An experimental investigation of the viscosity of graphene-engine oil: The impact of temperature and concentration of nanoparticles

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***Abstract*: This experimental study delves into the rheological properties of graphene-engine oil nanofluids, focusing on the effects of temperature and nanoparticle concentration. The aim is to enhance the understanding of how graphene (Gr), as a nanoparticle additive, influences the viscosity of engine oil under various conditions. The study systematically investigates the viscosity changes in engine oil with varying concentrations of graphene nanoparticles (0.1%, 0.5%, 1.0%, and 2.0% by weight) across a temperature range of 5°C to 65°C, focusing on enhancing the thermal and lubrication properties of the base oil. Graphene, a single layer of carbon atoms arranged in a two-dimensional honeycomb lattice, is renowned for its exceptional thermal conductivity, mechanical strength, and electrical conductivity. The Anton Paar MCR 302 Rheometer series was used to do the measurements. Correlations were proposed using the experimental data to estimate the dynamic viscosity of Graphene-engine oil at various temperatures. The outcomes of the experiment at various shear rates demonstrated that every nanofluid sample behaves in a Newtonian manner. The findings also showed that as the solid volume percentage rises, the nanofluid's viscosity does as well. Additionally, it has been discovered that the viscosity of nanofluids reduces with temperature, becoming more palpable at lower temperatures. Theoretical models were shown to be unable to accurately predict the viscosity values of the nanofluids at all solid volume fractions when compared to experimental observations. The results of the experiment also showed that the nanofluid's 48% more viscosity enhancement above the base fluids was.**

***Keywords:* Graphene nanoparticles, 20-40W engine oil, Rheometer, viscosity.**

I. INTRODUCTION

The addition of graphene nanoparticles to 20W-40W engine oil for improving its tribological properties represents a significant advancement in lubrication technology. Tribology, the science of wear, friction, and lubrication, plays a crucial role in enhancing the efficiency, durability, and performance of mechanical systems. Traditional engine oils are designed to reduce friction and wear between moving parts, but the demands of modern engines for higher performance and longer life require more advanced solutions. Graphene, a single layer of carbon atoms arranged in a two-dimensional honeycomb lattice, has emerged as a promising material for this purpose due to its exceptional properties. Graphene is renowned for its extraordinary mechanical strength, high thermal conductivity, and excellent electrical conductivity. When used as an additive in engine oils, graphene nanoparticles can significantly improve the lubricant's performance. These nanoparticles interpose themselves between moving surfaces, forming a protective layer that can reduce friction and wear. The unique structure of graphene allows it to provide a durable barrier, enhancing the oil's ability to protect and prolong the life of engine components. Reduced Friction and Wear: Graphene's exceptional strength and lubricity contribute to a noticeable reduction in friction and wear between engine parts, leading to improved engine efficiency and longevity. Enhanced Thermal Conductivity: The high thermal conductivity of graphene helps in better heat dissipation from engine components, thus protecting the engine from overheating and contributing to a more stable operation. Improved Oil Stability: Graphene can increase the thermal and oxidative stability of the engine oil, ensuring that it maintains its protective properties over a wider range of temperatures and for longer periods. Increased Load-Bearing Capacity: The incorporation of graphene nanoparticles can enhance the load-bearing capacity of the oil, allowing it to protect engine components even under high stress and pressure conditions. Environmental Benefits: By extending the life of engine components and potentially extending oil change intervals, graphene-enhanced engine oils can contribute to waste reduction and environmental sustainability. Several studies have demonstrated the benefits of adding graphene nanoparticles to lubricants. For example, research has shown that even a small concentration of graphene in engine oil can lead to a noticeable reduction in friction and wear. Experiments often involve comparing the performance of standard lubricants with those infused with graphene under controlled conditions, measuring parameters such as friction coefficient, wear rate, and thermal conductivity.

One kind of coolant and lubricant that is utilized in numerous technical applications is motor oil. The friction between moving parts is reduced by the engine oils. These could help take heat away from moving components. Higher viscosity results in an improvement in bearing load capabilities, whereas lower viscosity makes oil pumping easier. Consequently, reduced fuel consumption and increased efficiency might result from using the proper engine oil. Numerous researchers introduced nanoparticles to working fluids (such as water, ethylene glycol, and oil) to increase their rate of heat transfer process known as nanofluids [1–8]. Measuring the thermo physical characteristics of nanofluids is becoming more and more essential as they replace conventional fluids in applications. K.Madhubabu et al. [1] Graphene nanoparticles (GNP) are among the most often utilized particles in the preparation of nanofluids, according to the literature. Numerous studies have documented that the concentration, size, shape, and base fluid of the nanoparticles, as well as their temperature, influence the thermal conductivity of alumina-based nanofluids [9–14]. On the other hand, the dynamic viscosity is altered when the nanoparticles are introduced to the base fluids. Numerous investigations into viscosity have demonstrated that viscosity in nanofluids is dependent upon temperature, concentration, and the size and form of nanoparticles [15–20]. Table.1 provides an overview of experimental research on the dynamic viscosity enhancement of nanofluids containing Gr nanoparticles. In these studies, the researchers concentrated on how the dynamic viscosity of nanofluids was affected by temperature, nanoparticle concentration, and size. The experiments and the classical models were compared in a few of the previously stated publications. Batchelor gave one of the classical models [23, 31-32].

Table. I: A summary of experimental studies on the viscosity enhancement of nanofluids containing GNP nanoparticles.

Author & year [Ref]	Nanomaterial	Base Fluid	Surfactant	observations
Ilyas et al. & 2020 [37]	GNP	NaCl- mixed in DI Water	SDS	The nanofluid had the best stability when the GNP: SDS ratio was 1:1.5. He also looked at how adding GNP to the surface tension of the nanofluid was impacted by the saline medium.
W. S. Sarsam et al. & 2016 [38]	GNP	Distilled water	GA, SDS, SDBS, CTAB	When compared to other surfactants, the GA-based nanofluid showed a superior increase in thermal conductivity, but they still suggested SDBS because it had the second-best thermal conductivity and the longest stability.
C. Demirkir & H. Erturk & 2020 [39]	GNP	Deionized water	Polyvinylpyrrolidone (PVP)	They investigated the nanofluid's rheological behaviour and were able to create a nanofluid that remained stable for up to 30 days. A conductivity increase of up to 96 % was reported.

C. Selvam et al. & 2016 [40]	GNP	water + Ethanol Glycol(EG)	SD	They suggested utilizing GNP 0.3 vol% to get the least amount of pressure drop, viscosity, and greatest heat transfer convective coefficient. In comparison to the basic fluid, the maximum rise is up to 170 %.
S. Das et al. & 2019 [41]	GNP	DI water	GA	In the examined nanofluid, Thermal conductivity (K_{TC}) and viscosity are negatively correlated with temperature; additionally, adding GNP reduces the nanofluid's overall thermal resistance.
M. Mehrali at al. & 2016 [42]	NDG	DI water	Triton X-100	The range of maximum K_{TC} improvement measured is between 22.15 and 36.78 %. The increase in heat transfer coefficient is between 7 and 50%, while the pressure drop of nanofluid is between 0.08 and 14.4%.

He provided a correlation that can be used to predict the viscosity of nanofluids containing spherical nanoparticles at volume concentrations of up to 10%. It is expressed as

$$\frac{\mu_{nf}}{\mu_{bf}} = (1 + 2.5\emptyset + 6.2\emptyset^2)$$

μ is the dynamic viscosity and ϕ is the solid volume fraction nanoparticles. Moreover, the subscripts of n f and b f indicate respectively nanofluid and base fluid. Enhancing the thermo physical qualities of engine oil is crucial for industrial needs due to its multiple applications. Consequently, there has been interest in the rheological behavior of engine oil among researchers. For instance, the impact of multi-walled carbon nanotubes on the viscosity index of lubricant cuts was reported by Vakili Nezhaad et al. [33]. The impact of Gr phases on the improvement of thermal conductivity and viscosity of nanofluids in motor oil was examined by Vasheghani et al. [34]. Ettefaghi et al. investigated the thermal and rheological characteristics of oil-based nanofluids derived from various carbon nanostructures [35-36]. There are, nevertheless, a few studies on the viscosity of oil.

II. MATERIAL AND METHODOLOGY

This study examines the viscosity of Graphene-engine oil experimentally while taking temperature and nanoparticle concentration into account. At solid volume fractions of 0.25%, 0.5%, 0.75%, 1%, 1.5%, and 2%, the nanofluid samples were made. The temperatures at which the experiments were conducted were 5 °C, 15 °C, 25 °C, 35 °C, 45 °C, 55 °C, and 65 °C. Rheology viscometer was used to investigate how temperature and nanoparticle concentration affected the dynamic viscosity of nanofluids. Additionally, a comparison is made between the viscosities of nanofluids that are measured and those that come from theoretical models. The dynamic viscosity of the nanofluid is finally predicted utilizing new correlations that are proposed based on experimental data for engineering applications.

The basic fluid for this investigation was 10W-40W engine oil. Graphene nanoparticles were scattered throughout the oil, with an average diameter of 20 nm. The TEM image of the nanoparticles is displayed in Fig.1 in order to determine the average diameter size of the particles. Table.2 displays the specifications of the graphene nanoparticles. A two-step procedure was used to prepare the nanofluid samples with the solid volume fractions of 0.25%, 0.5%, 0.75%, 1%, 1.5%, and 2%. Following 2.5 hours of magnetic stirring, the samples were placed in an ultrasonic processor for 7 h to create the most stable and homogenous possible product the photograph of samples is shown in Fig.2.

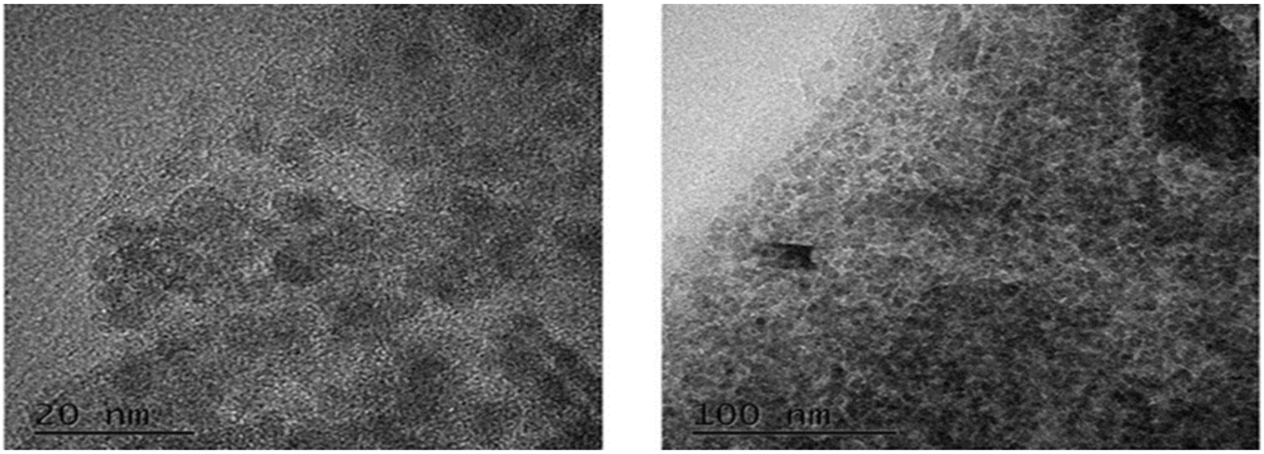


Fig.1. HRTEM image of Graphene nanoparticles

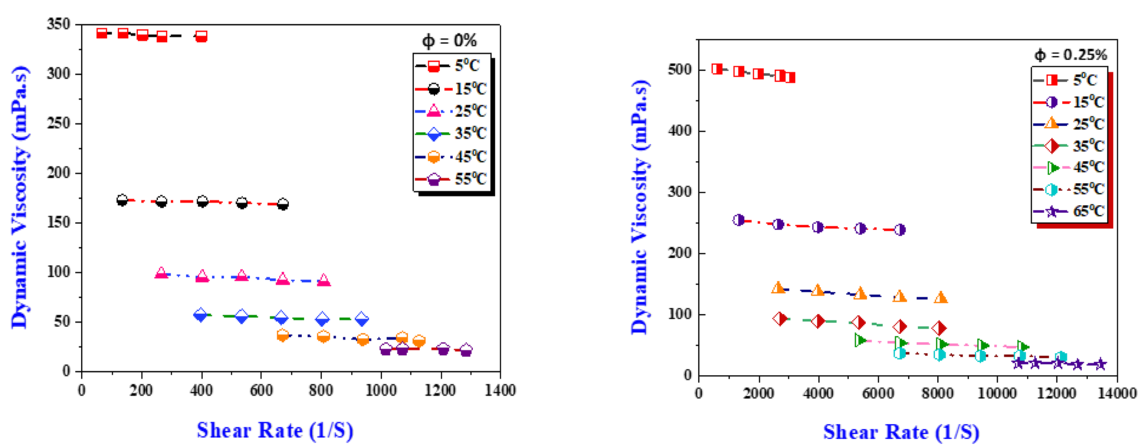
Table.II: Specification of Gr nanopowder [43-44]

Properties	Value
Optical transmittence	~ 97.7%
Planer surface area	2630 m^2. g^{-1}
Mobility charge carrier	~ 200,000 cm^2. V^{-1} s^{-1}
Youngs modulus	1100 GPa
Fracture strength	125 GPa
Density	215 kg. m^{-3}
Thermal Conductivity	~ 5000 W. $m^{-1}K^{-1}$
elastic modulus	1 TPa
Breaking strength	42 N. m^{-1}
Morphology	Honeycomb structure(hexagons)

Fig.2. the photographs of samples of Nano oil.

III. RESULTS AND DISCUSSION

Gr/engine oil nanofluids' dynamic viscosity was measured at temperature ranges of 5 °C to 65 °C for various samples with volume fractions of 0.25%, 0.5%, 0.75%, 1%, 1.5%, and 2%. Fig.3 shows the dynamic viscosity of nanofluids vs shear rate for various solid volume fractions at different temperatures to help understand the Newtonian or non-Newtonian behaviour of the samples. According to the experiment's findings, samples' viscosity somewhat decreased as the shear rate increased. Considerations for shear heating, which happen at high shear rates, may be connected to this behaviour.



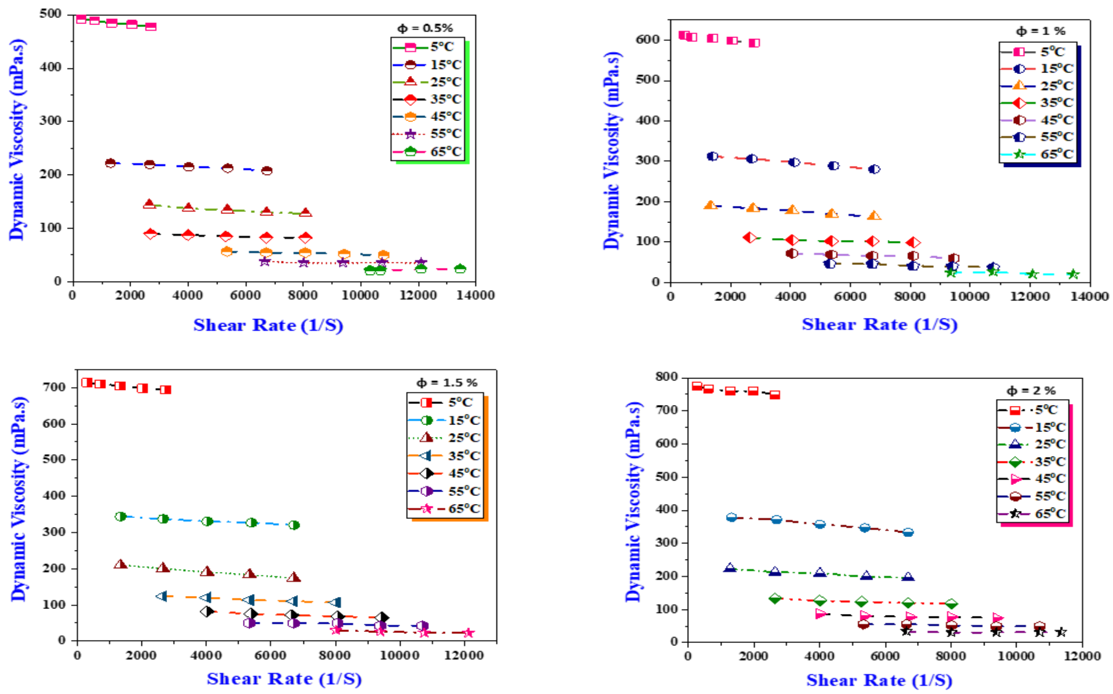


Fig.3. Dynamic viscosity of nanofluids versus shear rate for different solid volume fractions at various temperatures.

Additionally, it is discovered that each sample exhibits Newtonian behavior since the viscosity of the samples is independent of the shear rate. This picture also demonstrates how the solid volume fraction raises the nanofluid's viscosity. Furthermore, it is evident that the viscosity of nanofluids reduces with temperature, becoming more tangible at lower temperatures. The dynamic viscosity fluctuations of the nanofluids with solid volume fraction at different temperatures are displayed in Fig.4. It is evident that as the solid volume percentage rises, the nanofluid's viscosity does as well. Furthermore, at lower temperatures, the rise in dynamic viscosity with solid volume percentage is greater than that at higher temperatures.

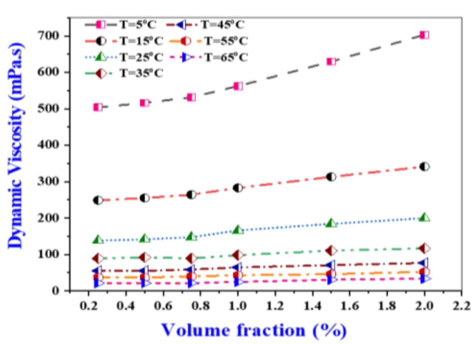


Fig.4. Variations of dynamic viscosity of the nanofluids with volume fraction for various temperatures.

Actually, the addition of nanoparticles to the oil causes the base fluid to become scattered with the nanoparticles. Larger Nano clusters arise as a result of the van der Waals interactions between the oil and the nanoparticles. The basic fluid's ability to flow across these Nano clusters is inhibited, increasing the viscosity. The dynamic viscosity of the nanofluid samples as a function of temperature is shown in Fig.5. It is evident that when temperature rises, the nanofluid's viscosity dramatically reduces. The deterioration of the intermolecular connections between the molecules is the source of this phenomenon.

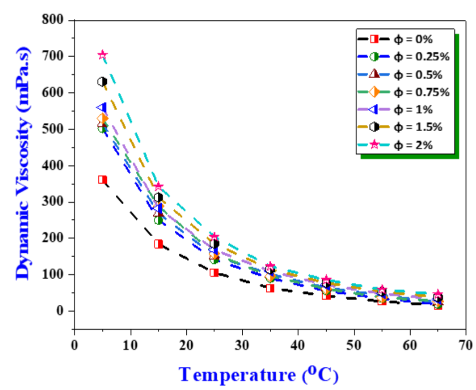


Fig.5. Dynamic viscosity of the nanofluid samples versus temperature.

The relative viscosity as a function of temperature and solid volume fraction is displayed in Fig.6. It is evident that at a temperature of 55 °C and a solid volume fraction of 2.0%, the maximum viscosity enhancement is 132%. Furthermore, it is evident that relative viscosity once more drops at temperatures above 55 °C. This is a significant discovery for the use of Gr/engine oil nanofluid in engineering applications like power pumping.

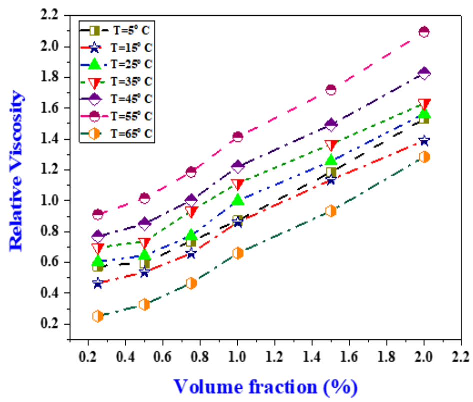


Fig.6. Relative viscosity as a function of temperature and solid volume fraction.

IV.CONCLUSION

The dynamic viscosity of Gr/engine oil nanofluids was measured in the current study for several samples with volume fractions of 0.25%, 0.5%, 0.75%, 1%, 1.5%, and 2% at temperature ranges from 5 °C to 65 °C. The outcomes of the experiment at various shear rates demonstrated that every sample behaves in a Newtonian manner. The findings also showed that as the solid volume percentage rises, the nanofluid's viscosity does as well. Furthermore, it has been discovered that the viscosity of nanofluids reduces with temperature, becoming more palpable at lower temperatures. Theoretical models were shown to be unable to accurately predict the viscosity values of the nanofluids at all solid volume fractions when compared to experimental observations. Additionally, according to the experimental data, the nanofluid's greatest viscosity augmentation above the base fluid's was 48%. Eventually, utilizing the experimental data, a number of appropriate correlations have been provided regarding the significance of forecasting the dynamic viscosity of Gr/engine oil nanofluid.

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