Analysis Of Heat Transfer Coefficient Of Nano Fluids

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ABSTRACT

Conventional fluids such as water, ethylene glycol are normally used as heat transfer fluids. They play an important role in many industry sectors including power generation, chemical production, air-conditioning transportation and microelectronics. Various techniques are applied to enhance the heat transfer; the low heat transfer performance of these conventional fluids obstructs the performance enhancement and the compactness of heat exchangers. The use of solid particles as an additive suspended into the base fluid is a technique for heat transfer enhancement. Improving of the thermal conductivity is a key idea to improve the heat transfer characteristics of conventional fluids. Since a solid metal have large thermal conductivity than a base fluid, suspending metallic solid fine particles into the base fluid is expected to improve the thermal conductivity of that fluid. The enhancement of thermal conductivity of conventional fluids by the suspension of solid particles, such a millimeter or micrometer-sized particles has been well known for more than 100 years. However they have not been of interest for practical applications due to problems such as sedimentation, erosion, and fouling and increased pressure drop of the flow channel. The recent advance in materials technology has made it possible to produce nanometer sizes particles that can overcome these problems.

Keywords: Nano particles,Thermal conductivity, viscosity, specific heat and velocity.

LIST OF SYMBOLS

Symbol	Description	Unit
Nomenclature		
A	Cross sectional area	m^2
C_p	Specific heat	J/Kg k
D	Diameter	m
h	Heat transfer coefficient	$w/m^2 k$
K_L	Thermal conductivity of base fluid	w/m k
K_s	Thermal conductivity of nanoparticle	w/m k
m	Mass flow rate	Kg/s
T	Temperature	° C
v	Velocity	m/s
n_f	Nanofluid	
Greek symbols		
ϕ_S	Mass fraction	
ρ_f	Density of fluid	Kg/m^3
ρ_p	Density of nanoparticle	Kg/m^3
μ	Dynamic viscosity	Kg/ms
ψ	Sphericity	
Abbreviation		
CFD	computational fluid dynamics	
CFX	Tonne of refrigeration	
Al_2O_3	Aluminium di oxide	
CuO	Cupper oxide	
ZrO_2	Zinc oxide	
SiO_2	Silica oxide	

1.INTRODUCTION

In nano technology, a particle is defined as a small object that behaves as a whole unit in terms of its transport and properties. It is further classified according to size: In terms of diameter, fine particles cover a range between 100 and 2500 nanometers, while ultra fine particles, on the other hand, are sized between 1 and 100 nanometers. Similarly to ultra fine particles, nanoparticles are sized between 1 and 100 nanometers, though the size limitation can be restricted to two dimensions. Nanoparticles may or may not exhibit size-related properties that differ significantly from those observed in fine particles or bulk materials. This suspended nano particles can change the transport and the thermal properties of the base fluid. A recent development is that nanoparticles can disperse in conventional heat transfer fluids such as water, glycol or oil to produce a new class of high efficiency heat exchange media. The superior properties of nano particle fluid mixtures relative to those of fluids without particle or with large sized particle include high thermal conductivities, stability and prevention of clogging in micro channels. A liquid suspended with particles of nanometer dimension is termed a nanofluid.

Nano fluids have novel properties that make them potentially useful in many application in heat transfer, including micro electronics fuel cells, pharmaceutical processes, hybrid powered engines, engine cooling /vehicle thermal management, domestic refrigerator chiller, heat exchanger, nuclear reactor coolant in grinding, machining, in space technology , defense and ships and in boiler flue gas temperature requisition they exhibit enhanced thermal conductivity and convective heat transfer coefficient compared to the base fluid.

In analysis such as computational fluid dynamics (CFD), nanofluids can be assumed to be a single phase fluid, classical theory of single fluids can be applied, where physical properties of nanofluid is taken as a function of properties of both constituent and their concentrations.

There are many different types of nanofluids that can be made by using different nano particles and base fluid combinations. Some of the most common nanoparticles used are Alumina Oxide (Al_2O_3), Copper Oxide (CuO), Zinc Oxide (ZrO_2), and Silica Oxide (SiO_2), silver, copper. The most common base fluids used for nanofluids are de-ionized water, oil and ethylene glycol.

Heat transfer enhancement is an active and important field of engineering research. Based upon the research three possible mechanisms proposed for heat transfer enhancement. They are decreasing the thermal boundary layer, increasing the flow interruptions and increasing the velocity gradient near the heated surface. The addition of small particles to the fluid can sometimes provide heat transfer enhancement. However the works in this area provide the suspension of micro to macro size particles bear the following major disadvantages.

- The particles settle rapidly, forming layer on the surface and reducing the heat transfer capacity of the fluid.
- If the circulation rate of the fluid is increased sedimentation is reduced by the illusion of the heat transfer devices, pipe lines etc. increase rapidly.
- The large size of the particles tends to clog the flow channels particularly if the cooling channels are narrow.
- The pressure drop in the fluid increase considerably

Therefore the route of suspending particle liquid was well known but rejected option for heat transfer enhancement. To enhance the heat transfer rate of conventional fluids the following techniques such as active techniques and passive techniques are used. Active technique means use of external energy sources to actively alter the flow where as passive technique means they do not require additional energy to modify the flow. The suspended nano particles in the conventional fluids called nano fluids. The attractive features that made nano particles suspension in fluids are a large surface area, high mobility; the nano sized particles are properly dispersed. The nanoparticles commonly used for heat transfer enhancement are aluminum oxide, aluminum, copper, copper oxide, silver etc.

2. LITERATURE SURVEY

Many researches are carried out to improve the heat transfer rate of base fluids using nano fluids.VisineeTrisakri[1] shows the use of additives is a technique applied to enhance the heat transfer performance of base fluids. Recently as an innovative material, nanometer-sized particles have been used in suspension in conventional heat transfer fluids. The suspended metallic or nonmetallic nanoparticles change the transport properties and heat transfer characteristics of base fluid. Eastman Et.Al [2] showed that 10mm copper particles in ethylene glycol could enhance the conductivity by 40% with small particle loading fraction. With cupric oxide the enhancement was 20% for a volume fraction of 4%. These results clearly show the effect of particle size on the conductivity enhancement.Das Et.Al [3] measured the conductivities of alumina and cupric oxide at different temperature ranging from 20^0C to 50^0C and found linear increase in the conductivity ratio with temperature. However the same load fraction the ratio of increase was higher for cupric oxide than alumina.Lee et al.[4] (1999) reported a substantial enhancement of thermal conductivity of water and ethylene glycol based nano- fluids with Al_2O_3 or CuOnano-particles at room temperature. In a recent study (Das et al., 2001) the present authors have shown that the enhancement of thermal conductivity of nano-fluids increases even more at elevated temperature which makes it more attractive for cooling at high heat flux applications[3]. This enhancement of thermal conductivity received an impressive breakthrough when Eastman et al. (2001) reported an increase of thermal conductivity by an outstanding 40% with only 0.04% of nano-particles of pure copper having average size less than 10 nm.[2] The above works indicate that usual theories of thermal conductivity of suspensions such as the Hamilton and Crosser (1962) model fail in case of nano- fluids. Pak andCho [5] studied the heat transfer performance of Al_2O_3 and TiO_2nano particles suspended in water and expressed that convective heat transfer coefficient is 12% smaller than that of pure water at 3% volume fraction.

Yulong Ding[6] concludes that at given particle concentration and flow conditions aqueous based carbon nano tube nanofluids gives the highest enhancement of convective heat transfer coefficient followed by aqueous based titanianano fluids, aqueous based alumina nano fluids and aqueous based nano-diamond nano fluids. For aqueous-based titania and titanate and carbon nanotube nanofluids the convective heat transfer co-efficient generally increases with increasing flow rate or increasing particle concentration and the enhancement exceeds by a large margin the extent of thermal conduction enhancement indicating that thermal conduction enhancement is not the dominant mechanism for the convective heat transfer enhancement. For titaniananofluids we found no clear trend in the effect of particle size on the convective heat transfer co-efficient for particles between 95 and 210nm. Eden mamut[7] shows simple empirical correlation to predict thermal conductivity of Al_2O_3 + H_2O, Al_2O_3 + ethylene glycol, Cu+ H_2O, CuO+ H_2O, TiO_2+ H_2O and TiO_2 + ethylene glycol nano fluid mixtures considering the effect of temperature, volume fraction and particle size is presented and good agreement with experimental results. Wen.d. And ding.y.[8] shows Laminar heat transfer in the entrance region of a tube flow that was using alumina water nano fluids was the focus of the work; viscosity of nano fluid was not measured and was assumed to follow the Einstein equation. For nano fluids that contained 1.6% nano particles by volume, the local heat transfer coefficient at the entrance region was 41% higher than at the base fluid with same flow rate. So it was observed that the enhancement is particularly significant in the entrance region and decreases with axial distance. The thermal developing length of nano fluids was greater than that of the pure base liquid and increased with an increase in particular concentration.

3. PROPERTIES OF NANOFLUIDS

3.1 Thermophysical Properties Of Nanoparticles And Base Fluids

The thermal conductivity measurement of nanofluids was the main focus in the early stages of nanofluidresearch[9]. Recently studies have been carried out on the heat transfer coefficient of nano fluids in natural and forced flow. Most studies carried out to date are limited to the thermal characterization of nanofluids without phase change. However, nanoparticles in nanofluids play a vital role in two-phase heat transfer systems and there is a great need to characterize nanofluids in boiling and condensation heat transfer. In any case the heat transfer coefficient depends not only on the thermal conductivity but also on the other properties such as the specific heat, density and dynamic viscosity of a nanofluid. The thermo physical properties of nano particles are listed in the table 1 and thermo physical properties of the base fluids are listed in table 2.

Table 1- Properties of nano particles

Property	**Aluminum oxide**	**Aluminum**	**Copper**	**Copper oxide**	**Silver**
Thermal conductivity (K_S)W/mK	40	237	400	20	429
Density (ρ_p)kg/m^3	3970	2710	8933	6500	10500
Specific heat (C_P) J/kg K	765	900	385	535.6	234

Table 2-Properties of base fluids

S.No	Property	Water	Ethylene glycol
1	Thermal conductivity (K_L)W/mK	0.605	0.252
2	Density (ρ_f)kg/m^3	997.1	1111
3	Specific heat (C_f)J/kgK	4179	2415
4	Dynamic viscosity (μ_0) Kg/m^3	0.001003	0.0157

3.2 Density Of Nano Fluid

The density of a nano fluid can be calculated by using the mass balance as:

$$\rho_{nf}= (1-\phi_S)\, \rho_{f}+ \phi_S\rho_p \text{----------------} \quad (3.1)$$

For typical nanofluids with nanoparticles at a value of volume fraction less than 1%, a change of less than 5% in the fluid density is expected.

3.3 Specific Heat Of Nano Fluids

The specific heat of nanofluids can be calculated by using mass balance as:[10]

$$C_{nf} = \frac{(1-\phi_S)\rho_f C_f+ \phi_S\rho_p C_P}{\rho_{nf}} \quad \text{--------} \; (3.2)$$

Using the above equation one can predict that small decreases in specific heat will typically result when solid particles are dispersed in liquids.

3.4 Dynamic Viscosity Of Nano Fluids

The effective dynamic viscosity of nano fluids can be calculated using different existing formulas that have been obtained for two-phase mixtures. It can be calculated as:

$$\mu = \mu_0 (123\ \phi_S^2 + 7.3\phi_S + 1) \text{ -------------- (3.3)}$$

3.5 Thermal Conductivity Of Nano Fluids

Many theoretical and empirical models have been proposed to predict the effective thermal conductivity of nanofluids. The commonly used models are listed below with their formulas:

3.5.1 Maxwell Model

$$K = K_L \frac{K_S + 2K_L + 2(K_S - K_L)\phi_S}{K_S + 2K_L - (K_S - K_L)\phi_S} \text{ -------- (3.4)}$$

3.5.2 Hamilton And Crosser Model

$$K = K_L \frac{K_S + (n-1)K_L - (n-1)(K_L - K_S)\phi_S}{K_S + (n-1)K_f + (K_L - K_S)\phi_S} \text{ -------- (3.5)}$$

Where n depends on particle shape and K_S/K_L, $n = 3/\psi$ for $K_S/K_L>100$, n=3 for other cases

3.5.3 Jeffrey Model

$$K_{eff} = 1+3\phi_S\frac{(K_S/K_L-1)}{K_S/K_L+2}+3\phi^2_S\frac{(K_S/K_L-1)^2}{K_S/K_L+2}\left[1+\frac{1(K_S/K_L-1)}{4(K_S/K_L+2)}+\frac{3(K_S/K_L-1)(K_S/K_L+2)}{16(K_S/K_L+2)(2K_S/K_L+3)}\right] \text{ ------- (3.6)}$$

3.5.4 Davis Model

$$K = K_L * 1 + \frac{3*(K_S/K_L-1)[\phi_S + f.\ \phi^2_S + O(\phi^3_S)]}{(K_S/K_L+2) - ((K_S/K_L-1)\phi_s} \text{ ---------(3.7)}$$

3.5.5 Bruggeman Model

$$K = K_L * [(3\phi_S-1) *(K_S/K_f) + [2-3\phi_s)+\Delta^{0.5}]]/4 \text{ -----------------(3.8)}$$

$$\Delta = ((3\phi_S-1)^2(K_S/K_L)^2 + (2-3\phi^2_s)+2*(2+9\phi_s - 9\phi^2_s)(K_S/K_L) \text{ ------(3.9)}$$

3.5.6 Suresh Model

$$\frac{K_{nf}}{K} = \frac{K_S+(n-1)K+(n-1)(1+\beta)^3\phi(K_S-K)}{K_S+(n-1)K-(1+\beta)^3\phi(K_S-K)} + C\frac{\phi(T-T_o)}{\mu K\alpha^4} \text{ ---(3.10)}$$

Using the formula in equation 2.4 to 2.10 the thermal conductivity is calculated for nanoparticles percentages from one to thirty for all the six models. In the below charts the thermal conductivity of nano fluids is listed i.e. the combinations of a) aluminum +water (Nano fluid) b) aluminum oxide + water (Nano fluid) c) copper + water (Nano fluid) d) copper oxide + water (Nano fluid) e) silver + water (Nano fluid). Similarly the thermal conductivity of nano fluids i.e. the combinations of a) aluminum + ethylene glycol (Nano fluid) b) aluminum oxide + ethylene glycol (Nano fluid) c) copper + ethylene glycol (Nano fluid) d) copper oxide + ethylene glycol (Nano fluid) e) silver + ethylene glycol (Nano fluid). The thermal conductivity is found for all the six models. In figure 1 -10 shows the thermal conductivity of the six thermal conductivity model and its comparison.

3.6. Thermal Conductivity Of Nano Fluids

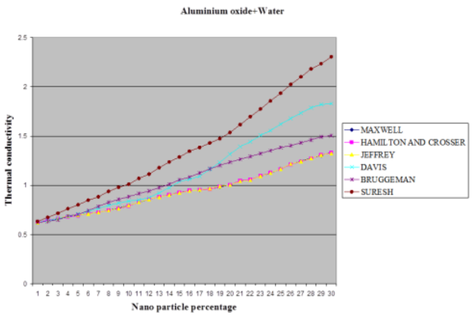

Fig. 1 Aluminium Oxide with water.

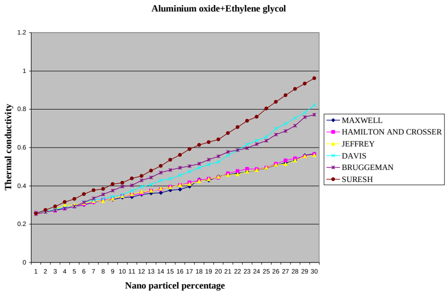

Fig.2 Aluminium oxide with Ethylene glycol

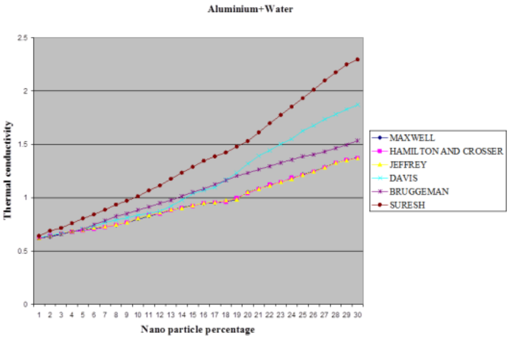

Fig. 3 Aluminium with water.

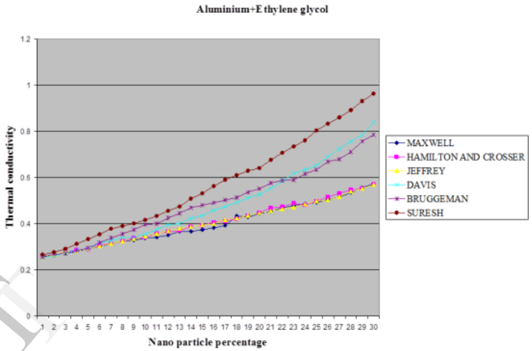

Fig.4 Aluminium with Ethylene glycol

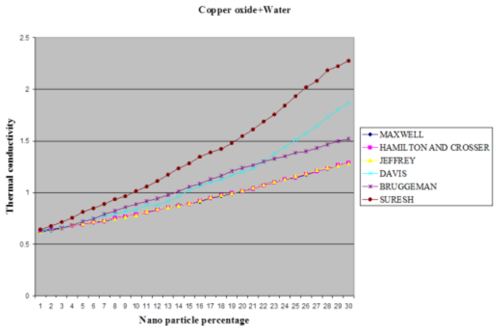

Fig. 5 Copper Oxide with water.

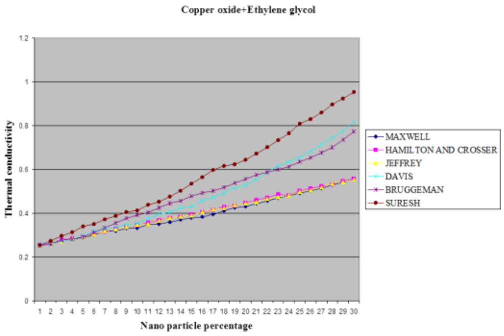

Fig.6 Copper oxide with Ethylene glycol

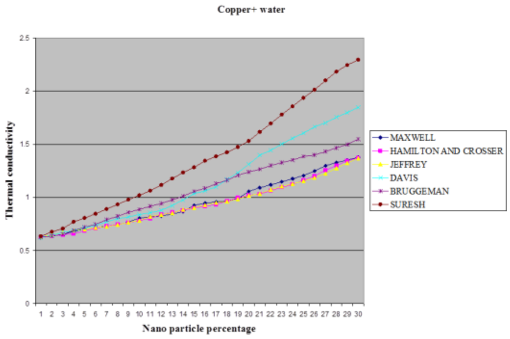

Fig. 7 Copper with water.

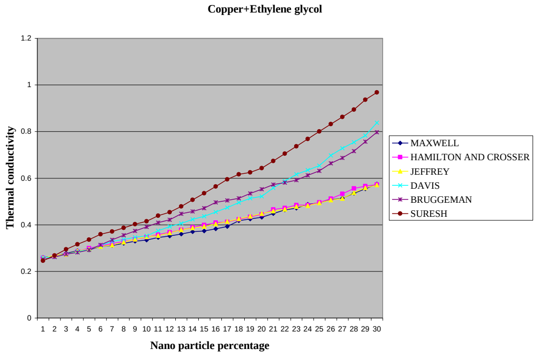

Fig.8 Copper with Ethylene glycol

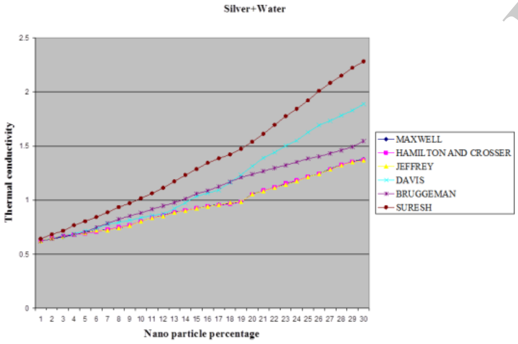

Fig. 9 Silver with water.

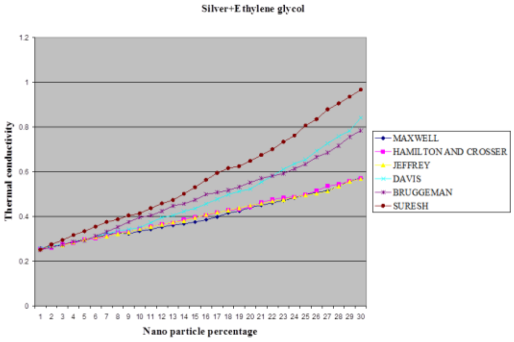

Fig.10 Silver with Ethylene glycol

Nano fluids containing small amounts of nano particles have substantially higher thermal conductivity than those of base fluids. The thermal conductivity enhancement of nano fluids depends on the particle volume fraction, size and shape of nano particles, type of base fluid and nano particles, PH value of nano fluids and type of particle coating. It is still not clear which is the best model to use for the thermal conductivity of nano fluids. From the above graphs and tables it is well find out that Maxwell model shows some regular variations compared to other models. Suresh and Davis model shows higher thermal conductivity values whereas Suresh model shows large thermal conductivity value than all other models. Bruggeman model gives somewhat higher thermal conductivity models compare to Suresh and Davis model. Hamilton and crosser model gives some closer values to the Jeffrey model. So comparing all these models we take Maxwell model for finding thermal conductivity of nanofluids for the present work.

4.EXPERIMENTAL PROCEDURE

In this project the two base fluids are selected namely water and ethylene glycol. To enhance the heat transfer rate of the above said base fluids the nano particles of Aluminum, Aluminum oxide, copper, copper oxide and silver were chosen. The properties of the nano fluids are calculated by formulas. The thermo physical properties of water, ethylene glycol, Aluminum, Aluminum oxide, copper, copper oxide and silver are tabulated and it is substituted in the formulas for finding the properties of nanofluids. In order to analyze the heat transfer rate of the base fluid and nanofluid CFX software is used. The nano fluids and the base fluids are analyzed under the same Reynolds number. And also a comparative work is done between the thermal conductivity models namely Maxwell, Hamilton and Crosser, Jeffrey, Davis, Bruggeman and Suresh models.

4.1. Nano Fluids And Its Preparation

The superior properties of nano particle fluid mixtures relative to those of fluids without particle or with large sized particle include high thermal conductivities, stability and prevention of clogging in micro channels. A liquid suspended with particles of nanometer dimension is termed a nanofluid. The nanoparticles used to produce nanofluids are aluminum oxide, aluminum, copper, copper oxide and silver. Nanoparticles can be produced from several processes such as gas condensation, mechanical attrition or chemical precipitation techniques. Gas condensation processing has an advantage over other techniques. This is because the particles can be produced under cleaner conditions and its surface can be avoided from the undesirable coatings. However the particles produced by this technique occur with some agglomeration, which can be broken up with smaller clusters by supplying a small amount of energy. The preparation of nanofluid begins by direct mixing of the base fluid with nanoparticles. The delicate preparation of a nanofluid is important because nanofluids need special requirements such as an even suspension, durable suspension, stable suspension, low agglomeration of particles and no chemical change of the fluid. The reason for using nano fluids are when the nano-sized particles are properly dispersed nano fluids are expected to give many advantages. Higher heat conduction is a major advantage of nanofluids as the large surface area of nano particles allow for more heat transfer. Particles finer than 20nm carry 20% of their atoms on their surface making then instantaneously available for thermal interaction and also stability is another benefit of nano fluid as the particles are small, they weigh less and their chances of sedimentation are also less. This reduced sedimentation can overcome one of the major draw backs of suspensions, the setting particles and make the nano fluids more stable.

4.2. Modelling Procedure And Meshing

We have considered the problem of forced convection flow of fluid inside a uniformly heated tube that is submitted to a constant and uniform heat flux at the wall. The modeling section chosen for the project work is a uniform heated tube of diameter 211mm and length 217mm. The modeling work is done in ANSYS WORKBENCH 11.0 software.

The ANSYS Workbench platform is the framework upon which the industry's broadest and deepest suite of advanced engineering simulation technology is built. An innovative project schematic view ties together the entire simulation process, guiding the user through even complex multiphysics analyses with drag-and-drop simplicity. With bi-directional CAD connectivity, an automated project level update mechanism, pervasive parameter management and integrated optimization tools, the ANSYS Workbench Platform delivers unprecedented productivity, enabling Simulation Driven Product Development.

4.3. CFX Analysis

In this analytical work we have considered the problem of forced convection flow of liquid inside a uniformly heated tube that is submitted to a constant and uniform heat flux at the wall. The modeling of the heated pipe is completed in ANSYS WORKBENCH 11.0 software and it is discussed in the chapter 3. The heat transfer rates are analyzed for both the base fluids and the nanofluids under the same Reynolds number and uniform heat flux in the uniform heated pipe and the analytical work is dine in CFX11.0 software.

4.3.1 Sample Calculation For Finding Velocity (For Water)

The velocity is given as input parameter in the material properties in the CFX 11.0 properties. The heat transfer co-efficient was analyzed for base fluids and the nanofluids under the same Reynolds number

10000. A sample calculation is given for finding the velocity of water. Similarly the velocity of ethylene glycol and the nanofluids are found and given as input parameters in the material properties during their analytical work.

Reynolds number $Re = \frac{ud\rho}{\mu}$

Reynolds number Re = 10000
Diameter d = 0.211m
Density ρ = 997.1 kg/m^3 (Density of water)
Dynamic viscosity μ = 0.001003 kg/ms (Dynamic viscosity of water)

Therefore Velocity $u = Re\mu / d\rho$
$= 0.047675$ m/s

4.3.2Sample Calculation For Finding Heat Transfer Co-Efficient (For Water)

A sample calculation is given for finding the heat transfer co-efficient of water. Similarly the heat transfer co-efficient of ethylene glycol and the nanofluids are found and are tabulated in the chapter 5.Heat transfer co-efficient $U = Q/A.\Delta T$

Heat flux = 70 kW
Area = 0.0992 m^2
Inlet temperature = 40°C
Outlet temperature = 40.0222°C (Result obtained from CFX)
Temperature difference = 40.0222-40
= 0.0222 k
Heat transfer co-efficient
U= 31785.81 kW/ (m^2.K)

4.4. FLUENT Analysis

In this analytical work we have considered the problem of forced convection flow of liquid inside a uniformly heated tube that is submitted to a constant and uniform heat flux at the wall. The modeling of the heated pipe is completed in CAMBIT 2.3.16 software and it is discussed in the chapter 3. The heat transfer rates are analyzed for both the base fluids and the nano fluids under the same Reynolds number and uniform heat flux in the uniform heated pipe and the analytical work is dine in Fluent software.This section provides an overview of flow boundaries in FLUENT and how to use them. FLUENT provides 10 types of boundary zone types for the specification of flow inlets and exits: velocity inlet, pressure inlet, mass flow inlet, pressure outlet, pressure far-field, outflow, inlet vent, intake fan, outlet vent, and exhaust fan.

The inlet and exit boundary condition options in FLUENT are as follows:

- Velocity inlet boundary conditions are used to define the velocity and scalar properties of the flow at inlet boundaries.
- Pressure inlet boundary conditions are used to define the total pressure and other scalar quantities at flow inlets.
- Mass flow inlet boundary conditions are used in compressible flows to prescribe a mass flow rate at an inlet. It is not necessary to use mass flow inlets in incompressible flows because when density is constant, velocity inlet boundary conditions will fix the mass flow.

5. RESULTS AND DISCUSSION

5.1. Heattransfer co-efficient at 40^0c (water with nanoparticles and ethyleneglycol with nanoparticle)

Heat transfer co-efficient of water (At 40^0C) = 483.0633 kW/ (m^2.K).The results obtained in the Fluent 6.2 software for the heat transfer coefficient of combinations of water with nanoparticles at 40^0C comparison is shown in figure 11.Heat transfer co-efficient of ethylene glycol (At 40^0C)=202.8903 kw/(m^2.K).The results obtained in the Fluent 6.2 software for the heat transfer coefficient of combinations of ethylene glycol with nanoparticles at 40^0C is shown in figure 12.

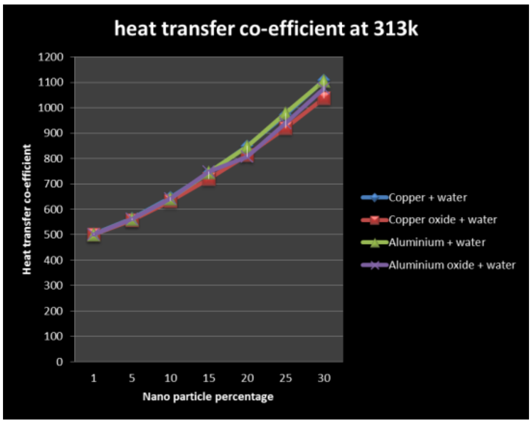

Fig. 11-Heat transfer co-efficient at40^{0}C(water with nano particles)

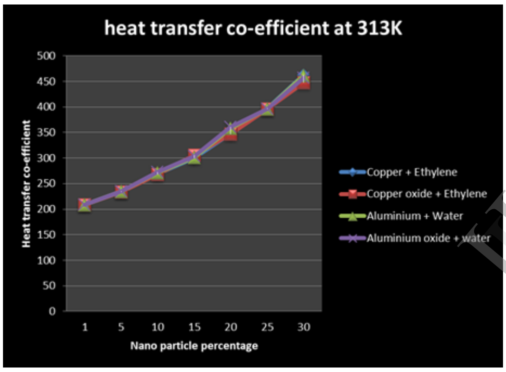

Fig. 12Heat transfer co-efficient at40^{0}C (ethylene glycol with nano particles)

5.2 Heat transfer co-efficient at 50^{0}C (water with nanoparticles and ethylene glycol with nanoparticle)

Heat transfer co-efficient of water (At 50^{0}C) = 313.834 kW/ (m^2.K).The results obtained in the Fluent 6.2 software for the heat transfer coefficient of combinations of water with nanoparticles at 50^{0}Cis shown in figure 13.

Heat transfer co-efficient of ethylene glycol (At 50^{0}C)= 144.655 kw/(m^2.K).The results obtained in the Fluent 6.2 software for the heat transfer coefficient of combinations of ethylene glycol with nanoparticles at 50^{0}Cis shown in figure 14.

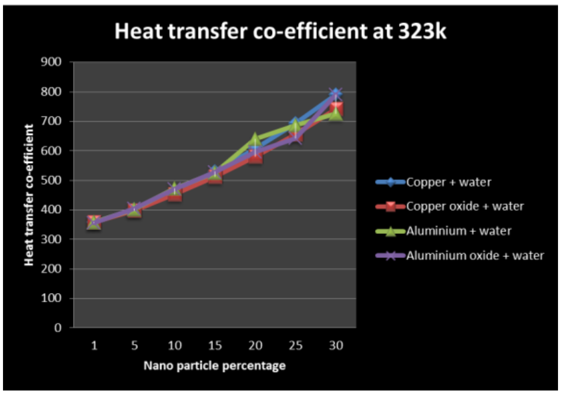

Fig. 13-Heat transfer co-efficient at 50^{0}C(water with nano particles)

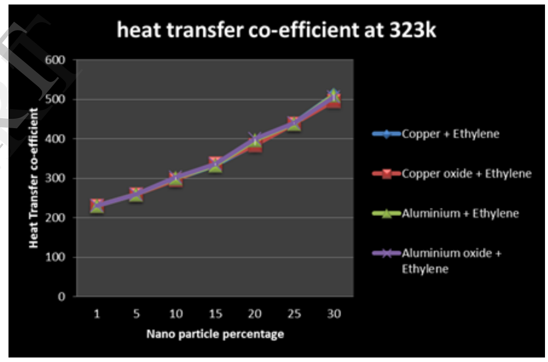

Fig. 14Heat transfer co-efficient at 50^{0}C (ethylene glycol with nano particles)

5.3 Heat transfer co-efficient at 60^{0}C (water with nanoparticles and ethylene glycol with nanoparticle)

Heat transfer co-efficient of Water (At 60^{0}C) = 535.2048 kW/ (m^2.K).The results obtained in the Fluent 6.2 software for the heat transfer coefficient of combinations of water with nanoparticles at 60^{0}C is shown in figure 15.

Heat transfer co-efficient of ethylene glycol (At 60^{0}C)= 224.7901 kw/(m^2.K).The results obtained in the Fluent 6.2 software for the heat transfer coefficient of combinations of ethylene glycol with nanoparticles at 60^{0}Cis shown in figure 16.

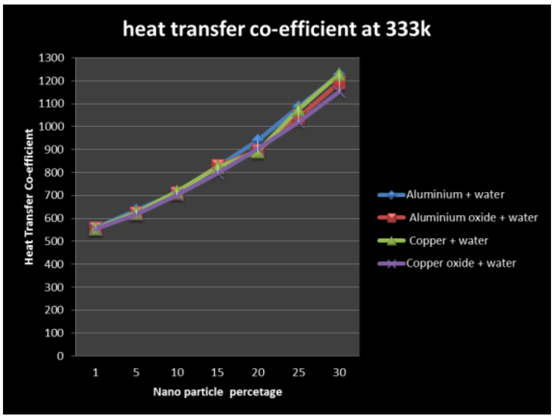

Fig. 15-Heat transfer co-efficient at 60^0C(water with nano particles)

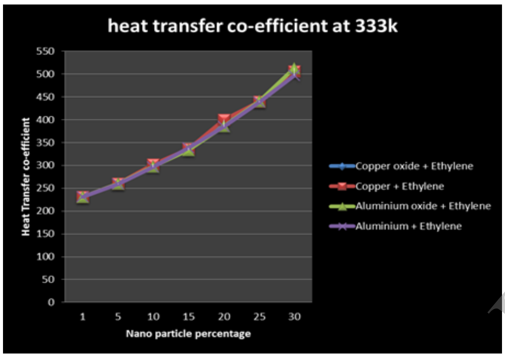

Fig. 16Heat transfer co-efficient at 60^0C (ethylene glycol with nano particles)

The heat transfer coefficient of water at 40^0C, 50^0Cand 60^0C. From figure 11-16t is clearly shows that the nanofluids (i.e.) nanoparticles of aluminum, aluminum oxide, copperand copper oxide with water shows that increased heat transfer coefficient than the water in all percentages.. The heat transfer coefficient of ethylene glycol at 40^0C,50^0 C and 60^0C,fromfigure11- 16 it is clearly shows that the nanofluids (i.e.) nanoparticles of aluminum, aluminum oxide, copper,and copper oxide with ethylene glycol shows that increased heat transfer coefficient than the ethylene glycol in all percentages..

6. CONCLUSION

The convective heat transfer features of,

a. Water (Base fluid)
b. Ethylene glycol (Base fluid)
c. Water + Nano particles of Aluminum(Nano fluid)
d. Water + Nano particles ofAluminum oxide (Nano fluid)
e. Water + Nano particles of Copper (Nano fluid)
f. Water + Nano particles of Copper oxide (Nano fluid)
g. Water + Nano particles of Silver(Nano fluid)
h. Ethylene glycol + Nano particles ofAluminum (Nano fluid)
i. Ethylene glycol + Nano particles ofAluminum oxide (Nano fluid)
j. Ethylene glycol + Nano particles of Copper (Nano fluid)
k. Ethylene glycol + Nano particles of Copper oxide (Nano fluid)
l. Ethylene glycol + Nano particles ofSilver(Nano fluid)

in a uniform heated tube were analyzed at temperatures 40^0C, 50^0C and 60^0C. The results shows that the nano fluids have large heat transfer co-efficient than the original base fluids under the same Reynolds number. The suspended nano particles remarkably increased the forced convective heat transfer performance of the base fluid. At the same Reynolds number the heat transfer of the nano fluid increased with the particle volume fraction.

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