Viscosity and Oxidative Stability of Copper (II) Oxide Nanofluid Dispersed in Sunflower Oil

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Abstract

Nanofluid is a substance that containing nanoparticle which has the unique make them potentially useful in many applications in heat transfer. Nanoparticle has started to play an important role as lubricant additive for their potential in emissions reduction and improving fuel economy. The nanoparticle that usually used in nanofluids is typically made from metal, oxide, and carbides, or carbon nanotubes. The purpose of these experiments is to identify the effects of copper (II) oxide nanoparticle to viscosity and oxidation induction time for Sunflower Oil. In this experiment, six samples were prepared with different volume percent of 0.001, 0.002, 0.003, 0.004 and 0.005 in sunflower oil and one sample act as a reference (0% Copper (II) Oxide). The experiment for viscosity test was conducted by using Rotational Brookfield Viscometer DV2T and the type of spindle to perform in this experiment is LV-62. It was tested at the different speed from 60 RPM to 200 RPM with 10RPM increment every 5 minutes run. The number of absolute viscosity (cP avg) will be calculated to take the average before plot the data results. The experiment for oxidation induction time was conducted by using DSC software program. The conclusion from the result of an experiment of viscosity test shows that 0.005 of volume percent of mixture copper(II) oxide nanoparticle and sunflower oil have the highest viscosity compared to others. From this experiment, the samples show that base fluid contained the copper (II) oxide nanoparticle additive are Newtonian fluid. From the oxidation stability experiment, it can be concluded that it does not give any effects if the time increasing when the copper (II) oxide nanoparticle was added to the sunflower oil.

Keywords: Nanofluids, Lubricant Additive, Nanoparticles, Viscosity, Oxidation Induction Time.

1.0 INTRODUCTION

Nanofluid is a compound that has many applications and it works with a simple mechanism that makes it very useful Barati-Harooni, (2017). Nanofluid is a combination of basic components of nanoparticles and any various base such as water, natural oil, and ethylene glycerol. Nowadays, many researchers are exploring the best compounds for heat exchanger systems application is the combination of base fluid and the addition of nanoparticle Alawi, Sidik, Xian, Kean, & Kazi, (2018). Nanofluid is also defined as quasi-single phase stable colloidal dispersion of ultrafine nanometric particles suspended in a very low amount of dispersion (< 1 vol%) in common heat transfer fluids like water and oils Sahoo, Bhattacharjee, & Das, (2013).

According to Das, (2017), that the nanoparticle has suitable size depends on the type of material use that makes it special and variety and the range size of the nanoparticle is 1 to 100 nm. Some of the typical nanoparticles that used in nanofluid are made from metals, oxides, carbides, or carbon nanotubes. According to Dung Dang, Tuyet Le, Fribourg-Blanc, & Chien Dang, (2011), the metallic nanoparticles have received significant attention due to their unique properties, such as depression of melting temperature, conductivity, magnetism and light absorption in comparison with bulk metals. Copper (II) oxide is one of the nanoparticles that used as lubricant additive. It is possible because copper has lower shear stress and is softer than ceramics (oxides) Dai, Kheireddin, Gao, & Liang, (2016).

Every nanoparticle that often used in nanofluid has their unique properties such as increased electrical conductivity, toughness, and ductility, increased hardness and strength of metals and alloys, luminescent efficiency of semiconductors, formability of ceramics, Grigore, Biscu et al., (2016). Copper (II) oxide (CuO) nanoparticle appears as a brownish-black powder. Next, copper oxide nanoparticles also can be used as ceramic resistors, magnetic storage media, gas sensors, near-infrared tilters, photoconductive and photothermal applications. Another application is it can be used as semiconductors, solar energy transformation, and high-tech superconductors Grigore et al., (2016). The chemical properties of copper (II) oxide nanoparticles are outlined Table 1 below:

Table 1 : Copper (II) Oxide properties.

Chemical Composition	
Element	Content (%)
Copper	79.87
Oxygen	20.10
Physical Properties	
Properties	Metric
Density	6.31 g/cm^3
Molar Mass	79.55 g/mol
Thermal Properties	
Properties	Metric
Melting Point	1201°C
Boiling Point	2000°C

The most important in nanofluid is the fluid friction which is it can also define as viscosity. The previous researchers Ranga Babu, Kumar, & Srinivasa Rao, (2017), they found that the best criteria of nanofluid for cooling application or heat transfer application are low density, low viscosity and have high of thermal conductivity and specific heat that make nanofluid are more efficient in heat transfer application. Some of the researchers found that the viscosity also can be affected by the size of nanoparticles. According to Koca et al., (2017), they said that the values of viscosity are parallel with the number of nanoparticles used. The more nanoparticle use in base fluid, the higher the value of nanofluid viscosity. Others factors that also can affected the viscosity is the interparticle magnetic interactions, van der Waals interaction between the particles and between the surfactants from the nearby particles Lenin & Joy, (2017). Regarding the effects of particles size and viscosity on thermal conductivity enhancement graphene oxide nanofluid was performed by Esfahani, Languri, & Nunna, (2016).

Based on Bashirnezhad et al., (2016) shows that by using copper as nanoparticles of nanofluid show that it significantly reduces friction and wear. From the viscosity test, it can be inferred that viscosity of oil that contains copper nanoparticles is a function of nanoparticles concentration. According to the Guzman Borda et al., (2018), it was found that the concentration of copper (II) oxide nano-addictive at 0.3% showed significant friction-reduction properties for minerals base oil. However, there is also have improvement when the addition of copper nanoparticles at concentration 3.0% showed the significant increase in friction coefficient.

Regarding to Asnida et al., (2017), the additive used and gave the best tribological behavior when the addition of copper nanoparticle used around 0.005wt% to 0.0086wt%. It is possible because the concentration of copper oxide nanoparticles worked at lower and higher concentrations. However, it also depended on the surface roughness and the friction contact during the operation. The effect of shear rate was performed by Nabeel Rashin & Hemalatha, (2013). In various copper (II) oxide nanoparticle concentration (0.5-2.5 wt %) in coconut oil show that at 2.5 wt% gave the fluid is stable after for 7 days after which the sedimentation starts. Since the bio-oil gave the highest viscosity and it also gave a result in saving approximately 16 percent more energy Singh, Farooq, Raza, Mahmood, & Jain, (2017). In other hand, vegetable oils are environment-friendly and nontoxic nature.

The oxidation induction time is also known as OIT using a Differential Scanning Calorie engine to measure the level of nanofluid stability to oxidation. According to Seidler, Archodoulaki, & Lu, (2006) was found that the onset of oxidation process can be determined by OIT. This process is based on nanofluid properties associated with exothermic peak temperature in heat flow temperature. The OIT is depended on the concentration of antioxidant and their effectiveness. In the report of Seidler, Archodoulaki, & Lu, (2006) also stated that a mass loss of 3% relative to the initial sample mass because the commonly used tangent-method resulted in poor repeatability. According to Wong & Hsuan, (2014), between the carbon black and irganoxR

1010 leading a rapid decrease of values in both OIT tests. In Phease, Billingham, & Bigger, (2000), the OIT decreases as the level of carbon black increases. It is possible because there is a linear relationship between the OIT and the level of carbon black.

There are many advantages and specialty of nanofluids that make it as variation product that can be used in the variety of applications. Nanofluid can be used in electronic application, transportation, heat transfer intensification and medicine field. Even nanofluid has many benefits in technology, however, it also has numerous of limitation. Nanofluid is quite costly, because of materials used, production of nanofluid process and require advanced equipment. In addition, nanofluids also have lower specific heat compared with the base fluid.

The main objective of this experiment is to study the effect of copper (II) oxide nanoparticle additive effects on viscosity which is to find the types of nanofluid, pseudoplastic, and dilatant fluid by ensuring its viscosity effect to different RPM (rotation per minutes). Next, is to find the oxidative stability of nanofluid.

2.0 LITERATURE REVIEW

2.1 Materials Preparation

Nanofluids samples were produced from nanoparticles and base fluid. Six samples of nanofluid were prepared to be test and analyzed in this study. Nanoparticles copper (II) oxide, (CuO) and natural oil (Sunflower Oil) is used as a base fluid. Method used for nanofluid production is two-step method. Copper (II) oxide, CuO dry powder were prepared and measured by using an analytical balance equipment. The weight of nanoparticles Copper (II) Oxide is depends on the volume fraction of nanoparticles as shown in Table 2. The equation of volume fraction (Equation 1) used to find nanoparticles weight. Finally, the nanosized powder that scattered in base fluid with different label will be mix by using ultrasonic bath at 25 °C before being tested.

$$Vol\% = \frac{\left(\frac{m \quad particles}{\rho \quad particles}\right)}{\left(\frac{m \quad particles}{\rho \quad particles}\right) + base \quad volume}$$

Equation 1 : Volume fraction formula equation.

Table 2: Number of volume fraction and mass Copper (II) Oxide used for each sample.

Sample	Volume Fraction of nanofluids Vol%	Mass of Cooper (II) Oxide, m
	0	0
2	0.001	0.32
3	0.002	0.63
4	0.003	0.98
5	0.004	1.27
6	0.005	1.58

2.2 Viscosity Test

For this experiment, the equipment used to measure viscosity is Rotational Brookfield Viscometer DV2T and the type of spindle to perform in this experiment is LV-62. Spindle has been set as shown in Figure 1. Viscosity is measured by rotated the spindle used with different speed for 5 minutes for each speed. The torque that is required to accomplish a specific rotational speed is measured and plotted. The manipulated variable such as speed was set from 60 RPM to 200 RPM with 10RPM increment every 5 minutes run. The result (number of absolute viscosity, cP) of each sample will be recorded with respect to its different volume fraction. Results will calculate to take the average number of absolute viscosity (cP avg) before plot the data results. The new data will be plotted using Microsoft Excel.

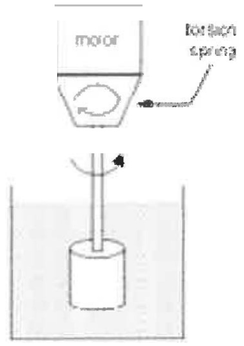

Figure 1: Spindle setting for Brookfield-type Viscometer.

2.3 Differential Scanning Calorimetry test.

The DSC analysis was conducted by using DSC software program in analytical lab. DSC is a thermoanalytical method that used to determine the amount of heat that is required to increase temperature of sample to achieve the temperature of reference. The DSC machine was conducted by following the standard procedure. The nitrogen gas tank and oxygen gas tank were opened 1 hour earlier to get better performance of cooling unit of DSC system. Then switch-on the cooling unit before performing any step. While waiting for DSC system ready to use, samples weight was measured first by using analytical balances on the sample tray. The analytical balance was switched on initially and being tare the empty sample tray to zero. Use dropper to transfer nanofluids sample from 500mL beaker to sample tray. Every sample was measured 10 mg as their constant measurement. DSC black swivel portion was open and sample will be placed on left side of DSC machine. This machine also used reference pan that placed on the right side of DSC machine to compare with sample. Once the sample and reference already load inside the DSC machine, the black swivel portion closed carefully to prevent damage. All necessary information was filled into DSC computer program to achieve desired result. Then, the constant information was setup in method editor to make this process operate automatically. Change the sample id name and enter the sample weight in sample info section. Set initial values of temperature 50.00 ^{0}C to 200.00°C at 20°C/min in program section and run the analysis. Once the DSC machine is operated, it takes almost 1 hour to finish the analysis. The data and result will be plotted on the computer monitor automatically and auto-save in the document file. Then open the black swivel portion and change the sample with another sample. The procedure to start up the DSC machine was repeated for 0.001 vol%, 0.002vol%, 0.003vol%, 0.004vol% and 0.005 vol% sample.

3.0 Results and Discussion

3.1 Viscosity test on nanofluid

Based on methodology above, The Brookfield Rotational Viscometer DV2T is used to determine nanofluid behavior in viscosity. The viscosity of nanofluid is a really important parameter that can specify the performances of nanofluids for flow resistance, pumping power and the usability of nanofluids Yang, Xu, Du, & Zhang, (2017). The high viscosity of fluid also not good to use as a medium in piping flow due to high energy required. However, it is depending on the application of fluid either high viscosity or low viscosity. The optimum is the best choice. The data and result of viscosity test show in Figure 2.

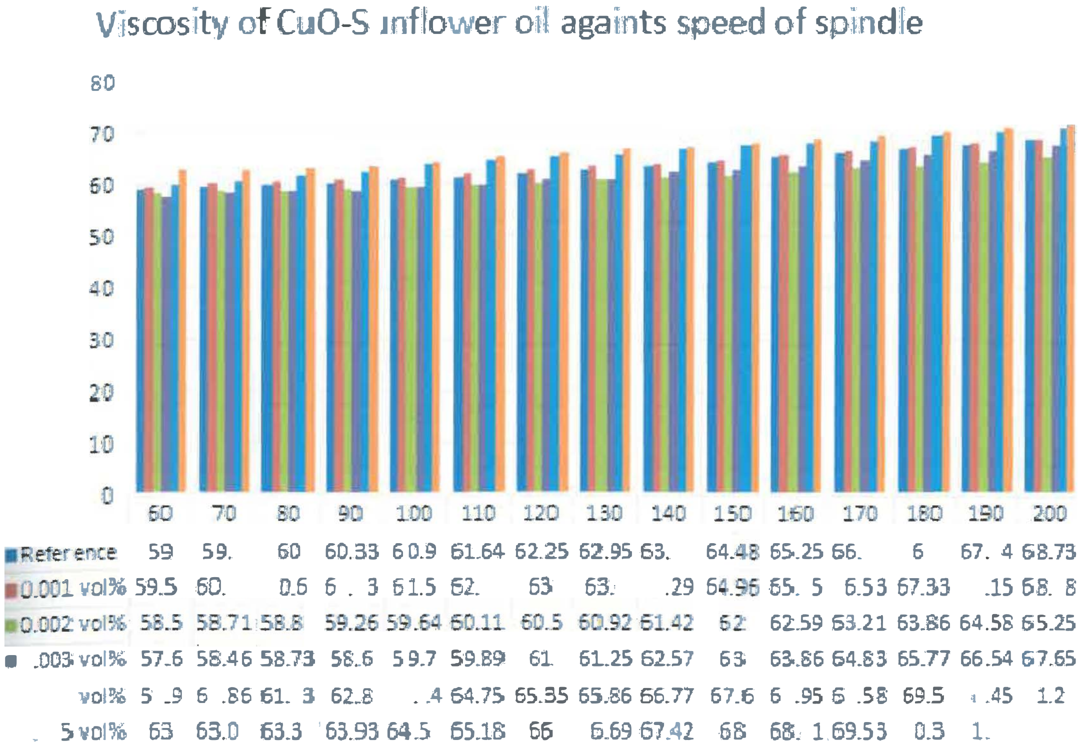

Figure 2- Graph of viscosity, cP - speed of disc spindle, RPM.

The viscosity of nanofluids has been increase depends on the type of nanoparticles and the amount of nanoparticles used. Previous research, Namburu et al,. (2007) which has been done by department of mechanical engineering of the University of Alaska found that the viscosity of nanofluids increase 3% when 0.3 vol% of CuO added in Ethylene Glycerol, EG, and water. The percentage of viscosity increase when the loading of nanoparticle increase. They act in a parallel way. However, the temperature plays an important role to make the viscosity stay high. The increases of temperature will decrease the viscosity of nanofluids. Based on reports of Nguyen et al., (2007), the optimum temperature of nanoparticles, copper (II) oxide is less than 20°C as it is possible to avoid any damage to the surface of the additive particles. However, the assumptions for the maximum temperature that can be reached is the CuO-Sunflower nanofluid oil is 30 °C. This is due to the use of copper (II) oxide as an additive for this samples. It shows that different types of base nanoparticles and fluids have different temperature resistance to maintain higher nanofluid viscosity performance.

For this test, five samples that contain different vol% of CuO will be compare with the reference, 0 vol% of CuO. The data has been summarized by using a graph of viscosity of nanofluids, cP against speed of spindle, RPM. The reference bars were constant to prove that the number of viscosity will be increase once CuO has been added. This test has 15 series of spindle speed, RPM which are 60 RPM until 200 RPM. The 0.001 vol% bars shows the improvement occurs in term of viscosity compared with the reference. The viscosity of CuO-Sunflower oil increase slowly every 10 RPM imposed on nanofluid. It is because the CuO totally blended in base fluid when nanofluid prepared thus it will increase the the density of base fluid. The increasing density will improve and increase the shear force of CuO-Sunflower oil movement. Next, the bars 0.002 vol% and 0.003 vol% on the graph showed that the viscosity of CuO-sunflower oil decreased. Estimated performance drop is 0.5% to 2%. The decreasing viscosity range is 0.95 cP. However, the result improves from 63.86 cP of 0.002 vol% to 65.77 cP of 0.003 vol% at 180 RPM. This is probably due to the different condition or temperature applied to CuO-Sunflower oil that stated by Namburu et al., (2007). Furthermore, the line of 0.004 vol% and 0.005 vol% of CuO-Sunflower oil are rapidly increase compared 0.002 vol% and 0.003 vol%. The stability condition especially temperature is an important measurement to identify the improvement of CuO-Sunflower oil viscosity accurately. The difference between 0.002 vol% and 0.004 vol% is 5.64 cP at 180 RPM. The percentage of both performances almost 5% increase. Otherwise, for 0.005 vol% CuO-Sunflower oil performance is greater than 0.001 vol%, 0.002 vol%, 0.003vol% and 0.004 vol%. That shows 0.005 vol% is more viscous than others. The viscosity of 0.005vol% is 72 cP at 180 RPM. The best result is 0.005 vol% of CuO-Sunflower oil with 1.5754 mg of CuO used.