

PREPARATION AND CHARACTERIZATION OF NANOFLUID (CUO – WATER, TIO₂ – WATER)

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Abstract:-

Over the past decade, research in heat transfer enhancement using nanofluids - suspensions of nanometer-sized solid particles in a base liquid has received considerable attention all over the world. Several theoretical works to predict the effective thermo physical properties of the suspension, range from a homogeneous model to complex two phase flow model have been proposed. This work explains the preparation methods of the nanofluids (CuO-water, TiO₂-water) and characterizing the nanofluid of different concentrations (0.025%, 0.05%, 0.075%, 0.1% and 0.5%). Here in this work used to calculate the density, viscosity, specific heat of nanofluids and steady state parallel plate method is used to calculate thermal conductivity of nanofluids experimentally. Results of this work show the increase in thermal conductivity, viscosity of the nanofluid by increasing the concentration and decrease of density and specific heat of nanofluid by increasing the concentration.

Keywords:- Nanofluid, Thermal conductivity, Specific Heat, Density, Viscosity, Volume Fraction

INTRODUCTION

Fluids have been applied in the cooling in the most important industries including Microelectronics, manufacturing, metrology, etc. With increasing thermal loads that require advances in cooling the new higher power output devices with faster speeds and smaller feature, the conventional heat transfer fluids, such as water, engine oil, ethylene glycol, etc., demonstrate the relative low heat transfer performance. The use of solid particles as an additive suspended in the base fluid is a potential alternative technique for the heat transfer enhancement, i.e. thermal conductivity of metallic or nonmetallic solids might have two orders of magnitude higher than the conventional fluids. The enhancement of thermal conductivity of conventional fluids with the suspension of solid particles, such as micrometer-sized particles, has been well known for more than 100 years. However, the conventional micrometer-sized particle liquid suspensions require high concentrations (>10%) of particles to achieve such an enhancement. Because they have the rheological and stability problems such as sedimentation, erosion, fouling, and pressure drop in flow channels, the fluids with the micrometer-sized particle have not been of interest for practical applications. The recent advance in materials technology has made it possible to produce nanometer-sized particles that can overcome these above problems. The innovative fluids suspended with nanometer-sized solid particles can change the transport and thermal properties of the base fluid, and make the fluid stable. Modern nanotechnology can produce materials with average particle sizes below 50 nm. All solid nanoparticles with high thermal conductivity can be used as additives of nanofluids. These nanoparticles that have been usually used in the nanofluids include: metallic particles (Cu, Al, Fe, Au, Ag, etc.), and nonmetallic particles (Al₂O₃, CuO, Fe₃O₄, TiO₂, SiC, carbon nanotube, etc.). The base media of nanofluids are usually water, oil, acetone, decene, ethylene glycol, etc. A 40% increase in thermal conductivity was found in the Cu oil-based nanofluids with 0.3% volume concentration, while the Al₂O₃ water-based nanofluids exhibited a 29% enhancement of thermal conductivity for the 5% volume concentration nanofluids. Nanofluids are a new class of solid-liquid composite materials consisting of solid nanoparticles, with sizes typically in the order of 1 - 100 nm, suspending in a heat transfer liquid. Nanofluids are expected to have superior properties compared to conventional heat transfer fluids. The much larger relative surface area of nanoparticles should not only significantly improve heat transfer capabilities, but also increase the stability of the suspensions. In addition, nanofluids can improve abrasion-related properties as compared to the conventional solid/fluid mixtures. Successful applications of nanofluids would support the current trend toward component miniaturization by enabling the design of smaller but higher-power heat exchanger systems.

PREPARATION OF NANOFLUID

The preparation of nanofluids is that the first key step in experimental studies with nanofluids. There are two methods for the preparation of nanofluid that is single step and two step method.

Single Step Method

In the single step method, the nanoparticles preparation and nanofluid preparation are carried out simultaneously. The nanoparticles are directly prepared by a physical vapor deposition technique or a liquid chemical method. In this method, agglomeration of nanoparticles is minimized and the stability of the nanofluid is increased as storage, transportation, drying and dispersion of nanoparticles are avoided. However, this method only applicable for small scale production and, at current stage, it is almost impossible to scale up to industrial scale. Furthermore, this method is only applicable for low vapor pressure base fluid which limits its application.

Two Step Method

In the two step method, the nanoparticles manufacturing and nanofluid preparation is separated. Firstly, dry nanoparticles are produced; after which, they are dispersed in a suitable base fluid. This is simpler than single step method as it can easily buy readily available nanoparticles in market and then disperse them in the base fluid. However, it is well known that nanoparticles have a high surface energy which, in turn, leads to aggregation and clustering of nanoparticles and after some time, the particles will clog and sediment at the bottom of container. Partial dispersion may occur in the suspension which cause lower heat transfer enhancement compare to single step method, and hence, high amount of nanoparticles volume fraction is required. This method works well for oxide particle and carbon nanotube; however, it is less successful for metal nanoparticles.

CHARACTERIZATION OF NANOPARTICLES

Table 1: Properties of Nanoparticles

Properties	Copper Oxide	Titanium Dioxide
Chemical Formula	CuO	TiO ₂
Color	Black	White
Morphology	Spherical	Spherical
True Density	6400 kg/m ³	4010 kg/m ³
Bulk Density	790 kg/m ³	150-250 kg/m ³
Sp. Surface Area	10 m ² /g	200-220 m ² /g
Phase	-	Anatase
Average particle Size	20-30 nm	10-20 nm
Specific Heat	531.020 J/kg K	690 J/kg K

Thermal Conductivity

A wide range of experimental and theoretical studies were conducted in the literature to model thermal conductivity of nanofluids. The existing results were generally based on the definition of the effective thermal conductivity of a two-component mixture. The Maxwell (1881) model was one the first models proposed for solid–liquid mixture with relatively large particles. It was based on the solution of heat conduction equation through a stationary random suspension of spheres. The effective thermal conductivity (Eq.1) is given by

$$k_{nf} = \frac{k_p + 2k_{bf} + 2\phi(k_p - k_{bf})}{k_p + 2k_{bf} - \phi(k_p - k_{bf})} k_{bf} \quad (1)$$

Where k_p is the thermal conductivity of the particles, k_{nf} is the thermal conductivity of nanofluid, k_{bf} is the base fluid thermal conductivity, and ϕ is the volume fraction of the suspended particles. The general trend in the experimental data is that the thermal conductivity of nanofluids increases with decreasing particle size. This trend is theoretically supported by two mechanisms of thermal conductivity enhancement; Brownian motion of nanoparticles and liquid layering around nanoparticles (Ozerinc et al, 2010). However, there is also a significant amount of contradictory data in the literature that indicate decreasing thermal conductivity with decreasing particle size. Published results illustrated neither agreement about the mechanisms for heat transfer enhancement nor a unified possible explanation regarding the large discrepancies in the results even for the same base fluid and nanoparticles size. There are various models available for the measurement of effective thermal conductivity of nanofluids (Wang and Mujumdar, 2007) but there exists large deviations among them. Currently, there are no theoretical results available in the literature that predicts accurately the thermal conductivity of nanofluids.

Viscosity

Compared with the experimental studies on thermal conductivity of nanofluids, there are limited rheological studies reported in the literature for viscosity. Different models of viscosity have been used by researchers to model the effective viscosity of nanofluid as a function of volume fraction. Einstein (1956) determined the effective viscosity of a suspension of spherical solids as a function of volume fraction (volume concentration lower than 5%) using the phenomenological hydrodynamic equations (Eq.2). This equation was expressed by

$$\mu_{nf} = (1 + 2.5\phi + 6.2\phi^2)\mu_{bf} \quad (2)$$

Where μ_{nf} is the effective viscosity of nanofluid, μ_{bf} is the base fluid viscosity, and ϕ is the volume fraction of the suspended particles.

Specific heat and density

Using classical formulas derived for a two-phase mixture, the specific heat capacity (Pak and Cho, 1998) and density (Xuan and Roetzel, 2000) of the nanofluid as a function of the particle volume concentration and individual properties can be computed using following equations(Eqs 5, and 6) respectively:

$$\rho_{nf} = (1 - \phi)\rho_{bf} + \phi\rho_p \quad (3)$$

$$(\rho C_p)_{nf} = (1 - \phi)(\rho C_p)_{bf} + \phi(\rho C_p)_p \quad (4)$$

Experimental Method to Find Out the Thermal Conductivity of Nanofluid

The thermal conductivity of nanofluid can be experimentally measured by Transient and Steady state techniques. The transient technique involves the following different methods.

- Transient Hot Wire
- Transient Plane Source
- Temperature Oscillation
- 3ω
- Laser Flash
- Photocoustic

The steady state technique method involves the following different methods.

- Steady State Parallel Plate
- Cylindrical Cell

In this work steady state parallel plate method has been used to measure the thermal conductivity of nanofluid

Steady State Parallel Plate

Challoner and Powell (1956) first built an experimental setup for the measurements of thermal conductivity by means of a steady-state parallel plate method and it has been further used for nanofluid measurements (i.e., Wang et al. 1999). The fluid sample is put between two parallel round plates generally made of copper at distance 't' in a volume, in which the liquid can adapt as a consequence of the thermal expansion. A heater electrically supplies a heat flux directed from the upper plate to the lower plate through the liquid sample. Temperatures of the two plates and the electric power are measured continuously, so, if the heat conduction remains one dimensional, thermal conductivity can be calculated as

$$K = \frac{Q \cdot t}{\Delta T \cdot A} \quad (5)$$

where: A is the upper plate surface area

ΔT is the temperature difference between the two plates

However, the heat is not completely conducted from one plate to the other through the sample, so during these measurements it is necessary to evaluate all the heat losses.

Result and Discussion

Density

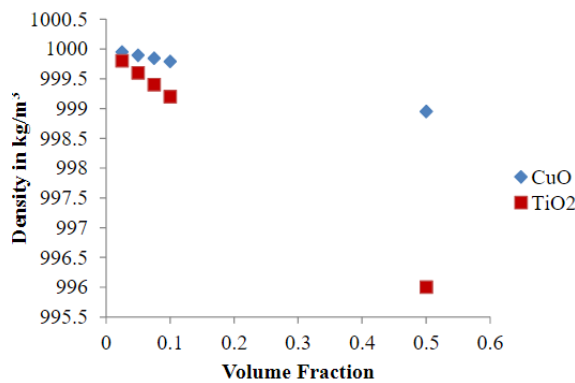


Figure 1: Volume Fraction versus Density

From Figure 1, by increasing the volume fraction (concentration) of nanoparticles in the fluid the density of nanofluids CuO-water and TiO2-water varies. Because, the bulk density of both nano particle is lesser than that of base fluid and we observed that decrease in density for both nanofluids by increasing the volume fraction (concentration) range from 0.025-0.5%

Viscosity

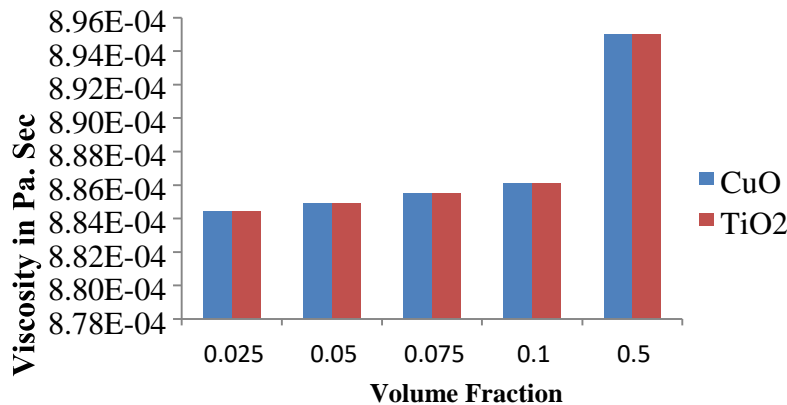


Figure 2: Volume Fraction versus Viscosity

From Figure 2, it is observed that viscosity of nanofluids CuO-water and TiO2-water increases by varying the volume fraction (concentration) of nanoparticles in the fluid. The viscosity of nanofluid is depending only on the volume fraction (concentration) of nano particles irrespective of the type of nano particle used. This shows the increasing of viscosity by increasing the concentration of nano particle in the range from 0.025-0.5%.

Thermal Conductivity

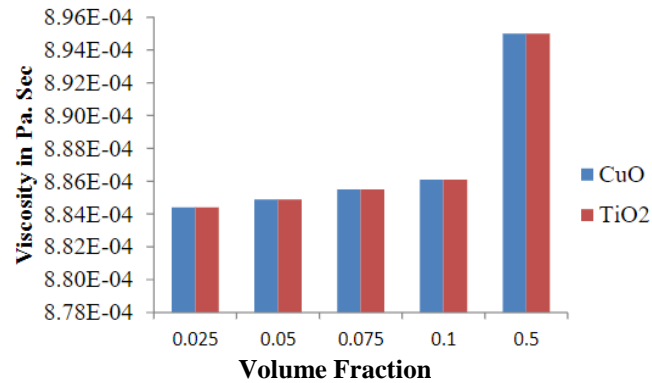


Figure 3: Volume Fraction versus Thermal Conductivity

From Figure 3, it is observed that variation of thermal conductivity of nanofluids CuO-water and TiO₂-water by varying the volume fraction (concentration) of nanofluids. Because thermal conductivity of both nano particle is higher than that of base fluid it has been observed that increase in thermal conductivity for both nanofluids by increasing the concentration range from 0.025-0.5%.

Specific Heat

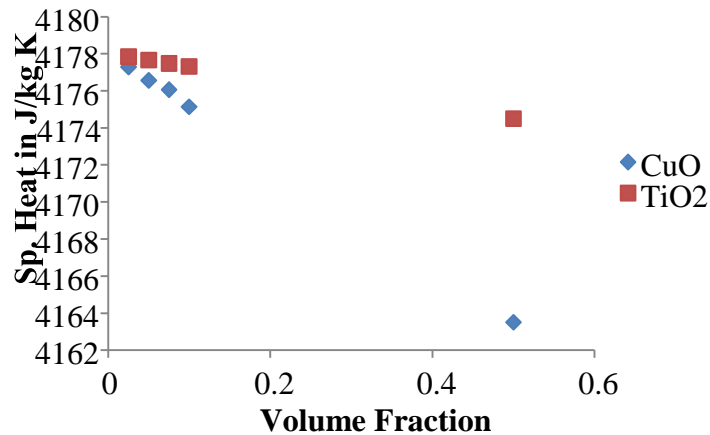


Figure 4: Volume Fraction versus Specific Heat

From Figure 4, it shows the variation of specific heat of nanofluids CuO-water and TiO₂-water by varying the volume fraction (concentration) of nanofluids. Because specific heat of both nano particle are lesser than that of base fluid, we observed that decrease in specific heat for both nanofluids by increasing the volume fraction (concentration) range from 0.025-0.5%.

Conclusion

In this work by observing the preparation methods of nano fluids and experimental results for Thermo physical properties of nano fluids, the following conclusions can be made.

- 1) The homogeneous and stable nanofluid can be obtained by making mechanical stirring.
- 2) Bulk density of nano particle is lesser than that of base fluid therefore there is decrease in density of the nanofluid by increasing the volume fraction.
- 3) Viscosity of nanofluid increases by increasing the volume fraction, because viscosity of nanofluid sis depends only on the volume fraction of nano particles.
- 4) Thermal conductivity of nanoparticles is higher than the base fluid hence as volume fraction increases in the fluid thermal conductivity of nanofluid increases.
- 5) Specific heat of nano particle is lesser than that of base fluid, which results volume fraction increases in the fluid specific heat of nanofluid decreases.

References

- [1]. Fei Duan,2012. Thermal Property Measurement of Al₂O₃-Water Nanofluids. Smart Nanoparticles Technology, 335-356
- [2]. Ra Zvan Silviu Luciu¹, Theodor Mateescu, Victoria Cotorobai and Thierry Mare, 2009. Nusselt Number And Convection Heat Transfer Coefficient For A Coaxial Heat Exchanger Using Al₂O₃- Water Ph=5 Nanofluid, Sectia, 71-80
- [3]. S.Lee, J A Eastman, et, al., 1999. Measuring Thermal Conductivity of Fluid Containing a Oxide Nanoparticles. ASME Vol. 121, 280-289.
- [4]. Vincenzo Bianco, Oronzio Manca, Sergio Nardini, Kambiz Vafai,2015. Heat Transfer Enhancement with Nanofluids, CRC Press Taylor & Francis Group, Boca Raton
- [5]. Xinwei Wang^α and Xianfan Xu, Stephen U. S. Choi, 1999. Thermal Conductivity of Nanoparticle-Fluid Mixture, Journal Of Thermophysics and Heat Transfer Vol. 13, No. 4