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Design and CFD Analysis of Hair Pin Heat Exchanger at Different Nano-Fluids

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ABSTRACT

Heat exchanger is a device used to transfer heat between one or more fluids. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power stations, chemical plants, petrochemical plants, petroleum refineries, natural-gas processing, and sewage treatment. These exchangers provide true counter-current flow and are especially suitable for extreme temperature crossing, high pressure, high temperature, and low to moderate surface area requirements. Our Hairpin Exchangers are available in single tube (Double Pipe) or multiple tubes within a hairpin shell (Multitude), bare tubes, finned tubes, U-tubes, straight tubes (with rod-thru capability), fixed tube sheets and removable bundle.

In this thesis, different nano fluids mixed with base fluid water are analyzed for their performance in the hair pin heat exchanger. The nano fluids are Aluminium Oxide, silicon oxide and Titanium carbide for two volume fractions 0.4, 0.5. Theoretical calculations are done determine the properties for nano fluids and those properties are used as inputs for analysis.

3D model of the hair pin heat exchanger is done in Pro/Engineer. CFD analysis is done on the hair pin heat exchanger for all nano fluids and volume fraction and thermal analysis is done in Ansys for two materials Aluminum and Copper for better fluid at better volume fraction from CFD analysis.

Key words: Finite element analysis, Hair pin heat exchanger, CFD analysis, thermal analysis.

1. INTRODUCTION

Heat exchangers are one of the mostly used equipment in the process industries. Heat

Exchangers are used to transfer heat between two process streams. One can realize their usage that any process which involve cooling, heating, condensation, boiling or evaporation will require a heat exchanger for these purpose. Process fluids, usually are heated or cooled before the process or undergo a phase change. Different heat exchangers are named according to their application. For example, heat exchangers being used to condense are known as condensers, similarly heat exchanger for boiling purposes are called boilers. Performance and efficiency of heat exchangers are measured through the amount of heat transfer using least area of heat transfer and pressure drop. A better presentation of its efficiency is done by calculating over all heat transfer coefficient. Pressure drop and area required for a certain amount of heat transfer, provides an insight about the capital cost and power requirements (Running cost) of a heat exchanger. Usually, there is lots of literature and theories to design a heat exchanger according to the requirements.

2. LITERATURE REVIEW

DESIGN AND ANAYSIS OF DOUBLE PIPE HEAT EXCHANGER USING COMPUTATIONAL METHOD

Heat transfer equipment is defined by the function it fulfills in a process. On the similar path, Heat exchangers are the equipment used in industrial processes to recover heat between two process fluids. They are widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, and natural gas processing. The operating efficiency of these exchangers plays a very key role in the overall running cost of a plant. So the designers are on a trend of developing heat exchangers which are highly efficient compact, and cost effective. A common problem in industries is to extract maximum heat from a utility stream coming out of a particular process, and to heat a process stream. Therefore the objective of present work involves study of refinery process and applies phenomena of heat transfer to a double pipe heat exchanger.

Keywords— Thermal, Heat transfer, Computational Flow Dynamics (CFD), Modeling, Heat Flux, Heat transfer Coefficient

3. PROBLEM DESCRIPTION:

The objective of this project is to make a 3D model of the hair pin heat exchanger and study the CFD and thermal behavior of the heat exchanger by performing the finite element analysis.3D modeling software (PRO-Engineer) was used for designing and analysis software (ANSYS) was used for CFD and thermal analysis.

The methodology followed in the project is as follows:

- Create a 3D model of the hair pin heat exchanger assembly using parametric software pro-engineer.
- Convert the surface model into Para solid file and import the model into ANSYS to do analysis.
- Perform thermal analysis on the heat exchanger assembly for thermal loads.
- Perform CFD analysis on the existing model of the surface heat exchanger for Velocity inlet to find out the mass flow rate, heat transfer rate, pressure drop.

4. INTRODUCTION TO CAD/CAE:

Computer-aided design (**CAD**), also known as **computer-aided design and drafting** (**CADD**), is the use of computer technology for the process of design and design-documentation.

4.1. INTRODUCTION TO PRO-ENGINEER

Pro/ENGINEER Wildfire is the standard in 3D product design, featuring industry-leading productivity tools that promote best practices in design while ensuring compliance with your industry and company standards. Integrated Pro/ENGINEER CAD/CAM/CAE solutions allow you to design faster than ever, while maximizing innovation and quality to ultimately create exceptional products.

Different modules in pro/engineer

Part design, Assembly, Drawing& Sheet metal.

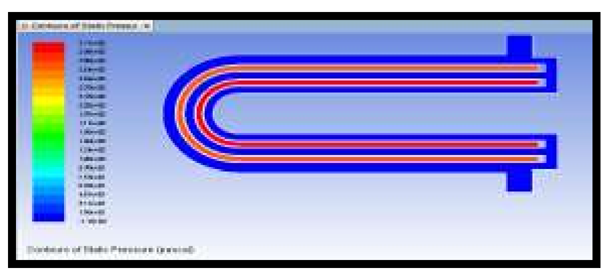
4.2. INTRODUCTION TO FINITE ELEMENT METHOD:

Finite Element Method (FEM) is also called as Finite Element Analysis (FEA). Finite Element Method is a basic analysis technique for resolving and substituting complicated problems by simpler ones, obtaining approximate solutions Finite element method being a flexible tool is used in various industries to solve several practical engineering problems. In finite element method it is feasible to generate the relative results.

5. RESULTS AND DISCUSSIONS:

5.1. CFD ANALYSIS OF HAIR PIN HEAT EXCHANGER

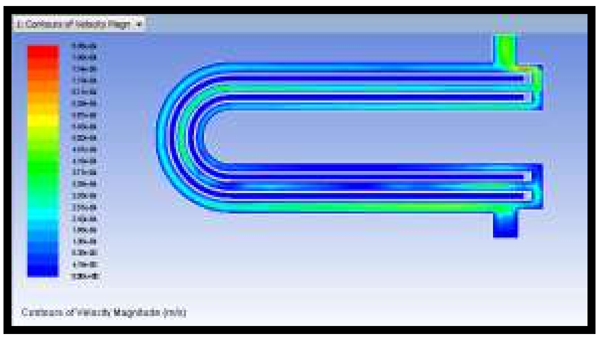
STATIC PRESSURE



According to the above contour plot, the maximum static pressure inside of the heat exchanger tubes because the applied the boundary conditions at inlet of the heat exchanger tubes and minimum static pressure at the shell and tube heat exchanger casing.

According to the above contour plot, the maximum pressure is 3.11e+02Pa and minimum static pressure is -1.16e-02Pa.

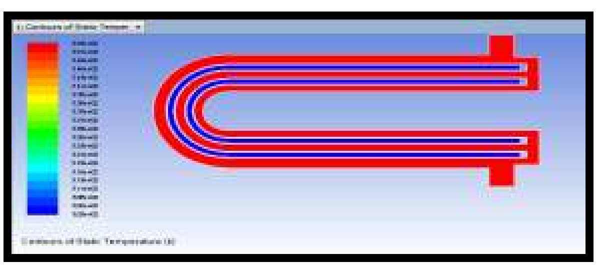
STATIC VELOCITY



According to the above contour plot, the maximum velocity magnitude of the heat exchanger at hot fluid inlet and minimum velocity magnitude at cold fluid outlet.

According to the above contour plot, the maximum velocity is 8.3e-04m/s and minimum velocity is 4.19e-05m/s.

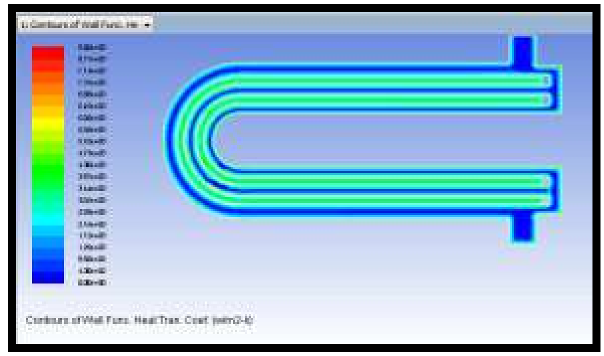
STATIC TEMPERATURE



According to the above contour plot, the maximum temperature of the nano fluid at inlet and outlet of the boundaries, because the applying the boundary conditions at inlet of the heat exchanger and minimum temperature at inside the tubes.

According to the above contour plot, the maximum temperature is 3.53e+02k and minimum temperature is 3.05e+02.

HEAT TRANSFER CO-EFFICIENT



According to the above contour plot, the maximum heat transfer coefficient of the heat exchanger at inside the tubes and minimum heat transfer coefficient inside the heat exchanger casing. According to the above contour plot, the maximum heat transfer coefficient is 8.60w/m^2-k and minimum heat transfer coefficient is 4.30e+02w/m^2-k.

HEAT TRANSFER RATE

Total Heat Transfer Rate	(w)
ci	474.39984
co	0
hi	4470.9307
ho	0
wall-_trm_srf	0
Net	4945.3305

5.2. THERMAL ANALYSIS OF HAIR PIN HEAT EXCHANGER

MATERIAL PROPERTIES:

ALUMINUM OXIDE

Density = 3880 kg/m^3

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Thermal conductivity =40 W/m-k

Specific heat = 910J/kg-k

TITANIUM CARBIDE

Density = 4930 kg/m^3

Thermal conductivity =330 W/m-k

Specific heat = 711 J/kg-k

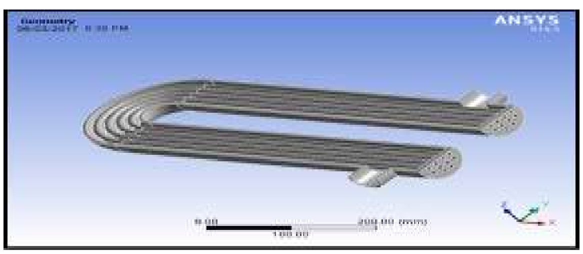
SILICON OXIDE

Density = 2650 kg/m^3

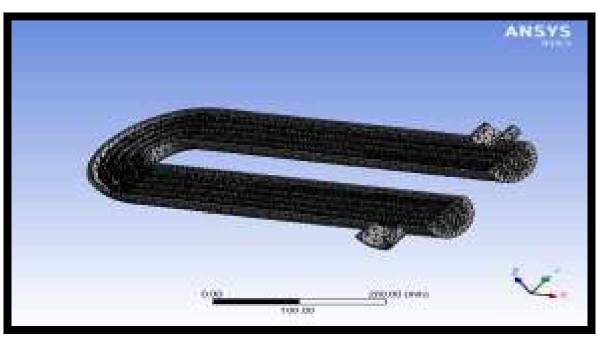
Thermal conductivity =1.3 W/m-k

Specific heat = 680 J/kg-k

IMPORTED MODEL

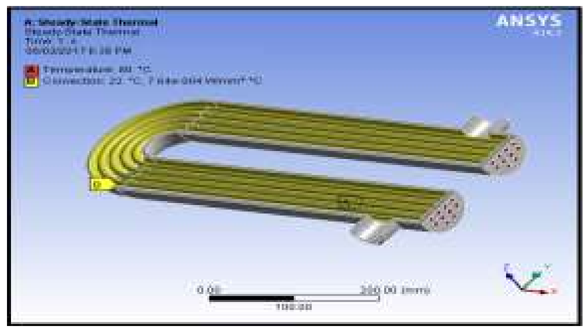


MESHED MODEL

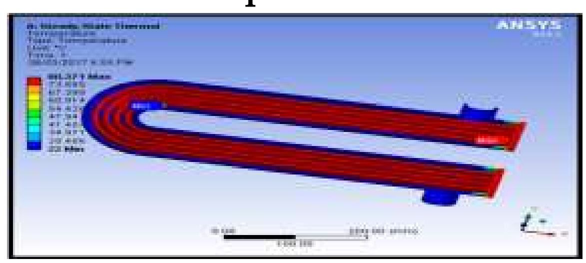


Finite element analysis or FEA representing a real project as a "mesh" a series of small, regularly shaped tetrahedron connected elements, as shown in the above fig. And then setting up and solving huge arrays of simultaneous equations. The finer the mesh, the more accurate the results but more computing power is required.

BOUNDARY CONDITIONS



Temperature



According to the contour plot, the temperature distribution maximum temperature at tubes because the nano fluid passing inside of the heat exchanger tubes. So we are applying the temperature inside of the tube and applying the convection except inside the tubes. Then the maximum temperature at tubes and minimum temperature at steam boiler casing.

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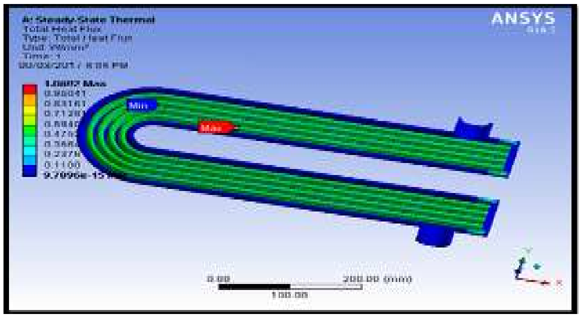
Heat flux



According to the contour plot, the maximum heat flux at inside the tubes because the nano fluid passing inside of the tube. So we are applying the temperature inside of the tube and applying the convection except inside the tubes. Then the maximum heat flux at inside the tubes and minimum heat flux at heat exchanger casing and outside of the tubes.

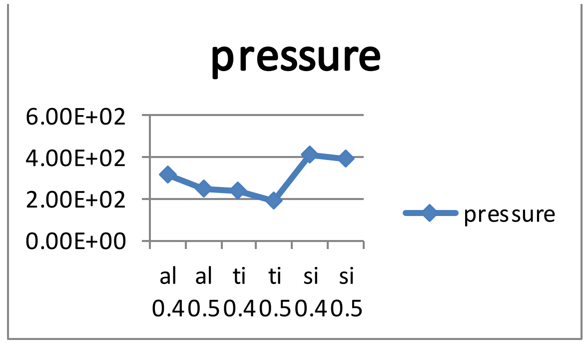
According to the above contour plot, the maximum heat flux is 1.06w/mm^2 and minimum heat flux is9.7896e-15w/mm^2

6. RESULTS AND DISCUSSIONS

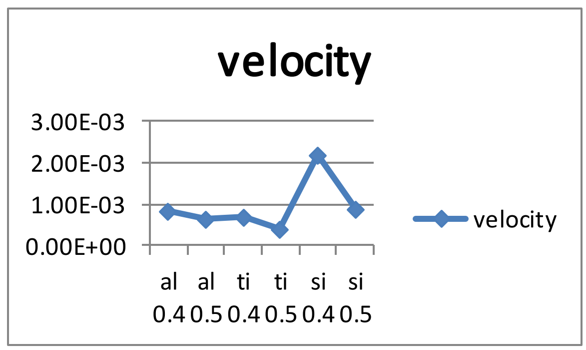
Fluids	Volume fraction (%)	Temperature(k)		Heat Flux (w/mm^2)
		Minimum	Maximum	
Aluminum Oxide	0.4	22	80.371	1.0692
	0.5	22	81.852	5.0286
Titanium Corbate	0.4	22	80.549	1.5716
	0.5	22	80.724	2.06
Silicon Oxide	0.4	22	80.031	0.22035
	0.5	22	80.035	0.2299

GRAPHS

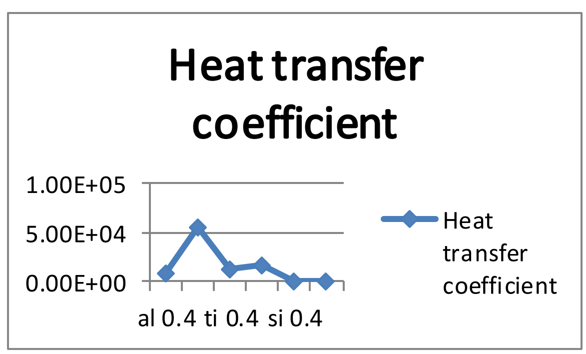
PRESSURE PLOT



VELOCITY PLOT



HEAT TRANSFER COEFFICIENT PLOT



HEAT TRANSFER RATE PLOT

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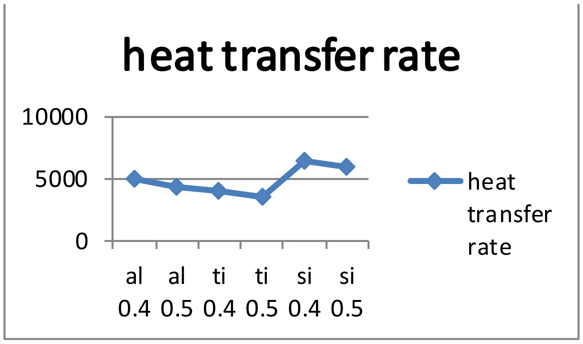
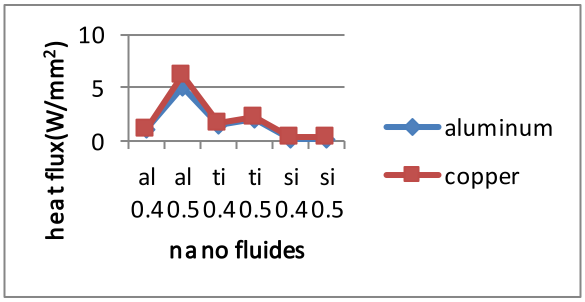


THERMAL ANALYSIS GRAPHS
HEAT FLUX PLOT



7. CONCLUSION

Numerical simulation has been carried out for double tube helical coil heat exchanger subjected to insulated outer wall condition using ANSYS FLUENT 15. The graphs are plotted for Nusselt number and heat transfer coefficient for the water and nanofluids in which flow condition is taken as turbulent. Following are the outcomes of the above study;.

- It is observed that heat transfer coefficient decreases with increasing curvature ratio. Because by increasing the coil diameter (doi), torsional behavior approaches towards linear behavior.
- Heat transfer coefficient increases with increase in Dean Number for convective heat transfer. Because at higher flow rates, the dispersion effects and chaotic movement of the nanoparticles intensifies the mixing fluctuations and causes increase in heat transfer coefficient. Nanofluid containing small amount of nanoparticles have substantially higher heat transfer coefficient than those of base fluids. And it increases with increase in particle volume fraction. Because increase in the nanoparticle volume fractions intensifies the interaction and collision of nanoparticles

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