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Investigation on Heat Transfer through an Annular Bend Tube for Various Nano Fluids using Thermal and CFD analysis

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Abstract

The heat convection can passively be enhanced by changing flow geometry, boundary conditions or by enhancing fluid Thermo-physical properties. A colloidal mixture of Nano-sized particles in a base fluid, called Nano fluids, tremendously enhances the heat transfer characteristics of the original fluid, and is ideally suited for practical applications due to its marvelous characteristics.

In this thesis, different Nano fluids are analyzed for their thermal behavior passing through an annular bend tube with turbulence flow. The Nano fluids considered in this thesis are Tri-Chloro ethylene glycol, Aluminium Nano fluid, Copper Nano fluid and Silicon Carbide Nano fluid made from base fluid water except Tri-Chloro ethylene glycol. Thermal and CFD analysis are performed to determine the thermal behavior using finite element analysis software Ansys16.0 and 3D modeling is done in Pro-E.

Keywords: *heat convection, boundary condition, Annular bend tube, turbulence flow, Nano fluid, Thermal and CFD analysis, Ansys, Pro-E*

1. Introduction

In the simplest of terms, the discipline of heat transfer is concerned with only two things: temperature, and the flow of heat. Temperature represents the amount of thermal energy available, whereas heat flow represents the movement of thermal energy from place to place.

On a microscopic scale, thermal energy is related to the kinetic energy of molecules. The greater a material's temperature, greater the thermal agitation of its constituent molecules (manifested both in linear motion and Vibrational modes). It is natural for regions containing greater molecular kinetic energy to pass this energy to regions with less kinetic energy.

Several material properties serve to modulate the heat transferred between two regions at differing temperatures. Examples include thermal conductivities, specific heats, material densities, fluid velocities, fluid viscosities, surface emissivity, and more. Taken together, these properties serve to make the solution of many heat transfer problems an involved process.

Heat transfer through a fluid is by convection in the presence of bulk fluid motion and by conduction in the absence of it. Therefore, conduction in a fluid can be viewed as the limiting case of convection, corresponding to the case of quiescent corresponding to the case of quiescent fluid.

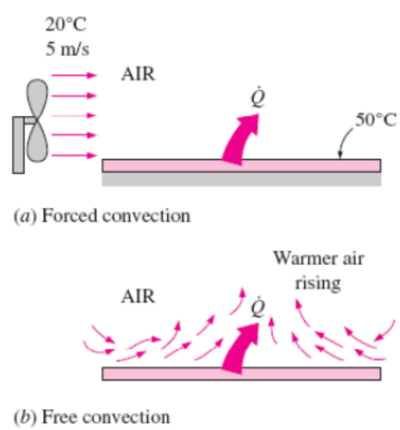

Fig 1.1. Forced Convection and Free Convection

$$\dot{q}_{conv} = h(T_s - T_\infty) \qquad W/m^2$$

$$\dot{Q}_{conv} = hA_s(T_s - T_\infty) \qquad W$$

2. Related work

In the thesis by WILLEM I. LOUW etal [1], helically wound tube-in-tube heat exchangers are manufactured by coiling two tubes, one placed inside the other. This method often results in the tubes not sharing the same center line, and therefore annular contact occurs in some cases. An experimental comparison was made of such tubes in a heat exchanger with annular contact, as opposed to an aligned (concentric) device without annular contact, in order to quantify the effect of annular contact in terms of heat transfer coefficients and pressure drop. By comparing the heat transfer characteristics, it was concluded that the heat transfer coefficient in the annulus was found to increase substantially. The result was an improved performance by the heat exchanger where annular contact occurs, compared to the heat exchanger with the inner tube in a concentric position. In the paper by Mohamed H. Shedid [2], Spalart-Allmaras (S-A) turbulence modeling is used to study numerically thermal behavior for annular flow of Nano fluids. The flow is subjected to a constant wall temperature at the outer wall. The Nano fluids considered are alumina (Al_2O_3) and oxide titanium (TiO_2) nanoparticles and water as the base fluid. To conduct the investigation, a grid is constructed that give y+ for all velocities below 1. The model is validated with Gnielinski correlation for the flow of pure water. Validated model was used for different concentration ratios of Al_2O_3 and TiO_2 for different Peclet numbers.

The results were compared with many correlations for convection of Nano fluids flow and revealed better agreement with Spalart-Allmaras [2] model rather than k-Ɛ model. Results of numerical simulations are compared and showed an enhancement of Nusslet number as Peclet number grows with increasing concentration ratio. In the paper by Mrunal P.Kshirsagar etal [3], Conventional heat exchangers are large in size and heat transfer rate is also less and in conventional heat exchanger dead zone is produce which reduces the heat transfer rate and to create turbulence in conventional heat exchanger some external means is required and the fluid in conventional heat exchanger is not in continuous motion with each other. Tube in tube helical coil heat exchanger provides a compact shape with its geometry offering more fluid contact and eliminating the dead zone, increasing the turbulence and hence the heat transfer rate. An experimental setup is fabricated for the estimation of the heat transfer characteristics. A wire is wounded in the core to increase the turbulence in turn increases the heat transfer rate. The paper deals with the pitch variation of the internal wounded wire and its result on the heat transfer rate. The Reynolds number and Dean number in the annulus was compared to the numerical data. The experimental result was compared with the analytical result which confirmed the validation. This heat exchanger finds its application mostly in food industries and waste heat recovery.

In the paper by A.D. Badgujar etal [4], the work deals with experimentation and CFD modeling related to U-type PTCs. Two cases of 'U' bends have been studied; gradual 'U' bends and sharp 'U' bends. Experimentation has been carried out using copper screens of 100-mesh size as flow straighteners. The optimum performance in terms of low temperature for the case of a gradual U bend was achieved with a stack of 18 flow-straightener screens. The no-load temperature for this case of a gradual 'U' bend, with and without flow straighteners, was 57.7 K and 88.8 K, respectively, for a charging pressure of 16 bar. When the gradual 180 degree bend at the cold end was replaced by a sharp U bend, the no load temperature increased from 88.8 K to 137 K without flow straighteners.

In the paper by Quamrul H. Mazumder [5], Solid particle erosion is a micromechanical process that is influenced by flow geometry, material of the impacting surface, impact angle, particle size and shape, particle velocity, flow condition and fluid properties. Among the various factors, particle size and velocity have been considered to be the most important parameters that cause erosion. Particle size and velocity are influenced by surrounding flow velocities and carrying fluid properties. Higher erosion rates have been observed in gas-solid flow in geometries where the flow direction changes rapidly, such as elbows, tees, valves, etc., due to local turbulence and unsteady flow behaviors.

2.1Concept of Nano fluid

Nano fluids are fluids containing nanoparticles (nanometer-sized particles of metals, oxides, carbides, nitrides, or nanotubes). Nano fluids exhibit enhanced thermal properties, amongst them; higher thermal conductivity and heat transfer coefficients compared to the base fluid. Simulations of the cooling system of a large truck engine indicate that replacement of the conventional engine coolant (ethylene glycol-water mixture) by a Nano fluid would provide considerable benefits by removing more heat from the engine.

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Nano fluids are dilute liquid suspensions of nanoparticles with at least one of their principal dimensions smaller than100nm. From previous investigations, Nano fluids have been found to possess enhanced thermos physical properties such as thermal conductivity, thermal diffusivity, viscosity and convective heat transfer coefficients compared to those of base fluids like oil or water. From the current review, it can be seen that Nano fluids clearly exhibit enhanced thermal conductivity, which goes up with increasing volumetric fraction of nanoparticles. The current review does concentrate on this relatively new class of fluids and not on colloids which are Nano fluids because the latter have been used for a long time. Review of experimental studies clearly showed a lack of consistency in the reported results of different research groups regarding thermal properties. The effects of several important factors such as particle size and shapes, clustering of particles, temperature of the fluid, and dissociation of surfactant on the effective thermal conductivity of Nano fluids have not been studied adequately. It is important to do more research so as to ascertain the effects of these factors on the thermal conductivity of wide range of Nano fluids. Classical models cannot be used to explain adequately the observed enhanced thermal conductivity of Nano fluids.

Recently most developed models only include one or two postulated mechanisms of Nano fluids heat transfer. For instance, there has not been much fundamental work reported on the determination of the effective thermal diffusivity of Nano fluids nor heat transfer coefficients for Nano fluids in natural convection. There is a growth is the use of colloids which are Nano fluids in the biomedical industry for sensing and imaging purposes. This is directly related to the ability to design novel materials at the Nano scale level alongside recent innovations in analytical and imaging technologies for measuring and manipulating Nano materials. This has led to the fast development of commercial applications which use a wide variety of manufactured Nano particles. The production, use and disposal of manufactured Nano particles will lead to discharges to air, soils and water systems. Negative effects are likely and quantification and minimization of these effects on environmental health is necessary. True knowledge of concentration and physicochemical properties of manufactured Nano particles under realistic conditions is important to predicting their fate, behavior and toxicity in the natural aquatic environment. The aquatic colloid and atmospheric ultrafine particle literature both offer evidence as to the likely behavior and impacts of manufactured Nano particles, and there is no pretense that a review duplicating similar literature about the use of colloids which are also Nano fluids is attempted in the current review. Owing to their enhanced properties as thermal transfer fluids for instance, Nano fluids can be used in a plethora of engineering applications ranging from use in the automotive industry to the medical arena to use in power plant cooling systems as well as computers.

3. Figures, Tables and Equations

3.1 Figures

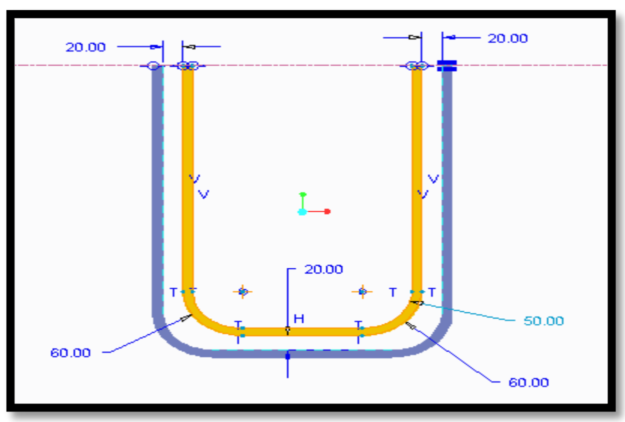

Fig 3.1.1 Annular bend tube 2D model with dimensions

3.2CFD analysis of 2D model of Annular Bend tube

(i) Without Contact

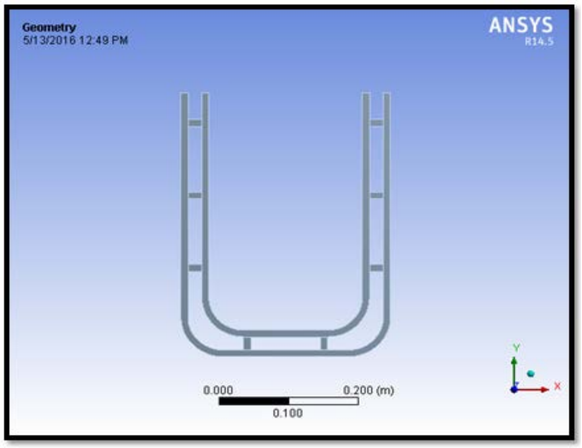

Fig 3.2.1. Annular bend tube imported model to ANSYS

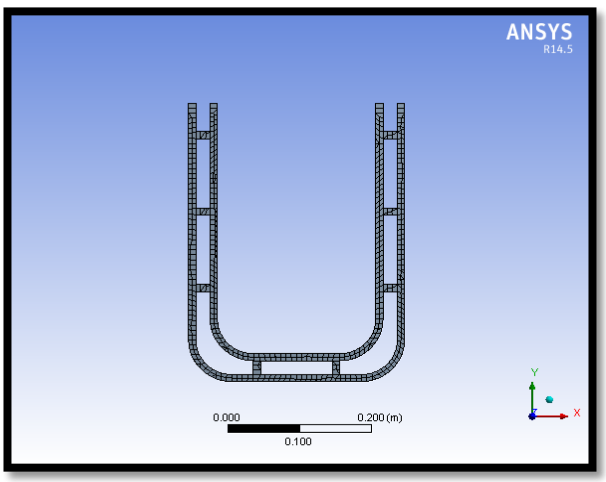

Fig 3.2.2. Annular bend tube meshed model

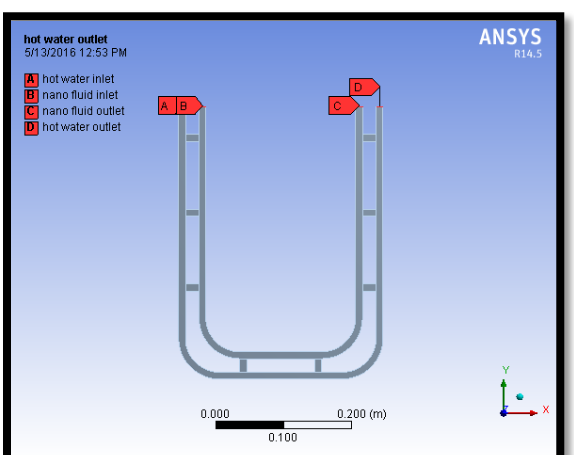

Fig 3.2.3. Annular bend tube inlet & outlet named model

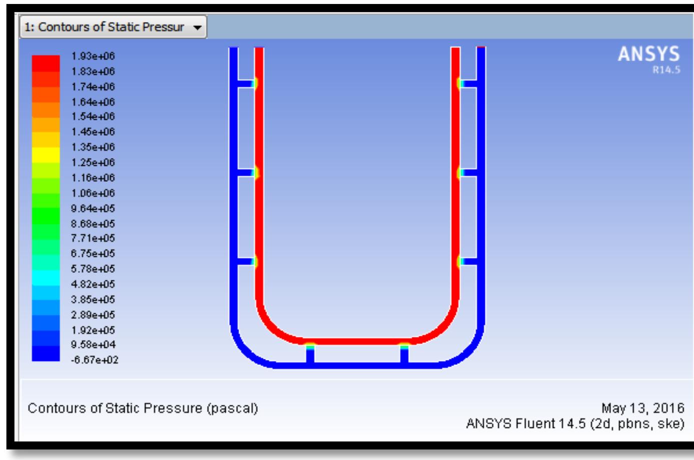

Fig 3.2.4. Contours of static pressure for Tri-chloro ethylene glycol

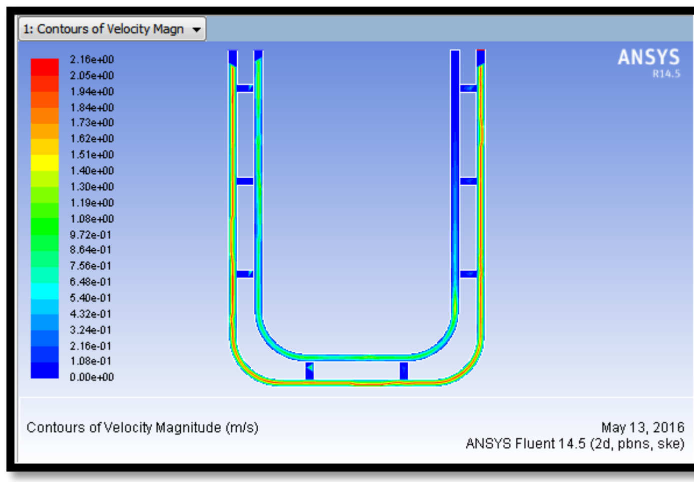

Fig 3.2.5. Contours of Velocity for Tri-chloro ethylene glycol

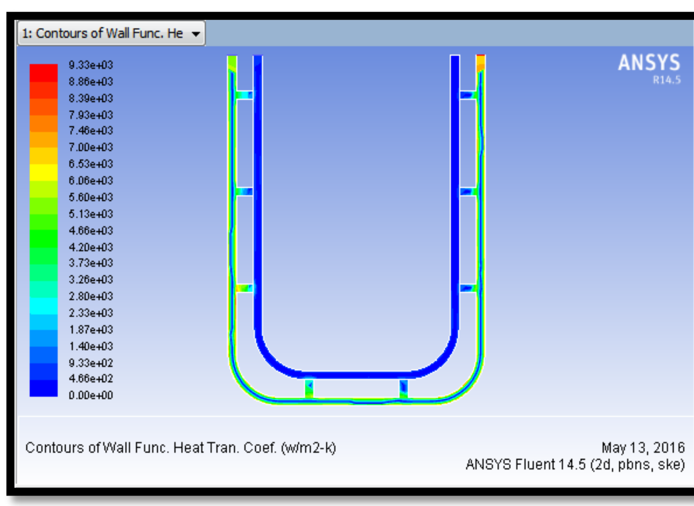

Fig 3.2.6. Contours of Heat transfer coefficient for Tri-chloro ethylene glycol

(ii) With Contact

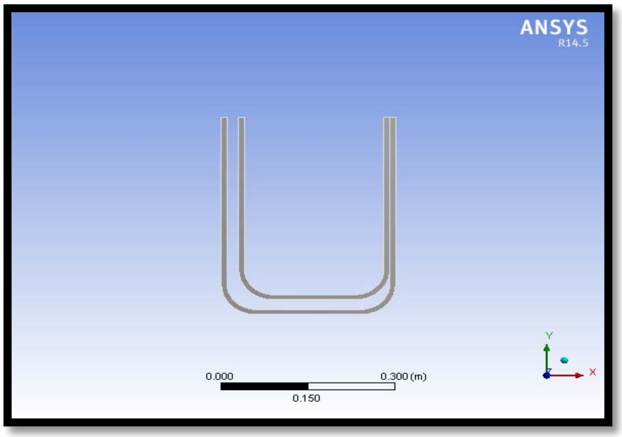

Fig 3.2.7 Annular bend tube imported model to ANSYS

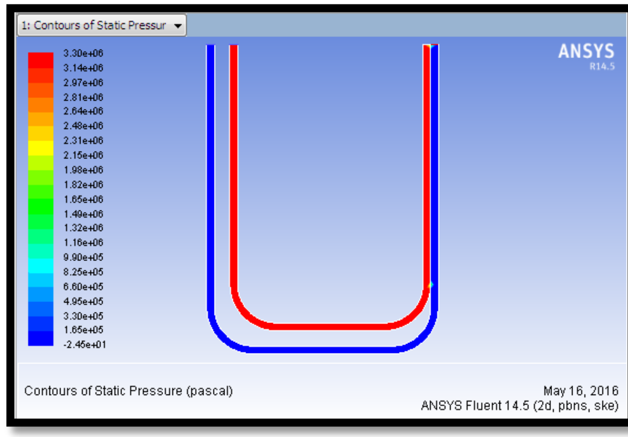

Fig 3.2.10. Contours of static pressure for Tri-chloro ethylene glycol

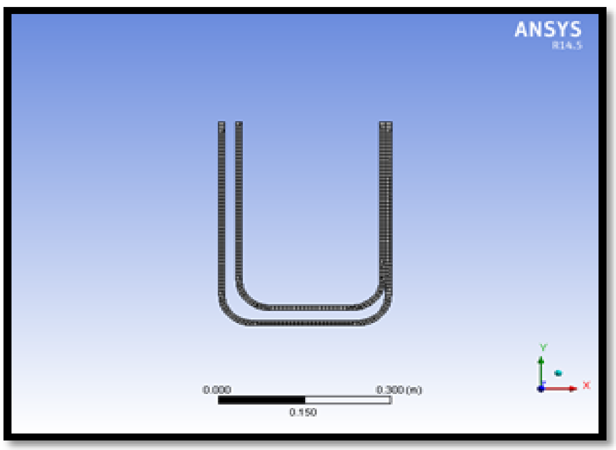

Fig 3.2.8. Annular bend tube meshed model

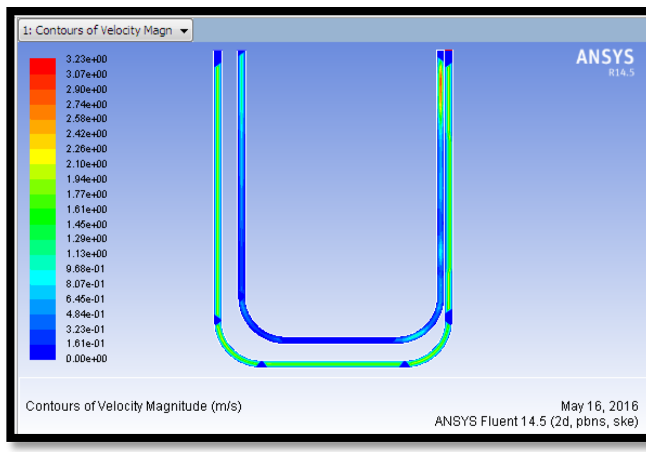

Fig 3.2.11. Contours of Velocity for Tri-chloro ethylene glycol

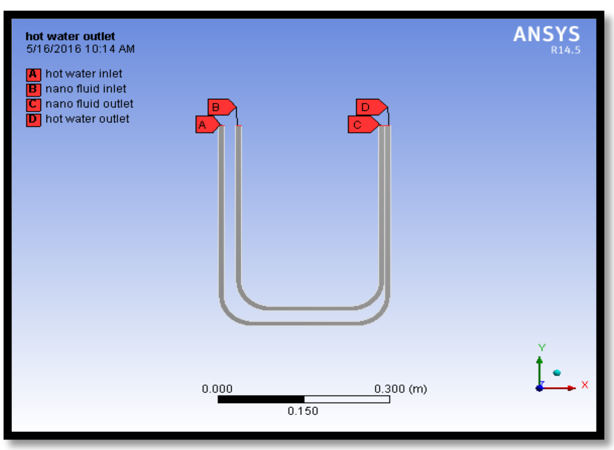

Fig 3.2.9. Annular bend tube inlet & outlet named model

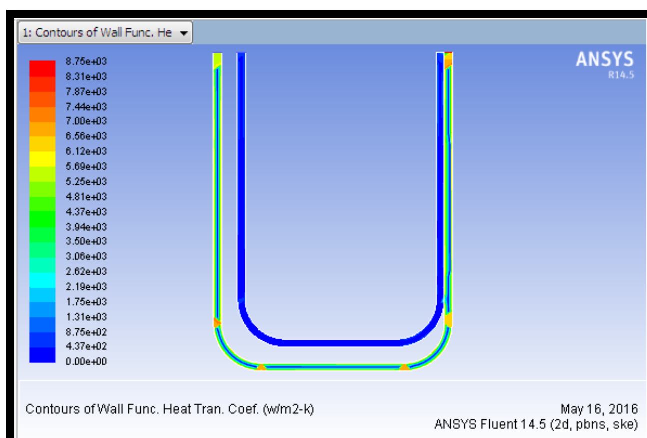

Fig 3.2.12. Contours of Heat transfer coefficient for Tri-chloro ethylene glycol

3.3Thermal analysis of 3D model of Annular Bend tube

(i) Without Contact

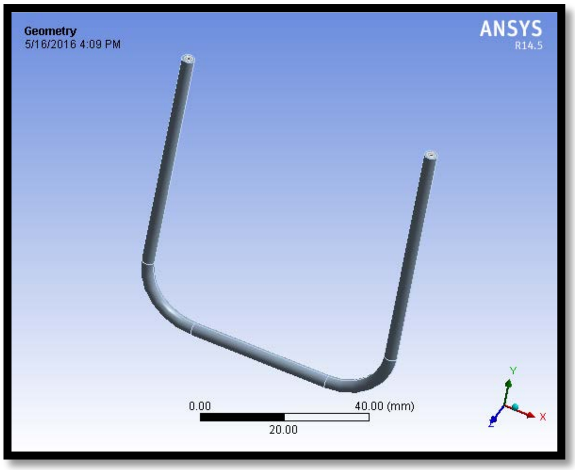

Fig 3.3.1. 3DAnnular bend tube imported model to ANSYS

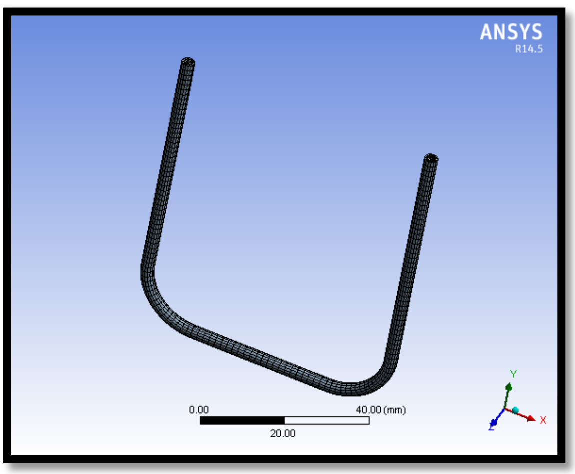

Fig 3.3.2.3DAnnular bend tube meshed model

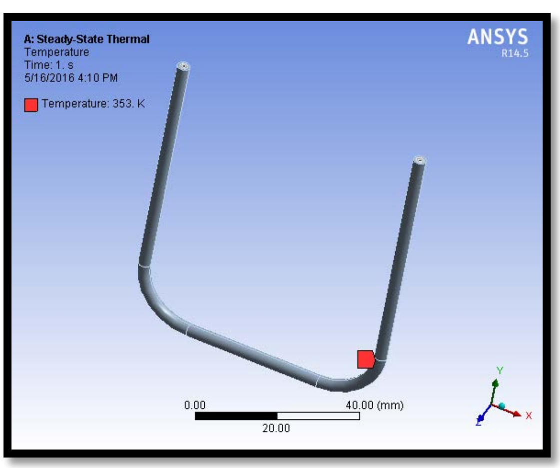

Fig 3.3.3. 3DAnnular bend tube with applied temperature

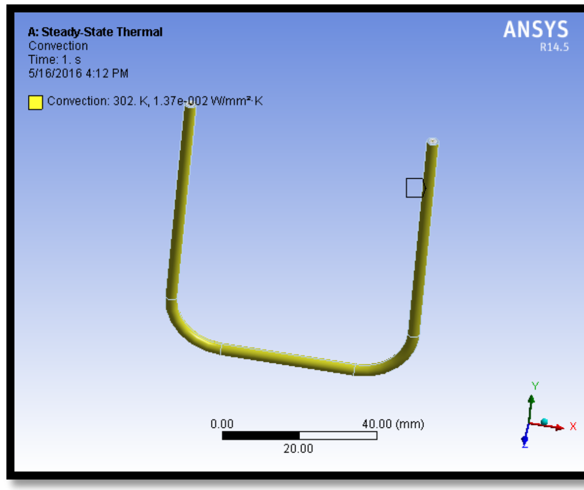

Fig 3.3.4. 3DAnnular bend tube with applied convection

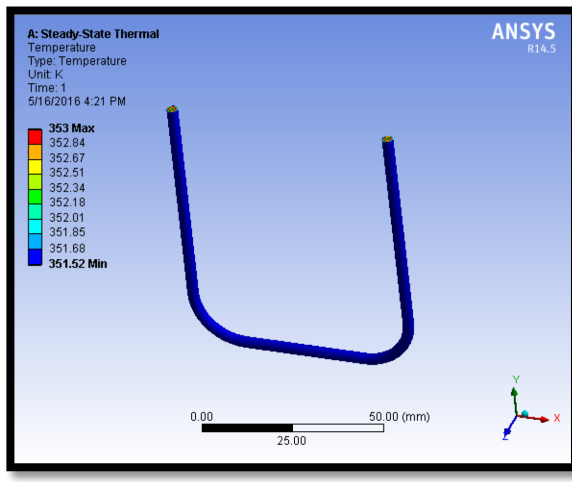

Fig 3.3.5. Results of Temperature

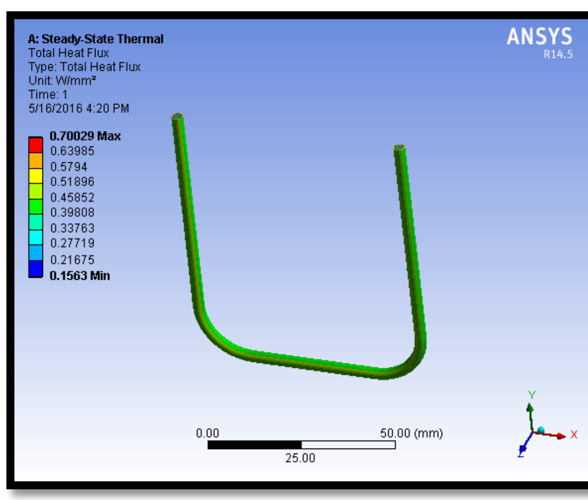

Fig 3.3.6. Results of Heat flux

(ii) With Contact

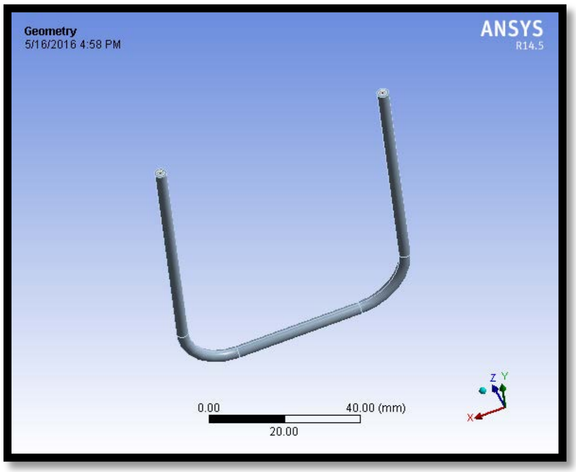

Fig 3.3.7. 3DAnnular bend tube imported model to ANSYS

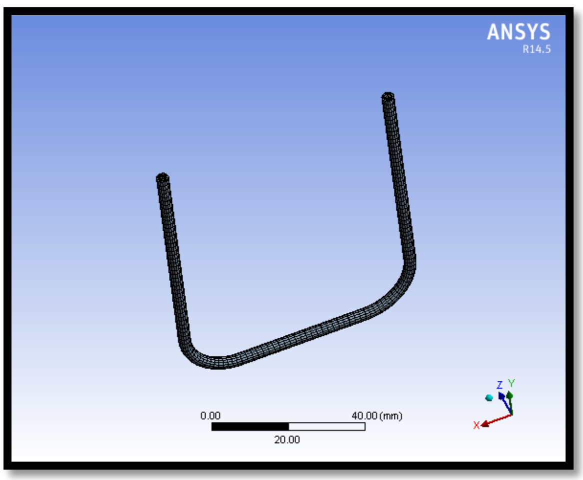

Fig 3.3.8.3DAnnular bend tube meshed model

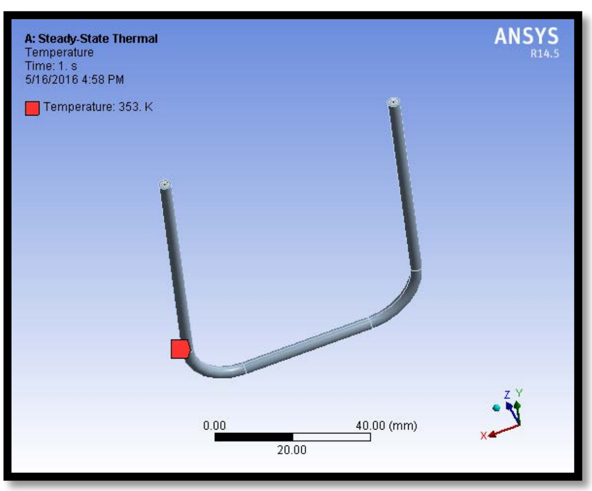

Fig 3.3.9. 3DAnnular bend tube with applied temperature

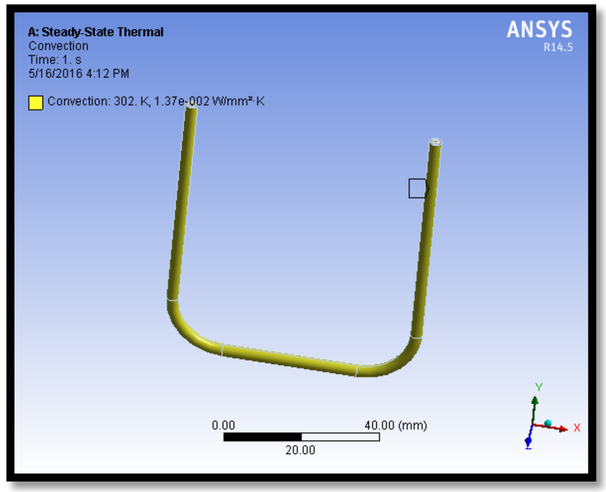

Fig 3.3.10. 3DAnnular bend tube with applied convection

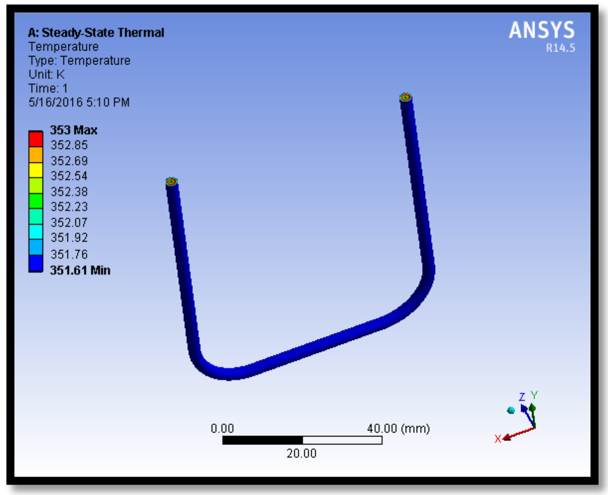

Fig 3.3.11. Results of Temperature

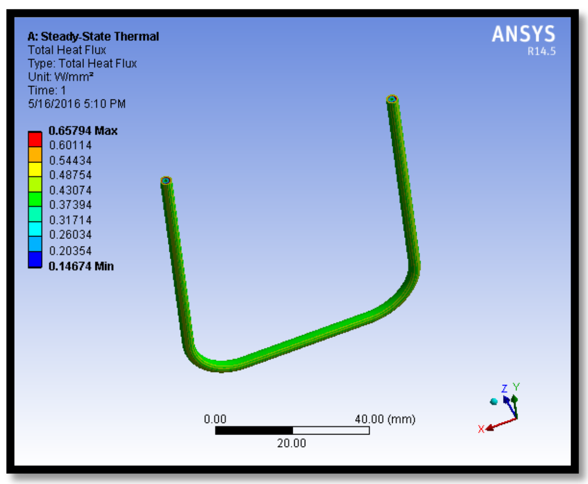

Fig 3.3.12. Results of Heat flux

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3.4 Tables

Table 3.4.1. CFD analysis results for Annular bend tube without contact.

Type of Nano fluid	Pressure (N/mm2)	Temp(K)	Velocity (m/s)	Heat Transfer coefficient (w/m^{2}k)	Heat Transfer Rate(w)
Aluminium Nano fluid	3.98e+06	3.82e+02	2.50e+00	1.37e+04	3204604
Copper Nano fluid	8.93e+06	3.82e+02	2.85e+00	9.73e+03	3009861.5
Tri-Chloro ethylene glycol	1.93e+06	3.83e+02	2.16e+00	9.33e+03	3696457.5
Silicon carbide	2.09e+06	3.82e+02	4.35e+00	8.88e+03	2581914.8

Table 3.4.2. CFD analysis results for Annular bend tube with contact.

Type of Nano fluid	Pressure (N/mm2)	Temp (K)	Velocity (m/s)	Heat transfer coefficient (w/m^{2}k)	Heat transfer Rate(w)
Aluminium Nano fluid	5.11e+06	3.82e+02	3.91e+00	9.09e+04	2942227.4
Copper Nano fluid	6.21e+06	3.82e+02	3.49e+00	9.16e+03	3025789.4
Tri-Chloro ethylene glycol	3.30e+06	3.82e+02	3.23e+00	8.75e+03	2717476.6
Silicon carbide	1.91e+06	3.82e+02	2.26e+00	8.74e+03	2730751.8

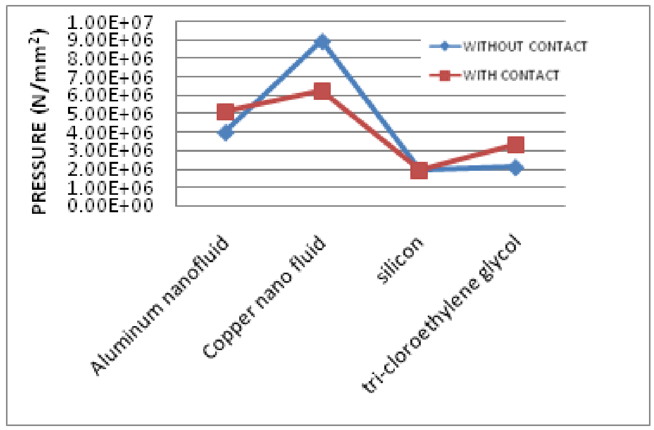
Table 3.4.3. Thermal analysis results for Annular bend tube without contact.

Type of Nano fluid	Temperature(k)	Heat flux (w/mm^2)
Aluminium Nano fluid	353	1.0145
Copper Nano fluid	353	0.72941
Tri-Chloro ethylene glycol	353	0.70029
Silicon carbide	353	0.66745

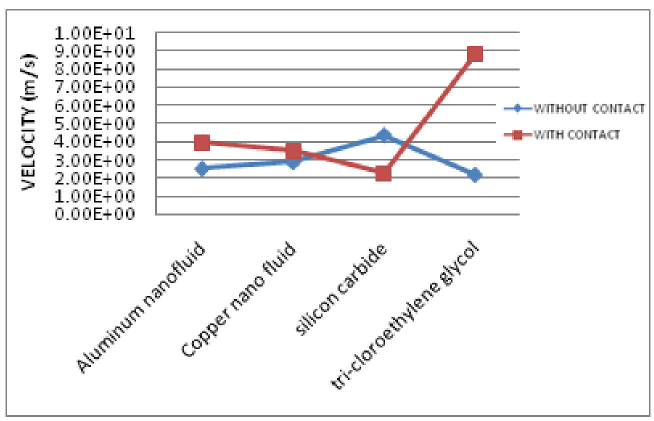
Table 3.4.4. Thermal analysis results for Annular bend tube with contact.

Type of Nano fluid	Temperature(k)	Heat flux (w/mm^2)
Aluminium Nano fluid	353	0.68278
Copper Nano fluid	353	0.68789
Tri-Chloro ethylene glycol	353	0.65794
Silicon carbide	353	0.65721

3.5Graphs



Graph 3.5.1. Annular bend tube without and with contact pressure comparison graph



Graph 3.5.2. Annular bend tube without and with contact velocity comparison graph

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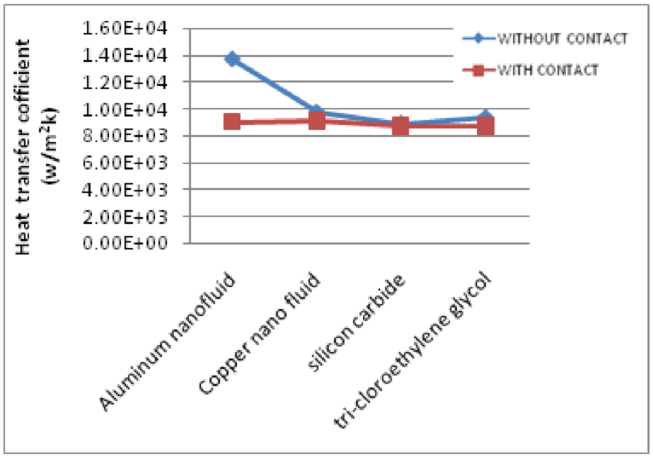
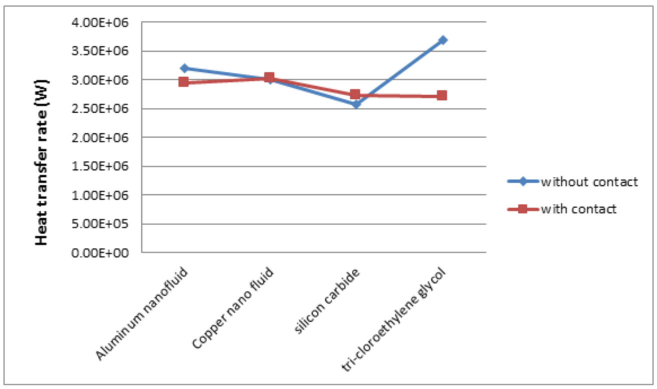
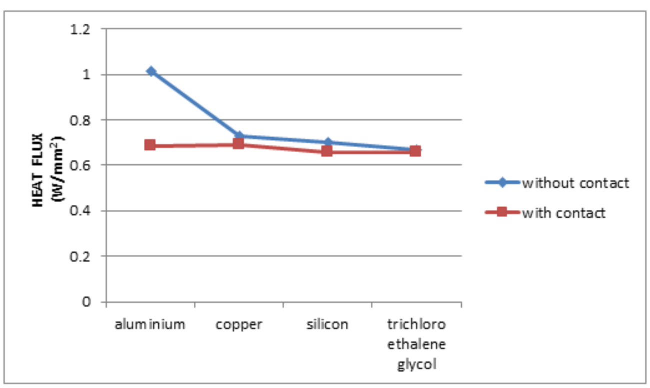


Graph 3.5.3. Annular bend tube without and with contact Heat transfer coefficient comparison graph



Graph 3.5.4. Annular bend tube without and with contact Heat transfer rate comparison graph



Graph 3.5.5. Annular bend tube without and with contact Heat flux comparison graph

4. Conclusions

I concluded that

1. By comparing the CFD analysis results, the heat transfer rate and heat transfer coefficient is more for without contact. The heat transfer rate is more when Tri-Chloro ethylene glycol is used and heat transfer coefficient is more when Aluminium Nano fluid is used.
2. By observing the thermal analysis results, the heat flux is more for without contact and Aluminium Nano fluid is used.

So it can be concluded that heat transfer rate is more in Annular bend tube without contact for Tri-Chloro ethylene glycol Nano fluid.

Acknowledgments

I would like to thank Head of Department Mr. Pulluru Srinivasulu sir, Guide Mr. Narukuti Gopal sir, Project coordinator Mr. Perala Raju Rao sir and the Principal and Management of Vaagdevi College of Engineering, Warangal for their constant support during this project.

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