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A Review Onnanofluid Heat Transfer Mechanism Based On Nanofluids

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Abstract: *Present investigation is focuses on a thorough review of Nanofluid heat move component and thermo-physical properties. The Nanofluid arrangement procedures, heat move instrument and thermo-physical properties are talked about in detail. Warmth move in Nanofluid is capacity of numerous parameters, as Brownian movement of molecule, sub-atomic layering of the fluid particles interface and nanoparticle grouping and so on and these parameters are talked about in detail. Likewise metal oxides nanoparticles had an extraordinary impact in heat move upgrade of the nanofluid. The coolants have high warm conductivities at low volume convergence of Nanofluid. Nanofluids' warm conductivity and thickness incredibly rely upon their size, volume fixation, shape and material. Nanofluid consistency may increment or lessening relying on the material of nanoparticle on bringing down the size. Thickness of nanofluid increments with increment in volume division of nanoparticle.*
Key Word*:Anoparticles, Nanofluid, Thermal Conductivity, Viscosity, VolumeConcentration, Heat Transfer.*

I. Introduction

The resources in nature are limited, with these fast depleting resources, maximizing efficiency is very important. Most of the Industries face the severe problem of heat transfer enhancement of thermal systems on account of limited resources, confined space etc. In electronic industries the electronic devices are manufactured into smaller volumes and major problem arises due to this is how to dissipate the heat generated from these devices. Therefore there is an increased emphasis on maximizing heat transfer rate. The minimization of energy waste by increasing the effectiveness of heat transfer is a trending area of research. The conventional fluids used for heat transfer purpose have low thermal conductivity. The increase of heat transfer through extended surfaces has already reached its limit. Therefore, we need to look for alternatives to achieve our objective. Nanofluid is looks to fill this gap and have been the recent advancement to increase heat transfer. Fluids with nanoparticles (diameter less than 100 nm) suspended in conventional fluids are called Nanofluids. Proper dispersion of nanoparticles into base fluid forms stable Nanofluids this exhibits several beneficiary features. The introduction of few nanoparticles in the base fluid increases thermal conductivity of the base fluid significantly. Their enhanced thermal conductivity in-turn can improve the heat transfer rate and energy efficiency in various fields like defence, transportation, space, power generation etc

II. Nanofluid Preparation

The preparation of Nanofluid is the first step for experimental studies. Nano fluid consists of metals, carbides, oxides and carbon nano tubes well dispersed in conventional fluids. Researchers are studied and used a two-step process to produce nano-tubes via inert gas condensation process [1-2]. This process involves the vaporization of a source material under vacuum conditions. An advantage of this technique is that nanoparticle agglomeration is minimized. The disadvantage is that only low vapour pressure fluids are compatible with the process [3] and the pure metallic nano particles cannot be produced. The formation of such a problem can be reduced by using a direct evaporation condensation method [4-6]. This method produces stable Nanofluids without surfactants by regulating the size of particle. Alumina Nanofluids can be synthesised by laser ablation method [7]. Gold and silver Nanofluids can be produced by pure chemical synthesis [8]. Nanofluids with copper nano particles dispersed in ethylene glycol are prepared using one-step pure chemical synthesis method [9].

III. Nanofluid Heat Transfer Mechanism

The heat transfer mechanism is altered in the coolants by adding the Nanofluids. Importantly the thermal conductivity of the coolant is enhanced. The reasons for higher thermal coefficients in Nanofluids are brought out by Keblinski et al. [10]. The theories behind the enhancements are discussed in the following sections.

3.1. Brownian Motion of a Particle

In the Brownian motion of nanoparticles, particles move through liquid and collide, thereby enabling direct solid to solid transfer of heat. This is essential for thermal conductivity enhancement along with increase in temperature and decrease in nanoparticles sizes [11]. Based on the experimental study the Wang et al. [12] found that the microscopic forces such as Vander Walls force, electrostatic force and stochastic force are responsible for increase in the Brownian motion of particles, this result in enhancing the heat transfer rate. As mentioned in the Stokes-Einstein formula [13], the Brownian motion depends on the particle diffusion constant (D) and it is given in Eq. 1., where kB is Boltzmann constant, η is the fluid viscosity, d is particle diameter. This equation can be used to estimate the dependence of thermal conductivity on Brownian motion by comparing time scale of particle movement with that of heat diffusion in liquid and the time required to travel the distance is τD, given by Eq. (2). Time required for heat to travel in liquid by the distance is given by τH in Eq. (3) and mean free length is calculated using Eq. (4), where, is Gruneisen parameter, Tm is melting point and 'a' is the lattice constant. For Al2O3 as nanoparticle, Tm/T ≈7 this gives l ≈ 35 nm at room temperature

3.2. Molecular Layering of the Liquid-Particles Interface

An interface effect of liquid around the particles could enhance thermal conductivity. Also this helps to get more ordered atomic structure of liquid layer than that of the bulk liquid [10]. A liquid shell around the particles behaves like solids, this helps to achieve high thermal conductivity

3.3. Nature of Heat Transport in Nanoparticles

Macroscopic heat transport can be explained using phonons. These phonons are responsible for carrying heat in Nanofluids. These phonons are characterized by randomness in their creation and propagation this gets scattered by each other and results in enhanced heat transfer.

3.4. Nanoparticle Clustering in Nanofluids

Clustering of nano particles play a vital role in thermal conductivity. As the temperature increases, a well diffused percolated structure is formed. Clusters accumulate and form isolated regions at lower temperatures resulting in formation of disconnected cluster networks. This leads to formation of "particle free-zones" and "particle rich-zones" regions [14]. A well diffused thermal pathway at higher temperatures would promote heat transport; while isolated clusters would have inverse effect on heat transport at lower temperature. The variation of cluster formation with respect to temperature can be seen the Fig.1 [15].

Figure 1 Images containing CNT: (a) Frozen sample (b) at room temperature (c) at 100°C [15]

IV. Thermo-Physical Properties Of Nanofluids

The present day research in Nanofluids is mainly concentrated to study the changes in thermo-physical properties like thermal conductivity and viscosity caused by nanoparticles.

4.1. Thermal Conductivity

Thermal conductivity enhancement is the most sought after research area in the field of nanoparticle. Enhanced thermal conductivity is required in many applications and Nanofluids show a great potential in achieving that. It is function of many parameters like, volume concentration of nanofluid, particle material, particle size and temperature etc. The effect of these parameters is discussed in the following sections.

4.1.1. Effect of Volume Concentration

Thermal conductivity is measured initially with oxide nanoparticles [16, 17]. It is found that the copper nanoparticles increased thermal conductivity significantly [18]. Al2O3 as Nanofluid used in different applications resulted in increase of thermal conductivity upto 29% at 5 vol% Volume fraction of 2, 4 and 6 resulted in enhancement in heat transfer by 12.1%, 11.5% and 11% respectively. The enhancement of 30-45% was found, when 1 vol% of nanoparticles is added into pure water [20]. Non-linear relationship between particle concentration and thermal conductivity was found with Fe-ethylene glycol nanofluid [21]. Oxides of copper displayed high heat transfer coefficient for a higher volume fraction. Thermal Conductivity enhancement of 8%

and 6% was found at 0.4 vol% and 0.15% respectively [22]. Also reported that 37% enhancement occurred in 1% weigh. Therefore, higher volume fraction displayed higher thermal conductivity. Many other researchers reported that the thermal conductivity increases with increase of volume fraction of particles [23-25].

4.1.2. Effect of Particle Material

Particle material has an important role in deciding the thermal conductivity of the nanofluid. Even though the thermal conductivity of Al2O3 is higher than CuO nanoparticle, CuO nanoparticle causes more heat transfer than the Al2O3 nanoparticles [17]. It is understood that the enhancement of thermal conductivity is decided majorly by Brownian motion [26]. Since Al2O3 forms larger agglomerates than CuO, which is responsible for the diminishing of the Brownian motion.

4.1.3. Effect of Particle Geometry

Particle shape influences the thermal conductivity of Nanofluids [27] for SiC nanoparticles with spherical and cylindrical shape for water and ethylene glycol. The cylindrical particles of average diameter 600 nm exhibit the enhancement of 22.9% and spherical particles enhanced up to 15.8%. So, cylindrical nanoparticles give higher enhancement in thermal conductivity than spherical nanoparticles. Stability of Nanofluids can be increased by functionalization and also the length of CNT is an important factor in enhancement of thermal conductivity [28].

4.1.4. Effect of Temperature

Temperature plays an important role in determining the thermal conductivity of nanofluid. Temperature dependence of nanofluid is attributed to the change in Brownian movement and clustering with change in temperature [29]. Enhancement of thermal conductivity is governed mainly by two factors namely Brownian motion and thermal carriers inside the particles [30]. Hussein et al. [31] reported that if the inlet temperature of SiO2 is changed from 60°C-80°C, heat transfer was enhanced by 39% to 56% respectively. The introduction of small amount of nanoparticles to the base fluid in liquid cooling system caused a significant decrease in operating temperature of processor [32]. If the inlet temperature of coolant to automobile is varied from 37-49 °C for 1 vol%, the heat transfer coefficient gone up by 7% [20, 33]. Thermal conductivity increment with temperature is reported using the coolant, CuO-water nanofluid [34] and Al2O3-water nanofluid [35].

4.2. Viscosity

Viscosity is an important parameter for heat transfer in Nanofluids. This is due to the fact that pressure drop directly depends on viscosity. The increase in viscosity leads to increase in pressure drop leads to increase in pumping power. Viscosity highly depends on factors such as volume fraction, particle size and temperature. The internal resistance force offered by the fluid is called viscosity and it is an important factor for all heat transfer application [36]. Many studies have been reported for effect of viscosity on heat transfer and it is discussed in the following sections.

4.2.1. Effect of Volume Fraction

Lu and Fan [37] studied the effect that the volume fraction of Al2O3 had on the shear viscosity of water and ethylene glycol Nanofluids. The result concluded that viscosity of pure ethylene glycol and mixture is less than that of the mixture. The shear viscosity increases upon addition of larger amounts of nanoparticles to the pure fluid. Similar results were reported for shear viscosity of gold-water nanofluid [38]. Prasher et al. [39] stated that the viscosity enhancement and amount of particles are directly proportional and viscosity is found to be higher around ten times that of base fluid. Increase of viscosity ratio is more for water based nanofluid as compared to ethylene glycol based nanofluid [40]. A contrary statement for the viscosity variation with volume fraction was reported for ethanol based SiO2 nanofluid [41]. In general, it is accepted that the viscosity of nanofluid enhances with increasing volume fraction.

4.2.2. Effect of Particle Size

On comparing the viscosity of SiO2 nanofluid of different particle diameter (20, 50, and 100 nm), it was concluded that greater viscosity was obtained from smaller diameter sized nanofluid for the same volume concentration because the quantity of particles was more along with the total surface area [42]. A lower viscosity is preferred since it would facilitate the Brownian motion of the nanofluid. The above trend is also noticeable in Al2O3-water and CuO-water Nanofluids [40, 43]. Some contrary results were also reported and it was noted that the viscosity of the nanofluid was less with smaller sized nanoparticle [36, 44]. A similar trend was followed by TiO2-water nanofluid too [45]. It can be concluded that the Nanofluid viscosity would increase depending upon the material used for nanoparticle.

4.2.3. Effect of Temperature

Most of the studies reported that the decrease in viscosity results increase in temperature. Water based Al2O3 and CuO nanofluid displayed this trend while increasing the temperature from 21°C to 75°C [40, 43]. Water based TiO2 and SiC Nanofluids also had the same trend of decreasing viscosity with increase in temperature [43, 46, and 47]. Some contradictory results were reported for water based carbon nanotubes. Some studies also concluded that the viscosity may be independent of temperature in the case of nanofluid [39, 48, 49]. Further studies are required involving many nano materials to ascertain the effect of temperature on Nanofluid.

V. Conclusion

Present study is a comprehensive review of Nanofluid heat transfer mechanism and thermo-physical properties. The Nanofluid preparation techniques, heat transfer mechanism and thermo-physical properties are discussed in detail. Metal oxides nanoparticles had a great effect in heat transfer enhancement of the nanofluid. Liquid layering and Brownian motion plays a major role in the mechanism of heat transfer. The major conclusions of this study are as follows
The coolants have high thermal conductivities at low volume concentration of Nanofluid.

Nanofluids' thermal conductivity and viscosity greatly depend on their size, volume concentration, shape and material.
Nanofluid viscosity may increase or decrease depending upon the material of nanoparticle on lowering the size.
Viscosity of nanofluid increases with increase in volume fraction of nanoparticle.
Further experimental studies are needs to be carried out involving many nano materials to ascertain the effect of temperature on Nanofluid.

Nomenclature

k_B	Boltzmann Constant
D	Particle Diffusion Constant
d	Particle Diameter
T	Temperature
l	Mean free path
C_p	Specific Heat
T_m	Melting Point
ρ	Density
η	Viscosity
χ	Thermoelectric Conductivity
a	Lattice Constant
γ	Gruneisen parameter

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