Experimental Investigation of Thermo Physical Properties of Synthetic Oil based Nanofluids

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ABSTRACT

By adding solid particles of very high thermal conductivity, the effective thermal conductivity of the resulting fluid can be increased thereby the heat transfer capability of the fluid can be increased. Al_2O_3 nano particles of size 40-50 nm are dispersed in the base fluid using a sonicator. Nano fluids are prepared for different volume fractions 0.1, 0.2, 0.5, 1.0, 1.5 and 2.0. The thermo physical property studies are done which include thermal conductivity and viscosity studies. The thermal conductivity of Al_2O_3/ Therminol 55 nanofluid was measured by using a KD2 Pro thermal properties analyzer and the viscosity of the nanofluid was measured using Brookfield cone and plate viscometer. The experimental data measured are compared with the theoretical model.

Keywords: Therminol 55, Al_2O_3, Thermal Conductivity, viscosity

1 INTRODUCTION

Heat Transfer studies have always been a subject of interest and intrigue to the scientific world. The thrust is always into finding methods to enhance properties like thermal conductivity and heat transfer rates. Heat transfer enhancement technology has been developed and widely applied to heat exchanger applications. Many active and passive techniques are available for augmentation. Nanofluids are one among the developing thrust areas in the enhancement of heat transfer as they offer novel exiting properties.

Water is the most cost effective and widely used thermal fluid available with high heat transfer efficiencies and easy to control. However, its main limitation is that at a temperature above 100ºC it starts to boil, become steam and hence can only be used as a pressurized system – imposing restrictions upon its handling and use to ensure safe operation. High temperature synthetic oil based thermic fluids can be a better substitute to water for applications where the working temperature of the fluids exceeds 100 ºC. Also with the introduction of nanosized particles into the high temperature base fluids, the enhancement of thermal conductivity is supposed to be higher.

Choi et al. [1] observed 160% enhancement in thermal conductivity of engine oil with 1.0% volume carbon nanotubes.

The use of thermal oil systems first started at the end of the 1930s. They were used due to their high energy efficiency and heat transfer rates. The first results on the enhanced effective thermal conductivity of nanofluids were reported by Eastman et al. [2]. By dispersing Al_2O_3 and CuO nanoparticles in water, the reported increase in thermal conductivity were 29% and 60%, respectively for a nanoparticle volume concentration of 5%. M Chandrasekar et al [3] conducted experimentally the heat transfer characteristics of Al_2O_3/water and CuO/ water-based nanofluids and found a considerable rise in the Nusselt number.

Elena V. Timofeeva et al. [4] conducted experimental investigations of thermal conductivity of SiO_2/therminol66 nanofluids. They found that, in the case of 1.2 vol.% at 15^oC, nanofluid viscosity was 23% higher than pure Therminol66, and at 125^oC the nanofluid was only 8% more viscous than the base fluid at the same temperature. Viscosity of the 3.6 vol.% suspension ranged from 70% more viscous at 15^oC down to only 30% more viscous at 125^oC. S.M. Hashemi et al. [5] investigated the heat transfer characteristics of CuO/base oil nanofluid in a horizontally helical coiled tube and got substantial rise in the Nusselt number. Numbers of research works have been carried out to study the thermal properties of the nanofluids and heat transfer capability of the oil based nanofluids [7-11].

It is clear from the investigations that, almost all of these works report the enhancement of nanofluid convective heat transfer. Only few works have been done in the enhancement of heat transfer of oil based nanofluids. Though some prior works have been done with CuO/base oil nanofluids, lesser numbers of works are there with Al_2O_3 and synthetic oil based nanofluids. Taking these factors into account an attempt was made in this work to prepare Al_2O_3/Therminol 55 based nanofluids and to experimentally investigate its thermal conductivity and viscosity.

2 EXPERIMENTS

The key step in the experimental investigation of the nanofluids is its preparation. Here the nanofluids are prepared by the conventional method 'two step technique'. In this method nanoparticles are synthesized separately and dispersed into the base fluid using an agitator or a sonicator. This method is well suitable for oxide nanoparticles. In our work nanofluid with a required volume concentration of 0.1%, 0.2%, 0.5%, 1%, 1.5%, 2% was prepared by dispersing a specified amount of Al_2O_3 nanoparticles in therminol55 by using magnetic stirrer followed by ultra-sonic vibration. The magnetic stirrer employs a rotating magnetic field which stirs the magnetic pellet immersed in a fluid thus allowing it to spin very quickly which in turn enabling the dispersion of the particles and ultrasonic vibrator (Toshiba, India) generating ultrasonic pulses of 100W at 36 ± 3 kHz ensures even dispersion of particles in the fluid. To get a uniform dispersion and stable suspension which determine the final properties of nanofluids, the nanofluids are kept under ultrasonic vibration continuously for 1 hour. No surfactants were used as they may have some influence on the effective thermal conductivity of nanofluids.

3 THERMAL CONDUCTIVITY

The effective thermal conductivity of nanofluids is measured with the aid of a KD2 thermal property meter (Lab cell Ltd, UK), which is based on the transient hot wire method. Here the thermal conductivities of the nanofluids and base liquid (therminol55) are measured at 293 K. The KD2Meter is calibrated using distilled water.

During thermal conductivity measurement, the temperature rise of nanofluid was in the range of 0.3 to 0.4^{o}C for a heating duration of 30s. This ensures that the heat pulse given by the sensor needle is very small and hence, thermally driven convection currents in the sample are avoided which in turn avoids any disturbances in the sample during measurements. The percentage increase in the Thermal conductivity is as shown in Fig 1.

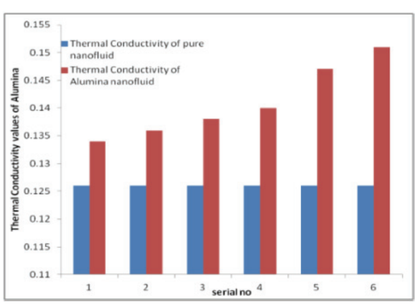

Fig.1. Percentage increase in the thermal conductivity with respect to volume fraction

3.1 Comparison of Measured Thermal Conductivity Values with the Maxwells model

Maxwell model [6] was the first model developed to determine the effective electrical or thermal conductivity of liquid–solid suspensions. This model is applicable to statistically homogeneous and low volume concentration liquid-solid suspensions with randomly dispersed, uniformly sized and non-interacting spherical particles. The Maxwell equation is

$$\frac{k_{nf}}{k} = \frac{k_s+2k+2\emptyset(k_s-k)}{k_s+2k-\emptyset(k_s-k)} \quad (1)$$

If the thermal conductivity of the particles is much higher than that of the liquid, for very small volume concentration φ, K_{nf} ratio can be written as

$$\frac{k_{nf}}{k} = 1 + k_k\emptyset \quad (2)$$

where $k_k = 3$

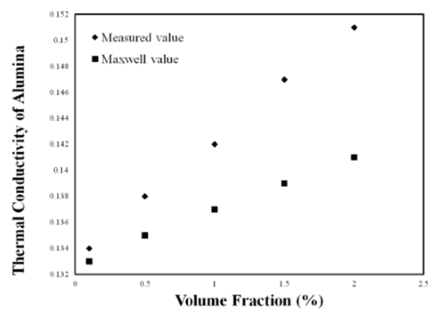

Fig.2 Comparison of the measured thermal conductivity values with the Maxwells model

The results show that the thermal conductivity of nanofluids significantly increases linearly with increasing particle volume concentration. The thermal conductivity enhancements of current Al_2O_3/TH55 nanofluids are 6.34%, 7.93%, 9.52%, 11.11%, 16.66% and 19.84% correlated to 0.1%, 0.2%, 0.5%, 1%, 1.5% and 2% volume fractions. The current experimental data is compared with the Maxwell model as shown in the fig. 2. A linear relationship between the thermal conductivity and volume concentration can be attributed to large regions of particle-free liquid with high thermal resistances created by highly agglomerated nanoparticles. Measured values of thermal conductivity are higher than the Maxwell value, microscopic motion of nanoparticles, the surface properties, and the structural effects might cause enhanced thermal conductivity of nanofluids.

The trend of thermal conductivity for any liquid tends to decrease with increase in temperature. However with the addition of nanoparticles with Therminol 55 there will not be a steep fall in the thermal conductivity values at high temperature. So Therminol 55 can effectively be used in high temperature heat transfer applications.

4. VISCOSITY OF Al_2O_3/THERMINOL 55

Factors effecting viscosity are Concentration, Size of particles and Temperature of nanofluid. The viscosity of nanofluids is measured with the use of a rotary viscometer (BROOKFIELD Co. DV-I + ProCP). The measurement is carried out at 293 K for the nanofluid of different concentrations. The experiment is repeated three times and the mean value is applied as an effective viscosity of the nanofluid.

4.1 Comparison of Measured Viscosity Values with the Batchelor's Equation

Batchelor equation for the effective viscosity of a fluid containing spherical particle in volume concentrations less than 5% is given by,

$$\frac{\mu_{nf}}{\mu} = 1 + (2.5 * \emptyset) + (6.2 * \emptyset * \emptyset \qquad (3)$$

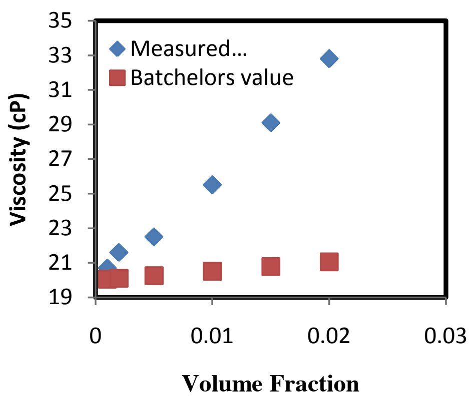

Fig. 3 Comparison of Measured Viscosity values with Batchelor's model

The result as in fig.3 shows that the relative viscosity increase is linear up to 0.5% volume concentration agrees well with the Batchelor equation. However at higher volume concentrations, the increase in relative viscosity shows a nonlinear relationship with volume concentration. This may be due to the hydrodynamic interactions between the particles which become important as the disturbance of the fluid around one particle interacts with that around another particle at higher volume concentrations.

5 CONCLUSIONS

In this investigation, Al_2O_3/Therminol 55 nanofluids of required volume concentrations were prepared by dispersing the Al_2O_3 nano powder in Thermniol55. Different volume concentrations of nanofluids (0.1%, 0.2%, 0.5%, 1%, 1.5%, 2%) were prepared by two step method by using an ultrasonic vibrator. The thermal conductivity and viscosity of the nanofluids were measured using a KD2 Pro thermal properties analyzer and Brookfield cone and plate viscometer respectively. The experimental results show that there is a significant enhancement in effective thermal conductivity of the prepared nanofluids compared with pure Therminol. It has also been observed that the thermal conductivity of nanofluids increases remarkably with increasing volume fraction of nanoparticles. Viscosity measurements indicate that Al2O3/Therminol 55 nanofluids have an increasing viscosity value with respect to particle addition. The experimental results have been compared with predictions by the existing theoretical models. It has been found that the experimental results are significantly higher than those predicted by existing models.

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