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CFD APPORACH IN FINDING HEAT TRANSFER RATE OF HELICAL COIL HEAT EXCHANGER USING ANSYS SIMULATION

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ABSTRACT:
Enhancing the heat transfer by the use of the double tube helical coil heat exchanger has been studied and researched by many researchers. It is due to the reason that the fluid dynamics inside the pipes of a double pipe helical coil heat exchanger offers certain advantages over the straight tubes, shell and tube type heat exchanger, in terms of better heat transfer and mass transfer coefficients. This helical coil heat exchanger provides the advantage of achieving high overall heat transfer coefficients and high compact structure. The two ends of the tube act as inlet and outlet manifolds. We are not use application of external power, but we can improve the heat transfer rate by modifying the design by providing the helical tubes, extended surface or swirl flow devices. We improve the heat transfer rate from helical coil tube-in-tube heat exchangers to use Computational Fluid Dynamics (CFD). My project aims to perform a numerical study of helical coil tube-in-tube heat exchanger with water as both hot and cold fluid to improve the effectiveness, D/d geometrical parameter will be varied for different boundary conditions. The impact of this modification on Cold water temperature, Hot water temperature, Cold water velocity, Hot water velocity, Reynolds number, with respect to D/d will also be studied. They serve the purpose of the entry and exit of hot as well as cold fluid. Through various researches, researchers have found that a complex flow pattern exists inside a helical pipe which enhances heat transfer rate. Centrifugal forces acting are governed by the curvature of the coil. These centrifugal forces result in the development of secondary flow. The velocity of the fluid streams on the outer side of the pipe is more than the fluid streams in the inner side of the pipe. Copper was chosen as the as metal for the construction of the helical tube. The fluid flowing through the tube was taken as water. Ansys fluent 14.5 used for analysis and Catia v5 r20 used for the design.

1.0 Introduction

Heat exchanger is a device, such as an automobile radiator, used to transfer heat from a fluid on one side of a barrier to a fluid on the other side without bringing the fluid into direct contact Usually, this barrier is made from metal which has good thermal conductivity in order to transfer heat effectively from one fluid to another fluid. Besides that, heat exchanger can be defined as any of several devices that transfer heat from a hot to a cold fluid. In engineering practical, generally, the hot fluid is needed to cool by the cold fluid. For example, the hot vapor is needed to be cool by water in condenser practical. Moreover, heat exchanger is defined as a device used to exchange heat from one medium to another often through metal walls, usually to extract heat from a medium flowing between two surfaces. In automotive practice, radiator is used as heat exchanger to cool hot water from engine by air surrounding same like intercooler which used as heat exchanger to cool hot air for engine intake manifold by air surrounding. Usually, this device is

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made from aluminum since it is lightweight and good thermal conductivity

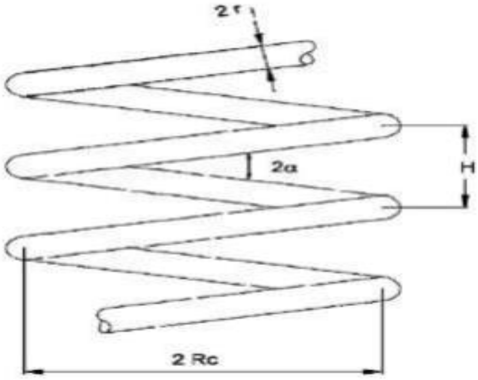

Figure: Basic geometry of a helical pipe

Function of heat exchanger

Heat exchanger is a special equipment type because when heat exchanger is directly fired by a combustion process, it becomes furnace, boiler, heater, tube-still heater and engine. Vice versa, when heat exchanger makes a change in phase in one of flowing fluid such as condensation of steam to water, it becomes a chiller, evaporator, sublimate, distillation-column reboiler, still, condenser or cooler-condenser.

Advantages of coils:

1) Helical coils give better heat transfer characteristics, since they have lower wall resistance & higher process side coefficient.
2) The whole surface area of the curved pipe is exposed to the moving fluid, which eliminates the dead-zones that are a common drawback in the shell and tube type heat exchanger.
3) A helical coil offers a larger surface area in a relatively smaller reactor volume and a lesser floor area.

Applications:

Helical coils are used for transferring heat in chemical reactors because the heat transfer coefficients are greater in helical coils as compared to other configurations. This is especially important when chemical reactions have high heats of reaction are carried out and the heat generated (or consumed) has to be transferred rapidly to maintain the temperature of the reaction. They are used widely in petroleum industries for different applications.

The helical coils have a compact configuration, and because of that they can be readily used in heat transfer application with space limitations, for example, marine cooling systems, central cooling, cooling of lubrication oil, steam generations in marine and industrial applications.

The helical coiled heat exchangers are used widely in food and beverage industries, like in food processing and pre-heating, pasteurization of liquid food items, and for storing them at desired temperatures.

Scope of the work:

The design of a helical coil tube in tube heat exchanger has been facing problems because of the lack of experimental data available regarding the behavior of the fluid in helical coils and also in case of the required data for heat transfer, unlike the Shell & Tube Heat exchanger. So to the best of our effort, numerical analysis was carried out to determine the heat transfer characteristics for a double-pipe helical heat exchanger by varying the different parameters like different temperatures and diameters of pipe and coil and also to determine the fluid flow pattern in helical coiled heat exchanger.

Objectives:

1. The objective of the project is to obtain a better and more quantitative insight into the heat transfer process that occurs when a fluid flows in a helically coiled tube.
2. The study also covered the different types of fluid flow range extending from laminar flow through transition to turbulent flow.
3. The materials for the study were decided and fluid taken was water and the material for the pipe was taken to be copper for its better conducting properties.

4. To understand the CFD requirement for analyse heat exchanger performance.

2.0 LITERATURE REVIEW

Daniel Flórez-Orrego [1], Walter Arias, Diego Lopez and Hector Velasquez have worked on the single-phase cone shaped helical coil heat exchanger. The study showed the flow and the heat transfer in the heat exchanger. An empirical correlation was proposed from the experimental data for the average Nusselt number and a deviation of 23% was found.

J. S. Jayakumar [2] observed that the use of constant values for the transfer and thermal properties of the fluid resulted in inaccurate heat transfer coefficients. Based on the CFD analysis results a correlation was developed in order to evaluate the heat transfer coefficient of the coil. In this study, analysis was done for both the constant wall temperature and constant wall heat flux boundary conditions.

Timothy J. Rennie [3] studied the heat transfer characteristics of a double pipe helical heat exchanger for both counter and parallel flow. Both the boundary conditions of constant heat flux and constant wall temperature were taken. The study showed that the results from the simulations were within the range of the pre-obtained results.

Usman Ur Rehman [4] studied the heat transfer and flow distribution in a shell and tube heat exchanger and compared them with the experimental results. The model showed an average error of around 20% in the heat transfer and the pressure difference.

Nawras H. Mostafa, Qusay R. Al-Hagag [5] studied on the mechanical and thermal performance of elliptical tubes used for polymer heat exchangers. The mechanical analysis showed that the streamlined shape of the outer tube had an optimal thermal performance.

3.0 Design specifications and methodology

Copper was chosen as the as metal for the construction of the helical tube. The fluid flowing through the tube was taken as water. Computational fluid dynamics (CFD) study of the system starts with the construction of desired geometry and mesh for modeling the dominion. Generally, geometry is simplified for the CFD studies. Meshing is the discretization of the domain into small volumes where the equations are solved by the help of iterative methods. Modeling starts with the describing of the boundary and initial conditions for the dominion and leads to modeling of the entire system. Finally, it is followed by the analysis of the results, discussions and conclusions

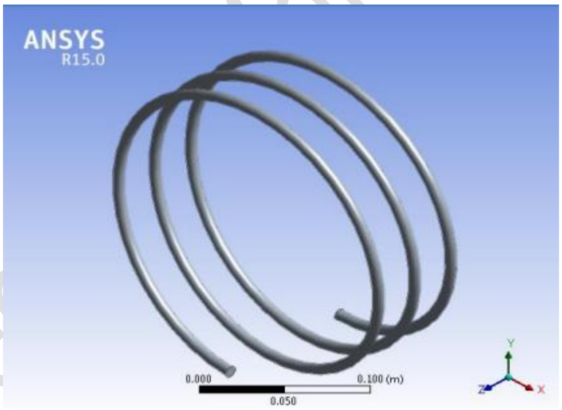

Figure: helicoil model view

Helical Coil Test Section:

The pipe used to construct the helical section has 10mm I.D. and 12.7mm O.D. The tube material is SS 316. The Pitch Circle Diameter (PCD) of the coil is 300mm and tube pitch is 30mm. The remaining parts of the setup are made of SS 304.The helical coil is enclosed in a vessel to simulate the shell side of heat exchanger. The cold fluid enters the shell through the bottom connection and flows up. It leaves the shell through the nozzle at the top. The coil and the baffle are welded to a top flange in such a way that they can be replaced with another coil assembly.

Design parameters of helical coil 1&2

- Pitch of helical coil 1&2 =0.01 mm
- Inner diameter of the tube =6.25 mm
- Tube thickness = 0.5 mm
- Diameter of evaporator coil 1=250mm

- Diameter of evaporator coil 2=170mm
- Length of coil 1 &2 =30cm

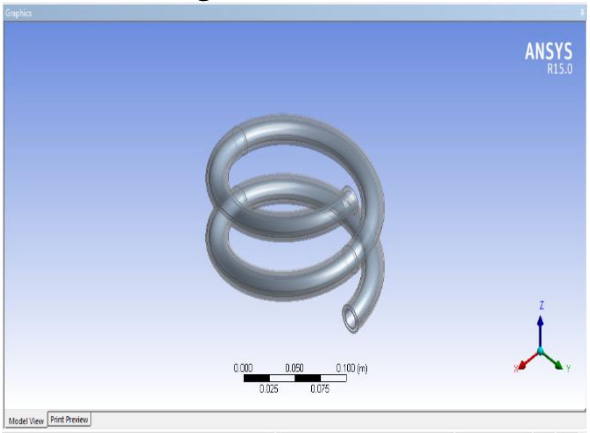

FIGURE: STRUCTURAL DESIGN OF A

FIGURE: GEOMETRY FOR MESHING

The mesh is checked and quality is obtained. The analysis type is changed to Pressure Based type. The velocity formulation is changed to absolute and time to steady state. Gravity is defined as y = -9.81 m/s2.

Experimental procedure:

To Enhance the COP of Vapor Compression Refrigeration Test Rig by Varying The throat diameters of the Capillary Tubes. The Following Experimental Setup and Procedure Used for Studies are Discussed In this Chapter.

Figure: Experimental-Setup Tube-in-Tube Helical Coil Heat Exchanger

Cold tap water will be used for the fluid flowing in the outer tube. The water in the outer tube will be circulated. The flow will control by a valve, allowing flows to be control and measure between 200 and 500 LPH. Hot water for the inner tube was heated in a tank with the thermostatic heater set at 600C. This water will be circulated via pump. The flow rate for the inner tube will control by flow metering valve as described for the outer tube flow.

Experimental setup:

a photographic view of vapor compression refrigeration test rig made with 30liter capacity for testing water. The evaporator was a steel container with a insulating material surrounding it. Filter-drier is installed before the capillary tube to absorb the moisture which may exist in the refrigerant circuit. As the refrigerant is condensed in the condenser, it flows through the high-side filter- drier into a capillary tube. The test rig used for the experiment is a vapor compression refrigeration test rig designed to work with R134a. It consists of an evaporator, wire mesh air cooled condenser and hermitically sealed reciprocating compressor. Four pressure gauges were installed at compressor inlet and outlet, condenser outlet and evaporator inlet. All these pressure gauges were fitted on the metal frame to avoid vibration during testing. There are five points of the thermo couple wire were connected to the thermocouple scanner.

4.0 RESULTS AND DISCUSSIONS

In computational fluid dynamics (CFD) software, using a numerical procedure the governing equations are solved simultaneously. Now, the domain is divided into number of cells and the partial differential equations (PDEs) are then applied to each cell. Therefore, each cell now becomes a domain and PDEs are discretized and applied to that cell. The approximate solution of differential equations is obtained by truncated Taylor series expansions or other similar methods.

CFD analysis

Computational fluid dynamics (CFD) study of the system starts with the construction of desired geometry and mesh for modeling the dominion. Generally, geometry is simplified for the CFD studies. Meshing is the

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discretization of the domain into small volumes where the equations are solved by the help of iterative methods. Modeling starts with the describing of the boundary and initial conditions for the dominion and leads to modeling of the entire system. Finally, it is followed by the analysis of the results, conclusions and discussions.

Table: Naming of various parts of the body with state type

Part Of The Model	State Type
Inner_ Fluid	fluid
Inner_ Pipe	solid
Outer_ Fluid	fluid
Outer_ pipe	fluid

Geometry:

Heat exchanger is built in the ANSYS workbench design module. It is a counter-flow heat exchanger. First, the fluid flow (fluent) module from the workbench is selected. The design modeler opens as a new window as the geometry is double clicked.

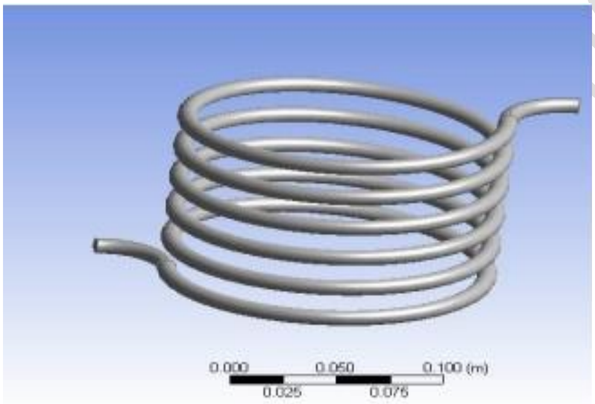


Figure: Geometry Model

Sketching

Out of 3 planes, viz, XY-plane, YZ-plane and ZX-plane, the YZ-plane is selected for the first sketch. A 4 inch line for the height of the helical structure is made.

Sweep

Sketch 2, 3, 4 & 5 are swept along the line made in sketch made in sketch 1 using the"add frozen" operation to construct the 3D model with different parts. The helical sweep is of 2 turns because the twist specification is defined in number of turns.

Merging

After sweep operation, it will show the model as 4 parts and 4 bodies. For merge operation, all the 4 parts are selected using control and merged as 1 part. At the end it will show as 1 part and 4 bodies. The 4 bodies within 1 part are named as follows Save the project at this point and close the window. Refresh and update the project on the workbench.

Mesh:

Initially a relatively coarser mesh is generated. This mesh contains mixed cells (Tetra and Hexahedral cells) having both triangular and quadrilateral faces at the boundaries. Care is taken to use structured hexahedral cells as much as possible. It is meant to reduce numerical diffusion as much as possible by structuring the mesh in a well manner, particularly near the wall region.

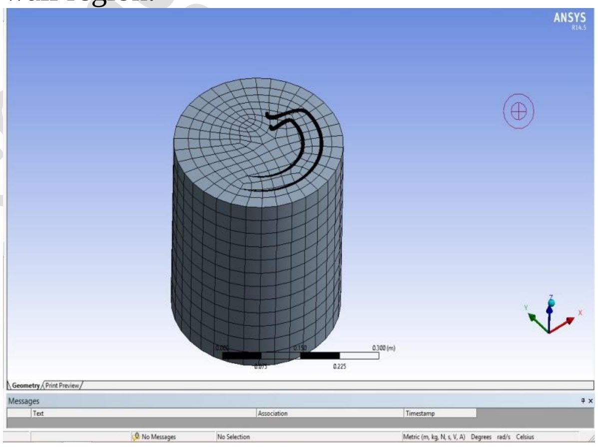


Figure: Node formation for helical coil heat exchanger

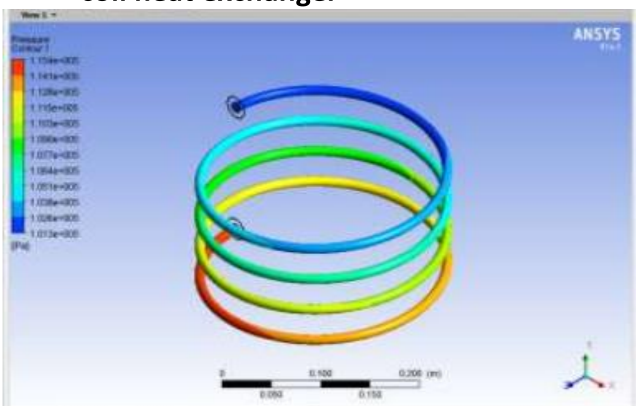


Figure: Pressure drop in inner tube at mass flow rate of 480 LPH (hot fluid)

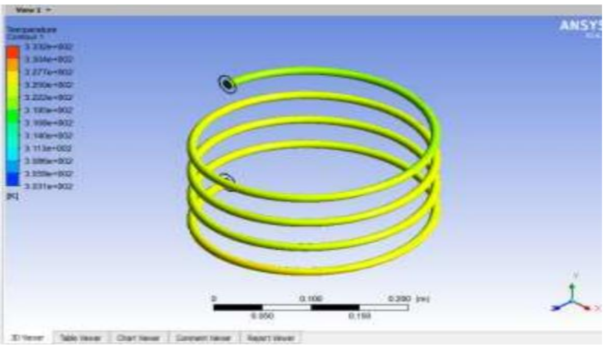


Figure: Temperature distribution in inner tube at mass flow rate of 480 LPH (hot fluid)

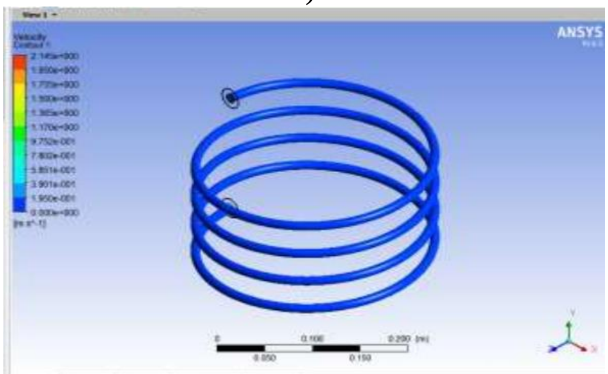


Figure: Velocity distribution in inner tube at mass flow rate of 480 LPH (hot fluid)

Effect of D/d Ratio on Design Parameters We can take hot fluid flow rate 120 LPH & cold fluid flow rate 480 LPH was constant and changes D/d Ratio 12.5,17.5, 22.5 & 32.5. CFD simulation was carried out by

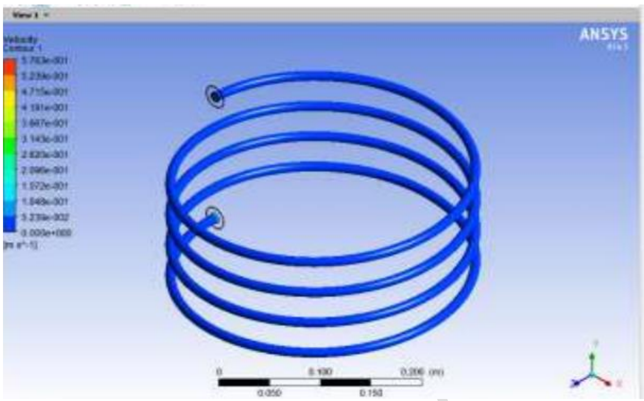


Figure: Velocity contour for hot fluid (D/d = 32.5)

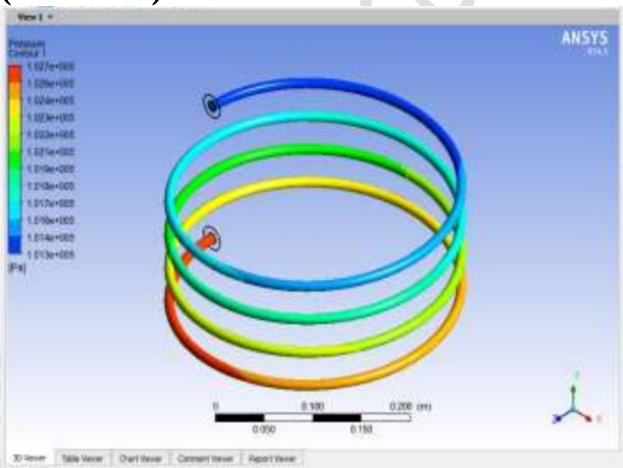
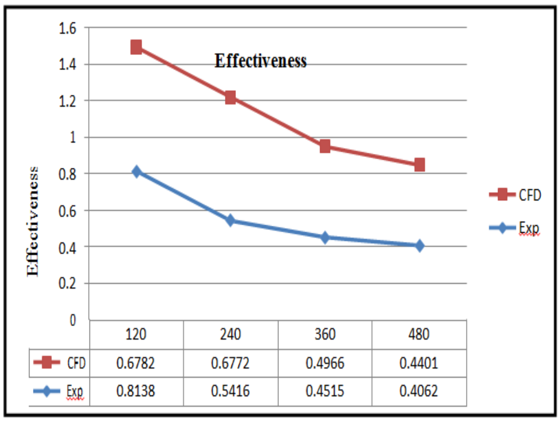


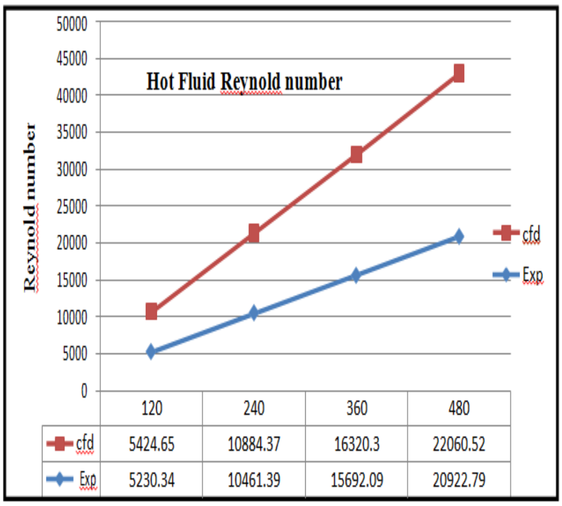
Figure: Pressure contour for hot fluid (D/d = 32.5)

Table: Compare experimental and CFD result of tube in tube helical coil heat exchanger

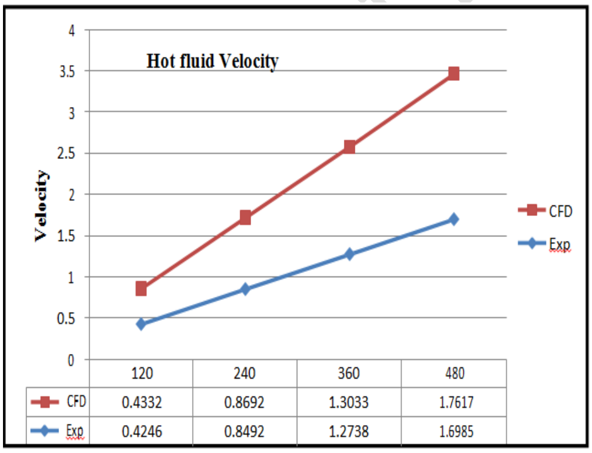
Hot water flow rate(LPH)	Effectiveness		Reynold number		Hot fluid Velocity		Nussult number	
	Exp	CFD	Exp	CFD	Exp	CFD	Exp	CFD
120	0.8138	0.6782	5230.34	5424.65	0.4246	0.4332	32.13	30.09
240	0.5416	0.6772	10461.39	10884.37	0.8492	0.8692	41.60	30.29
360	0.4515	0.4966	15692.09	16320.30	1.2738	1.3033	38.48	36.17
480	0.4062	0.4401	20922.79	22060.52	1.6985	1.7617	36.96	36.80



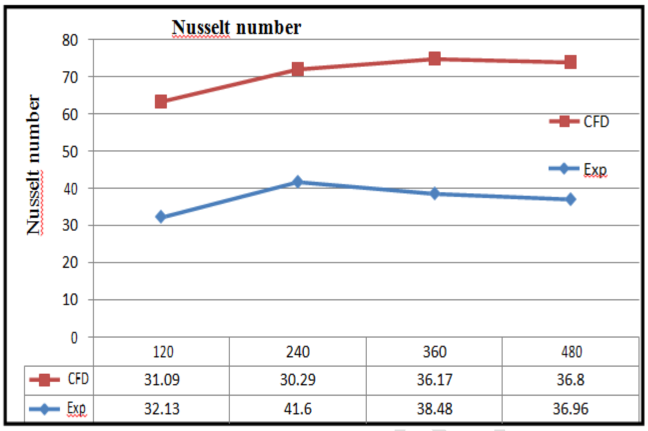
Graph: Experimental Vs CFD result of Effectiveness



Graph: Experimental Vs CFD result of Hot fluid Reynold number



Graph: Experimental Vs CFD result of Hot fluid velocity



Graph: Experimental Vs CFD result of Nusselt number

Contours:

The temperature, pressure and velocity distribution along the heat exchanger can be seen through the contours

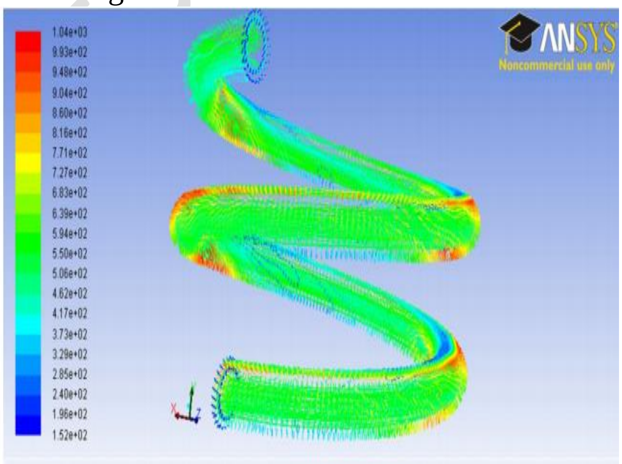


Figure: Contours of Dynamic Pressure in Pascal

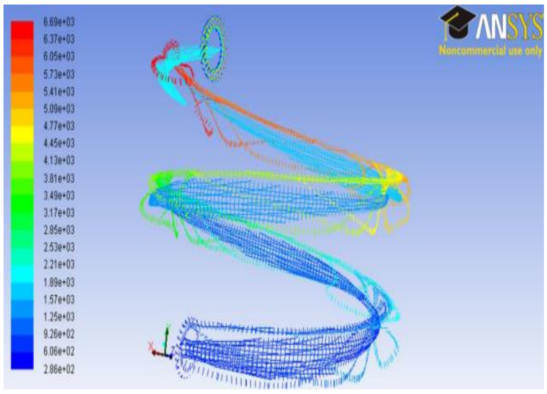


Figure: Contours of Total Pressure in Pascal

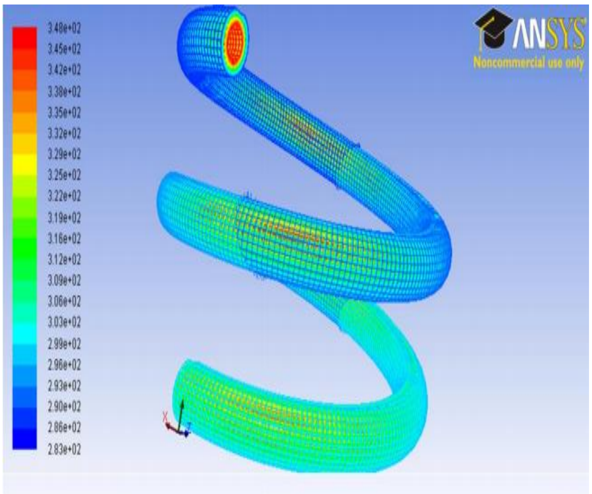


Figure: Contours of Static Temperature in K

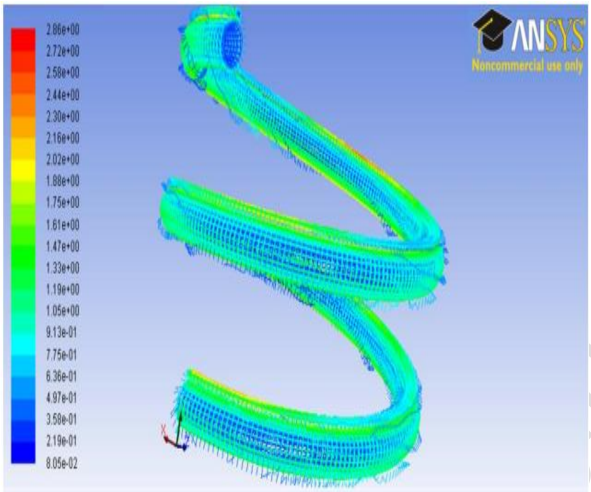


Figure: Contours of Turbulent Dissipation Rate (Epsilon) (m2 /s3)

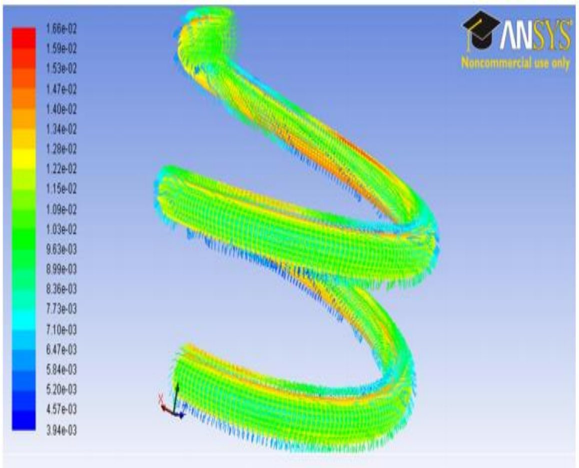


Figure: Contours of Turbulent Kinetic Energy k (m2 /s2)

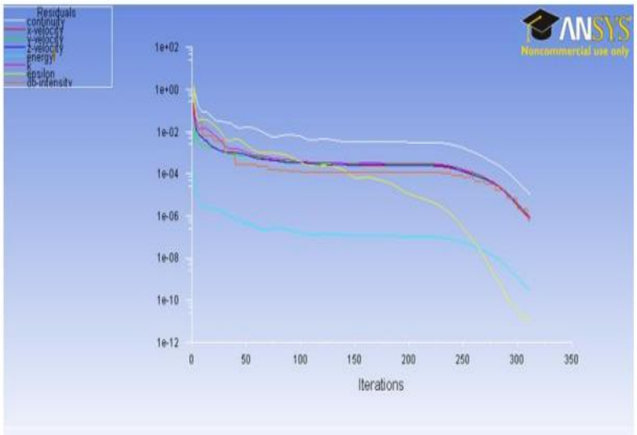


Figure: Scaled Residuals

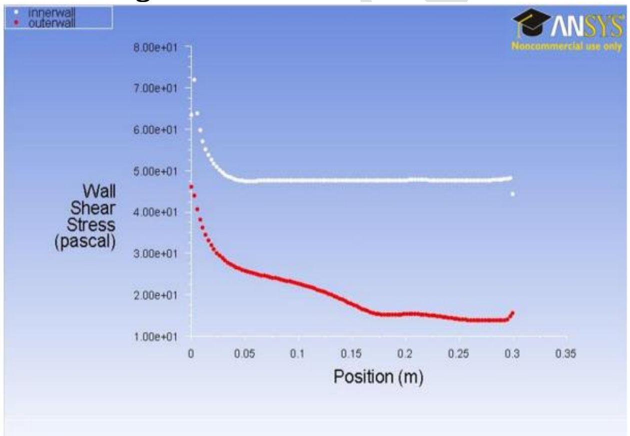


Figure: Wall Shear Stress Plot for Inner-wall And Outer-wall

The heat transfer characteristics of a double pipe helical heat exchanger for both counter and parallel flow. Both the boundary conditions of constant heat flux and constant wall temperature were taken. The study showed that the results from the simulations were within the range of the pre-obtained results.

Conclusions

The numerical study of heat transfer characteristics of a helical coiled double pipe heat exchanger for parallel flow and the results were then compared with that of the counter-flow. The CFD results when compared with the experimental results from different studies and were well within the error limits. The study showed that there is not much difference in the heat transfer performances of the parallel flow configuration and the counter-flow configuration. Nusselt number at different points along the pipe length was determined from the numerical data. The simulation was carried out for water to water heat transfer characteristics and different inlet temperatures were studied Characteristics of the fluid flow were also studied for the constant temperature and constant wall heat flux conditions. From the velocity vector plot it was found that the fluid particles were undergoing an oscillatory motion inside both the pipes. From the pressure and temperature contours it was found that along the outer side of the pipes the velocity and pressure values were higher in comparison to the inner values.

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