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ANALYSIS ONCIRCULAR C – PIPE FLOW HEAT EXCHANGER WITH NANO PARTICLES AL_2O_3& CUO MIXCED WITH BASE FLUIDS H_2O & EG

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Abstract

Steady state heat transfer enhancement though a circular c – pipeflow heat exchanger in vertically upward position under laminar flow has been done analytically using oil based Nano fluids Al2O3&CuO at 4 different concentrations say 2, 3, 4 and 5 in percentage. ANSYS CFX 16.2 simulation is used to study the effects of adding nanoparticles to the base fluids, pressure changes, velocity changes, and residual pipe contours. It was discovered that the rate of heat transfer in laminar flow regimes can be influenced by flow and thermal boundary conditions using numerical simulations based on various geometrical factors. According to the calculated results, a circular c-pipe flow heat exchanger developed with CATIA and ANSYS was found to be as accurate as the empirical formulae and actual testing. These results were examined to determine the correctness of the numerical results. According to the findings, as pressure drops are reduced, the rate of heat transfer increases.

Keywords : Nano Fluids, ANSYS, Heat Exchanger, Flow, Thermal Systems, Cooling systems, Automobile components.

Introduction

This heat exchanger is used for cooling or heating a substance by moving thermal energy from one medium into another. In cars, construction projects, and consumer electronics, radiators are primarily used. All the pressure drop is computed for different flow rates, and average wall heat flux as well as microchannel height, flow input angle, and working fluid are investigated for high heat flux applications with numerical simulations of velocity and temperature fields in one phase microchannel cooling systems with spiralling radial inflows. The use of distinct Nano fluids, particularly SiO2/water and ZnO/water Nano fluids, as cooling mediums was researched in order to improve automobile radiator thermal performance. Nanoparticles dispersed in water (5 weight percent) are being studied for their effects on heat transmission in vehicle radiators utilising spherical and hexagonal nanoparticle morphologies. This study primarily seeks to investigate this. Both coolant temperature and volume flowrate were used to conduct the trials; the current results were also compared to those from prior investigations [2]. An Al2O3 and TiO2 volumetric dispersion is being used in DW and EG to study the effects of these two oxide nanoparticles. There are a number of anti-corrosive features of these oxide-based Nano fluids that we chose since they are rarely examined or mentioned in the literature. A major focus is also devoted to providing an end-user with the necessary long-term stability (zeta potential), as well as a complete characterization of the Nano fluids (such as size, density, viscosity, thermal conductivity, and corrosive behaviour). Thermal performance was improved by 24.21 percent when Al2O3 was used at a volume fraction of 0.3 percent. Many industrial applications have benefited from improved heat transmission when solid nanoparticles are added to liquids. This is a hot issue from the previous decade. An automobile radiator's SiO_2 nanoparticle heat transmission was examined using friction factor and forced convection heat transfer in water as the working fluid. For this experiment, the Nano fluids were used in four different concentrations, ranging from 1% to 2.5% overall. Because to the adjustment, the flow rate went from 2 LPM to 8 LPM and the Reynolds number from 500 to 1750. According to the findings [4,] friction factor decreases as flow rate increases and increases as volume concentration increases. Volumn flow rates are between 2 and 8 litres per minute, input temperatures are between 60-80 ° C, and the Nano fluid volume concentration is between 1-2 percent. The Nusselt number grew somewhat in correlation with the rise in volume flow rate, according to the study's findings. Volumn flow rate, inlet temperature, and Nano fluid volume concentration were discovered to be the input and output (Nusselt number) for regression equations.

Forced convection heat transfer in automobile radiators is commonly used to cool water or water-and-antifreezing-materials combinations like ethylene glycol (EG). EG and pure water were compared to their binary mixes' heat transfer qualities in this investigation. There have also been experiments to evaluate the impacts of adding different concentrations of Al_2O_3 nanoparticle to these base fluids, and how that affects the radiator's ability to transfer heat. TiO_2-water Nano fluid friction and heat transfer coefficients in a horizontal double tube counter-flow heat exchanger operating in turbulent flow are investigated experimentally in this paper. We used a 0.2-2 vol% solution of nanoparticles in water containing 21 nm TiO_2 as the test fluid [7]. Nano fluids containing TiO_2 and Al_2O_3 nanoparticles are used to simulate forced convection flows in a horizontal tube with a constant wall temperature. CFD software is used to model and solve the horizontal test section's equations.. The correlations found by Palm et al. are used to figure out the Nano fluid's characteristics. The hydrodynamics and thermal behaviour of Nano fluid flow are studied using a single-phase model with two-dimensional equations and constant or temperature-dependent characteristics [8]. In this study, the forced convection heat transfer and flow parameters of a water-tinted TiO_2 nanofluid were examined. Researchers examine the TiO_2-water Nano fluid's heat transfer coefficient and friction factor in a horizontal, double-tube heat exchanger under turbulent flow conditions. The nanoparticles utilised in this work are called Degussa P25 TiO_2 and have a diameter of roughly 21 nm [9]. Metallic or non-metallic Nano particle suspensions in a base liquid are known as nano fluids and can be used to improve the pace at which heat is transferred in various applications. In order to achieve convection heat transfer, the researchers utilised an Al_2O_3/water Nano fluid in a circular tube with a constant wall temperature and laminar flow. Different concentrations of nanoparticles, as well as varying Peclet and Reynolds values, were used to get the Nusselt numbers of Nano fluids. The inclusion of nanoparticles in the fluid enhances heat transport, as demonstrated in the experiments [10].

To considerably improve the heat transmission capabilities of the original fluid, colloidal mixtures of Nano-sized particles are added to it, resulting in Nano fluids. Nano fluids are perfect for practical applications because of their wonderful properties. There are several unique properties of Nano fluids discussed in this article, such as improved heat transmission, increased surface volume ratio, Brownian motion, and thermophoresis, for example. Conventional heat transfer fluids can't compete with nano fluids, which are thought to have significant benefits over them [11]. More than a decade ago, scientists began investigating Nano fluids' thermal conductivity and viscosity. There have been recent publications in open literature on the use of nanometer-sized solid particle materials, metallic or non-metallic, in the base heat transfer fluids to improve heat transmission, revealing significant theoretical and practical results on convective heat transfer in those materials. This review paper aims to synthesise pertinent published publications on the use of Nano fluids to enhance forced convection heat transfer [12].

Nomenclature

dc = diameter of the coil(mm)

Dp = diameter of the pipe (mm)

p = pitch of the coil(mm)

Pc = pitch of the helical groove(mm)

h = height of the groove

ρ = density(kg/m3)

μ = dynamic viscosity

Φ = particle volume concentration

Cp = specific heat capacity(j/kg k)

l = tube length

Re = Reynolds number

μff = effective ,relative to the Nano fluid

K = thermal conductivity(w/m k)

T = temperature(k)

To = wall temperature(k)

bf = base fluid

Np = Nano particle

Nf = Nano fluid

Design & Analytical Methodology of Heat transfer in C – Pipe

Figure 1 shows the helical coil tube's 3D structure, while Figure 2 shows a circular c-pipe flow heat exchanger. For the initial computation, the pipe's dimensions, material, and boundary conditions are all taken from [1]. For calculating the Nano fluid with 2%, 3%, 4%, 5% concentration properties references given the formulae and basing on those formulae properties are calculated and tabulated in Table.1. Base paper dimensions and boundary conditions are; inner diameter of the pipe d_i = 100 mm, outer diameter of the pipe d_o = 106 mm, pitch of the helical grove p_c = 20mm, inlet temperature T_{in} = 90^0C, wall temperature Twall = 30^0C, inlet velocity is 0.001005 m/s.

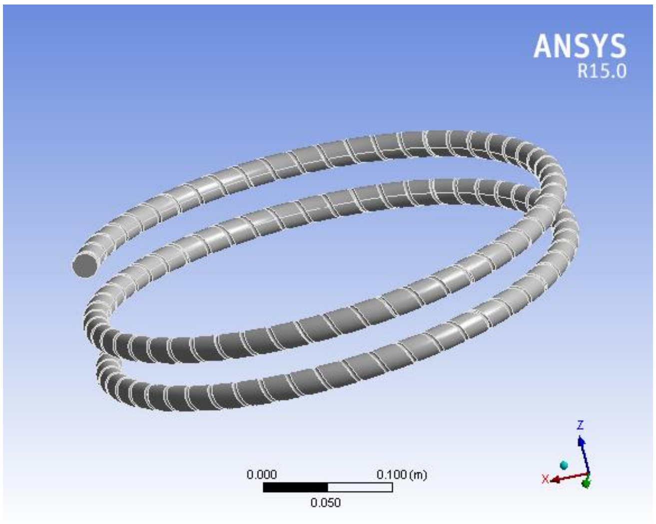

Fig 1.1 Helical coil tube heat exchanger

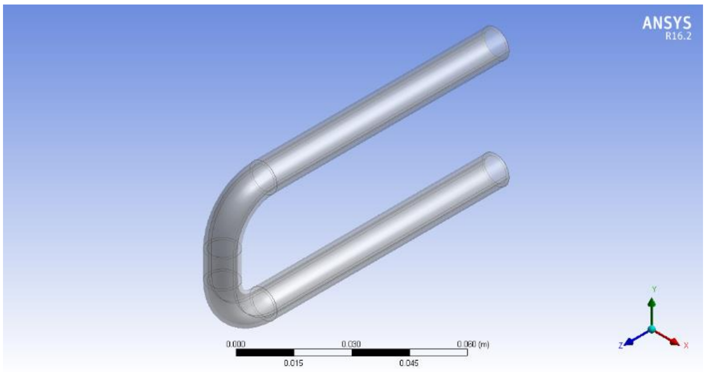

Fig 1.2 C pipe heat exchanger

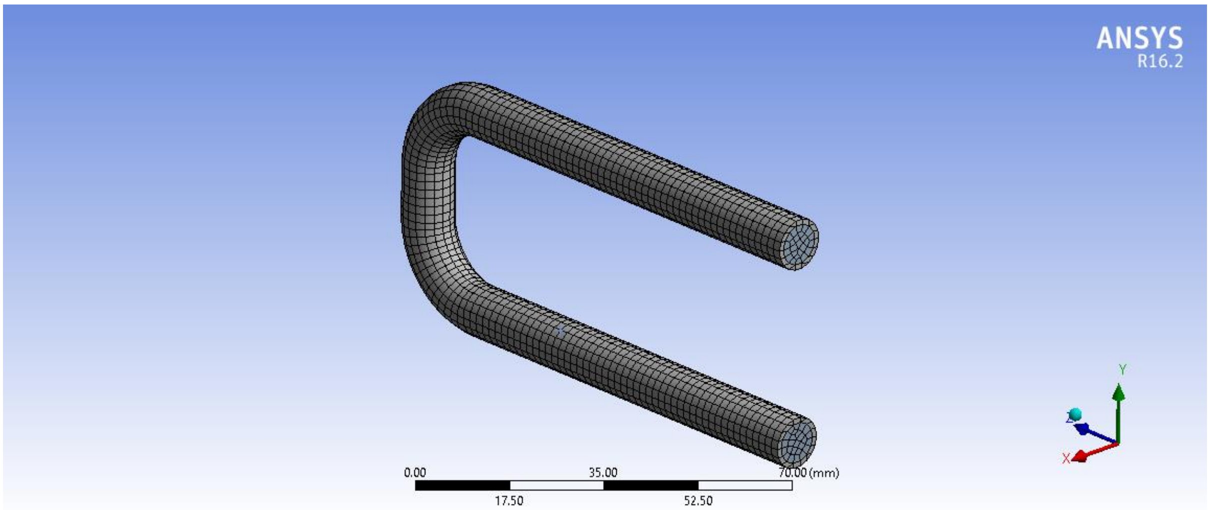

Fig 1.3 Meshed Model of C – Pipe

Materials &Properties of Nano Particles

Parameter	**AL_2O_3**	**CuO**
Density (Kg/m3)	3880	6510
Specific Heat (J/Kg.K)	773	540
Thermal Conductivity (W/m.K)	36	18

Properties of Base Fluids

Parameter	**H_2O**	**EG**
Density (Kg/m3)	998.2	1126
Specific Heat (J/Kg.K)	4182	2354
Thermal Conductivity (W/m.K)	0.597	0.256
Dynamic Viscosity (Ns/m2)	0.001003	0.021

Nano fluid with Al2O3 in water

It's not an easy operation to include Nano particles into the base fluid. Nano fluids can be prepared using a variety of methods. The two-step approach is most commonly utilised in these procedures. A chemical or physical approach first created dry powder nanoparticles. They are then mixed with high shear, homogenised, and ball milled while still submerged in the base fluid under magnetic force. As there is a limitation for the Two-Step method i.e., stability of the Nano-fluid at higher temperatures, advanced techniques were improved and developed two – step method. In two - step method, nanoparticles of the specified combination are vaporized and mixed with the base fluid. In this process stability of the Nano-fluids increases and stabilised even at the higher temperatures. Here as we have considered the theoretical analogies for the Nano fluids, their correlations are taken with respect to the estimation for the size of the Nano particle, concentration and the base fluid used.

For the properties of the Nano fluid Al_2O_3,the following correlations [5] are used

Density $\rho_{nf} = (1-\varphi)\ \rho_{bf} + \varphi\rho_{np}$ eqn (1)

Specific heat $(\rho C_p)_{nf} = (1-\varphi)\ (\rho C_p)_{bf} + \varphi\ (\rho C_p)_{np}$ eqn (2)

Thermal conductivity $K_{nf} = K_{Static} + K_{Brownian}$ eqn (3)

$K_{static} = \{(k_{nP}+2k_{bf}-2\ \varphi\ [k_{bf}+k_{nP}])/\ (k_{nP}+2k_{bf}-\ \varphi\ [k_{bf}+k_{nP}])\}\ *\ k_{bf}$ eqn (4)

$K_{Brownian} = 5*10^4\beta\ \varphi\ \rho_{bf}C_{P,\,bf}\ \{(kT/\ (\rho_{np}d_{np}))\}^{0.5}f\ (T,\ \varphi)$ eqn (5)

Where,

$f\ (T,\ \varphi) = (0.02817\ \varphi\ +0.003917)\ (T/T0)\ +(-0.030669\ \varphi\ -0.00391123)$ eqn (6)

$\beta = 8.4407(100\varphi)^{-1.07304}$ for $1\% \leq \varphi \leq 10\%$ of Al_2O_3

$k = 1.38^{-23}$

Dynamic viscosity is $\mu_{eff}= \mu_{bf}/\ (1-\varphi)^{(2.5)}$ eqn (7)

Molecular weight is $(\varphi\ *101.961276)\ +((1-\ \varphi)\ *(18.01528))$ eqn (8)

Table 1. Properties of Al2O3 Nano Fluid

AL2O3+H2O					
Concentration	Density	specific heat	Thermal conductivity	dynamic viscosity	Molecular weight
Φ	(Kg/m3)	(J/Kg.k)	(w/m.k)	(Ns/m2)	(kg/kmol)
2%	1055.836	3931.451	0.585087669	0.000953592	19.69419992
3%	1084.654	3816.162	0.578913812	0.00100284	20.53365988
4%	1113.472	3706.840	0.572614011	0.000905679	21.37311984
5%	1142.290	3603.035	0.566184077	0.000882279	22.2125798

Nano Fluids with CuO in Water

Several studies are done with different nano fluids, prepared by adding CuOnano particles in water with different particle sizes and concentration. Here the study is continued with CuOnano particle addition in water by considering the constant particle size and different concentrations. As different nano fluid is considered in this study, the properties are again needed to calculate. The properties required in this simulation are determined by the correlations taken from the reference. Density, specific heat, thermal conductivity, dynamic viscosity and molecular weight are calculated from the following formula

For density, specific heat, thermal conductivity and molecular weight of the CuO added nano fluid, the equations (1), (2), (3) and (5) are used as of the same correlations. So, dynamic viscosity formula from another source journal is

$$\mu eff = \mu bf\ *\ (1+0.025*\varphi+0.015*\varphi 2) \qquad \text{eqn (9)}$$

Table 2. Properties of CuO Nano Fluid

CuO+H2O					
Concentration	Density	specific heat	Thermal conductivity	dynamic viscosity	Molecular weight
Φ	(Kg/m3)	(J/Kg.k)	(w/m.k)	(Ns/m2)	(kg/kmol)
2%	1108.436	3525.215	0.585273757	0.001003502	19.2458824
3%	1163.554	3570.698	0.579202864	0.001003765	19.8611836
4%	1218.672	3403.795	0.57300914	0.001004023	20.4764848
5%	1273.790	3251.336	0.566689014	0.001004284	21.091786

Nano Fluids AL2O3 with Ethylene Glycol (EG)

Table 3. Properties of Al2O3 – EG Nano Fluid

AL2O3 + EG					
Concentration	Density	specific heat	Thermal conductivity	dynamic viscosity	Molecular weight
Φ	(Kg/m3)	(J/Kg.k)	(w/m.k)	(Ns/m2)	(kg/kmol)
2%	1181.080	2517.036	0.585061438	0.01996554	19.69419992
3%	1208.620	2453.375	0.578887401	0.02099664	20.53365988
4%	1236.160	2393.010	0.572587222	0.01896237	21.37311984
5%	1263.700	2335.690	0.56615681	0.01847244	22.2125798

Nano Fluids CuO with Ethylene Glycol (EG)

Table 4. Properties of CuO - EG Nano Fluid

CuO + EG					
Concentration	Density	specific heat	Thermal conductivity	dynamic viscosity	Molecular weight
Φ	(Kg/m3)	(J/Kg.k)	(w/m.k)	(Ns/m2)	(kg/kmol)
2%	1233.680	2260.097	0.585247844	0.0210105	19.2458824
3%	1287.520	2300.321	0.579175377	0.021016023	19.8611836
4%	1341.360	2203.379	0.572980211	0.02102142	20.4764848
5%	1395.200	2114.826	0.566658712	0.02102688	21.091786

Results & Discussions

The result for the simulation of the helical coil tube heat exchanger are taken in to consideration for validating the simulation followed for the W-pipe heat exchanger. The comparison is taken between the actual reference values and the same done in Ansys CFX for both helical coil and W-pipe heat exchangers. The below fig

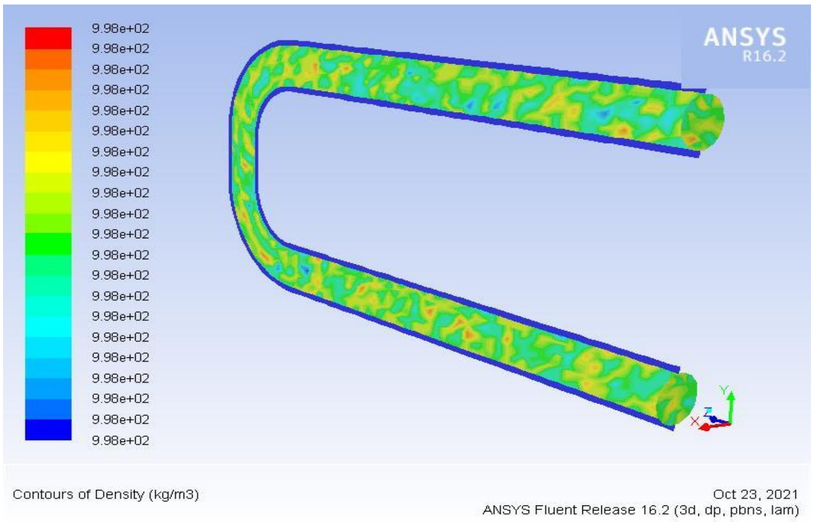

Fig 1.4 Density Contour for Base Fluid Water

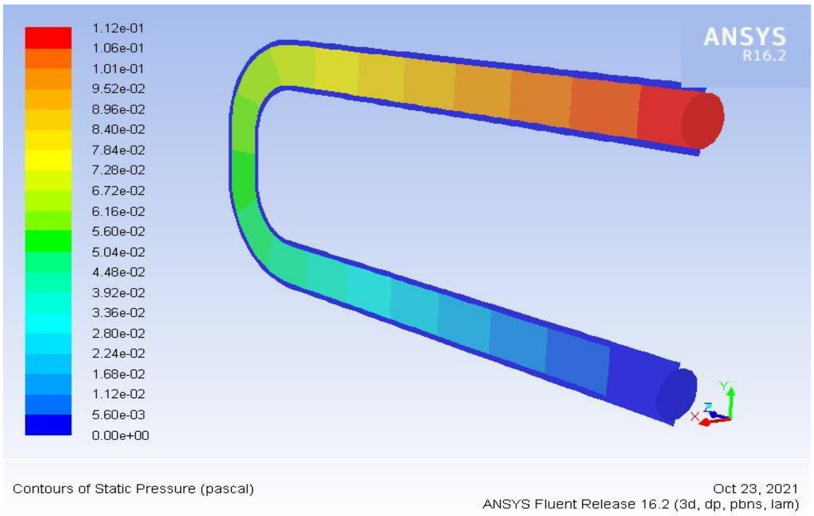

Fig 1.5 Pressure Contour for Base fluid water

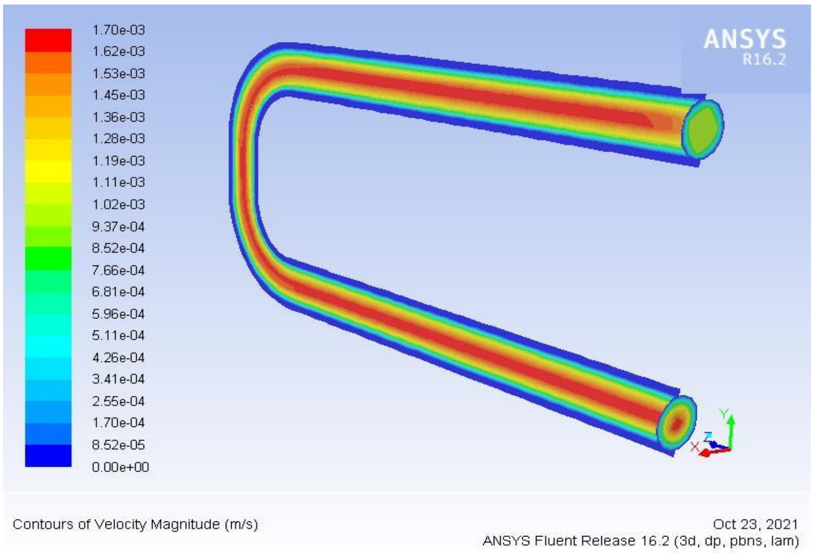

Fig 1.6 Velocity Contour for base fluid water

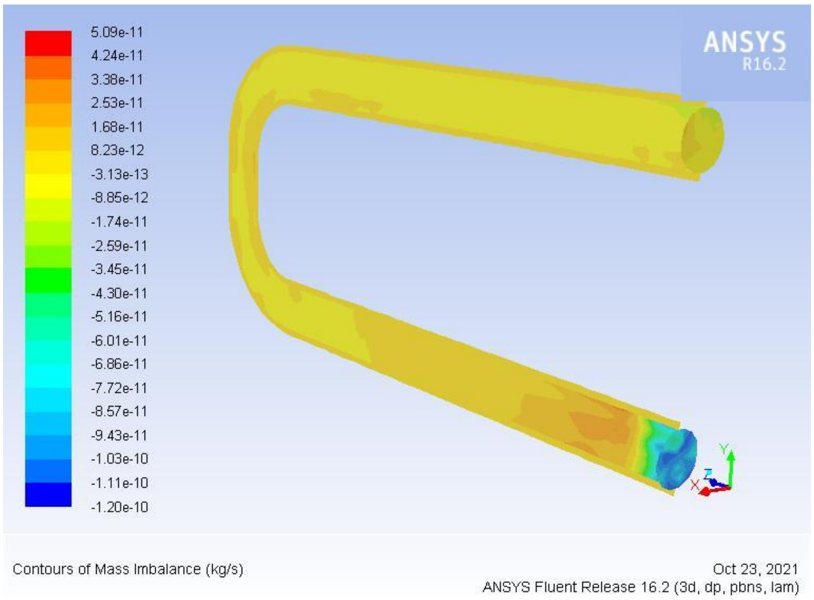

Fig 1.7 Residual Contour for base fluid water

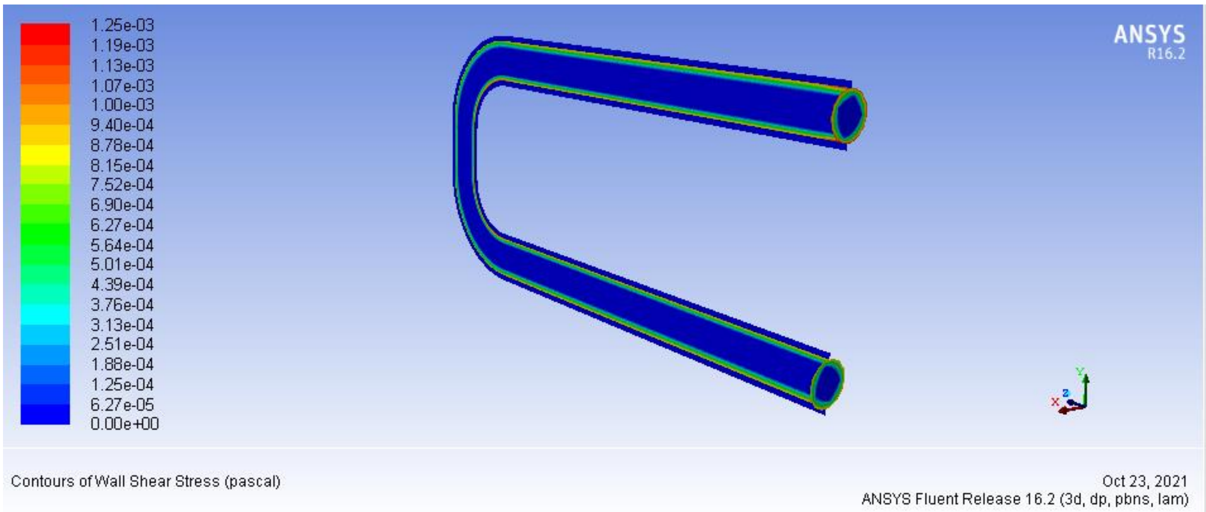

Fig 1.8 Wall shear stress of c – pipe

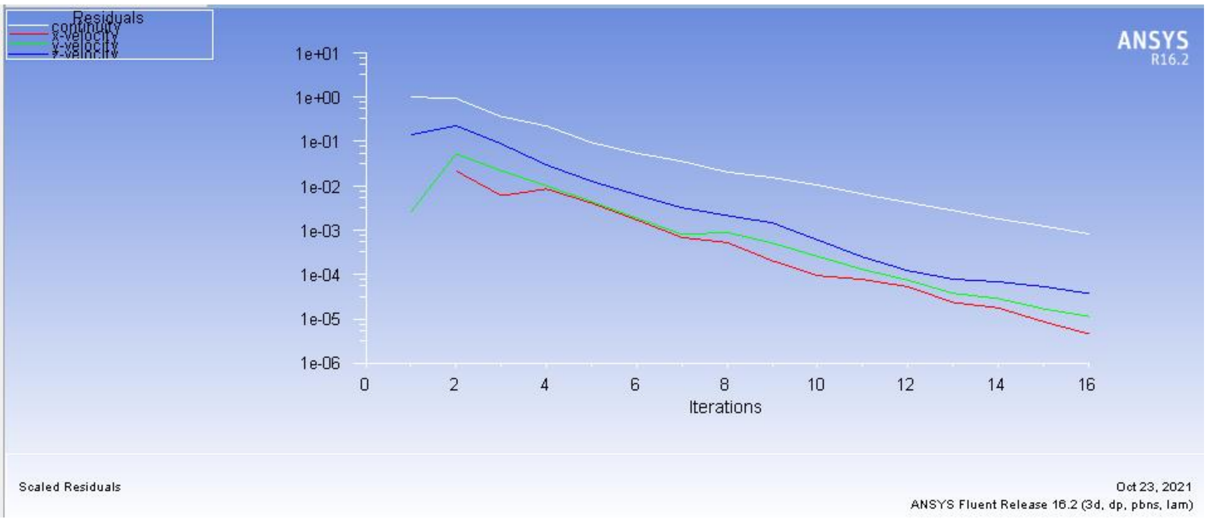

Fig 1.9 Residual Iterations for base fluid water

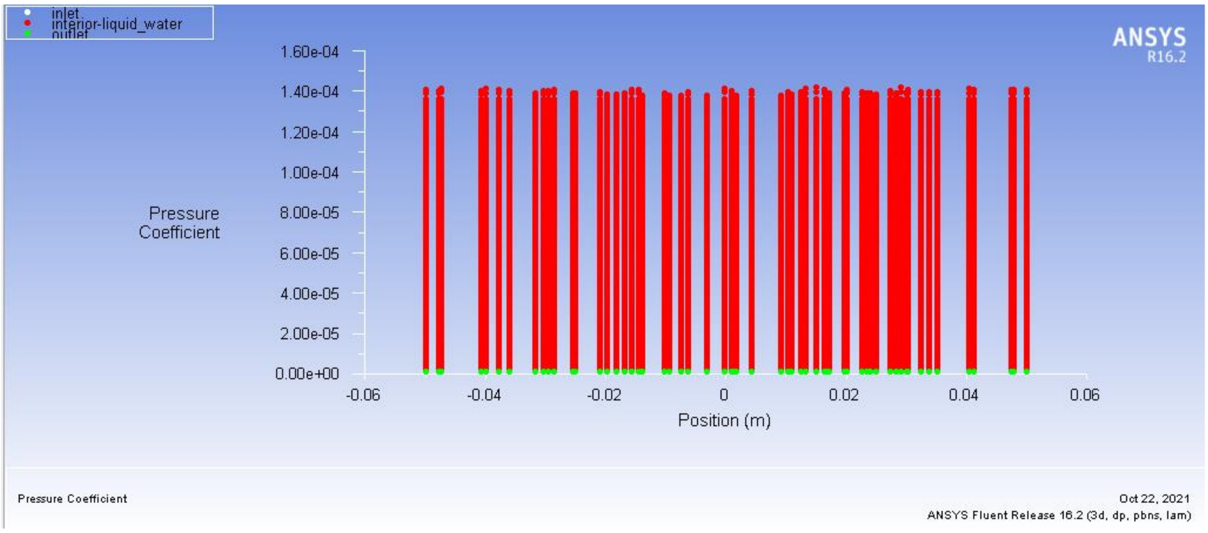

Fig 1.10 Position Vs Pressure Coefficient

Conclusions

The results are tabulated by considering the geometrical variation in the pipe and working fluid modification is compared. After the analysis, a pipe geometry with circular c – pipe heat exchanger has given better results than that of the Geometry with helical coil tube heat exchanger in performance view point. Also the Nano fluid of Al2O3, CUO, TIO2 with 2%, 3%, 4%, and 5% concentration is also giving good performance in the velocity and pressure contours when compared with the base paper which have been taken w.r.t more variation with the base paper.

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