Computational Heat Transfer Analysis of Forced Convection For Nanofluiid In A Compact Pipe

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Abstract- *The Current need for Heat transfer using forced convection is growing day by day since the use Heat is used rapidly in many industrial applications like power generation , Food processing Aerospace and defense the vast research by engineers now a days is increasing , Such is research is carried out in this thesis to investigate the Forced convection in a pipe using different Nano fluids like Al2O3 (aluminum trioxide) , CUO (Copper Oxide) , Sio2 (silicon Dioxide) with the Particle concentration mixed with the water where in this project we have simulated the Heat transfer conditions Between the pipe and the Nano Fluid at different particle concentration. For mass concentration of 1% , 2% , 3%, 4% Respectively for Al2o3 Cuo and Sio2 to Determine the Change in Temperature from inlet to outlet to determine the Better source for forced convection rather than the conventional techniques. This total project is Carried out using Computational Fluid dynamics with commercial cfd packages.*

Keywords- CFD , Forced Convection , Nano Fluid.

I. INTRODUCTION

Fluids of various kinds are generally utilized as heat bearers in heat transfer applications. Such applications where heat transfer fluids (HTF) have an imperative job are heat trading frameworks in power stations , cooling and heating frameworks in structures , vehicles cooling (AC) framework in transportations and cooling frameworks of the vast majority of the preparing plants . In the majority of the previously mentioned applications, the HTF's warm conductivity impacts the productivity of the heat transfer process and with it the general effectiveness of the framework. For such reason, specialists have persistently dealt with creating progressed HTFs that have altogether higher warm conductivities than traditionally utilized fluids .

Significant endeavors were made on heat transfer upgrade through geometrical change up to now yet were altogether compelled by the low warm conductivity of the heat transfer fluids utilized. In any case, in 1995, Choi built up a recently imaginative class of heat transfer fluids that relies upon suspending nanoscale particles of metallic inception with a normal molecule size of under 100 nm into customary heat transfer fluids and gave such sort of fluids the expression "nanofluids" . At the end of the day, the term nanofluid is utilized to portray a blend containing nanoscale particles of normal size under 100 nm with any base liquid that does not disintegrate the particles facilitated by it.The idea of dispersing solids in fluids was first proposed by Maxwell via his theoretical work more than 120 years ago [. It was later used to disperse mm and/or μm sized particles in fluids by Ahuja in 1975, Liu et al. in 1988, and researchers at Argonne National Laboratory (ANL) in 1992 [. Their work depended on the high thermal conductivity of metals at room temperature compared to fluids (i.e., order of magnitude higher in thermal conductivity). For instance, at room temperature, copper has a thermal conductivity 3000 and 700 times greater than that of an engine oil and water, respectively. The same difference in thermal conductivity cohabits between liquids, since metallic liquids have much higher thermal conductivity than nonmetallic ones. illustrates the thermal conductivities of different organic materials, heat transfer fluids, metals, and metal oxides. Therefore, by suspending metallic particles in a fluid, its thermal conductivity is expected to be enhanced.

II. LITERATURE REVIEW

Bianco et al. [1] detailed an investigation dependent on the second law of thermodynamics connected to a water-Al2O3 nanofluid in violent convection inside a round cylinder exposed to steady divider temperature. It was discovered that the considered channel condition impacts the distinctive systems and the measure of entropy age. Specifically, at a consistent Reynolds number, there is an expansion of entropy age, while at a steady mass stream rate or speed, entropy age diminishes. Afterward, Bianco et al. [2] built up an execution investigation of Al2O3-water nanofluids by breaking down entropy age and an execution assessment paradigm dependent on the first and second law of thermodynamics. Their outcomes exhibited that with an expansion of nanoparticle focus, the Nusselt number increments, as well as entropy age and siphoning power additionally increment.

III. METHODOLOGY

1) Geometry.

In the Current Simulation a pipe geometry is used simulate the Heat transfer in cfd for nanofluids the pipe is with the diameter of 4.5mm and the length of 1.17m is drawn using the tools present in the design modeler.

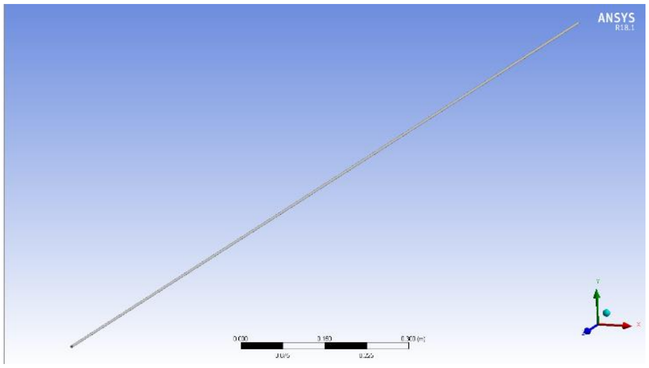


Figure 3 Designed Geometry of the Pipe in Design modeler As per the literature

2) Mesh.

Generally The process of dividing the Total volume in to number of sub domains is called mesh to discretize the domain we use mesh window in the Ansys workbench to Discretize the Total pipe using Quad elements.

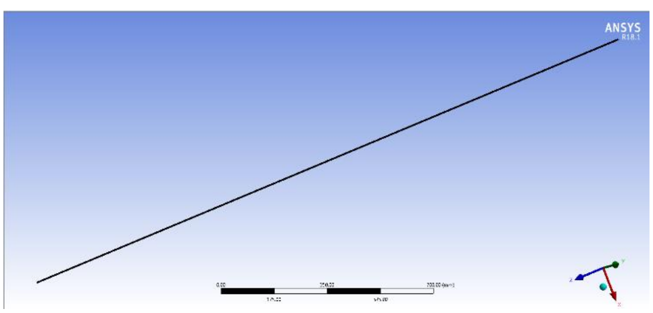


Figure 4 Meshed pipe in meshing module.

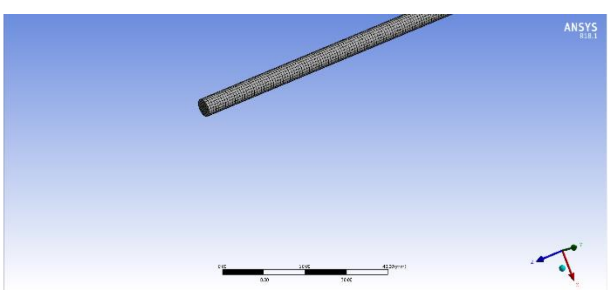
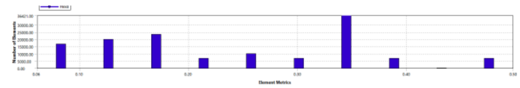


Figure 5 Closely sectioned View of meshed pipe.

Nodes	168912
Elements	132440



The above F igure Represents the Skewness of the elements in the pipe Where the range represents from the 0 to 1 values closer to 1 represents lower quality elements. We can observe from the figure that most of the elements are in good quality zone.

3) Setup.

Initially in the setup the Pressure based solver is used to define the type of problem along with the gravity Coming to the models The type of viscous flow is laminar to define the type of flow with energy equation on to simulate heat effects in the simulation.

Materials:

As the software database does not contain the Nano fluids by default we need to input the physical properties of the Fluid manually by calculating the Density Thermal Conductivity and Viscosity of the Fluid Manually by Consider the liquid water properties and the Solid nanopartice Pro

Specific Heat:

$$c_{p,nf} = \frac{(1-\varphi)(\rho c_p)_{bf} + \varphi(\rho c_p)_p}{\rho_{nf}}$$

Thermal Conductivity:

$$k_{nf} = \left[\frac{k_s + 2k_w + 2(k_s - k_w)(1+\beta)^3\varphi}{k_s + 2k_w - (k_s - k_w)(1+\beta)^3\varphi}\right] k_w$$

Viscosity:

$$\mu_{nf} = (123\varphi^2 + 7.3\varphi + 1)\mu_{bf}$$

Sample Calculation

- Density of nano Fluid Pnf=(1-0.01)*998.2+0.01*2400=1012.218 kg/m3.
- Specific Heat Cp=[(1-0.01)*(998.2*4182)+0.01(2400*837.5)]/1012.218=4102.698

- Viscosity M={(123*0.01*0.01)+7.3*0.01+1}*9.98e-4=1.08e-3
- Thermal Conductivity K=37.10981/35.27819=0.62799

The Above Calculated data is inputted into the Physical Properties of fluid for 1% 2% 3% 4% of all the Nano Fluids in the Simulation.

Boundary Conditions

Inlet Velocity (U m/s)= 0.32m/s
UHF(uniform Heat Flux(Q w/m2k))=5000W/m2k

IV. RESULTS

CUO with 1% nano particle concentration

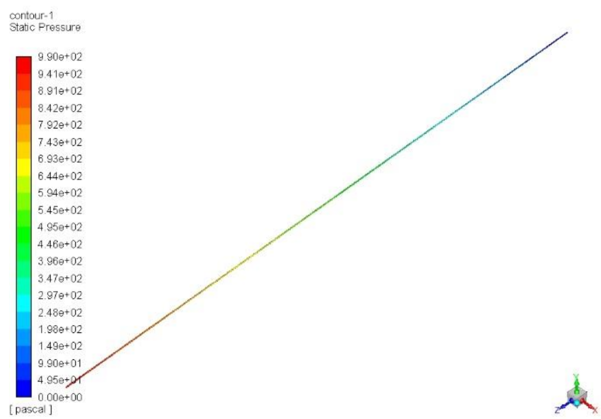


Figure 1:Pressure Distribution in CUOWith 0.01 Mass fraction

The above Figure represents the Pressure Distribution of the Fluid in side the Pipe with 1 percent of copper oxide mixture Where the Red color represents the high pressure and Blue color represents the minimum pressure , left side colored bar is the notation of the colored range from minimum to maximum for the Considered parameter with the maximum pressure of 9.90e2 Pa.

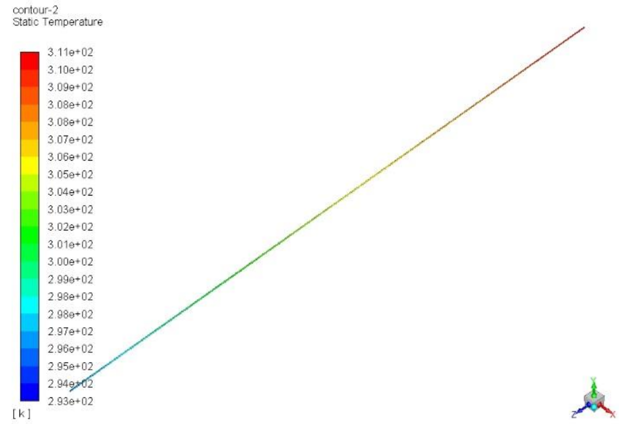


Figure 2: Temperature Distribution in CUO With 0.01 Mass fraction

The above Figure represents the Temperature Distribution of the Fluid inside the Pipe with 1 percent of Copper oxide mixture Where the Red color represents the high Temperature and Blue color represents the minimum temperature , left side colored bar is the notation of the colored range from minimum to maximum for the Considered parameter with the maximum temperature of 311K and the rated average outlet temperature is considered to be 305.178K.

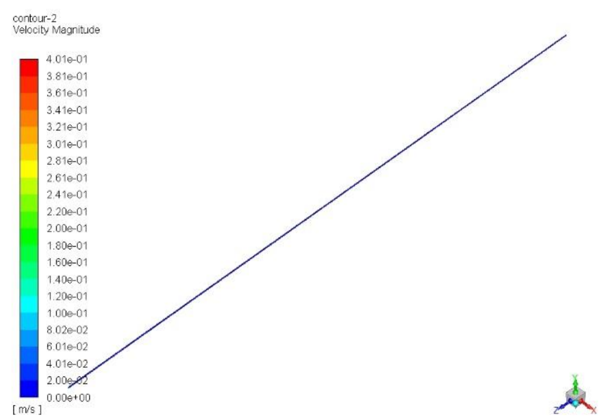


Figure 3: Velocity Distribution in CUO With 0.01 Mass fraction

The above Figure represents the Velocity Distribution of the Fluid inside the Pipe with 1 percent of copper oxide mixture Where the Red color represents the high Velocity and Blue color represents the minimum Velocity , left side colored bar is the notation of the colored range from minimum to maximum for the Considered parameter with the maximum Velocity is 0.401m/s.

CUO with 2% nano particle concentration.

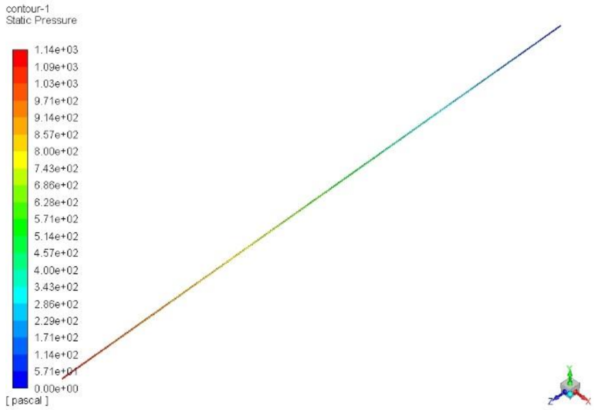


Figure 4: Pressure Distribution in CUO With 0.02 Mass fraction

The above Figure represents the Pressure Distribution of the Fluid in side the Pipe with 2 percent of copper oxide mixture Where the Red color represents the high pressure and Blue color represents the minimum pressure , left side colored bar is the notation of the colored range from minimum to maximum for the Considered parameter with the maximum pressure of 1.14e3 Pa.

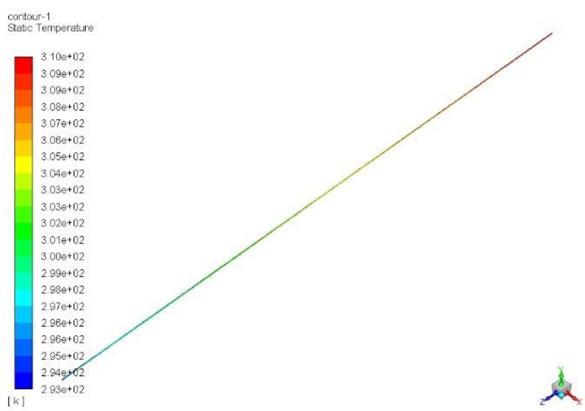


Figure 5: Temperature Distribution in CUO With 0.02 Mass fraction

The above Figure represents the Temperature Distribution of the Fluid inside the Pipe with 2 percent of Copper oxide mixture Where the Red color represents the high Temperature and Blue color represents the minimum temperature , left side colored bar is the notation of the colored range from minimum to maximum for the Considered parameter with the maximum temperature of 311K and the rated average outlet temperature is considered to be 304.668K.

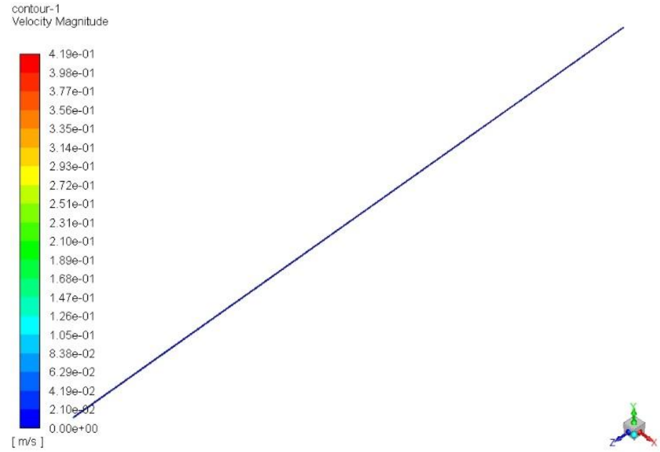


Figure 6: Velocity Distribution in CUO With 0.02 Mass fraction

The above Figure represents the Velocity Distribution of the Fluid inside the Pipe with 2 percent of copper oxide mixture Where the Red color represents the high Velocity and Blue color represents the minimum Velocity , left side colored bar is the notation of the colored range from minimum to maximum for the Considered parameter with the maximum Velocity is 0.419m/s.

CUO with 3% nano particle concentration

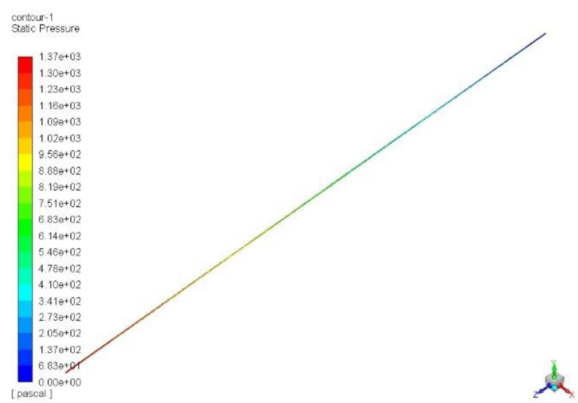


Figure 7 Pressure Distribution in CUO With 0.03 Mass fraction

The above Figure represents the Pressure Distribution of the Fluid in side the Pipe with 3 percent of copper oxide mixture Where the Red color represents the high pressure and Blue color represents the minimum pressure , left side colored bar is the notation of the colored range from minimum to maximum for the Considered parameter with the maximum pressure of 1.37e3 Pa.

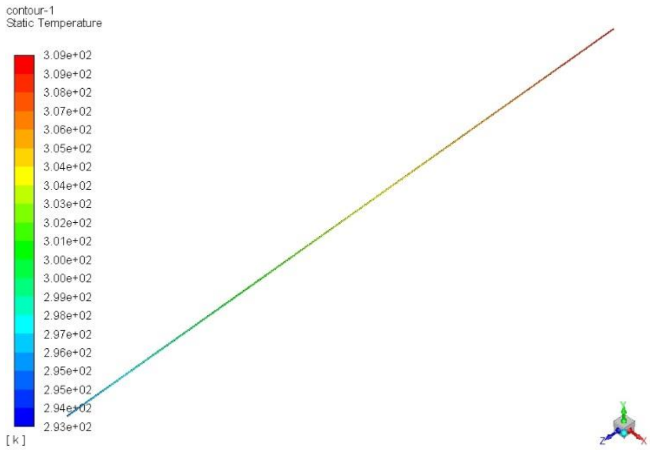


Figure 8 Temperature Distribution in CUO With 0.03 Mass fraction

The above Figure represents the Temperature Distribution of the Fluid inside the Pipe with 3 percent of Copper oxide mixture Where the Red color represents the high Temperature and Blue color represents the minimum temperature , left side colored bar is the notation of the colored range from minimum to maximum for the Considered parameter with the maximum temperature of 311K and the rated average outlet temperature is considered to be 303.948K.

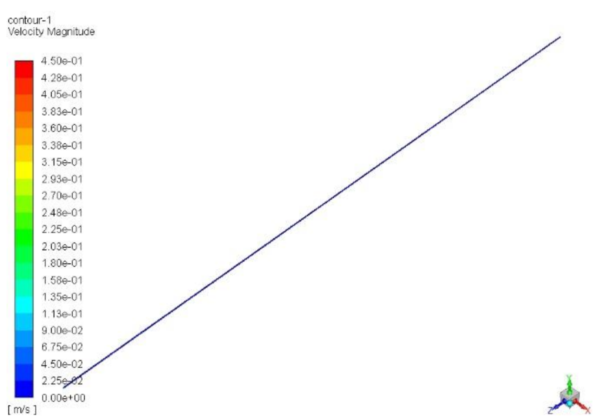


Figure 9 Velocity Distribution in CUO With 0.03 Mass fraction

The above Figure represents the Velocity Distribution of the Fluid inside the Pipe with 3 percent of copper oxide mixture Where the Red color represents the high Velocity and Blue color represents the minimum Velocity , left side colored bar is the notation of the colored range from minimum to maximum for the Considered parameter with the maximum Velocity is 0.450m/s.

CUO with 4% nano particle concentration

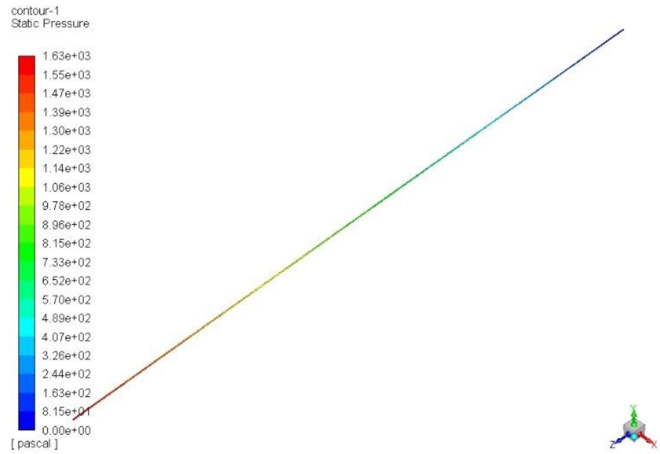


Figure 9:Pressure Distribution in CUO With 0.04 Mass fraction

The above Figure represents the Pressure Distribution of the Fluid in side the Pipe with 4 percent of copper oxide mixture Where the Red color represents the high pressure and Blue color represents the minimum pressure , left side colored bar is the notation of the colored range from minimum to maximum for the Considered parameter with the maximum pressure of 1.63e3 Pa.

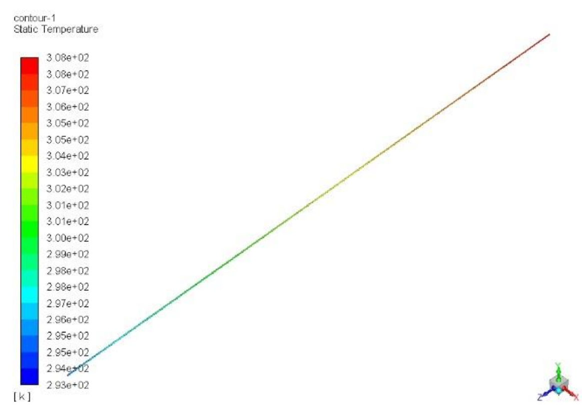


Figure 10: Temperature Distribution in CUO With 0.04 Mass fraction

The above Figure represents the Temperature Distribution of the Fluid inside the Pipe with 4 percent of Copper oxide mixture Where the Red color represents the high Temperature and Blue color represents the minimum temperature , left side colored bar is the notation of the colored range from minimum to maximum for the Considered parameter with the maximum temperature of 311K and the rated average outlet temperature is considered to be 303.336K.

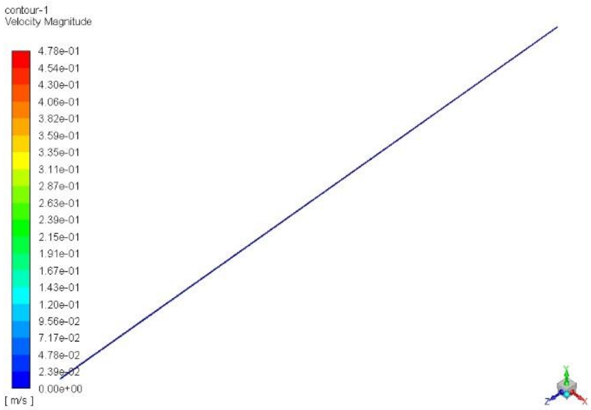
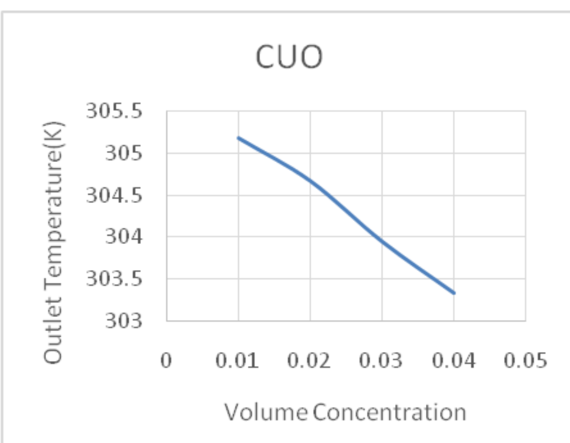


Figure 11: Velocity Distribution in CUO With 0.04 Mass fraction

The above Figure represents the Velocity Distribution of the Fluid inside the Pipe with 4 percent of copper oxide mixture Where the Red color represents the high Velocity and Blue color represents the minimum Velocity , left side colored bar is the notation of the colored range from minimum to maximum for the Considered parameter with the maximum Velocity is 0.478m/s.

Table 1: Outlet temperature of CUO

CUO	
Volume Concentration	outlet Temperature
0.01	305.178
0.02	304.668
0.03	303.948
0.04	303.336



Plot 1 : Mass Fraction Vs Outlet Temperature of CUO.

The above Plot represents the Outlet Temperature of different Nano particle volume concentrations of 1% 2% 3% 4% where u can see the Temperature is dropping with the percentage is increasing.

Table Comparisons of Theoretical and Computational Heat transfer coefficient of CUO

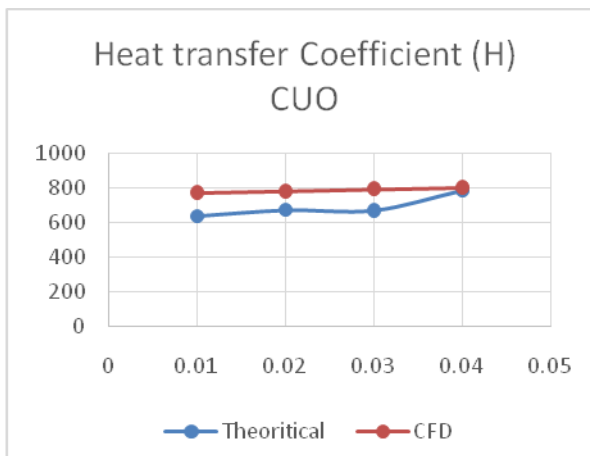
Nano Fluid	CUO	
Mass Fraction	Theoritical	CFD
0.01	637.2673974	776.019
0.02	671.1409396	786.1686
0.03	669.8821008	796.046
0.04	784.4367744	805.6689

Table 3 Values of Wall And Bulk temperatures of Pipe With CUO Nano Fluid

Heat transfer coefficient CUO			
φ	Q	T_w	T_b
0.01	5000	304.313	296.467
0.02	5000	304.313	296.863
0.03	5000	304.313	296.849
0.04	5000	304.313	297.939

$$h = Q/(T_w - T_b)$$

Where h is the Heat transfer Coefficient Q is the UHF or uniform heat flux of the Pipe $T_w$is the Wall temperature T_b is the Bulk temperature of the Fluid φ is the Mass fraction of nano particle in the homogeneous mixture



Plot 2: Comparisons of Theoretical and Computational Heat transfer coefficient of CUO

V. CONCLUSION

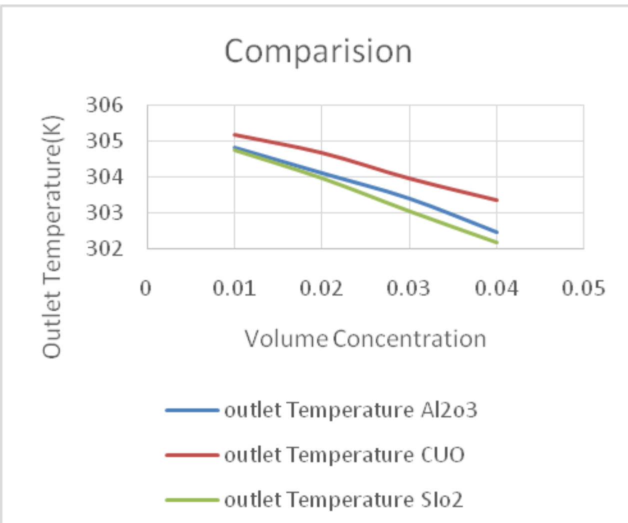
The Simulation Done for the Straight Pipe Forced Convection Shows that by the 4 particle concentration 1% , 2% , 3% , 4% of all the 3 particles used Al2o3 Sio2 , Cuo respectively by the input uniform heat flux given 5000w/m2k the outlet temperature is subsequently higher in the Cuo when compared to the other two nanofluids.The heat transfer coefficient also calculated both theoretically and Analytically

Table 4 Comparision of Outlet temperatures in the Nano fluid

Volume Concentration	outlet Temperature Al2o3	outlet Temperature CUO	outlet Temperature SIo2
0.01	304.823	305.178	304.724
0.02	304.114	304.668	303.944
0.03	303.401	303.948	303.024
0.04	302.462	303.336	302.152

Table 5 Comparision of Theoritical and Analytical Heat transfer Coefficient H

Nano Fluid	Al2o3			CUO			sIo2	
Mass Fraction	Theoritical	CFD	Mass Fraction	Theoritical	CFD	Mass Fraction	Theoritical	CFD
0.01	625.078	775.705	0.01	637.267	776.019	0.01	617.894	775.66
0.02	655.90	785.442	0.02	671.140	786.16	0.02	679.62	785.35
0.03	669.88	794.96	0.03	669.882	796.04	0.03	649.519	794.83
0.04	716.024	793.90	0.04	784.436	805.66	0.04	712.859	804.09



Plot 3 Graphical representation of Temperature outlet in nano fluids

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