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Investigation of Al_2O_3 Nanofluid Viscosity for Different Water/EG Mixture Based

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Abstract

Viscosity of Al_2O_3 nanoparticle dispersed in mixture of water and ethylene glycol (EG) were investigated experimentally. The effect of based fluid ratio (water:EG) to nanofluid viscosity was investigated. Nanofluids with volume concentration up to 2.0 % were prepared with 13 nm Al_2O_3 nanoparticles for viscosity measurement. Two-step methods were used in preparation of Al_2O_3 nanoparticles. The nanoparticles were suspended in three different ratios of water:EG which are 40:60, 50:50 and 60:40 by volume percent. The measurements of viscosity were performed using Brookfield LVDV III Ultra Rheometer for nanofluid temperature of 30 to 70 ^oC. Viscosity of nanofluid was observed to be influenced by nanofluid concentration, temperature and ethylene glycol concentration in the base fluid.

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Keywords: nanofluid; aluminium oxide; viscosity; water and EG mixture

1. Introduction

In the present study, three mixture ratio of water and ethylene glycol (EG) was prepared by considering the application of using EG in coolant for automotive cooling system. Researches have investigated the effect of different nanomaterials on viscosity. The viscosity of nanofluid significantly affect the overall heat transfer performance of a system which have been proven by previous studies [1, 2]

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A study on effect of base fluid and temperature to heat transfer characteristics found that the efficiency of nanofluid improves with increasing in the temperature [3]. The efficiencies are higher for nanofluid suspension mixture base compare to water based. They used SiC nanoparticles dispersed in ethylene glycol-water mixture in volume ratio of 50:50 in their investigation. A study was initiated by Sundar et al. [4] with Fe_3O_4 nanoparticles dispersed in three mixture of ethylene glycol/water ratio (60:40, 40:60 and 20:80). They observed that 1.0 % volume concentration nanofluid in 60:40 EG/W is enhanced by 2.94 % compared to other based fluids. Another mixture base fluid used in investigation is 55:45 (W:EG) by Yu et al. [5]. They found that the temperature and volume concentration significantly affect the nanofluid viscosity. Also, the nanofluid exhibit Newtonian behaviors below 45 ^{o}C. Aluminium oxide nanofluid in mixture base was studied by Said et al. [6] for ratio of 40:60 W:EG. The same behavior notice where the nanofluid exhibits Newtonian behavior for low concentration below 40 ^{o}C [5].

The objective of present work is to study the effect of nanofluid viscosity in various ratio of W:EG mixture for temperature range of 30 to 70 ^{o}C. Investigation on this rheological properties is very important to expand the application of nanofluids with addition of EG in the coolant. The selection of Al_2O_3 nanoparticle in 13 nm sized is due to its stability period that withstand up to three months.

Nomenclature

EG	ethylene glycol	ρ	density
ϕ	volume concentration	*W*	water
m	mass	*T*	temperature
μ	viscosity		

2. Methodology

2.1. Nanofluid Preparation

Nanoparticle used in the sample preparation is 13 nm Aluminium Oxide (Al_2O_3) in powder form. Three mixture ratio of water to ethylene glycol used are 60:40, 50:50 and 40:60 as the base fluid. Two-step method was used in the preparation of nanofluid. Sonication process was employed to help improve the dispersion of nanoparticles in the base fluid. Eq. (1) used to determine the mass of Al_2O_3 to disperse in the base fluid. The nanoparticles are dispersed in the base fluid using magnetic stirrer and sonicated in ultrasonic bath for two hours, followed the studies by Azmi et al. [1, 2, 7]. Samples prepared are found to be stable for more than three months.

$$\phi = \frac{\dfrac{m_{Al_2O_3}}{\rho_{Al_2O_3}}}{\dfrac{m_{Al_2O_3}}{\rho_{Al_2O_3}} + \dfrac{m_{W:EG_3}}{\rho_{W:EG}}} \times 100 \qquad (1)$$

2.2. Viscosity Measurement

Viscosity was measured with Brookfield LVDV III Ultra Rheometer. The range of applicability of measurement is from 1 to 6 x 10^6 mPa.s. Nanofluid with 16 ml volume sample was inserted into cylinder jacket and attached to the rheometer. A *RheoCal* program was installed for the data measurement at the designated torque and temperature. The sample was heated from 30 to 70 ^oC for viscosity measurement. Figure 1 shows the arrangement of sample nanofluid during measurement.

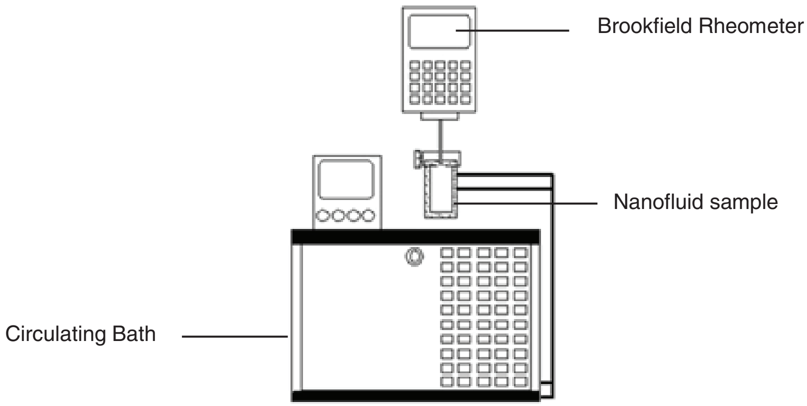


Fig. 1.Viscosity measurement.

3. Results and Discussion

The measurement of viscosity is initially started with the base fluid. Figure 2 shows the distribution of base fluid measurement data, compared to ASHRAE Handbook [8]. Previous studies that use the same procedure are Kulkarni et al. [9] and Vajjha et al. [10]. According to Namburu et al. [11], the mixture of water and ethylene glycol shows Newtonian behavior hence it governs the rheological property and the nanofluid behaves like Newtonian. The deviation of base fluids used in the present study and ASHRAE is shown in Table 1.

Table 1: Deviation of base fluids studied with ASHRAE [8]

		Deviation [%]		
W/EG ratio	:	60:40	50:50	40:60
Minimum	:	0.0	0.6	0.5
Maximum	:	9.3	4.8	20.7

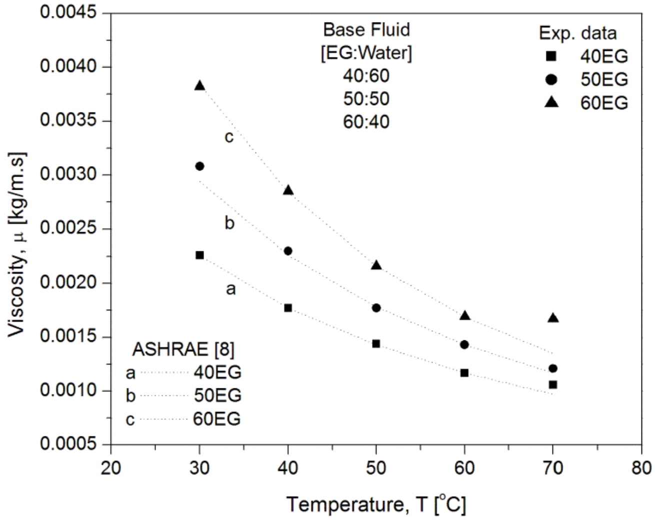
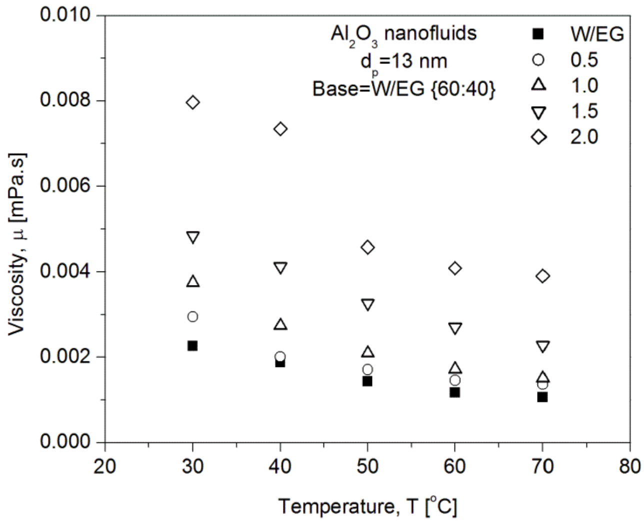
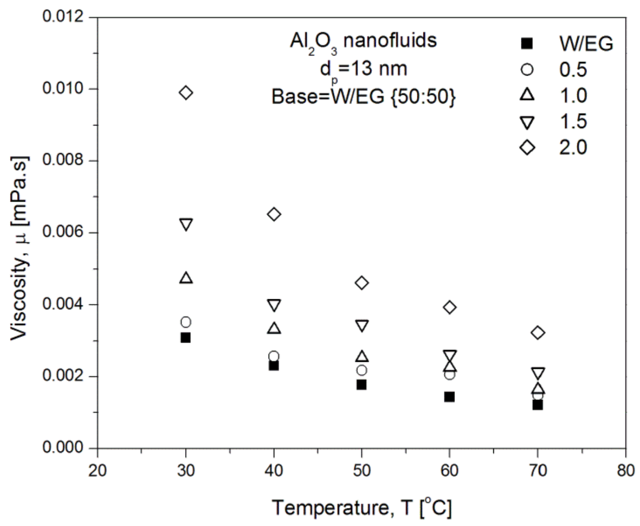


Fig. 2. Benchmark test for various mixture base fluids.

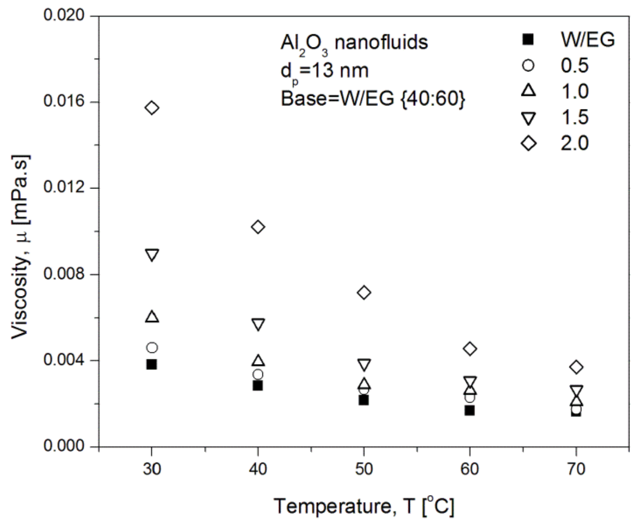
Figure 3(a), 3(b), and 3(c) show the variation of nanofluid viscosity with temperature for all nanofluid concentrations at base ratio (W/EG) of 60:40, 50:50 and 40:60. In general, the nanofluid viscosity follows the base fluid trend where it decreases exponentially with temperature. However, as the nanoparticle loading in the base fluid increase, the viscosity value is increased. This is consistent with the fact that increase in nanoparticle concentration in nanofluid increases the fluid internal shear stress, hence the viscosity [12]. The similar effect of volume concentration to the viscosity for each set of temperature has been found by the previous literature [11, 13, 14]. For concentration of 1.5 % and 2.0 %, the viscosity at all ratios shows great enhancement with increment greater than 100 % compare to the base fluid.



(a) Base ratio (W/EG) of 60:40



(b) Base ratio (W/EG) of 50:50



(c) Base ratio (W/EG) of 40:60

Fig. 3. Variation of nanofluid viscosity with temperature for different concentrations and base ratios

The relative viscosities of Al_2O_3 nanofluid are almost constant for volume concentration 0.5 to 1.5% independent of temperature at base fluid (W/EG) 40:60 and 50:50. However, at volume concentration 2.0% the distinction is higher where temperature dependence can be observed. It is more noticeable for higher concentration in base fluid that contains more EG i.e. (W/EG) 40:60.

4. Conclusions

In this study, the viscosity of Al_2O_3 nanofluid in EG based for three different ratios of water and EG are presented. The result indicates that the viscosity of alumina in EG based nanofluid is increased with the increased of particle loading. However, the nanofluid viscosity decreased exponentially with the increased of temperature. The relative viscosities are independent with the temperature for concentrations of less than 1.5 %.

Acknowledgements

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