The effect of nanoparticles on the flow and physical behavior of engine lubricant oil

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Abstract:-

This work studies the effect of nanoparticles (NPs) on the flow and physical properties of engine oil. The controlling on the viscosity, flash, fire point and thermal conductivity is essential issue to improve the engine oil lubricant performance. Recently nanoparticles can be used as an additive to the engine oil to improve its properties. The graphite (Gr) and zinc oxide (ZnO) NPs with main diameter of 40 nm were mixed with the 20W50 oil using magnetic stirrer and ultrasonic process. Cone-plate is used to check the dynamic viscosity. SYD3536 flash point apparatus is used to test the flash and fire point, also the effect of ZnO and Gr NPs on the thermal conductivity of nano-oil is tested using KD2 probe instrument. The results indicated that the higher concentration of NPs, the better properties of the base nano-oil, the flash and fire point generally increases with the NPs concentration increasing. The Gr nano-oil generates higher flash and fire point than that of ZnO nano-oil. The dynamic viscosity produces a slight change due to NPs concentration increasing at different temperatures especially at 40ºC for both nano-oil. At temperatures over 40ºC the viscosity increases with the NPs concentrations increasing, while below 40ºC the viscosity decreasing.

The thermal conductivity increases with NPs percentage increasing, where the Gr nano-oil the higher value than that of ZnO nano-oil.
Keywords:- flow behavior, ZnO and graphite nanoparticles, engine oil, nanofluid, viscosity, flash and fire point.

Introduction:

Lubrication is an interdisciplinary science that involves physics, chemistry, materials, fluid mechanics and contact mechanics. Numerous mechanical systems require a variety of functional lubricants to decrease the friction and wear of contacting surfaces as well as to significantly reduce the total energy consumed by mechanical systems [4]. Today, practically all types of lubricating oil contain at least one additive, and some oils contain additives of several different types. The amount of additive used varies from a few hundredths of a percent to 30% or more [11]. Nanotechnology has become an effective technology used in many fields. One of them is lubrication where nanoparticles can be used as an additive to the engine oil [5]. Nanomaterials specifically graphite, were only applied as dry lubricants in very harsh environments such as high temperature applications, where organic lubricants are considered to be unsuitable. Addition of nanoparticles in lubricating oil could significantly reduce the interfacial friction and improve the load-bearing capacity of the parts, which has been regarded as having great potential as lubricant additives [6]. The environmental and toxicity issues of conventional lubricants as well as their rising cost related to a global shortage and their poor biodegradability led to renewed interest in the development of environmental friendly lubricants. There has been increasing demand for green lubricants and lubricant additives in recent years [7].

Rheology plays an important role in the flow behavior of engines oils during preparation and processing. Beside all of these, rheological testing can provide the present behavior of the oil as well as its behavior after week, months, years, and even decades [8].Viscosity index (VI) representing the effect of temperature on the kinematic viscosity of lubricant oils. It measures the stability of the kinematic viscosity with temperature. The higher VI, the more stable the kinematic viscosity with temperature [9].

Marinalva Ferreira and et al, 2014,[10] studied the properties of biolubricants of vegetable oils and (ZnO and CuO) nanoparticles are added at 0.5wt% in order to improve abrasion resistance and friction. The nanosolution is prepared by ultrasonic at 30min. The developed biolubricants showed good tribological properties besides being more adapted to the environment.

Different material with varies nanoscale are used as additives to improve the lubricants properties, 0.1, 0.2 and 0.5 wt.% of CuO nanoparticles are added to SAE 20W50 engine oil. The dispersing nanoparticles inside engine oil using planetary ball mill. The nanolubricant with 0.2 wt% concentration is the best sample for CuO/ oil because pour point and flash point are improve which viscosity has not changed much, Ehsan-O- Llah, et al [1]. Using of nanodimension oil additives in agricultural tractor engines would reduce wear in cylinder, gaskets, drive, shaft, gear camshaft and valve mechanisms by 68%, Gh, Nasini-Khuzani et al[2].The effect of surfactant was also studied and it was found that not only it was beneficial in dispersion the nanoparticles in oil, but also produced some reduction in friction and wear, Nicholaos G. Demas [3].

The aim of this work is to enhance the engine oil performance by mixing it with different ratio of nanoparticles. Different percentage of ZnO and Gr NPs are mixed with 20W50 oil and studying different properties such as flash point, fire point, thermal conductivity and dynamic viscosity.

Material and Method:-

One of the major hurdles in introducing the NPs into the lubricants is agglomeration, inhibiting ideal homogeneity and dispersion. An ultrasonic de-agglomerates (Sonicator) with magnetic stirrer have been used to ensure homogeneous mixing and dispersion of the nanoparticles into lubricants without agglomeration. The base lubricant used in this study is SAE 20W50 engine oil which is typically, mineral base oil, widely used in automobile. ZnO and Gr NPs are mixed in different content 0.001, 0.003, and 0.006 wt. % with the base lubricant to prepare the nanofluid. The main conditions of the mixing process are 30°C for 15 minutes for magnetic stirrer and 20 minutes and 480 watts for sonication process. The specifications of ZnO and Gr nanoparticles are shown in Table (1 and 2).

Table (1): The specifications of ZnO NPs

Specification	Results
ZnO %	**95.2**
Pb %	**0.03**
Mn %	**0.005**
Cu %	**0.003**
Water soluble matter %	**0.7**
Specific surface area (m^2/g)	**36**
Particle size	**40 nm**

Table (2): The specifications of Gr NPs

Specification	Results
Purity	**99.9%**
Density (g/cm^3)	**2.26**
Morphology	**spherical**
Specific surface area (m^2/g)	**60**
Particle size	**40 nm**

Characterizations:-

1- Flash and Fire point:-

The effect of ZnO and Gr NPs on the flash and fire points of lubricant oil are examined using SYD3536 flash point apparatus. A specified volume of sample is introduced by a syringe into the cup of the apparatus that is set and maintained at the specified temperature. After a specific time a test flame is applied and an observation made as to whether or not a flash occurred, while the fire point is measured at the temperature that the fire is continuous to burn.

2- Dynamic Viscosity:-

The dynamic viscosity of lubricant nano-oil is examined using cone-plate viscometer with the cone diameter 25mm and cone angle of 0.8 according to ASTM-D 2893.All experiments are conducted at a constant gap of 0.5mm and an initial stabilization period of 2 minute is given for achieving the temperature equilibration.

3- Density:-

The measuring of density was performed at room temperature by using (Matsu Haku HIGH Precision DENSITY TESTER GP-120S D=0.0001 g/cm^3). The density of nanofluid calculated based on Archimedes law.

4- Surface tension

Samples measurements obtained by using JZYW-200B Automatic Interface Tensiometer supply by BEING UNITED TEST CO., LTD to show the effect of ZnO and Gr NPs on the surface tension of the oil.

5- Thermal conductivity:-

The effect of ZnO and Gr NPs on the thermal conductivity of engine oil lubricant is tested using KD2 probe instrument (DECAGON Devices inc.).

Results and Discussion:-

1- Flash and Fire point:-

Fig.1 the results show that the flash point decreases at 0.001 wt% and then increases up to 0.006 wt% for both of ZnO and Gr Nps. For Gr nano-oil exhibits flash point higher than that of ZnO nano-oil at all concentrations. The flash point increases by about 22ºC and 12ºC at 0.006 concentrations for Gr and ZnO NPs respectively. The increasing in flash point due to Gr addition is ascending which may be leads to more improvement with further concentration. Also the increasing in flash point after 0.003 of ZnO become small and the higher concentration is not encouraging.

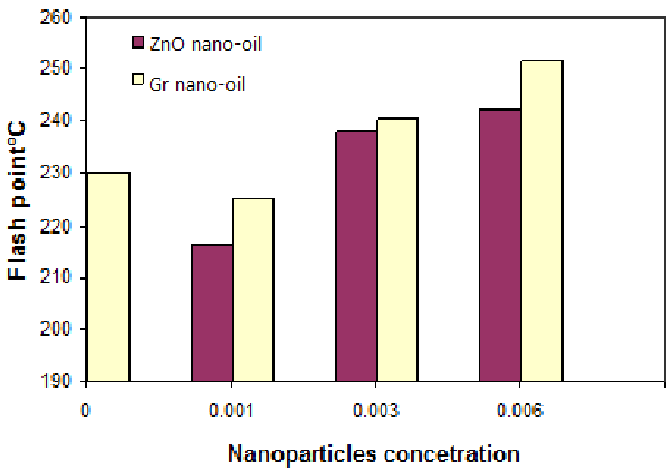

Fig.1: Flash point behavior of 20W50 engine oil as a function of ZnO and graphite nanoparticles concentration

Fig.2: shows the fire point behavior of ZnO and Gr nano-oil lubricant. The results show that the fire point decreases at 0.001 wt% for both of the ZnO and Gr NPs, then increases up to the 0.006 wt% of NPs. The fire point of Gr nano-oil is higher than that of the ZnO nano-oil for all concentrations. Again the ascending increasing of fire point of Gr nano-oil may be produce interesting modification.

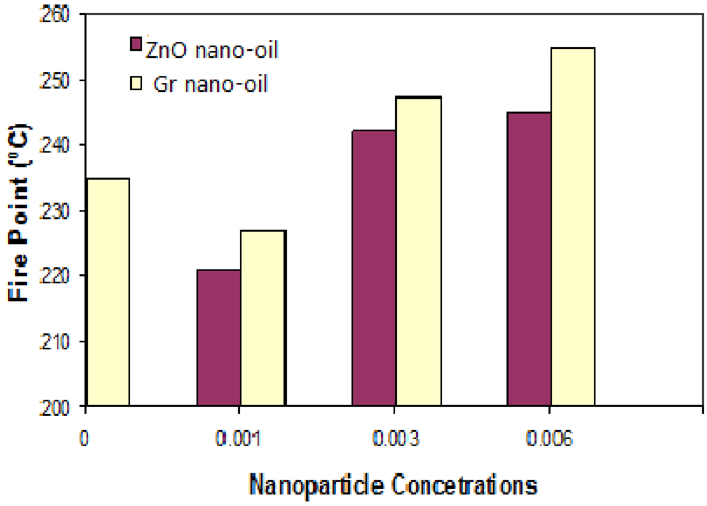

Fig.2: Fire point behavior of 20W-50lubricant oil as a function of ZnO and graphite nanoparticles content

Density:-The density results for base oil at different ZnO and Gr NPs percentage are shown in **Fig.3**. The density of the oil increases with NPs percentage increases for both ZnO and Gr NPs; the Gr is more effective on the density than that of ZnO NPs at higher concentrations.

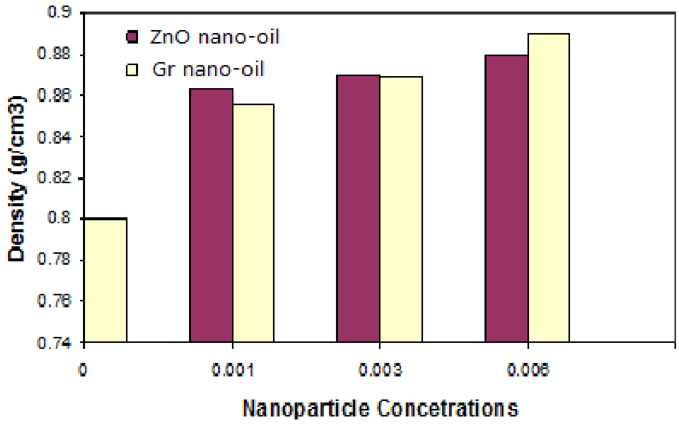

Fig.3: Density behavior of lubricant oil as a function of ZnO and Gr NPs concentrations

Dynamic Viscosity:-

The viscosity of a fluid is a measure of its resistance to gradual deformation by shear stress and governs the sealing effect of oils. **Figs.4 and 5** show the variation of viscosity of the base oil filled with ZnO and Gr NPs at different temperatures. The general viscosity behavior of Gr nano-oil is very close to that of base oil than that of ZnO nano-oil. The results show that the viscosity decreases with temperature increasing. The viscosity decreases slowly at higher temperatures, while rapidly changes occur between 30 to 50 ºC for both ZnO and Gr nano-oil. At 40 ºC the viscosity of all concentration coincides in the same point. The difference in viscosity value at high and low temperatures for nano-oil decreases with the NPs concentration increasing. The oil thermal stability depends on this viscosity difference. The stability of Gr nano oil over 40 ºC is higher than that of ZnO nano oil. The stability increases with NPs concentration increasing. The viscosity increases over 40ºC and decreases below 40 ºC with NPs concentrations increasing.

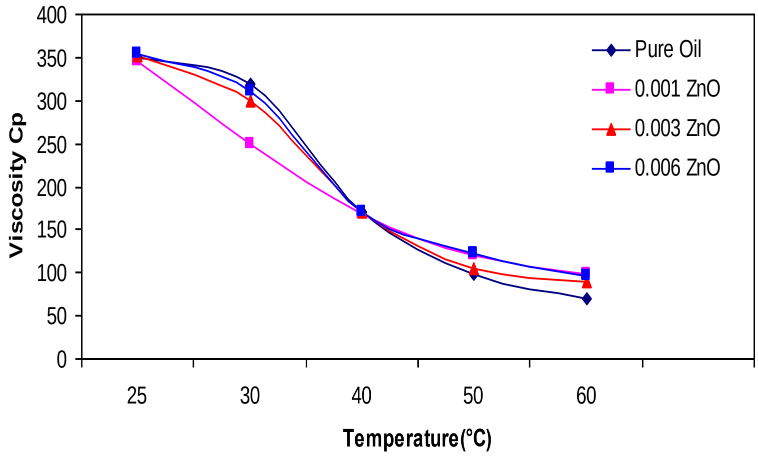

Fig. 4: Viscosity Behavior with different ZnO nano-oil at different NPs concentration and temperatures

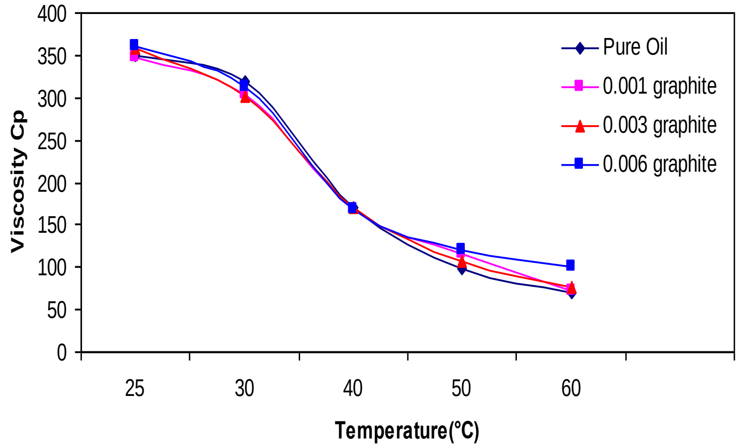

Fig. 5: Viscosity Behavior of Gr nano-oil at different NPs concentration and temperatures

Figs. 6 and 7: Show the effect of ZnO and Gr NPs concentrations on the dynamic viscosity of the 20-W50 oil nanofluid at different temperatures. The results show that the viscosity decreases at lower ratio of ZnO and Gr NPs then increases with NPs percentage compared with lubricant without additives. The viscosity is more stable with Gr NPs at different temperatures than that of ZnO NPs. At 40 ºC the viscosity indicates higher stability of the lubricant for both nano-oil.

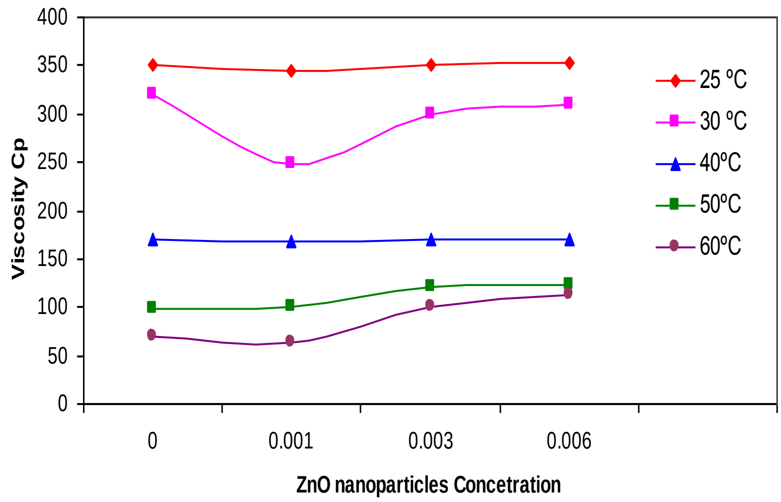

Fig. 6: Viscosity Behavior of ZnO nano-oil at different temperature and ZnO NPs concentration

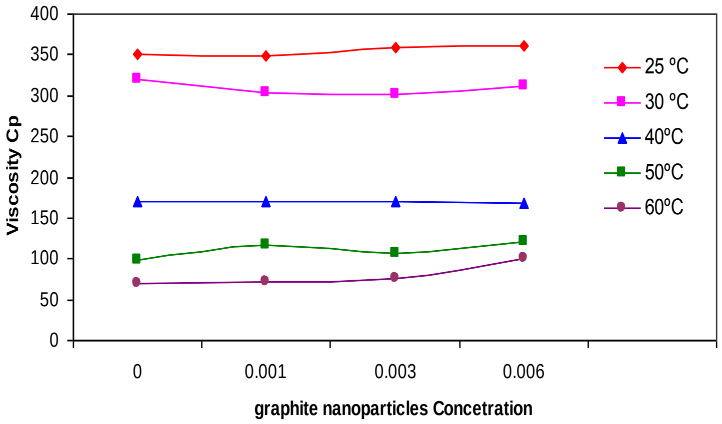

Fig.7: Viscosity Behavior of Gr nano-oil at different temperature and graphite NPs concentration

On the other hand, at higher temperature, the viscosity of each nano-oil is decreased where the higher nanoparticle contents make the oil more viscous in low and high temperatures. The viscosity of nano-oil is higher than that of the oil without NPs. The 0.6 % of ZnO and Gr NPs has the highest effect on the viscosity of lubricant among the other NPs concentrations.

Surface tension:

The results of surface tension are shown in table (2). The surface tension increases for Gr NPs and slightly decreasing for ZnO nanoparticles concentration increasing.

Table (2):-The surface tension values of the base lubricant at different concentration of ZnO and Gr NPs

Gr NPs	**Surface Tension**	ZnO NPs	**Surface Tension**
0	29.92	0	29.92
0.001	30.06	0.001	28.66
0.003	30.25	0.003	29.75
0.006	31.25	0.006	29.65

Thermal conductivity:-

Figs 8: Show the effect of ZnO and Gr NPs concentrations on the thermal conductivity of the 20W50 nano-oil. The results show that the thermal conductivity increases with nanoparticles concentration increases for both of ZnO and Gr NPs. The effect of Gr NPs more effective than that of ZnO NPs this is because that the thermal conductivity value of Gr is greater than of ZnO NPs. The increasing of flash and fire point indicate that the thermal conductivity increasing and vice-versa so that these test supports each other.

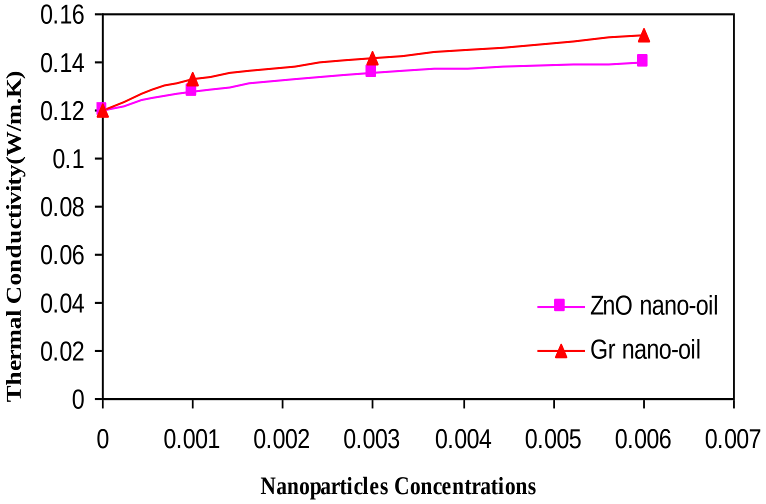

Fig.(8):- Thermal conductivity behavior of nano-oil at different concentration of nanoparticles

Conclusion:-

Nonmetals nanoparticles such as ZnO and graphite obtained interesting change on the flash point, fire point and dynamic viscosity over 40ºC. The graphite NPs are more effective than ZnO nanoparticles.0.6% ZnO and Gr NPs dispersed in lubricant produced better improvement in all properties than the other concentrations of 0.0.1and 0.3%. The general behavior of nano-oil viscosity not changes with temperature increasing. Also the viscosity keeps constant for the base oil and the nano-oil at 40ºC. At temperature over 40ºC the viscosity increases, while decreasing below 40ºC with the Gr and ZnO NPs increasing.

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