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Thermal and CFD Analysis of Different Nan fluids Through a Circular Double Bend Tube

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ABSTRACT

Heat transfer by convection is very important for many industrial heating and cooling applications. The heat convection can passively be enhanced by changing flow geometry, boundary conditions or by enhancing fluid thermos 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 nanofluids were analyzed for their thermal behavior through a circular bend tube with turbulence flow. The fluids considered in this thesis are water, ethylene glycol, copper and aluminum nanofluids. Thermal and CFD analysis is performed to determine the thermal behavior using finite element analysis software Ansys. 3D modeling is done in Catia. All the obtained results were tabulated and compared at the end.

I. 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 Vibration 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 uninvolved process.

A. Nanofluids

Nanofluids are fluids containing nanoparticles (nanometer sized particles of metals, oxides, carbides, nitrides, or nanotubes). Nanofluids 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 Nanofluid would provide considerable benefits by removing more heat from the engine. Additionally, a calculation has shown that a graphite based Nanofluid developed jointly by Argonne and Valvoline could be used to eliminate one heat exchanger for cooling power electronics in a hybrid electric vehicle. This would obviously reduce weight, and allow the power electronics to operate more efficiently. The benefits for transportation would be Radiator size reduction, Pump size, Possible of elimination of one heat exchanger for hybrid electric vehicles and Increased fuel efficiency. Using silicon carbide nanoparticles from partner Saint Gobain, the team has created an ethylene glycol/water fluid with silicon carbide nanoparticles that carries heat away 15 percent more effectively than conventional fluids.

Nanofluids are dilute liquid suspensions of nanoparticles with at least one of their principal dimensions smaller than100nm. The current review does concentrate on this relatively new class of fluids and not on colloids which are Nanofluids 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

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shapes, clustering of particles, temperature of the fluid, and dissociation of surfactant on the effective thermal conductivity of Nanofluids 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 Nanofluids. Classical models cannot be used to explain adequately the observed enhanced thermal conductivity of Nanofluids.

B. Preparation of Nanofluids

In general, there are two methodologies used to produce nanofluids, namely the single-step method, where nanoparticles are produced and dispersed simultaneously into the base fluid, and the two-step method, where the two aforementioned processes are accomplished separately.

A single-step method is usually employed for metal nanofluid preparation. The main advantage of the single-step technique is the minimization of nanoparticle agglomeration. In this method, dry nanoparticle are first produced, and then they are dispersed in a suitable liquid host, but as nanoparticles have a high surface energy, aggregation and clustering are unavoidable and will appear easily.

C. Need of Nanofluids

Some basic needs of nanofluids are as follows.

- Due to nanosized particles, pressure drop is minimum.
- Higher thermal conductivity of nano particles will increase the heat transfer rate.
- Successful employment of nanofluid will lead to lighter and smaller heat exchanger
- Drastic change in properties of base fluid, by suspending nanofluids.
- Heat transfer rate increases due to large surface area of nano particles in the base fluid.

Nanofluids can be used for the wide variety of industries, ranging from transportation to energy production.

D. Applications of Nanofluids

Nanofluids can be used to cool automobile engines and welding equipments and to cool high heat flux device such as high power microwave tubes, and high power laser diode array. Nanofluids could flow through tiny passage in MEMS to improve the efficiency.

Some important common applications are:

- Engine cooling
- Engine transmission oil
- Boiler exhaust fuel gas recovery
- Cooling of electronics circuits
- Nuclear system cooling
- Solar water heating
- Refrigeration
- Defence and space applications
- Thermal storage
- Bio-medical applications

E. Curved pipe configurations

Curved pipe configurations are of immense practical importance in almost all piping systems, the human cardiovascular system, and in several engineering devices such as heat and mass exchanges, chemical reactors, chromatography columns, and other processing equipment. Owing to the wide range of applications, the interest in the study of flow characteristics in these configurations has grown enormously during the last decades

Chidanand K Mangrulkar and Vilayatri M Kriplani [1] presented a detailed study on nanofluids. J.A. Eastman *et al.* [2] developed new nanophase materials preparation system using electron beam heating to vaporize materials in inert or reactive gaseous environments. Anurag Hatwar [3], Sarit Kumar Das *et al.*[4], L. Syam sundar and K. V. Sharma [5], Roberto Bubbico *et al.*[6], experimentally investigated the convective heat transfer of different nanofluids in a plain horizontal tube. In a study by M. Hejri, M. Hojjat and S. Gh. Etemad [7], laminar flow forced convective heat transfer of Al2O3/water nanofluid thorough channels with isosceles triangle cross section with constant wall heat flux was studied numerically. Bayram Sahin *et al.*[8] experimentally studied the heat transfer and pressure drop of CuO-water nanofluid. M. A. Akhavan-Behabadi, M. Karami and B. Sajadi [9] studied heat transfer and pressure drop of oil flow inside a four-time corrugated copper tubes surrounded by a steam chamber. Ahmed Elsayed *et al.*[10] numerically investigated the turbulent flow heat transfer and pressure drop of Al_2O_3/water nanofluid in helically coiled tubes. CFD analysis of heat transfer and friction factor characteristics of ZnO/water through circular tube with rectangular helix inserts with different thicknesses by Amit Singh Bisht *et al.* [11] provided a better picture on how tube geometry influences heat flowing capabilities. In the article by Reza Davarnejad *et al.* [12], the heat transfer coefficient in the developed region of pipe flow containing Al_2O_3-water nanofluid during the constant heat flux was simulated using CFD. B. Sairamprasad, N. Gopal and P. Srinivasulu [13] did an investigation on Heat transfer through an Annular bend tube for various nanofluids using Thermal and CFD analysis.

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Golakiya Satyakumar *et al.*[14] theoretically analyzed the radiator with different kind of nanofluids. P. Kumar conducted [15] a CFD analysis to study heat transfer enhancement in pipe flow with Al_2O_3 nanofluid. Ashok K. Barik *et al.*[16] conducted a CFD study of forced convective heat transfer enhancement in a 90^o bend duct of square cross section using CuO, Al_2O_3 and TiO_2 nanofluids. Modeling and CFD analysis of tube in tube helical coil heat exchanger by Triloki Nath Mishra [17] show how a tube in tube helical coil can improve heat transfer rate. It was observed that the heat transfer capabilities of any system increases if the conventional fluid being used is replaced by a nanofluid. Different papers indicated the properties of different nanofluids and their utilization to study different parameters used to identify heat transfer properties. Nanofluids made from metallic oxides are considered in most of the research papers as they are cheaper than metals. But it is clearly known that metals have better thermal properties than metallic oxides and also increases durability and efficiency of the system. Copper and Aluminium based nanofluids are observed as best nanofluids whereas water and ethylene glycol are observed as the best base fluids. Moreover, water is commonly used base fluid than ethylene glycol. Hence these four fluids are considered to use for analytical purpose in the current study. Several components were used either in experimental or in CFD studies. But most of the industries are using plain circular tubes for heat transfer purposes. Circular pipe with two perpendicular bends was taken in the present thesis as this allows us to observe the effect of nanofluids at the bends.

II. REQUIRED DATA

A. Tube

Before an intelligent decision can be made, the potential purchaser must understand the basics of tube bending. Rather than delve into bending theory, we will look at the required physical information about the part. The proposed machinery must have the physical and technical characteristics required to bend the part. The major factors influencing this are:

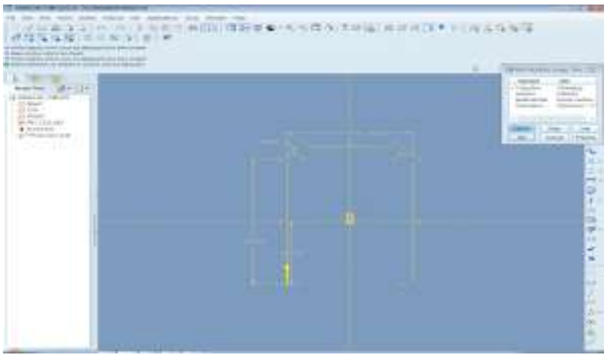
a) Outside diameter (OD) = 10mm
b) Wall thickness = 1.5mm
c) Bending radius (usually measured from tube center line) = 20mm
d) Material = Aluminium
e) Part configuration

B. Nanofluids

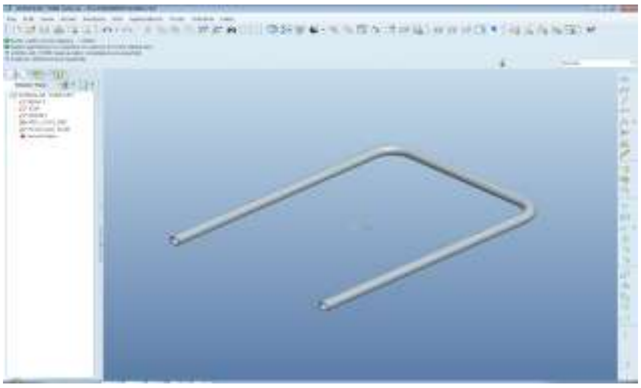
	Density (kg/m^3)	Specific heat (J/kg-k)	Thermal conductivity (w/m-k)	Viscosity (kg/m-s)
Water	998.2	4182	0.6	0.001003
Aluminum nanofluid	2780	875	151	1.72e-05
Cooper nanofluid	7940	385	385	1.7894e-05
Ethylene glycol	1114	2443	0.256	0.0157

III. DESIGN OF TUBE

A. Pattern

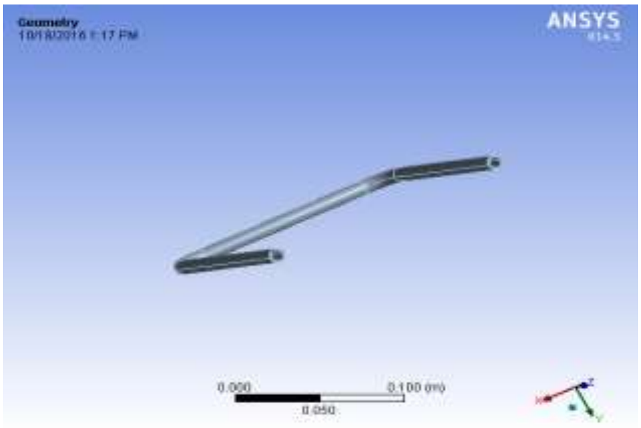


B. Preview



IV. THERMAL ANALYSIS OF BEND TUBE USING COOPER NANOFLUID

A. Geometry



B. Meshed file

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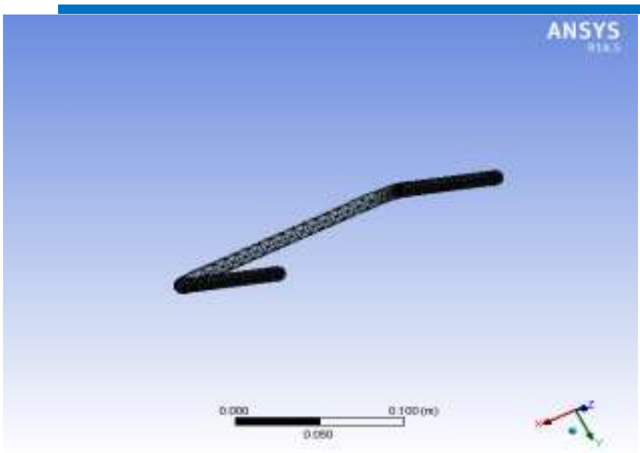
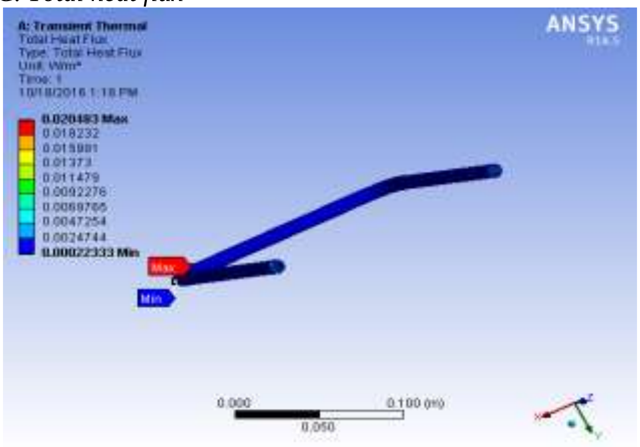
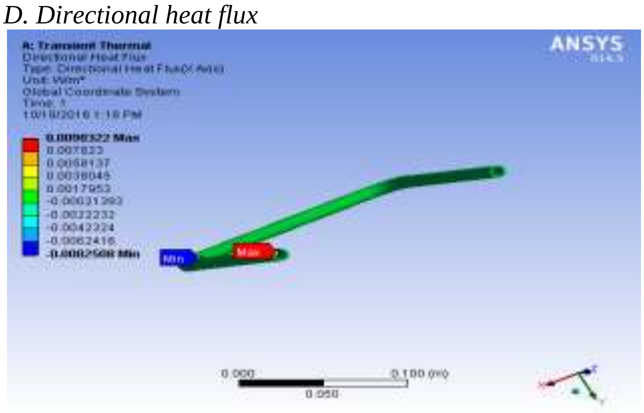


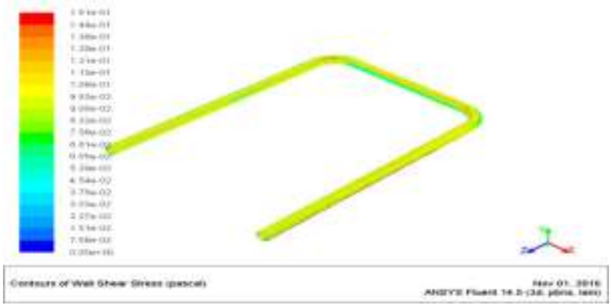
C. Total heat flux

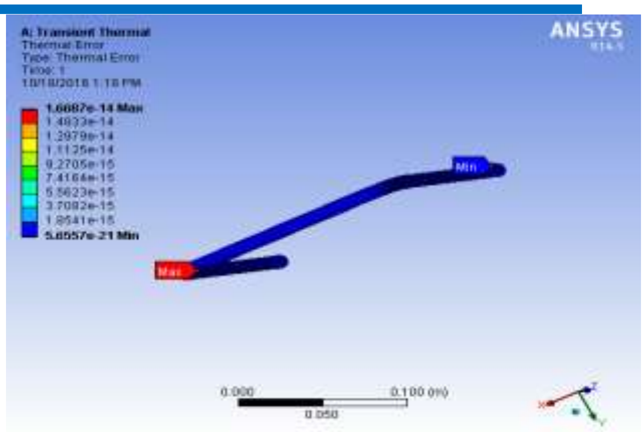


D. Directional heat flux



D. Stress Distribution

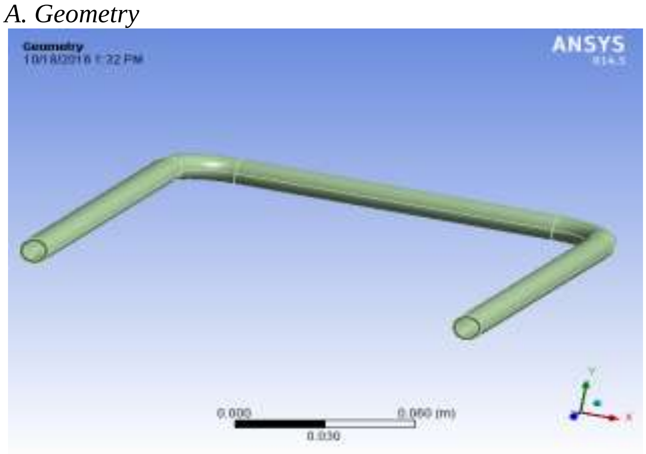




E. Thermal error

V. CFD ANALYSIS OF BEND TUBE SING COPPER NANOFLUID

A. Geometry



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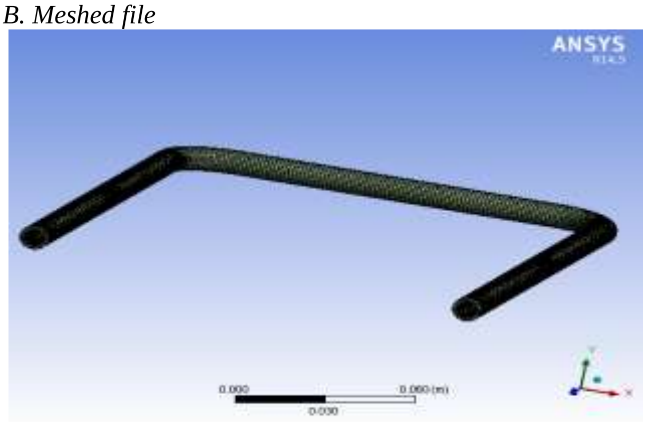
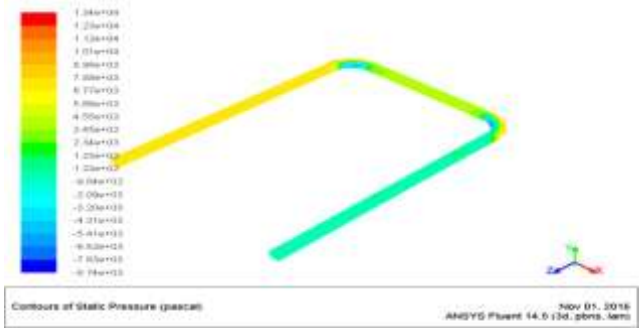


C. Pressure Distribution



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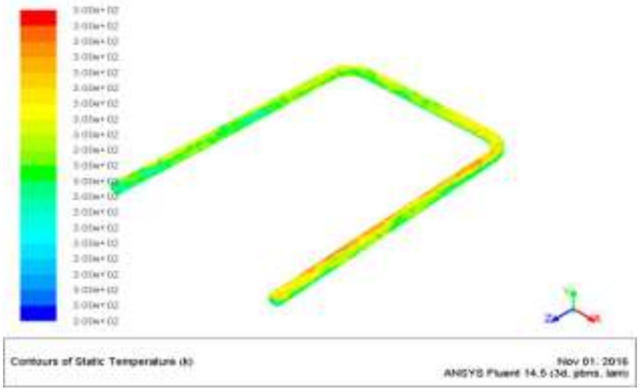
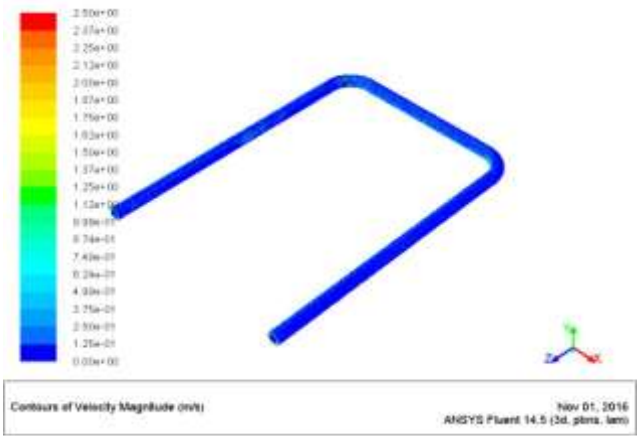
E. Temperature Dstribution



F. Velocity Distribution



VI. RESULT TABLES

A. Thermal analysis table

		Al 2024 nanofluid	**Cooper nanofluid**	**Ethylene glycol**
Temperature	**min**	127	127	127
	max	127	127	127
Total heat flux	**min**	0.052435	0.00022333	0.060955
	max	0.19226	0.020483	0.19009
Directional heat flux	**min**	-0.17945	-0.0082508	-0.18484
	max	0.18803	0.0098322	0.18664
Thermal error	min	4.1685 e^{-} 17	5.6557e^{-21}	1.6296 e^{-14}
	max	7.6292 e^{-} 13	1.6687e^{-14}	5.159 e^{-10}

B. CFD analysis table

Conditions		**Density (kg/m^3)**	**Pressure (pa)**	**Stress (pa)**	**Temperature (k)**	**Velocity (m/s)**
Al 2024 Nanofluid	**Min**	2.78e 03	- 3.74e^{0} 3	0	3.00e^{02}	0
	Max	2.78e 03	4.72e^{0} 3	1.50e^{-} 01	3.00e^{02}	2.53
Copper Nanofluid	**Min**	7.94e 03	- 8.74e^{0} 3	0	3.00e^{02}	0
	Max	7.94e 03	1.34e^{0} 4	1.51e^{-} 01	3.00e^{02}	2.50
Ethylene glycol	**Min**	1.11e 03	0	0	3.00e^{02}	0
	Max	1.11e 03	6.71e^{0} 4	1.24e 02	3.00e^{02}	2.52
Water	**Min**	1.23e 00	0	0	3.00e^{02}	0
	Max	1.23e 00	7.63e^{0} 1	1.41e^{-} 01	3.00e^{02}	2.51

VII. CONCLUSION

All the obtained values after the analysis were represented in tabular format. As our aim is to find the best nanofluid for the bend tube, we can easily find it by comparing the values of some properties of four fluids using tables and graphs prepared.

If we observe the analysis, temperature is almost same for all the fluids, but if we compare the pressure, here we can observe clearly that the Cooper fluid is having the least pressure created inside the tube. While coming to the velocity, here also the cooper got the lesser value than the other materials. But the stress is less for water than cooper fluid. We can also observe that heat flux and thermal error are low for copper nanofluid.. Considering all the comparisons cooper fluid is having the better flow and thermal properties.

So by observing all the results we can conclude that if we use cooper nanofluid as the operating liquid for bend tubes, the life ans efficiency of component increases and gives better output. Hence copper nanofluid is the best among the fouralternatives for the tubular flow.

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