3, pp. 71-76, 2022/09/01/ (2022).

[3] Z. A. A. A. Ali, A. M. Takhakh, and M. Al-Waily, "A review of use of nanoparticle additives in lubricants to improve its tribological properties," *Materials Today: Proceedings,* vol. **52**, pp. 1442-1450, 2022/01/01/ (2022).

[4] A. Chouhan, S. Kumari, T. K. Sarkar, S. S. Rawat, and O. P. Khatri, "Graphene-Based Aqueous Lubricants: Dispersion Stability to the Enhancement of Tribological Properties," *ACS Applied Materials & Interfaces,* vol. **12**, no. 46, pp. 51785-51796, 2020/11/18 (2020).

[5] M. Kamal Kamarulzaman *et al.*, "Improving the thermophysical properties of hybrid nanocellulose-copper (II) oxide (CNC-CuO) as a lubricant additives: A novel nanolubricant for tribology application," *Fuel,* vol. **332**, p. 126229, 2023/01/15/ (2023).

[6] D. M. Abd Elhaseeb, M. K. A. Ali, M. Ezzat, and M. Mourad, "A review of the tribological properties of nanoparticles dispersed in bio-lubricants," *Proceedings of the Institution of Mechanical Engineers, Part J: Journal of Engineering Tribology,* vol. **237**, no. 1, pp. 27-52, (2023).

[7] V. Georgakilas *et al.*, "Noncovalent Functionalization of Graphene and Graphene Oxide for Energy Materials, Biosensing, Catalytic, and Biomedical Applications," *Chemical Reviews,* vol. **116**, no. 9, pp. 5464-5519, 2016/05/11 (2016).

[8] G. Cao, "Atomistic Studies of Mechanical Properties of Graphene," *Polymers*, vol. **6**, no. 9*,* pp. 2404-2432

[9] C. S. Shivananda, S. Madhu, G. Poojitha, A. R. Sudarshan, S. Jeethendra, and K. Nagi Reddy, "Structural, chemical and morphological properties of graphite powder, graphene oxide and reduced graphene oxide," *Materials Today: Proceedings,* vol. **89**, pp. 49-53, 2023/01/01/ (2023).

[10] A. S. Al-Janabi, M. Hussin, and M. Z. Abdullah, "Stability, thermal conductivity and rheological properties of graphene and MWCNT in nanolubricant using additive surfactants," *Case Studies in Thermal Engineering,* vol. **28**, p. 101607, 2021/12/01/ (2021).

[11] C. Vira, A. Aziz Hairuddin, and N. Mazlan, "Promising use nanoparticles in the base fluid of a system (preparation, stability test and critical analysis): A review," *Materials Today: Proceedings,* vol. **66**, pp. 3135-3139, 2022/01/01/ (2022).

[12] H. Eshgarf, M. Afrand, and M. Hemmat Esfe, "Experimental investigation of the effects of temperature and nanoparticles volume fraction on the viscosity of non-Newtonian hybrid nanofluid," *Modares Mechanical Engineering,* vol. **16**, no. 3, pp. 98-104, (2016).