An Experimental Investigation into the Thermal Properties of Nano-Fluid

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Abstract—In this paper, the results of the experimental investigation on the thermal properties of nano-fluid are presented. The effect of sonication time, settling time and temperature on the thermal conductivity, viscosity and specific heat of zinc oxide (ZnO), 14nm and 25nm size and single walled carbon nano-tube (SWCNT, 10nm size) based nano-fluid are investigated and the results of ZnO with DI water and ethylene glycol (EG) as base fluids are compared. The experimental results indicate that the studied parameters have a remarkable effect on the thermal properties of nano-fluid. The rate of enhancement in the thermal conductivity of EG based nano-fluid is found to be less than that of water based nano-fluid. The SWCNT based DI water nano-fluid found to be very unstable i.e. the nano-particles settle down very rapidly. The 0.02% volume fraction of SWCNT nanoparticles suspension results in 10% increase in the specific heat of DI water. A decrement of 24% and 13% in the specific heat of 14nm size ZnO based nano-fluid were obtained at a volume fraction of 0.001% and 0.002% respectively.

Keywords—Nano-fluid, Thermal conductivity, Viscosity and Specific heat

I. INTRODUCTION

Nano-fluid came into picture in the field of heat transfer in systems since it was introduced by Choi [1]. The heat transfer coefficient of a fluid depends on thermal properties like conductivity, viscosity and specific heat. So far the effect of particle size, volume fraction and temperature was studied by many researchers [2 to 5], but the effect of sonication and settling time on nano-fluid is studied by few researchers [6,7]. Calvin [8] investigated effect of volume fraction and temperature on the CuO and Al₂O₃ nano-particles based water nano-fluid and the results showed an increase of 52% in the thermal conductivity of DI water, when CuO nano-particles were dispersed at a volume fraction of 6%. Also, an increase of 30% in the conductivity of Al₂O₃ based nano-fluid was reported at volume fraction 10% in a temperature range of 27.5 to 34.7°C. Jang [9] investigated the effect of temperature and volume fraction on the viscosity Al₂O₃ nano-particles dispersed in water, the results reported an increase of 2.9% in the viscosity of base fluid at a volume fraction of 0.3% and with the increase in temperature the viscosity of nano-fluid decreases continuously.

The results of Zhou [10] showed that the specific heat of water decreases by 50%, when Al₂O₃ nano-particles were dispersed in a volume fraction range of 0 to 21.7%. In this paper, the effect of volume fraction, sonication time, settling time, diameter of particles and temperature on the thermal properties of zinc oxide and single walled carbon nano-tube based nano-fluids is presented.

II. EXPERIMENTAL PROCEDURE

In order to study the effect of various parameters on thermal properties (Thermal conductivity, viscosity and specific heat) of nano-fluid, zinc oxide (ZnO) nanoparticles and single walled carbon nano-tube (SWCNT) has been purchased from Rainste Nano Ventures Pvt. Ltd., Noida. The average diameter of ZnO powders are 14 nm and 25nm with 1nm surfactant coating of oleic acid and of SWCNT is 10nm. The density of ZnO nanoparticles and SWCNT is 5600kg/m³ and 0.05kg/m³ respectively. The received powders are sealed, dried and loosely agglomerated. The two step method was used to prepare ZnO based ethylene glycol (EG) nano-fluids of two different volume fractions; 0.01% and 0.05%. The relative thermal conductivity and viscosity of EG based ZnO nano-fluids are compared with DI water based ZnO nano-fluids. The experiments were also carried out with SWCNT as nano-particles and water as base fluid for a volume fraction of 1%. The thermal conductivity was measured by Decagon devices KD2Pro Thermal Properties Analyzer (Decagon Devices Inc., Pullman, WA, USA). The Viscosity of the sample is measured by the instrument named Brookfield DV III Rheometer (Brookfield DV III Ultra Manual). This rheometer is a cone plate viscometer which is a precise torque meter.

III. RESULTS AND DISCUSSION

Several measurements were carried out for DI water and ethylene glycol as base fluids, to investigate the effect of sonication time, settling time and temperature on the thermal properties of the nano-fluid. In Figure 1, the relative thermal conductivity of ZnO nano-fluids increases for both base fluids ethylene glycol and DI water.
The relative thermal conductivity of ZnO ethylene glycol based nano-fluids shows low enhancement as compared to DI water based nano-fluids, because the ethylene glycol has more viscosity due to which ZnO nanoparticles take more time to disperse in ethylene glycol base fluids. As a result, surface to volume ratio decreases in ethylene glycol based nano-fluids. In Figure 2, the samples were prepared by dispersing nano-particles in ultra bath sonicator up to 8 hours with base fluids ethylene glycol and DI water. The relative thermal conductivity of ZnO ethylene glycol and DI water based nano-fluids decreases as the settling time increases because, as time increases the nano-particles which were dispersed in base fluids, starts agglomerated due to which cluster formed and settle down as the time increases. The decreases rate of relative thermal conductivity in ethylene glycol based nano-fluids is less as compared to DI water based nano-fluids because, the viscosity of ethylene glycol is more due to which nanoparticles will not settle down, as in DI water based nano-fluids.

Figure 1: Comparison of relative thermal conductivity with base fluids EG and DI water versus sonication time.

Figure 2: Comparison of relative thermal conductivity with base fluids EG and DI water versus settling time.

Figure 3 shows the relative thermal conductivity of ZnO-ethylene glycol and ZnO-DI water nano-fluids increases as the temperature increases because with the increase in temperature, Brownian motion of nano-particles increase which excites the particles due to which random motion of nano-particles increases and the particles starts strikes with each other and transfer the heat energy. Figure 4 shows that the relative viscosity of EG-ZnO nano-fluid decreases with the increase in sonication time, but increases in the case of water-ZnO nano-fluid. The viscosity of water based nano-fluid is more than ethylene glycol based nano-fluid. Also with the increase in size and volume fraction of nanoparticles in base fluid, the relative viscosity of nano-fluid increases continuously. The relative viscosity of ethylene glycol based nano-fluid comes very close to 1 at zero hours of sonication. In Figure 5, the rate of enhancement in viscosity of EG-ZnO nano-fluid is less as compared to water-ZnO nano-fluid. This is because the particles in nano-fluid start to settle down and agglomerate as the sonication of nano-fluid is stopped. As the viscosity of ethylene glycol is comparatively higher than that of water, which makes the particles suspended for a longer time due to which, there is less increase in the viscosity of ethylene glycol based nano-fluid.
In Figure 6 and 7, the variation of specific heat of 14nm and 25nm sized ZnO-water nano-fluid with temperature is shown. The specific heat of nano-fluid is found to be increasing with the increase in temperature for a range of 30° to 50°C. But the specific heat of water remains unchanged [11] for the specified range.

In Figure 8 and 9, the relative thermal conductivity of SWCNT-water nano-fluid increases with the increase in sonication time and decreases with the increase in settling time. In Figure 10 and 11, the viscosity of nano-fluid is decreasing with the increase in sonication time and increases with the increase in settling time. Also with the increase in power of sonication, the conductivity of nano-fluid is increasing and viscosity of nano-fluid is decreasing.
**Figure 8**: Thermal conductivity ratio variation with sonication time at different sonication power.

**Figure 9**: Thermal conductivity ratio variation with settling time at different sonication power.

**Figure 10**: Variation of viscosity of water based single walled carbon nano-tube nano-fluids with sonication time.

**Figure 11**: Variation of viscosity of water based single walled carbon nano-tube nano-fluid with settling time.

**IV. CONCLUSION**

The results of the current investigation clearly indicate that the thermal conductivity of nano-fluid increases with the increase in the sonication time, but the viscosity of nano-fluid decreases with it. Also with the increase in settling time, the thermal conductivity decreases and viscosity increases. With the increase in temperature, the thermal conductivity and specific heat of nano-fluid increases and viscosity decreases.

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**NOMENCLATURE**

- $K$ = Thermal conductivity
- DI = Deionized
- $nf$ = nano-fluid
- $bf$ = base fluid

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