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Enhancement in Thermal Conductivity of Nanofluids

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Abstract – Nanofluid technology is becoming an innovative challenge for heat transfer fluids due to considerable enhancement in thermal conductivity of nanofluids at lower nanopartical volume fraction. Nanofluid is a two phase mixture which is made up of suspension of nano-size particles into base fluid (water, ethylene glycol, engine oil), in order to enhance the heat transfer property of base fluids. Choi reported the enhancement in thermal conductivity of base fluid by dispersion of metallic or non metallic nano-size particles. After Choi many researchers have reported their theoretical, experimental and numerical, results on the thermo-physical properties of nanofluids. In the literature several researchers reported that there are various operating parameters which affect the thermal conductivity of nanofluids. In the present paper the results of several researches in the field of enhancement of nanofluid thermal conductivity have been compiled.

Index Terms – nanofluid, heat transfer, thermal conductivity.

1. INTRODUCTION

Thermal properties of a liquid play a very significant role in cooling application in various industries. Thermal conductivity is one of the important physical properties of liquids which decide the heat transfer performance of fluid. Conventional heat transfer fluids have inherent drawback of poor thermal conductivity which make them poor coolant for industrial applications. In order to enhance the poor heat transfer property of fluids Maxwell [1] dispersed micrometer size solid particles into conventional fluids. However the problems occurring with micrometer size particles are settlement of solid particles into base fluids and clogging of flow passages. To overcome the drawback of suspension of micro size particles into a fluid, in 1995 Choi [2] created a concept of dispersion of nano size particles into liquids such as water, engine oil and ethylene glycol. Dispersion of nanosize particles enhances the heat transfer properties of base fluid. Nanofluids offer numerous advantages over conventional base fluids with micrometer size particles like higher thermal conductivity, homogeneity and minimum clogging to flow passages, stability due to particles of nanometer size [3,4]. There are various fields where applications of nanofluids have been found like: automotive industries, domestic refrigerator, industrial cooling application, solar devices etc. For the preparation of nanofluids, several materials such as metallic oxides (Al_2O_3, CuO, SiO_2), carbide ceramics (SiC, TiC), nitride ceramics (AlN, SiN), metals (Cu, Ag, Au, fe), semiconductors (TiO_2, SiC), single, double or multi walled carbon nanotubes (SWCNT, DWCNT, MWCNT), alloyed nanoparticles etc are used [5]. There are some important factors such as even suspension of particles into base fluid, durability and stability of suspension,no change in chemical property of base fluid and low agglomeration of particles are taken into consideration while preparing the nanofluids. There are different methods for the preparation of nanofluids. Three common methods which are used for the preparation of stable nanofluids are [5]: (i) Adding surface active agents and/or dispersants to disperse particles into liquid (ii) addition of acid or base to change the PH value of suspension and (iii) by ultrasonic vibration.

In literature several methods are reported for the measurement of thermal conductivity of nanofluids such as [6]:

- (i) Transient hot-wire method
- (ii) Transient short-hot-wire (SHW) method
- (iii) Temperature oscillating method
- (iv) steady-state parallel-plate method

There are several parameters such as size of the nanoparticles, shape of nanoparticles, volume concentration of nanoparticles in base fluid, temperature of nanofluid studied in the literature which affects the thermal conductivity of nanofluids [7-12]. Present paper compiled the findings of several researchers in order to enhance the thermal conductivity of nanofluids.

2. Thermal Conductivity of Nanofluids

Wang and Xu [7] investigated the thermal conductivity of nanofluids made up of metal oxides Al_2O_3 and CuO. Ethylene glycol, water, vacuum pump fluid and engine oil are used as a base fluid for preparation of nanofluids. They measured the thermal conductivities of the nanofluids by a steady-state parallel-plate technique method. They reported that thermal conductivity of nanofluid increases with increase in volume fraction of nanoparticles but for a given volume fraction thermal conductivity rise is different for different base fluids. They reported that the increase in thermal conductivity of engine oil and ethylene glycol is highest and that of pump oil is lowest. They also reported that there is 26% increase in effective thermal conductivity of ethylene glycol when around 5% volume of aluminum oxide powder is added and for 8% volume of aluminum axide powder there is increase of 40% (Figure 1). They also reported the thermal conductivity ratio of CuO nanofluid where water and ethylene glycol is as a base fluid, for both the type of nano fluid thermal conductivity ratio increases with volume fraction (Figure 2). They concluded that thermal conductivity of nanofluid increases with decreases in particle size and enhancement of thermal conductivity is also a function of dispersion technique. They reported that it is found that thermal conductivitie determined by theoretical models are much lower than experimentally obtained data.

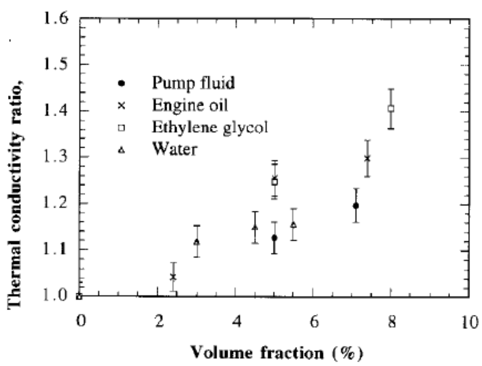

Figure 1: Thermal conductivity ratio as a function of volume fraction of Al_2O_3 powders into different base fluids [7].

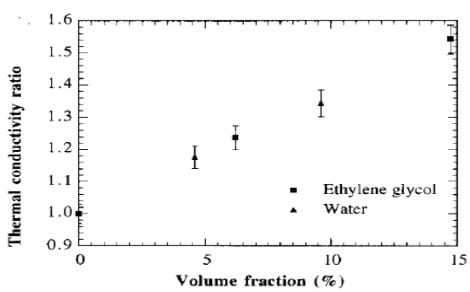

Figure 2: Thermal conductivity ratio as a function of volume fraction of CuO nanoparticles in H_2O and ethylene glycol [7].

Mintsa et. al [8] investigated the thermal conductivity of CuO and Al2O3 water based nanofluids. Samples prepared for the measurement of thermal conductivity of nanofluid consist nanoparticels with volume fraction of 3%, 6% and 9% in the temperature range of 20 ºC to 40ºC. There results showed that thermal conductivity of nanofluid increases with temperature as well as volume fraction (Figure 3). Thermal conductivity also increases with smaller diameter particles.

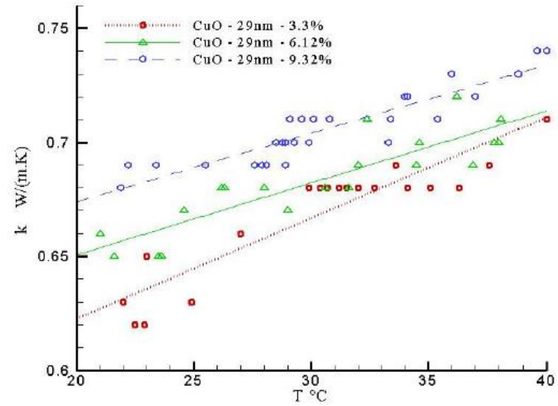

Figure 3: Thermal conductivity for water-CuO with paticles of 29 nm size [8].

Kwak and Kim [9] investigated the rheological properties and thermal conductivity of CuO-ethylene glycol based nanofluid. They reported that the shape of individual nanoparticle is of prolate spheroids and mostly particles are under aggregated states. When particle concentration is below the dilute limit then there is a substantial enhancement in thermal conductivity enhancement in thermal conductivivty. They also reported that it is dangerous to use nanosize metal powder due to its flammability and due to large density difference metal particles are liable to sedimentation. Metal oxides are more suitable to suspend in nanofluid, if agglomeration can be minimized. They reported that rotational Brownian motion plays an important role in the thermal conductivity enhancement. Important requirement for efficient nanofluid nanoparticle should be of spherical shape to have a higher critical dilute limit.

Zhu et al. [10] synthesized the nanoparticles by transforming an unstable $Cu(OH)_2$ precursor to CuO in water with a blend of ultrasonic and microwave irradiation. They reported that under microwave irradiation precursor is completely transformed to CUO nanoparticle in water. To prevent the growth and aggregation of nanoparticles in the preparation, ammonium citrate has been used which in turn stable CuO aqueous nanofluid. They reported that prepared CuO nanofluid showed higher thermal conductivity than those prepared by other dispersing methods.

Chang et al. [11] synthesized the nanoparticles by using a spinning disk reactor. They reported that thermal conductivity of the prepared nanoparicles with NaHMP as surfactant increases with increasing content of CuO upto 0.40 volume%.
Das et al. [12] investigated the effect of temperature on thermal conductivity of Al_2O_3 and CuO water based nanofluids. The experimental set up used for investigation of thermal conductivity is temperature oscillation technique which is a modification of the technique used by Czarnetzky and Roetzel [13]. Figure 4 showed the effect of temperature on thermal conductivity of Al_2O_3 water based nanofluids.

From the figure it can be seen that for both the volume fraction of 1% and 4% there is a considerable increase in the enhancement of thermal condutivity for the temperature range of 21ºC to 51ºC. With 1% particle volume fraction at 21ºC enhancement is reported only about 2% but same is reported as 10.8% at 51ºC. At 4% volume fraction enhancement is reported from 9.4% to 24.3% with temperature range of 21°C to 51°C. They also reported that particle size is a very important factor in thermal conductivity.

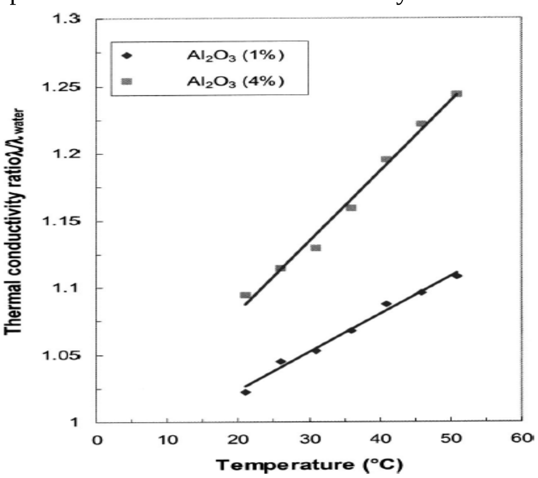

Figure 4: Temperature dependence of thermal conductivity enhancement for Al_2O_3-water nanofluids [12].

5. CONCLUSION

Thermal conductivity has significant role in enhancement of heat transfer property of nanofluids. Following points can be concluded by reviewing the literature of several researchers:

(i) Thermal conductivity of nanofluid can be increased by increasing volume fraction of nanoparticles into base fluid. (ii) Thermal conductivity of nanofuids can also be increased by decreasing the size of nanoparticles.

(iii) Method of dispersion of nanoparticles into base fluid is a important factor which decides the enhancement in thermal conductivity of nanaofluids.

(iv)Methods of synthesizing nanoparticles also have significant effect on the nanofluids thermal conductivity enhancement.

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