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CONJUGATE HEAT TRANSFER ANALYSIS OF HELICAL COIL HEAT EXCHANGE USING CFD

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ABSTRACT

Heat exchangers are one of the important engineering system has variety of applications like food industries, chemical processing, heat recovery systems, and air conditioning. The configuration of helical coil has very effective for heat exchangers food industries due to their larger heat transfer area in a smaller space and has high heat transfer coefficient. In the available configurations basic and most common design consist of a series of stacked helical coil placed in outer cylindrical cover. Ends of the inner tube connected to the manifold act as fluid entry and exit locations, outer tube also connected to the inlet and outlet manifold becomes the passage of cold fluid. The complex fluid flow inside the helical coil heat exchanger has offer certain advantages over the straight tube, shell and tube type heat exchangers in terms of area or volume ratio, with enhancing of heat transfer and mass transfer coefficients. In a heat exchanger the convective heat transfer between surface and surrounding fluid has a major issue and take long time to study.

In this particular study, attempt has made to analysis parallel flow through helical tube, where cold fluid flows in inner tube and outer tube contains hot fluid. Different dimensions of helical coil parameters are taken into considerations for analyses.

Key words: Heat exchanger, Helical coil, Straight tubes.

I. INTRODUCTION

Heat exchanger is a device used to facilitate heat transfer from one medium to other medium in order to carry process energy. Heat exchanges between flowing fluid is most important process and in different type of installation variety of heat exchangers are used, as in process industries, compact heat exchangers, nuclear power plant, heating ventilation and air conditioning, refrigeration etc. The purpose to get an efficient heat transfer from one fluid to another is by direct or indirect type of contact. Conduction, convection and radiation are three modes of heat transfer. When heat from high temperature fluid flows to surrounding solid wall occurs conduction and is maximized by maintaining the wall thickness minimum of highly conductive material. In performance of heat exchanger convection plays the major rule. To increase efficiency, heat exchanger are designed in such a way that to maximize the wall surface area and minimize the resistance of fluids flowing through the heat exchangers. In addition of corrugation in one or both direction to increase surface area and do turbulence can affect its performance.

II. OBJECTIVE

In the present study numerical analysis is carried out to determine the heat transfer characteristics of helical coil heat exchanger by varying the coil parameter like pitch with different mass flow rates. The main aim is to obtain the higher heat transfer rate that happens when fluid flows through the helical coil tube.

CFD Analysis of helical heat exchanger for various configurations.

- Comparison of parameters like coefficient of heat transfer and temperature variation for various pitch configurations.
- Generation of contours and vectors for temperatures, Pressures and velocities.

III. METHODOLOGY

The methodology involved in carrying out this work is discussed below:

Selection of the material: Aluminium material with high thermal conductivity and low density is investigated.

Modeling

- **Geometry**: 2D and 3D design of the double pipe helical coil is generated according to the dimensions with CATIA V5 R20.
- **Domain**: A physical domain of desired dimension is generated subjected to the atmospheric conditions using ANSYS ICEM CFD 15.
- **FV-analysis:** 3D model is meshed and boundary conditions and loading are applied with ANSYS CFX 15.

FV analysis: FV model is subjected to the required analysis using ANSYS CFX

Interpretations of results: The FV results are analysis with the experimental data.

Presentation of data: the plots, graphs are presented in MS-excel.

Prototype model: The tool for the final design is realized and the actual component is fabricated by adopting a related manufacturing technology.

3.1 Geometry

A 3D model of helical coil has been created using CATIA V5R20 as shown in fig. A helical pipe with 5 turns is taken as the model for the analysis has the coil diameter is taken as 300 mm and diameter of inner tube is 50 mm, outer diameter of annulus is 100 mm, inner diameter of annulus is 65 mm is taken. In the analyses pitch values and different mass flow rates are taken, keeping coil diameter as well as pipe diameter constant. The fluid properties are assumed to be constant.

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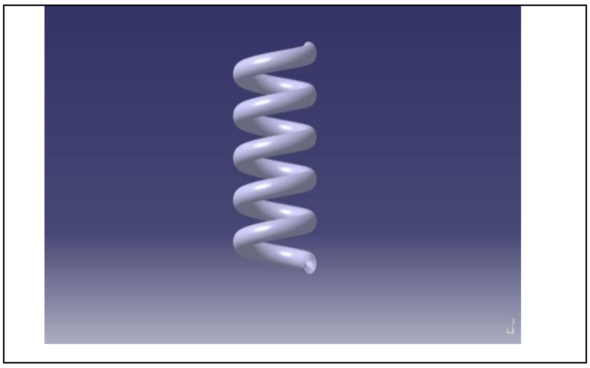

Fig 3.1 3D model of Helical pipe.

3.2. Selection of material

Material selection plays vital role in the modeling process. It is one of the most important steps the designer must make before creating the model. To select an appropriate material, the designer should look at their characteristics and behavioral feature required for the component. The overall performance, efficiency, service life of the structural component depends on the material used. Following factors should be considered while selecting the material are,

- Geometry of the component.
- Operating environment.
- Required Service life.
- Performance required.
- Modes of failure.
- Loadi.ng conditions.
- Cost.

3.3 Boundary conditions

According to the need of the model boundary conditions are used. Inlet Velocity and outlet pressure defined as the inlet and outlet conditions. Parallel flow is the condition taken here, has two inlets and outlets. No slip condition is considered for each wall is separately specified with respective boundary conditions. The turbulence model applied for present analysis was SST model.

Working fluid: water

Flow: Turbulent

Inner tube = Cold fluid

- Mass flow rate at inner tube inlet = 5 kg/s
- Temperature at inner tube inlet = 273.15 K
- Static pressure at inner tube outlet =1 bar

Annulus = Hot fluid

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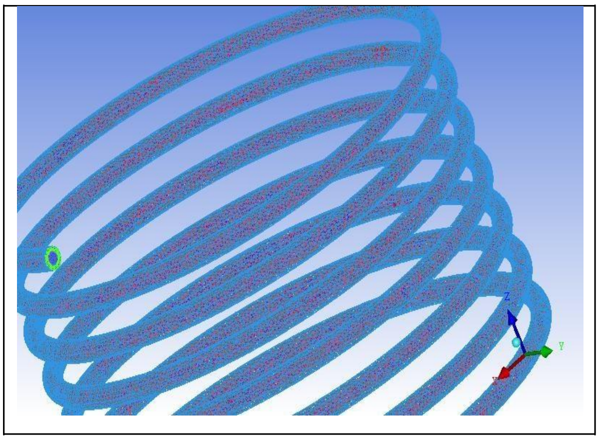
- Mass flow rate at outer tube inlet = 2.5 kg/s, 5 kg/s.
- Temperature at outer tube inlet = 353.15K
- Static pressure at outer tube outlet =1bar

3.4Tetra mesh

The mesh of the model is shown in fig. It depicts that the domain was meshed with tetra cells. Initially a relatively coarser mesh is generated. This mesh contains triangular faces at the boundaries. Care is taken to use structured tetra cells as much 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. Later on, a fine mesh is generated panel is increased from 0.75 mm to 1.00mm.



3.4.1 Meshing of the mode

IV. RESULTS

The contours for the temperature distribution, velocity distribution, and heat transfer co-efficient distribution on double pipe helical coil are studied first. Then the effect of these distributions on helical coil, heat transfer enhancement is evaluated by studying the heat transfer co-efficient and temperature variation on inner coil and outer coil. The result is analyzed for different mass flow rates.

4.1.Velocity Contour

The velocity contours along the length of the coil as shows that velocity profile at a cross section is found symmetric. Subsequently, this uniform velocity pattern changes to a pattern with a high velocity region located at the outer side of the coil. This behavior is seen predominantly and continues to develop. It can be seen that, the high velocity region is present only in outer half cross-section. Area of high velocity region further reduces the flow gets developed covers approximately1/3rd of the flow area. No significant change in flow pattern is observed downstream.

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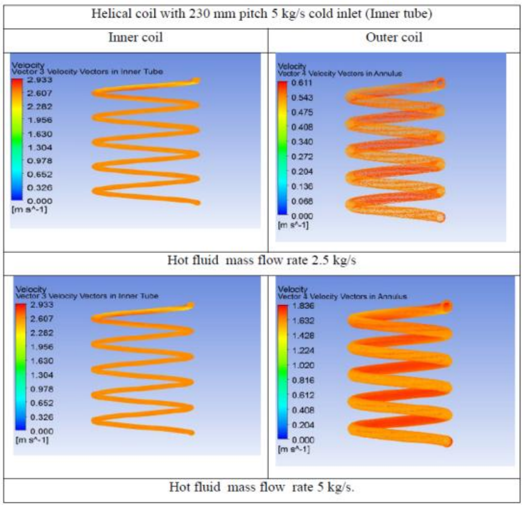

Fig 4.1 Velocity distribution of inner and outer coil at 230 mm coil pitch

4.2.Temperature Contours:

The temperature distribution of inner and outer helical coil at 230 mm coil pitch for 2.5 kg/s to 5 kg/s mass flow rate is shown in above Figures. The temperature of cold fluid goes on increases from 12.00 K to 20.46 K and hot fluid goes losses its temperature from 23.22 K to13.25 K. As it can seen that temperature of hot fluid decreases as increase in the coil pitch. It is due to curvature effect occurs in helical coil.

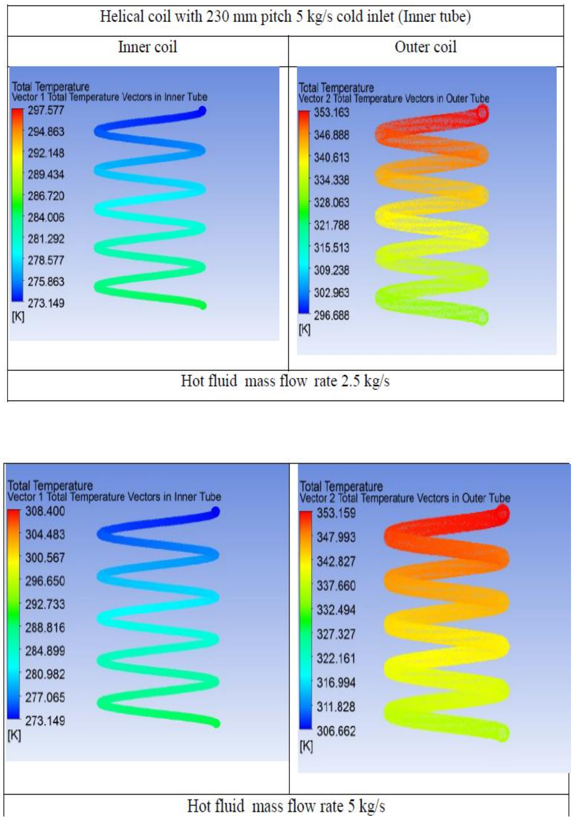

Fig 4.2 Temperature distribution of inner and outer coil at 230 mm coil pitch

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So this temperature variation is higher for 230 mm pitch with 5 kg/s as compared to 2.5 kg/s. Thus from these contours it shows that, thermal loading on a 230 mm pitch with 5kg/s is high.

V.CONCLUSION

By observing above results comparing with practical values at different coil pitches the heat transfer coefficient increases due to increase in pitch of helical coil at different mass flow rates. The heat transfer coefficient causes for increases the rise in temperature of cold fluid.

The increase in heat transfer coefficient has been listed for each hot inlet mass flow rate and this heat transfer coefficient can be observed with different hot inlet mass flow rates and for pitch values of 230 mm. Comparing results observed that, for each pitch of helical coil, rise in temperature of cold fluid is more in 230 mm coil pitch with 5kg/s. Due to increases in mass flow rate i.e. increase in velocity causes increase heat transfer coefficient.

Table : Rise in total temperature

Rise in total temperature of cold fluid(K)		
Mass flow rate	2.5 kg/s	5 kg/s
230 mm	11.44	16.41

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