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Viscosity of Mono vs Hybrid Nanofluids: Measurement and Comparison

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Abstract. The authors aimed to look into the viscosity investigation of mono and hybrid Aluminium Oxide/Silicon Oxide (Al2O3/SiO) based nanofluids. The viscosity methods were carried out for mono nanofluids as well as hybrid nanofluid, which are suspended in base fluid (water). Both mono and hybrid nanofluids of Al2O3/SiO were developed in concentration, which vary from 0.01% to 1.00%. The methodology invoked for viscosity measurement was done by spindle rotation technique, which uses Anton Paar RheolabQC rotational rheometer at temperatures of 30 - 70 ° C. The results imply that viscosity of nanofluids was directly proportional to volume concentration and temperature.

1. Introduction

The ideal of considering nanofluids as thermal fluid imply to the actual discussion of its properties. The potential of thermo-physical properties of nanofluids mainly focused on; thermal conductivity and specific heat, viscosity, as well as density. The main function of these properties is to deal with overall heat transfer performance of nanofluids. Generally, thermophysical properties are measured using globally standard scientific instruments. Most of the investigations on viscosities of nanofluid are conducted for mono nanofluid. Since less information exists on the viscosity of hybrid nanofluid, the aim of this work is to investigate and provide actual information for nanofluid of mono and hybrid using Al2O3/SiO. The present study is focused on the investigating the behavior of viscosity using mono and hybrid nanofluids of Al3O2 and SiO for a range from 0 to 1.0 % at temperature range from 30 to 70 ° C. Moreover, the impact of shear rate and nanoparticle concentration on the behavior of the nanofluids. The traditional coolants have superior lubrication characteristics, but, their poor thermo physical properties restrict their application as industrial lubricants. The thermo physical properties of the conventional lubricants can be enhanced by mixing small sized particles (preferably nano sized) into it. However, their mixing shows serious issues such as erosion, micro sized channel clogging, pressure drops and importantly, the stability for longer times. To overcome these problems, the particles size is reduced to nano level, which helped in the evolution of specific class of lubricants named as 'Nanofluids' [1]. These nanofluids yield superior thermal conductivity, improved stability and lower pressure drop over conventional lubricant. Nanofluids containing different nanoparticles suspended in typically conventional fluids have shown significant improvement in thermal conductivity and convective heat transfer performance of the base fluids. Effect of viscosity variation was experimentally done by several researchers [1-4]. Numerous authors suggest that apart from particle size and volume concentration, temperature also plays very important role in viscosity variation [5-7]. The rheological behaviour of nanofluids plays an important role to understand its viscosity profile, whether changing or fixed with shear rate. To the best of author's knowledge, only a few researches are available on rheological behavior of nanofluids. Moreover, the available literature on nature is limited and has not been justified. The reviewed literature made it clear that it's a Newtonian behavior. However, more investigations need to be attempted to explore detailed explanation for such behavior of nanofluids. The present study is focused on the investigating the effect of temperature on the nanofluids' viscosity at wide range of concentrations and temperatures. Moreover, the effect of shear rate and nanoparticle concentration on rheological behavior of the nanofluids is discussed.

2. Method and materials

2.1. Nanofluids Preparation

The commercially available nanofluids in water dispersion containing Aluminium Oxide (Average Diameter 30nm at 20wt% in water) and Silicon Oxide (Average Diameter 30nm at 25wt% in water) were procured from US Research Nanomaterials, Inc. The nanofluids were diluted by mixing base fluid to get the required concentration levels of 0.01 to 1 vol. %. Conversion from weight concentration of raw. Aluminium Oxide and Silicon Oxide of needed quality were completed using Eq. (1) for the maximum concentration prepared; 1.0% where ω -weight concentration, ϕ - volume concentration. The dilution process for lower concentrations was done using Eq. (2) where, ΔV- volume of additional base fluid; V_1 and V_2 are initial and final volumes, respectively:

$$\phi = \frac{\omega\rho_{bf}}{\frac{\omega}{100}\rho_{bf}+\rho_p\left(1-\frac{\omega}{100}\right)}$$

$$\Delta V = (V_2 - V_1) = V_1\left(\frac{\phi_1}{\phi_2} - 1\right)$$

The above process was repeated until and until all considered sample were completed for both Aluminium Oxide and Silicon Oxide nanofluid. A mixture of Al_2O_3 and Silicon Oxide in a volume ratio of 50:50 was used as the hybrid nanofluid. The prepared nanofluid samples were placed under ultrasonic vibration for 2 hours to achieve stability in fluid. A magnetic stirrer and an ultrasonic vibrator (make: Telsonic SG-24-500-P) capable of generating 300 W @ 36KHz frequency were used to break down agglomeration of the nanoparticle. In order to attain a longer stability, the processes of mechanical mixing and ultrasonication were adopted. Moreover, to prevent possible agglomeration, a fresh sample was prepared and tested immediately. Table 1 shows the transmission electron microscopes (TEM) of nanoparticles of Al_2O_3 and Silicon Oxide.

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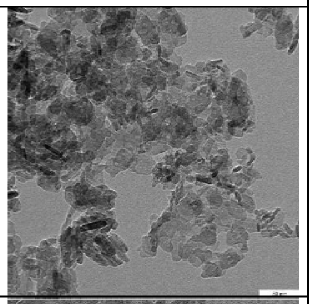
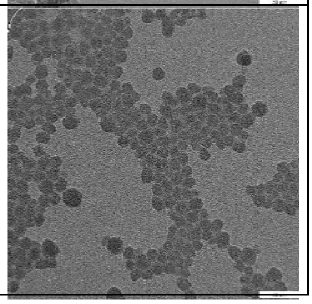
Table1: TEM photos of Al2O3 and Silicon Oxide nanoparticles

Material	Specification/ Supplier	TEM Image
Al2O3 Nanopowder/ Nanoparticles Water Dispersion	20wt%, 30nm US Research Nanomaterials, Inc	
Top of Form SiO2 Nanopowder / Nanoparticles Water Dispersion Bottom of Form	25wt%, 30nm US Research Nanomaterials, Inc	

2.2. Viscosity Measurement

The viscosity of prepared nanofluid samples were carried out by Anton Paar RheolabQC rotational rheometer with controlled temperature device. This device has a viscosity was in the range of 1 mPa.s to 1×10^9 mPa.s and temperature range from -20°C to 180°C. The minimum amount of 12 mL of nanofluid sample was used for the viscosity measurements using double gap measuring system where the temperature ranges from 70°C to 30°C at 10°C intervals and volume concentration range from 0.01% to 1.00%. As the spindle rotates, the viscous drag of the liquid applied on the spindle is determined by the spring's deflection. The steady state was attained before the measurements. The nanofluid samples were remained in cylinder for 10 min until measurement done. Figure 1 shows the pictorial image of Anton Paar RheolabQC.

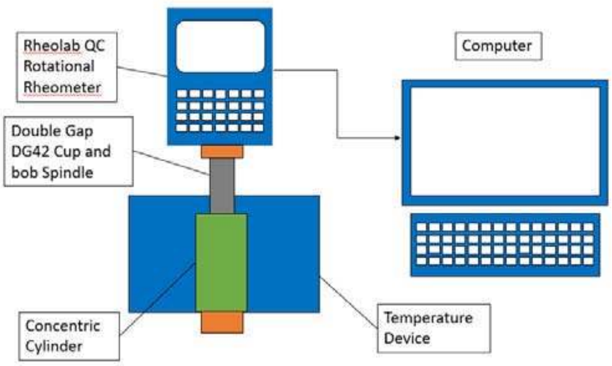


Figure 1: the schematic diagram of Anton Paar RheolabQC

3. Results and discussion

3.1. Observation of Stability

After the production of the nanofluid, it is observed that the mono and hybrid nanofluid are stable for a week. Figure 2 represent the stable hybrid nanofluid a mixture of 50%Al2O3+50%SiO.

Figure 2: Hybrid Nanofluid Al2O3/SiO at different concentration

3.2. Mono Nanofluid and Hybrid Nanofluid viscosity

Figure 3 Fluctuation in of mono and hybrid nanofluid viscosity with respect to temperature. It mainly indicates nanofluids behavior of the base fluid trend where it decreases with temperature. However, as the concentration jumps with the increase in viscosity

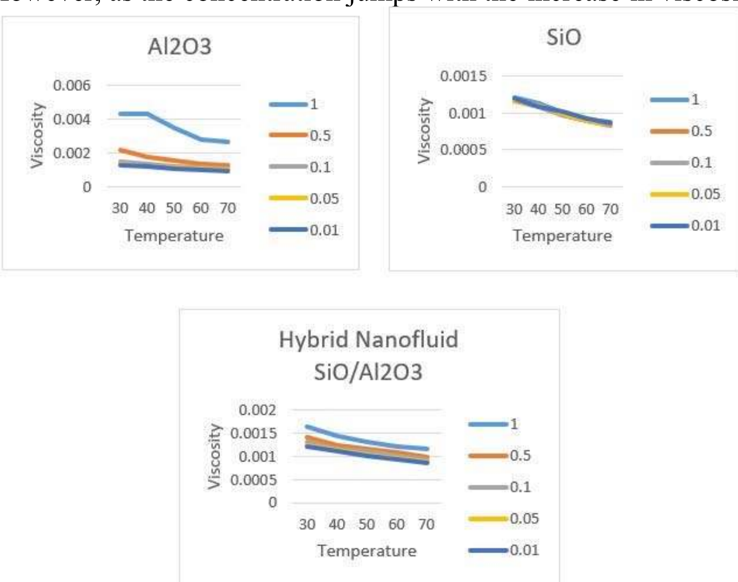


Figure 3: Effect of temperature to nanofluid viscosity

Figure 4 shows impact of volume concentration with respect to the viscosity. The increase in nanoparticle shall impact on the resistance of the molecules (base fluid), thus the viscosity increases. While the viscosity of nanofluid reduces gradually with increase temperature. At this situation the velocities of individual molecules increase. In addition the interaction time plays important role; which resulting in value of viscosity decrease. In case of hybrid nanofluid viscosity parameter was modified with the mixture of Al2O3 and SiO individual viscosity properties.

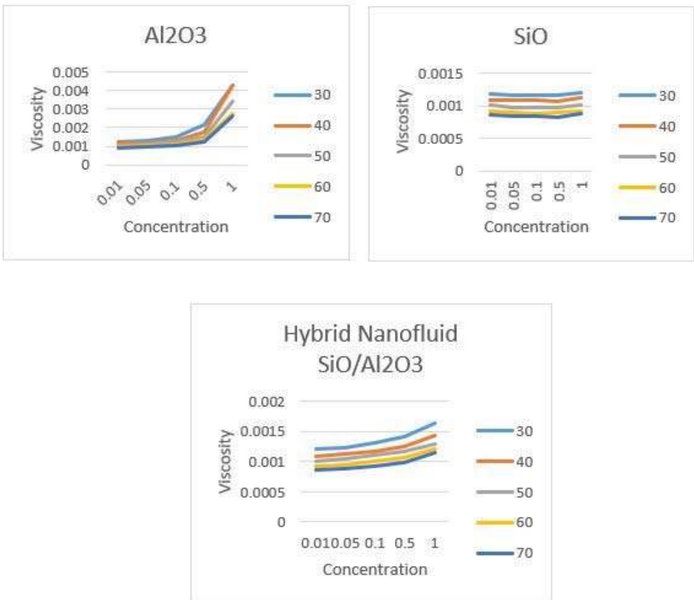


Figure 4: Effect of concentration to nanofluid viscosity.

4. Conclusion

In present study, the viscometric properties of various hybrid nanofluids of different concentrations (0.01 to 1.00 vol. %) are examined at temperatures 30 to 70 ° C. All the way through this study it is establish that temperature and volume concentration have substantial upshot over viscosity of hybrid nanofluids. This turn out due to the deteriorating of intermolecular communications and adhesion forces among the molecules. The viscosity of Al2O3 and SiO2 in mixture based was proportional to volume concentration. However, temperature parameter will reduce the viscosity. This condition was advantageous for nanofluids to be focused on heat transfer application.

5. Acknowledgment

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6. References

[1] Sujit Kumar Verma, Arun Kumar Tiwari."Progress of nanofluid application in solar collectors: A review", Energy Conversion and Management, 2015
[2] Mohammad Amin Rahimi, Ahmad Ramazani, S.A, Hossein Alijani Alijanvand, Mohammad Hossein Ghazanfari, Mahdi Ghanavati. "Effect of ultrasonic irradiation treatment on rheological behaviour of extra heavy crude oil: A solution method for transportation improvement", The Canadian Journal of Chemical Engineering, 2017

[3] Ramin Ranjbarzadeh, Alireza Akhgar, Sogand Musivand, Masoud Afrand. "Effects of graphene oxide-silicon oxide hybrid nanomaterials on rheological behavior of water at various time durations and temperatures: Synthesis, preparation and stability", Powder Technology,2018
[4] Mahdi Ghanavati, Mohammad-Javad Shojaei, Ahmad Ramazani S. A.. "Effects of Asphaltene Content and Temperature on Viscosity of Iranian Heavy Crude Oil: Experimental and Modeling Study", Energy & Fuels, 2013
[5] K Abdul Hamid, W H Azmi, M F Nabil ,Rizalman Mamat, "Viscosity determination of titanium dioxide in water and ethylene glycol mixturebased nanofluid", Indian Journal of Pure & Applied Physics, 2019
[6] Ovais Gulzar, Adnan Qayoum, Rajat Gupta, "Experimental study on stability and rheological behaviour of hybrid Al2O3-TiO2 Therminol-55 nanofluids for concentrating solar collectors", Powder Technology, 2018
[7] S. Sharma, A. K. Tiwari, S. Tiwari, R. Prakash, " Viscosity of hybrid nanofluids: Measurement and comparison", Journal of Mechanical Engineering and Sciences, 2018