Investigated the flow, thermal, physical and stability behavior of lubricant oil filling with organic and bio-nanoparticles

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Abstract:-

This work studies the effect of organic and bio nanoparticles (NPs) on the flow, thermal, physical properties and stability of engine oil. The controlling on the viscosity, flash, fire point and thermal conductivity is essential issue to improve the engine oil performance. Recently nanoparticles can be used as additives to the engine oil to enhance its properties. The graphite (Gr) and zinc oxide (ZnO) NPs with main diameter of 40 nm were mixed with the SAE 20W50 oil using magnetic stirrer and sonication process. Cone-plate viscometer and KD2 probe (transient hot wire) are used to check the effect of NPs concentrations and temperature increasing on the dynamic viscosity and thermal conductivity behavior. SYD3536 flash point apparatus is used to test the flash and fire point due to the NPs concentrations increasing. The surface tension, density and stability after five months also tested. The results indicated that the higher concentration of NPs, the better properties of the nano-oil. The flash and fire point generally increase 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-oils. At temperatures over 40ºC the viscosity increases with the NPs concentrations increasing, while below 40ºC the viscosity decreasing. The thermal conductivity increases with the NPs percentage and temperatures increasing, where the Gr nano-oil produces the higher value than that of ZnO nano-oil. A small change in the surface tension and density is observed due to the additives increasing. The measured viscosity and thermal conductivity after five months show a high stability of both nano-oil.

Keywords:- flow behavior, ZnO and Gr NPs, nanofluid, viscosity, thermal conductivity, flash and fire point and stability.

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 [2,11]. 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[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]. Nanofluids have been found topossess enhanced thermophysical properties such as thermal conductivity, thermal diffusivity, viscosity, and convective heat transfer coefficients compared to those of base fluids like oil or water. It has demonstrated great potential applications in many fields. For a two-phase system, there are some important issues we have to face. One of the most important issues is the stability of nanofluids, and it remains a big challenge to achieve desired stability of nanofluids. [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.

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 while viscosity has not changed much, Ehsan-O- Llah, et al [1].

Ehsan-o-llah Ettefaghi and et al,2013 [3] study thermal and rheological properties of oil-based nanofluids from different carbon nanostructures. Multi-walled carbon nanotubes (MWCNTs), graphene nanosheets (G), carbon nanoballs (CNBs) and fullerene NPs (C_{60}) were added to SAE 20W50 engine oil to show the effect of these NPs on the thermal conductivity coefficient, viscosity, pour point and flash point of engine oil. The results showed that changes in base oil's properties were different and depended on the type of additive structures. Spherical fullerene NPs and carbon nanoball particles had the best stability conditions, respectively. Also, carbon nanoball particles had the most positive effect on thermal conductivity and flash point of base oil by about 18% and 13.8%, respectively. [3].

Baogang Wang and et al, 2012 [12] prepared colloidal graphite/oil nanofluids by mechanical ball milling method. Their thermal conductivity (TC) and rheological properties were detailedly investigated. The TC tests show that the TC enhancements of the nanofluids depend strongly on the volume fraction (vol.%) of graphite and increase nonlinearly with increasing loading. The rheological measurements were also conducted to demonstrate the microstructure and fluid behaviors of the colloidal graphite/oil nanofluids. Compared with the Newtonian fluid behaviors of base liquids and other nanofluids, the shear thinning, significant viscosity increase is observed.

The aim of this work is to investigate the lubricant oil performance by mixing it with different ratios of organic and bio-nanoparticles. Physical, flow and thermal behavior of nano-oils are tested. Different percentage of ZnO and Gr NPs are mixed with 20W50 oil and the flash point, fire point, dynamic viscosity, thermal conductivity, surface tension and density were tested, also dynamic viscosity and thermal conductivity measured after five months to predicate the stability.

Material and Method:-

Nano-oil preparation:

One of the major hurdles in introducing the NPs into the lubricants is agglomeration, inhibiting ideal homogeneity and dispersion. The magnetic stirrer and ultrasonic de-agglomerates (Sonicator) have been used to ensure homogeneous mixing and dispersion of the NPs 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 nano-oil. The main conditions of the mixing process are 30ºC 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. Set the required and switch on the heater. After a certain time the flame is applied and observed whether a flash is occurred or not. The fire point is measured at a 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. The viscosity tested at 25, 30, 40, 50 and 60 ºC for both nano-oil at different concentrations. After five months the viscosity at 25 ºC is measured to check the stability of nano-oils.

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 lubricant.

5- Thermal conductivity:-

The effect of ZnO, Gr NPs concentrations and temperatures on the thermal conductivity of lubricant oil is tested using KD2 probe instrument (DECAGON Devices inc.). The nano-oil thermal conductivity are tested at 25, 30, 40, 50 and 60 ºC, After five month thermal conductivity is tested to examine the stability of nano-oil.

Results and Discussion:-

1- Flash and Fire point:-

Fig.1 shows that the flash point decreases at 0.001 wt% and then increases up to 0.006 wt% for both of ZnO and Gr NPs. The Gr nano-oil exhibits higher flash point 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 NPs 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 adding of higher concentrations is not useful.

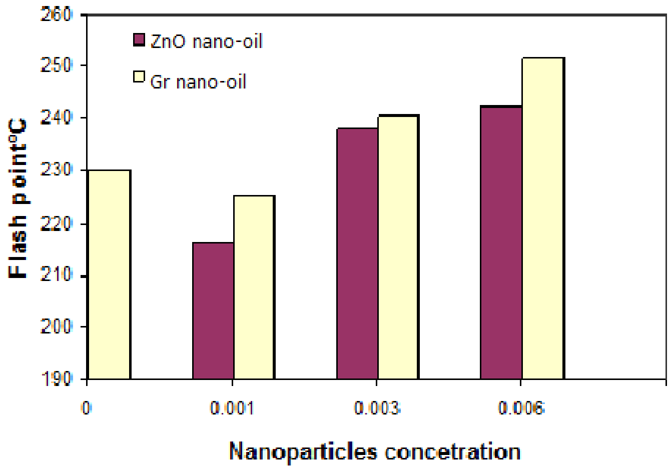

Fig.1: Flash point behavior of 20W50 engine oil as a function of ZnO and graphite nanoparticles concentration

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. The change in flash point after 0.003 wt% of ZnO NPs is not important.

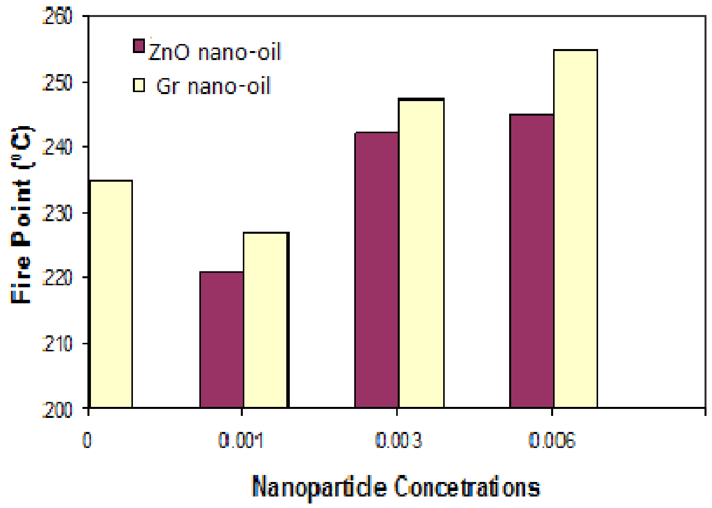

Fig.2: Fire point behavior of 20W-50lubricant oil as a function of ZnO and graphite nanoparticles content

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.

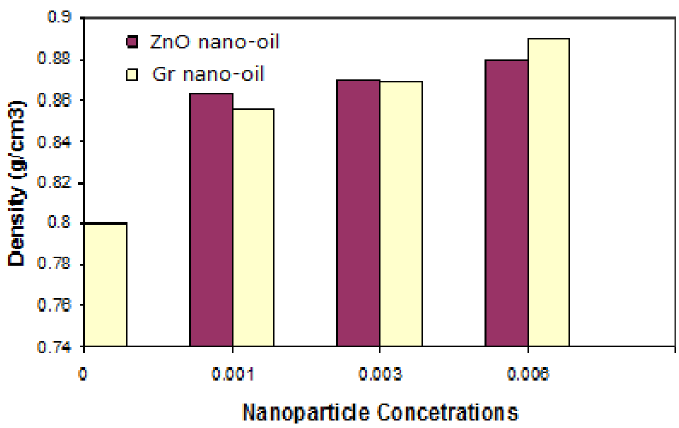

Fig.3: Density behavior of lubricant oil as a function of ZnO and Gr NPs concentrations

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.

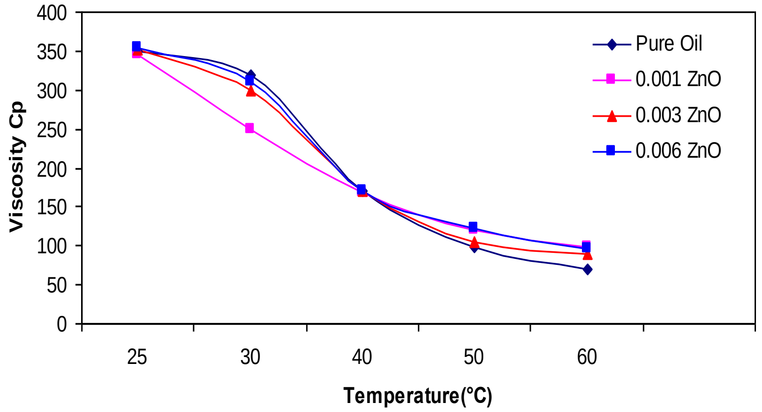

Fig. 4: Viscosity Behavior with different ZnO nano-oil at different NPs concentration and temperatures

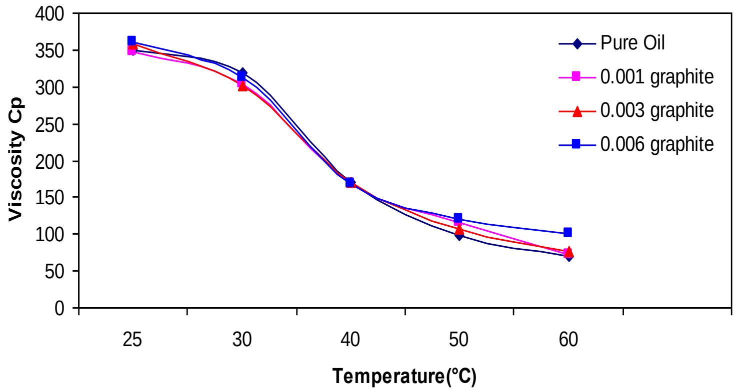

Fig. 5: Viscosity Behavior of Gr nano-oil at different NPs concentration and temperatures

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 this is good agreement with [12]. 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.

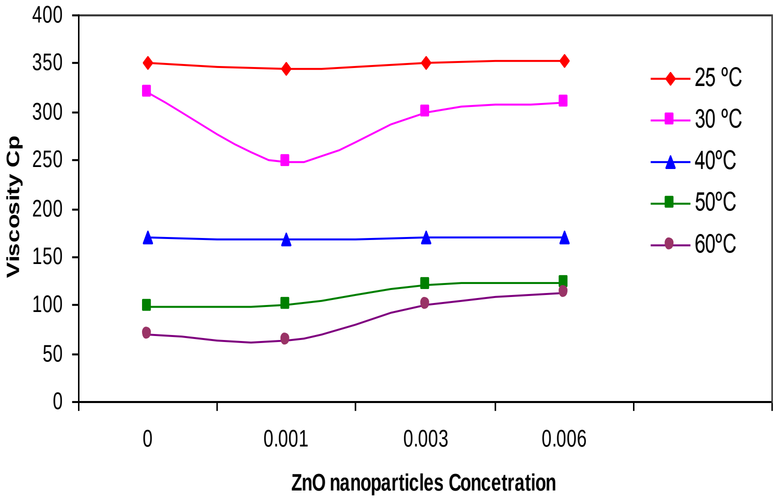

Fig. 6: Viscosity Behavior of ZnO nano-oil at different temperature and ZnO NPs concentration

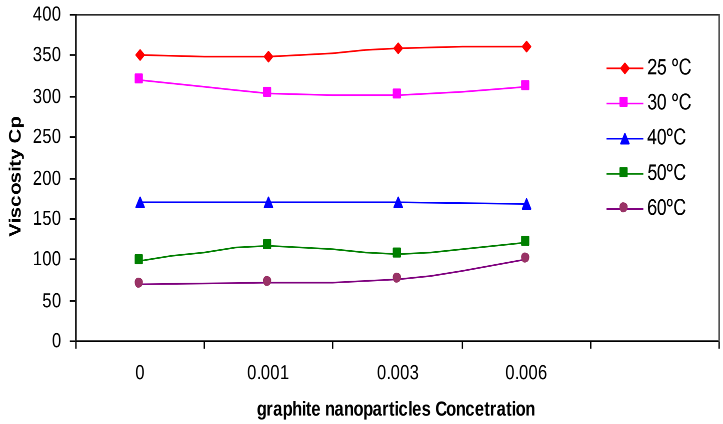

Fig.7: Viscosity Behavior of Gr nano-oil at different temperature and graphite NPs concentration

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 Fig.(8). The surface tension increases for Gr NPs and slightly decreasing for ZnO nanoparticles concentration increasing. The surface tension of both nano-oil decreases at 0.001 concentration nd increases up to the 0.006 concentration. The Gr nano-oil indicates higher surface tension than that of ZnO nano-oil for all concentrations. The surface tension increased with increasing of the NPs concentrations and dispersion.

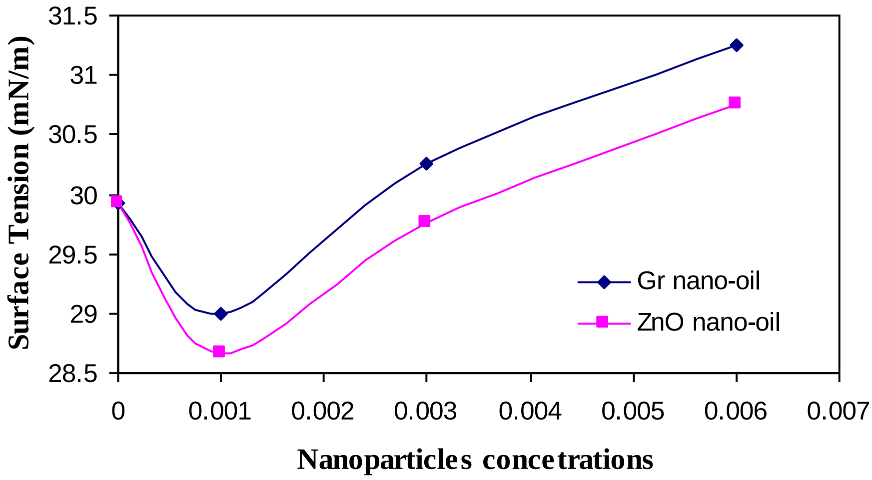

Fig.(8):- Surface Tension behavior of nano-oil at different concentration of ZnO and Gr NPs

Thermal conductivity:-

The thermal conductivity as a function of ZnO and Gr NPs and temperatures for nano-oils is shown in **Figs 9 and 10** respectively. The results show that the thermal conductivity of nano-oil increases with the temperature and NPs concentrations increasing this is a good agreement with [12]. The effect of Gr NPs is more effective than that of ZnO NPs this is because that the thermal conductivity value of Gr NPs is greater than of ZnO NPs. The thermal conductivity behavior confirms with the flash and fire points results.

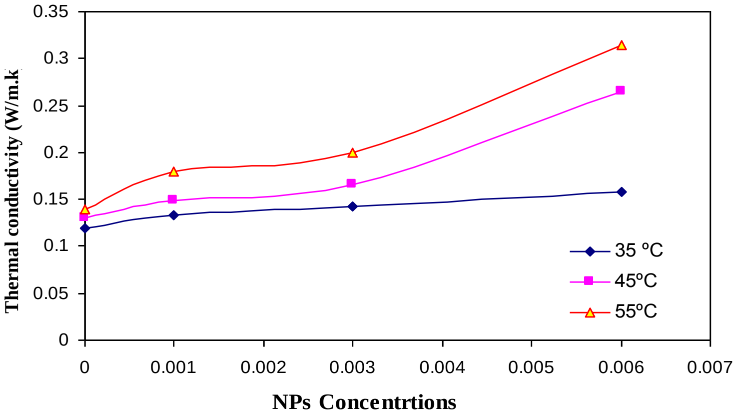

Fig.(9):- Thermal conductivity behavior of Gr nano-oil with temperatures increasing at different concentrations

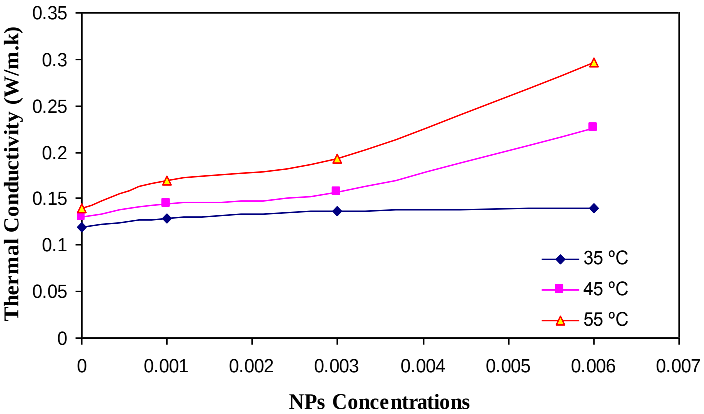

Fig.(10):- Thermal conductivity behavior of ZnO nano-oil with temperatures increasing at different concentrations

Nanofluid stability:-

The dynamic viscosity and thermal conductivity of nano-oil at different concentration of Gr and ZnO NPs and 25°C were measured after 5month to investigate the stability of nano-oils. A small change in the viscosity and thermal conductivity values after five months of nano-oil compared with the fresh sample. **Fig.(11)** The viscosity behavior of Gr and ZnO nano-oils with concentrations increasing. The stability of Gr NPs in oil is more than ZnO NPs.

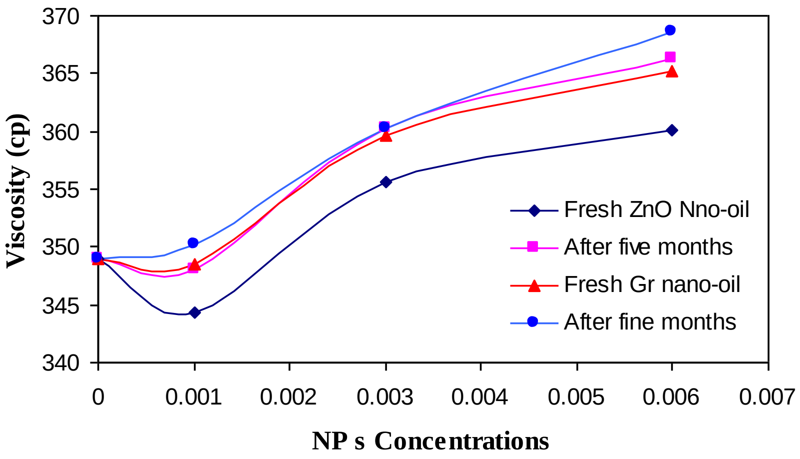

Fig.(11):- Viscosity behavior of nano-oil at different concentration of Gr and ZnO NPs after 5 months

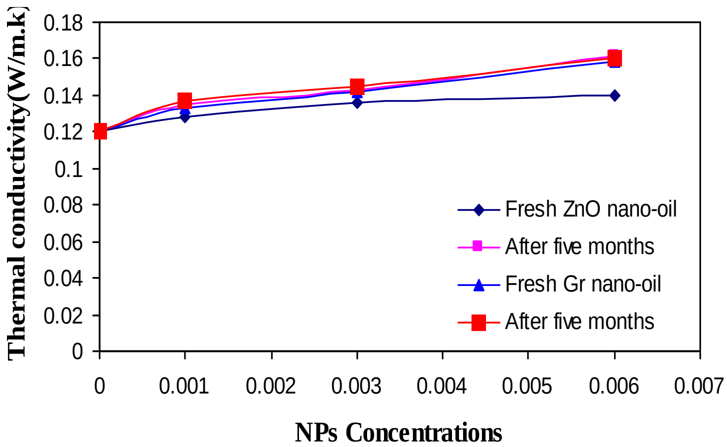

Fig.(12):- Thermal conductivity behavior of nano-oil at different concentration of Gr and ZnO NPs after 5 months

Conclusions:-

Nonmetals nanoparticles such as ZnO and graphite obtained interesting change on the flash point, fire point, dynamic viscosity over 40ºC and thermal conductivity. The graphite NPs are more effective than ZnO nanoparticles.0.6% ZnO and Gr NPs dispersed in lubricant oil produced better improvement in all properties than the 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. Although the Gr NPs produces higher properties of ZnO NPs, but it direction towered ZnO NPs because it's biomaterial with less pollution and no effect on the environment and human health. The Gr and ZnO NPs is approximately stable in lubricant to about 5 month also Gr NPs is more stable than ZnO NPs.

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