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Effect of particle volume concentration on thermo physical properties of Silicon Carbide Water based Nanofluid

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Abstract

Nanofluids are used as coolant in heat exchangers because of their thermal properties. Silicon carbide nanoparticles are used to prepare nanofluid with DI water as base fluid with concentrations of 0.01, 0.05 and 0.1%. In this review, the effect of particle concentrations on thermal conductivity and absolute viscosity of SiC nanofluid is studied theoretically and experimentally. Thermal conductivity enhancement is seen at 0.05% V/V as 17.11% and decrease as concentration increases. Viscosity of nanofluid increases with increase in particle concentration. Correlations based on experimental results are developed and shown in figures.

Keywords: *Nanofluid, Thermal conductivity, Viscosity, Concentration, Stability, Base fluid.*

1. Introduction

Nano science takes huge leaps in present world of technology and innovation. As of the applications of heat transfer and research on Nano fluid as cooling agent on coolant is predominant. Nano fluids are nothing but colloidal dispersion of Nano particles in a base fluid as a single phase medium. They have shown significance in increase of thermal conductivity and even heat transfer coefficient. Mostly used Nano-particles are

1. Metal oxide NP
2. Ceramic NP(Ex. SiC)
3. Carbon based NP (CNT)

Effective heat transfer is required in Power plants, automobiles, refrigerators etc. The convection heat transfer is mostly used for heat transfer in this context by using Newton's Law

$$Q = hA\Delta T \qquad [1]$$

Where,

h – Convective heat transfer coefficient
A – Surface area
ΔT – Temperature difference across the flow of heat

Stability of Nano fluid is important factor in enhancing thermo-physical properties. This can be obtained by adding external chemicals which leads to reduction in thermo-physical properties. Nano fluid can be synthesized using two methods

1. One step method
2. Two step method – direct dispersion of NP's in base fluids.

Studies involving base fluids have been reported in literature. Water and ethylene glycol are used in nanofluids preparation. Effect of base medium on thermal conductivity can be predicted.

In one step method, materials of size in range of millimeters are ball milled and nanoparticles are produced. Then they dispersed in base fluid from ultra sonication obtaining stability. In two step method nanoparticles are directly dispersed in base fluid. One step method is preferable for better stability than compared to the two step method of preparation.

The Maxwell model for finding thermal conductivity is for low volume fraction nanofluids with large size particles and is based on a steady-state solution [1].Consideration of shape of Nanoparticles is done by Hamilton and Crosser, where the introduction of different shapes of Nanoparticles are used for thermo physical properties enhancement [2] . Amount of heat transfer depends on heat coefficient and thermo-physical properties of Nano-fluid, achieved through better dispersion stability of nanofluids (Xuan& Li) [3]. The type of Nano-particles and base fluid results complete colloidal suspension results in increase in thermal conductivity (Chen et al [4], Eastmen et al [5], Wang et al [6], and Das et al [7]). Preparation of Nano-fluid by two step method using ultrasonic vibration and surfactant for better dispersion of particles in base fluid (Xuan& Li) [3], Das et al [7]). Thermal conductivity can be measured using transient hot wire technique (Lee et al 1999 [8]). The effect of different base fluids on thermal conductivity ratio is observed and a new model for finding thermal conductivity of nanofluids (Kim et al 2007 [9], Lee et al 1999 [8], He at al [10]). Einstein has developed a viscosity correlation in terms of Nano-particle volume concentration in the base fluid, when the Nanoparticles volume concentration is lower than 5%[11].

Research says thermal conductivity of different models might be true according their context. Complete influence can't be concluded in this case, different models like Maxwell, Hamilton-crosser, Davis etc., gave equations for Thermal conductivity. In this paper we analyze the thermo physical properties silicon carbide water based nanofluids without using surfactants for dispersion strengthening, Even though SiC particles offer higher thermal conductivity, research articles are limited. The effect of different particle concentrations on thermal conductivity and viscosity are being compared and studied in this article.

2. Nanofluids

2.1 Preparation of nanofluids:

Nano fluids is prepared by dispersion of nanoparticles in base fluid i.e., water (DI), Silicon carbide Nanoparticles are brought from US Research nanomaterials, Inc., Texas. Three volume concentrations of 0.01%, 0.05%, 0.1% are prepared by using two methods.

- Magnetic stirring of particles in water for 30 minutes.
- Ultrasonication of solid liquid medium phase for one and half hour.

The major concern for preparation of nanofluids is its stability. As particle concentration increases, agglomeration of particles is seen. No surfactant or external chemical agent is used in preparation of nanofluids, because of their inclusion results in change in particles. There is agglomeration seen in nanofluids samples.

2.2 Experimental

2.2.1 Thermo-physical properties:

Thermal conductivity:

The proposed models of Maxwell [1], Hamilton-Crosser [2] and Davis are used to find theoretical thermal conductivity of Nanofluid.

Experimental measurement of thermal conductivity of Nano fluid is obtained using KD2 pro analyzer from decagon devices, USA. This setup use the hot wire technique for measurement (transient), the sensor needle senses the temperature change and time taken for temperature rise. The needle of the probe consists of heating element and thermistor. The probe was completely immersed in a test tube with nanofluid and constant heat was supplied to measure the necessary temperature rise. For a given applied heat input (*q*), the thermal conductivity, *k*, was calculated from the Fourier's law as:

$$k = \frac{Q}{4\pi[T_2 - T_1]} * (\ln{(t_2/t_1)}) \qquad [2]$$

T_1, T_2 – Temperatures of sample at respective time's t_1, t_2

Experiments to study the effect of particle concentration on thermo physical properties is conducted at room temperatures (i.e. 30 ^{o}C)

Viscosity:

Theoretical model proposed by Einstein [11] is used to find viscosity of nanofluids. The main problem of using nanofluids in applications is due to increase of viscosity with increase in particle concentration, which leads to clogging effect in pipes or cylinders.

Experimental measurement of viscosity of Silicon carbide nanofluids is obtained using Brookfield DV2T, U.S.A. at 50 RPM

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3. Tables, Figures and Equations

3.1 Tables and Figures

V % (100 ml)	Sonication time (hours)	Stability
0.01%	1.5	Good
0.05%	1.5	Average
0.1%	1.5	Below average

Table 1: Stability of nanofluid

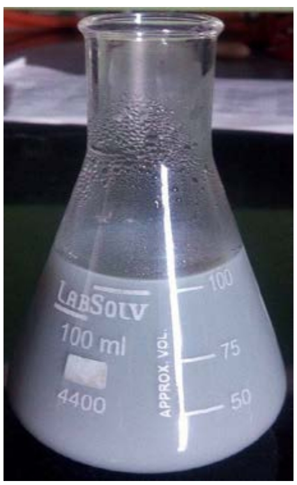

Figure 1: Silicon carbide nanofluids, 0.01% volume concentration

Figure 2: Silicon Carbide nanofluids,0.05% volume concentration

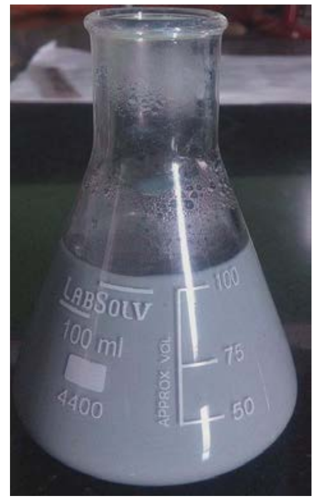

Figure 3: Silicon Carbide Nanofluid, 0.1% volume concentration

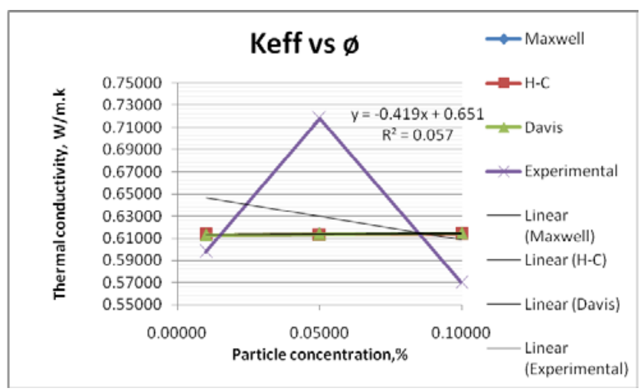

Figure 4: Effect of particle concentration on thermal conductivity of Silicon carbide compared with proposed theoretical models

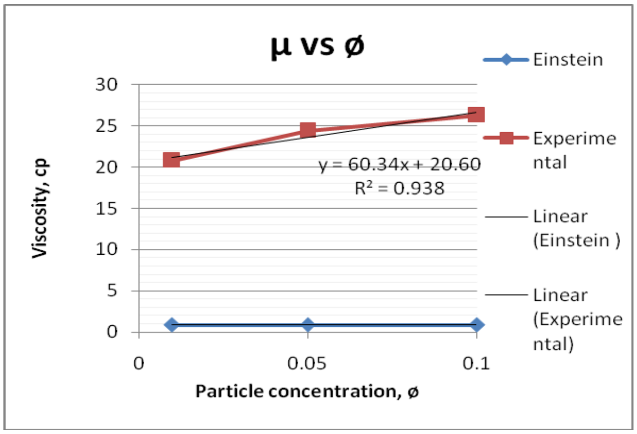

Figure 2: Effect of particle concentration on viscosity of Silicon carbide compared with Einstein model

3.2 Equations

m_p- Mass of Nanoparticles, Kg
m_{bf}- Mass of base fluid ,Kg
ρ_p- Density of Nanoparticles, Kg/m3
ρ_{bf}- Density of base fluid, Kg/m3
V%- Volume concentration
k_p - Thermal conductivity of Nanoparticles
k_f - Thermal conductivity of base fluid
ø -Particles volume concentration
k_{eff} - Effective thermal conductivity of Nano fluid.
α - k_p/k_f
n -Sphericity,
μ_{nf} - Viscosity of nanofluids
μ_f - Viscosity of base fluid i.e. DI water

$$V\% = \frac{\frac{m_p}{\rho_p}}{\frac{m_{bf}}{\rho_{bf}} + \frac{m_p}{\rho_p}} * 100 \quad [1]$$

3.2.1 Theoretical models for thermal conductivity

a) Maxwell model:

$$\frac{k_{eff}}{k_f} = \frac{k_p + k_f + 2ø(k_p - k_f)}{k_p + k_f - ø(k_p - k_f)} \quad [2]$$

b) Hamilton – crosser model:

$$\frac{k_{eff}}{k_f} = \frac{\alpha + (n-1) - (n-1)(1-\alpha)ø}{\alpha + (n-1) + (1-\alpha)ø} \quad [3]$$

Where,

n=3/Ψ, Ψ_{cube} = 0.806.

c) Davis model:

$$\frac{k_{eff}}{k_f} = 1 + \frac{3(k_p - k_f)}{[k_p + k_f - ø(k_p - k_f)]}(Ø + 0.5Ø^2) \quad [4]$$

3.2.2 Theoretical model for Viscosity of nanofluids:

Einstein has developed a viscosity correlation in terms of Nano-particle volume concentration in the base fluid, when the Nanoparticles volume concentration is lower than 5%, and is given by

$$\mu_{nf} = \mu_{bf}(1 + 2.5ø) \quad [5]$$

3.3 Results and Discussion:

3.3.1 Thermal conductivity of SiC water based nanofluid:-

The Silicon carbide Nanoparticles are used for dispersion in DI water with concentrations of 0.01%, 0.05%, 0.1%. A graph showing effect of particle concentration on thermal conductivity ratio i.e k_{eff} is given in Figure 4. The comparision between existing correlations given by maxwell, Hamilton-crosser, Davis for thermal conductivity is observed in the following figure. The thermal conductivity increases till certain concentration of 0.05% and later decreased as particle concentration increases. This may be due to sedimentation of nanoparticles from dispersed nanofluid.

As of all the theoretical correlations proposed by several researchers, the thermal conductivity values from experimental data does not support them. The obtained values are non-linear. When compared with all models, at 0.05 % volume concentration the thermal conductivity is very high with respect to base fluid. There are promising results, as of not using any surfactants or external chemicals for better suspension of nanoparticles in DI water. The correlation obtained for thermal conductivity of SiC Nanofluid after experimentation is as follows,

$$k_{eff} = -0.419 * \o + 0.651 \qquad [6]$$

$$R^2 = 0.057$$

3.3.2 Viscosity of SiC nanofluids:-

Nano-fluids with volume concentrations of 0.01, 0.05, and 0.1 % are prepared and viscosity is measured at 30 ^{o}C and comparison with existing Einstein model is given in the Figure 5. The correlation after regression analysis for experimental values of viscosity of SiC nanofluid is as follows,

$$\mu = 60.34 * \o + 20.60 \qquad [7]$$

4. Conclusions

The Silicon carbide Nanoparticles are used to study the effect of the different particle concentrations on thermo-physical properties at 30 ^{o}C. The concentrations of 0.01, 0.05 and 0.1% are prepared using magnetic stirring and ultra-sonication for certain period without adding any surfactants. The measured thermal conductivity values are compared with the proposed models of Maxwell, Hamilton- Crosser, Davis etc., and the shown in figure. As compared to models, as particle concentration increases, thermal conductivity increase till 0.05% and decreases at 0.1%. This is due to agglomeration of particles in nanofluids. Regarding viscosity, the experimental results also does not coincide with proposed model of Einstein. The viscosity of nanofluids increases with increase in particle concentration. The results indicate that the measured data are quite different from those obtained by other researchers. It may be due to size of the particle, shape of the particle, particle synthesis procedure, the measuring technique. At the end, there is agreement between the proposed correlations for the thermal conductivity and viscosity of nanofluids and the experimental results.

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