

## VISCOSITY EFFECT OF TITANIUM OXIDE AND ALUMINUM OXIDE NANOLUBRICANTS: AN EXPERIMENTAL STUDY

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**Abstract:** Viscosity is a very important phenomenon for surfaces with relative motion. The effect of  $TiO_2$  and  $Al_2O_3$  addition to capella mineral oil and ethylene glycol lubricant were considered in this study. The result from the study shows that at an average temperature of  $338^0K$ , the average viscosity value of 0.0025g/ml concentration of mineral Oil + $TiO_2$ , mineral Oil + $Al_2O_3$ , Ethylene Glycol + $TiO_2$  and Ethylene glycol + $Al_2O_3$  were 0.0154, 0.0165, 0.01083 and 0.0117 Pascal seconds. This study shows that pure mineral oil has higher viscosity value of 9.7 and 2.98% than 0.0025g/ml concentration each of mineral Oil + $TiO_2$  and mineral Oil + $Al_2O_3$  respectively. Also, pure Ethylene glycol has higher viscosity than 0.0025g/ml concentration each of Ethylene Glycol + $TiO_2$  and Ethylene glycol + $Al_2O_3$  by 14.1 and 7.1% respectively. Moreso, 0.0025g/ml concentration of mineral Oil + $TiO_2$  has a slightly higher viscous value of 29.5% than that of Ethylene glycol + $TiO_2$  and same concentration of mineral Oil + $TiO_2$  has higher viscous value of 28.9% than Ethylene glycol + $Al_2O_3$ , whereas pure mineral Oil has a viscous value of 25.3% than pure Ethylene glycol lubricant. Pure mineral oil and ethylene glycol is more viscous without  $TiO_2$  and  $Al_2O_3$  nanoparticle addition, meaning they have higher resistance to flow.

**Keywords:** Mineral Oil, Ethylene glycol, concentration,  $TiO_2$  and  $Al_2O_3$  nanoparticle.

### 1. INTRODUCTION

The ball bearing effect which is a mode of minimizing engine wear was the preliminary reason for development of nanolubricants (Tao et al., 1996). They shield moving layers against friction and wear in a broad range of applications. One proposed application of nanolubricants is to improve the efficiency of compressors in refrigerators (Bi et al., 2007, Ajuka et al., 2017). The knowledge of the viscosity of nanolubricants is important for its application to equipment since compressors have specific requirements for lubricant viscosity. Sheikzadeh et al. (2013), the viscosity of nano-lubricants has been considered an important heat transfer property based on its effects on refrigerant boiling heat transfer, and also its influence on performance of the compressor and evaporator of the refrigeration system.

Among research on compressor studies for investigation of nanolubricants as a way of improving evaporator heat transfer efficiency in HVAC&R equipment are; Kedzierski and Gong (2009) who reported that copper-oxide nanoparticles can enhance refrigerant/lubricant pool boiling for as much as 245 % and Kedzierski (2011, 2012) also noted that aluminum-oxide nanoparticles can produce almost same enhancements for refrigerant/lubricant pool boiling. Bi et al. (2007) and Ajuka et al. (2017) reported that the use of titanium dioxide-based nanolubricants produced energy savings of more than 25 and 34.6% respectively in domestic refrigerators.

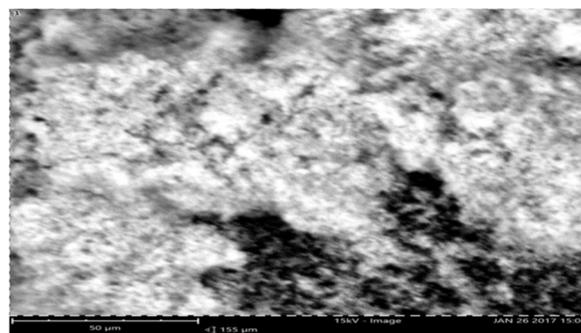
Consequently, the liquid viscosity, density, and thermal conductivity measurements of nanolubricants are not only of interest to science and engineering of friction, lubrication and wear, but also of interest to those involved in fundamental research and new designs for improving the efficiency of air-conditioning and refrigeration equipment.

The type of nanoparticle and size has effect on the viscosity. While Kedzierski (2013) has reported that surfactant can either increase or decrease the viscosity of a nanolubricant. This may be due to the individual property of the surfactant which may may necessary to determine if it is to be used as a stabilizer. In the study by Venerus et al. (2010), they reported that viscosity measurements for nanofluids with non-spherical particle shapes can be affected by shear to a greater degree than nanofluids with spherical particles. Also, the study of Buongiorno et al. (2009) informed that particle shape and conduction opposition at the nanoparticle-fluid interface affect conductivity, but other proposed effects such as Brownian microconvection, super-conductive liquid layering, and aggregation percolation are not likely to be important.

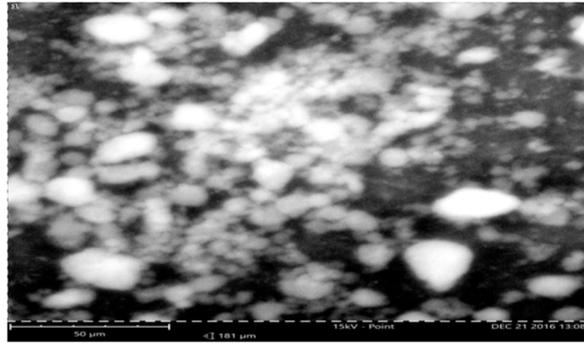
Consequently, because nanoparticle characteristics have been identified as of primary importance in determining nanolubricant transport properties, the focus of the present study is to investigate the impact of nanoparticle properties and mass fraction on viscosity of selected titanium oxide and aluminum oxide-based nanolubricants. Figure 1 below shows the Scanning Electron Microscopy (SEM) images of the  $\text{TiO}_2$  and  $\text{Al}_2\text{O}_3$  nanoparticles. The manufacturer states the size of the  $\text{TiO}_2$  and the  $\text{Al}_2\text{O}_3$  nanoparticle as 15 nm and 13 nm, respectively, based on the surface-area.

## 2. MATERIALS AND METHODOLOGY

The time of flow between the two marks of the Oswald type viscometer was taken for each of the prepared samples; pure mineral oil, ethylene glycol, 0.0025g/ml concentration each of mineral Oil + $\text{TiO}_2$ , mineral Oil + $\text{Al}_2\text{O}_3$ , Ethylene glycol + $\text{TiO}_2$  and Ethylene glycol + $\text{Al}_2\text{O}_3$ . The nanolubricants were mechanically homogenized using an ultrasonic oscillator (Branson M2800H) for three (3) hours each. The apparatus in the study (Viscometer, beakers, Pipet, Thermometer e.t.c) were washed and dried with an oven. Some of the other apparatus are shown in the figures below.



(a)



(b)

Figure 1: Scanning Electron Microscopy (SEM) images of (a)  $\text{TiO}_2$  (15nm) and (b)  $\text{Al}_2\text{O}_3$  (13nm) nanoparticles



(c)



(d)

Figure 2: (c) Viscometer; and (d) Nanoparticle Samples  $\text{TiO}_2$  (15nm) and  $\text{Al}_2\text{O}_3$  (13nm) nanoparticles.



Figure 3: Hot Plate (Showing sample heating).

## 2.1 Experimental Procedure

The time of flow for distilled water and sucrose (20% by weight) at 35 and 25°C were taken and recorded for standardization and used to determine the constants A and B in the Equation 1 below. The time of flow of pure mineral oil, pure ethylene glycol, mineral oil + TiO<sub>2</sub>, ethylene glycol+ TiO<sub>2</sub>, mineral oil + Al<sub>2</sub>O<sub>3</sub>, ethylene glycol + Al<sub>2</sub>O<sub>3</sub> nano-lubricant were recorded at varying temperatures.

**Formulation:** Ostwald Viscometer

$$\eta = A dt - B(d/t) \quad (1)$$

For calibration;

Water:  $\eta = 0.891 \text{ Centipoise}$  } @35°C  
 $d = 0.9971 \text{ g/ml}^{-1}$  }

20% Sucrose  $\eta = 1.699 \text{ Centipoise}$  } @25°C  
 $d = 0.9971 \text{ g/ml}^{-1}$  }

## 3. RESULTS AND DISCUSSION

The study carried out shows that at an average temperature of 338<sup>0</sup>K, the average viscosity value of 0.0025g/ml concentration of mineral Oil +TiO<sub>2</sub>, mineral Oil +Al<sub>2</sub>O<sub>3</sub>, Ethylene Glycol +TiO<sub>2</sub> and Ethylene Glycol +Al<sub>2</sub>O<sub>3</sub> are 0.0154, 0.0165, 0.01083 and 0.0117 Pascal seconds. Based on time of flow between the upper and the lower mark of the viscometer, it can be inferred that is lighter Ethylene Glycol than mineral oil both purely and with the addition of TiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> nanoparticle.

The figure 4 below shows that pure mineral oil has higher viscosity value of 9.7 and 2.98% than 0.0025g/ml concentration each of mineral Oil +TiO<sub>2</sub> and mineral Oil +Al<sub>2</sub>O<sub>3</sub> respectively. Also, the

figure 5 below shows that the viscosity of pure Ethylene glycol has higher viscosity than 0.0025g/ml concentration each of Ethylene Glycol +TiO<sub>2</sub> and Ethylene Glycol +Al<sub>2</sub>O<sub>3</sub> by 14.1 and 7.1% respectively. This implies that pure mineral oil and ethylene glycol is more viscous without TiO<sub>2</sub> and Al<sub>2</sub>O<sub>3</sub> nanoparticle addition. Therefore, it implies that the resistance to the flow offered by pure mineral oil ethylene glycol lubricant is higher.

The figure 6 show that 0.0025g/ml concentration of mineral Oil +TiO<sub>2</sub> has a slightly higher viscous value of 29.5% than that of Ethylene Glycol +TiO<sub>2</sub> (Egti) and same concentrations of mineral Oil +TiO<sub>2</sub> has higher viscous value of 28.9% than Ethylene Glycol +Al<sub>2</sub>O<sub>3</sub> (Egal), whereas pure mineral Oil (pmo) has a viscous value of 25.3% than pure Ethylene Glycol (Ego) lubricant.

### 3.1. Figures

The viscosity of the pure mineral and ethylene glycol as control against a blend of titanium and aluminium oxide each are shown in figure 4 and 5 while figure 6 shows the flow resistance for each of the lubricants.

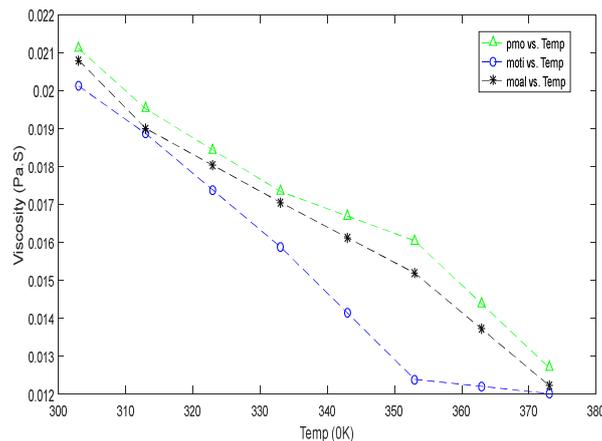


Fig.4. Viscosity of mineral oil (Capella) against varying temperature

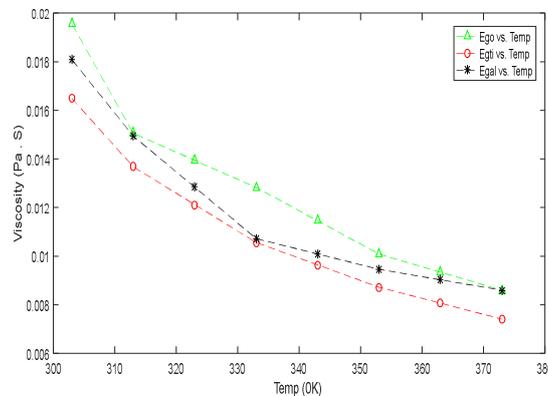


Fig.5. Viscosity of Ethylene Glycol against varying temperature

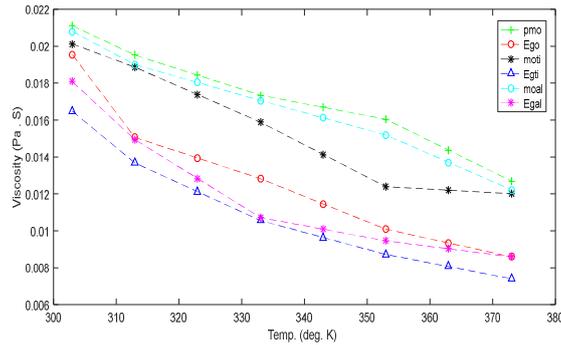


Fig.6. Viscosity of Mineral Oil (Capella) and Ethylene Glycol against varying temperature

### 3. CONCLUSION

The addition of  $\text{TiO}_2$  (titanium oxide) and  $\text{Al}_2\text{O}_3$  (Aluminium Oxide) nanoparticle to pure lubricants reduces the time of flow which in turn reduces the viscosity of the nanolubricant mixture. This in addition to other thermophysical properties of nanoparticles offers variety of benefits in the mechanical equipment where tribology is considered important. Figures 4 to 6 show generally that viscosity decreases with an increase in temperature.

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## DEFINITIONS

pmo - pure mineral oil
moal - mineral oil + Aluminium Oxide
moti - mineral oil + Titanium Oxide
Ego - Pure Ethylene Glycol
Egti - Ethylene Glycol + Titanium Oxide
Egal - Ethylene Glycol + Aluminium Oxide

## APPENDIX

*Table 1. Characteristics of the Lubricating Oils*

S/N	Measured Data	Manufacturers Specification	Range	Uncertainty
1	Temperature	Thermometer	10°C - 100°C	±1°C
2	Digital Weighing Scale	Mass (grams)	0.001 – 50g	±0.01g

*Table 2: Characteristics of the Selected Nanoparticle*

S/N	Particle type	Particle Size (nm)	Purity (%)	Manufacturer	P code
1	Titanium dioxide (TiO <sub>2</sub> )	15nm	99.7	Alfa Aesar	-
2	Aluminium oxide (Al <sub>2</sub> O <sub>3</sub> )	13nm	99.8	AldrichChemistry	1001922903

**Table 3: Characteristics of the Lubricating Oil**

<b>S/N</b>	<b>Lubricating Oil characteristics</b>	<b>Units</b>
<b>1</b>	<b><u>Oil type - Capella mineral oil</u></b>	
<b>a</b>	ISO viscosity grade	68
<b>b</b>	Flash point	-36°C
<b>c</b>	Density	0.91(at 15°C kg/L)
<b>d</b>	Kinematic viscosity (mm <sup>2</sup> /s) at 40°C	68
<b>e</b>	Kinematic viscosity (mm <sup>2</sup> /s) at 100°C	6.8
<b>f</b>	Viscosity index	22
<b>g</b>	Code	41562
<b>2</b>	<b><u>Ethylene Glycol</u></b>	
<b>h</b>	Flash point	116°C
<b>i</b>	Density	1.115 (at 20°C g/cc)
<b>j</b>	viscosity, cP@ 25°C	16.9