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CFD Analysis of Heat Transfer in Helical Coil

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Abstract - *The purpose of this research is to study the effect of coil diameter and inlet temperature of steam on the heat transfer coefficient in the helical coil. The study was based on fluid to fluid heat transfer. CFD analysis was carried out for two different mass flow rate of water. Heat transfer coefficient was calculated for various inlet temperatures ranging from 100-105°C. A CFD simulation was carried out for three different coils. The results show that there is an increase in heat transfer coefficient with the increase in inlet temperature of steam.*

***Key Words*: CFD, Heat Transfer Coefficient, Helical Coil, Mass Flow Rate**

1. INTRODUCTION

A helical coil has a wide range of application in industries over the straight tube because of its greater heat transfer, mass transfer coefficient and higher heat transfer capability, etc. The relevance of helical coil has been identified in industrial application like automobile, aerospace, power plants turbine etc. because of above mentioned factors. Lots of researches are going on to improve the heat transfer coefficient of the helical coil. In this paper numerical study of helical coil is done for different boundary conditions and optimizes condition of heat transfer coefficient is found out for different coil diameter. The turbulent flow standard k-ε model is considered for analysis purpose. The effect of coil diameter on heat transfer coefficient is found out for different boundary conditions.

Rustum and Soliman did an early study in 1990. Shah obtained some reliable results in 2000. Grijspeerdt et al., did design optimization for heat exchangers using CFD as a tool in 2003. Van der vyver et al., did heat exchanging process in tube-in-tube heat exchanger using STAR-CD in 2003 and for Fractal heat exchangers the same code was applied for performance evaluation. Flavio et al., determined heat transfer coefficient for plate type heat exchanger in series and parallel configurations by both experimental and numerical techniques in 2006 using Fluent 6.1for numerical analysis. Rennie and Raghavan carried out Numerical analysis of double piped heat exchangers in 2005. Kumar et al., carried out Hydrodynamics and heat transfer characteristics of double pipe in fluent for helical coil in 2006[1]. Curved tubes are widely used passive heat transfer enhancement technique in several heat transfer applications. Heat transfer enhancement by using helical coil has been researched and studied by many researchers. Various helical coil configurations are possible, and the most common configuration is of vertically stacked helically coiled tube. Boundary conditions like constant heat flux or constant wall temperature were considered for investigations carried out on heat transfer coefficients. In this study the boundary condition considered is constant wall temperature. In spite of their abundant use in industrial application, there is limited computational information and correlations available in literatures on fluid to fluid heat transfer. Yang and Ebadian used the k-ε model to analyse the fully-developed turbulent convective heat transfer in a helical pipe with finite pitches. The result shows that as the coil pitch increases, temperature distribution in a cross-section of coiled tube becomes asymmetrical . The standard k-ε model was used by Lin and Ebadian for investigate of the convective heat transfer in the developing portion of helical pipes having finite pitches. For development of heat transfer phenomena effects of pitch, curvature ratio and Reynolds (Re) number were also discussed [2].

2. LITERATURE REVIEW

It is found that in the literature the research works dealing with two-phase flows in helical pipe are few. Out of these also, the majority handle pressure drop in such systems.This chapter presents a review of the research done on heat transfer in helical coils dealing with two-phase flow. Several studies found that helical coiled tubes are better than straight tubes when used for heat transfer applications. A validation of experimental work of condensation heat transfer in helical coils is presented.

Raghavan (2006) studied that, for numerical study of heat transfer characteristics of a double-pipe helical heat exchanger for both parallel flow and counterflow by using a computational fluid dynamics package (PHOENICS 3.3).

Constant wall temperature and constant heat flux boundary conditions were used to run the validations. The results of these simulations were well within the range of results obtained from the literature on helical coils. For inner Dean Numbers in the range of 38–350 overall heat transfer coefficients were evaluated. As the inner Dean number increases; overall heat transfer coefficient also increases however, the overall heat transfer coefficient was greatly influenced by the flow condition in the annulus[3].

Jayakumar (2008) found that, heat transfer characteristics of the heat exchanger with helical coil are also studied using the CFD code. The CFD predictions and experimental results are within error limit. They match reasonably well this can be seen in the results of both. Based on the results a correlation was developed to calculate the inside heat transfer coefficient of the helical coil. Study was carried out by varying pipe diameter, coil pitch and pitch circle diameter. Their influence on heat transfer and pressure drop has been brought out [4].

Bhardwaj (2009) worked on, Development of heat transfer coefficient correlation for concentric helical coil heat exchanger and found that, study deals with developing a Correlation for heat transfer coefficient for flow between concentric helical coils. Mathematical model is developed to analyze the data obtained from CFD and experimental results to see the effects of different functional dependent variables such as, tube diameter, coil diameter and gap between the concentric coils which affects the heat transfer. Optimization is done using Numerical Technique and it is found that the new correlation for heat transfer coefficient developed lies within error percentage of 3–4% [5].

Jayakumar **(**2010) carried out, CFD analysis for heat transfer to air–water two-phase mixture flowing through a helically coiled heat exchanger has been carried out using commercial CFD package of FLUENT 6.3. Previous researchers conducted hydrodynamics of air–water two-phase flow through helical pipes and validated against the experimental results on isothermal flow. For flow through an annular pipe heat transfer calculations for the two-phase flow are validated against experimental results. Studies have been carried out by varying parameters such as, coil pitch, pipe diameter, pitch circle diameter and void fraction at the inlet. Their influence on heat transfer and pressure drop has been studied [6].

Ferng (2012) carried out a numerical investigation and found that, a computational fluid dynamics (CFD) methodology is proposed in this paper to investigate effects of different Dean (De) number and pitch size on the thermal hydraulic characteristics in a helically coil-tube heat exchanger. The CFD methodology in this paper investigates the flow and heat transfer phenomena in a helically coil-tube heat exchanger. Effects of inlet De number and pitch size on these characteristics have been also studied. Present CFD methodology has been validated by the experiments from the previous works. Based on comparisons of the friction factor under variable Re numbers, experimental data are located within the local maximum and minimum predicted values. However, the mean friction factors averaged from the local predicted values are lower than the measurements [2].

Thundil (2014) did Numerical analysis of helically coiled heat Exchanger using CFD technique and found that, the present study, 3D numerical analysis of helically coiled tube is carried out by using commercial CFD tool ANSYS CFX 12.1. It is very difficult and time consuming if these analyses were carried out experimentally and therefore in the present work, efforts was taken to optimize the helically coiled tube with respect to heat transfer and flow parameters for different coil pitch. The analysis was done on the 30 mm and 60 mm coil pitch for the helical coil heat exchanger and observations were made. This observation can been seen very helpful for the enhancement in product life cycle of the heat exchanger especially in service and design sectors. Thus the heat transfer characteristics of a 60 mm coil pitch are better compared to a 30 mm coil pitch at higher Dean Number with limitation in space and more loss in pressure drop [1].

Imran (2015) did CFD Analysis of Heat Transfer Rate in Tube in Tube Helical Coil Heat Exchanger and outcomes were, with increase in the Reynolds number, the Nusselt number for the inner tube increase. With increases in flow rate turbulence between the fluid elements increases which will enhance the mixing of the fluid and the Nusselt number or the heat transfer rate also increases. With increases in D/d ratio (reciprocal of curvature ratio) the Nusselt number will decreases; for a particular value of Reynolds number. Nusselt number is maximum for D/d=25. The results show that outer wall boundary condition does not have any significant effect on the inner Nusselt number. Friction factor decreases with increase in Reynolds number due to relative roughness of surface, and velocity of flowing fluid. As Reynolds number increases, log mean temperature difference also increases at a steady rate. For heat transfer from the hot fluid any boundary condition can be assumed at outer wall of external tube because it will not affect significantly the heat transfer rate [7].

Triloki Nath Mishra (2015) concluded that, A CATIAV5r18 and CFD package (ANSYS FLUENT 13.0) was used for modeling and CFD study of heat transfer characteristics of a helical coiled double pipe heat exchanger for counter flow. Characteristics of the fluid flow were also studied for the constant temperature and constant wall heat flux conditions. Several important conclusions could be drawn from the present simulations and would be presented as follows. The fluid particles were undergoing an oscillatory motion inside both the pipes. Along the outer side of the pipes the velocity and pressure values were higher in comparison to the inner values. The shear stress at wall of inner pipe is greater than the wall of outer pipe. It is visible from the results that Nusselt Number depends on curvature ratio. It is increasing with increase in curvature ratio. In addition, the value of Nusselt number was found to increase with increase in mass flow rate. For articular value of Reynolds number with increase in D/d ratio (reciprocal of curvature ratio) the Nusselt number and frictional factor will decreases. Nusselt number and frictional factor has maximum value for D/d=10 and minimum value for D/d=30[8].

3. PROBLEM STATEMENT

Considerable experimental work has been done on condensation heat transfer coefficient through helical coils of circular cross section. Except few, rest all studies have developed correlations based on experimental data.

(1) To simulate the effect of variable inlet temperature of steam and mass flow rate of steam on condensation heat transfer co-efficient by using CFD.

4. OBJECTIVES

I. To validate the experimental data for condensation heat transfer coefficient by using CFD.

II. To study the effect of inlet temperature of steam on heat transfer coefficient by using CFD.

5. SOLUTION PROCEDURE

Solution for the above defined problem statement can be achieved through CFD. 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.

The simulation procedure consists of following steps:

(1) Geometry

(2) Mesh

(3) Solution

(1) Geometry:

Coil is built in the ANSYS workbench design module. It is a helical coil. 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. By following steps geometry is created.

i. Sketching

Out of 3 planes, i.e., XY-plane, YZ-plane and ZX-plane, the XZ-plane is selected for the first sketch. A line for the height of the helical structure is made. A new plane is created in reference with the XZ-plane. Cross section of the coil is drawn.

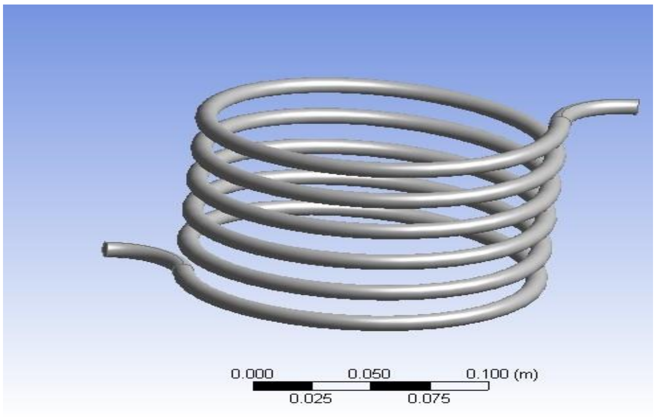

Fig -1: Geometry

ii. Sweep

Sketch is swept along the line made in sketch to construct the 3D model. The helical sweep is of 5.5 turns because the twist specification is defined in number of turns. Inlet and outlet are drawn in the form of arcs at 180^0 apart by three-point method.

iii. Name Selection

The different surfaces of the solid are named as per required inlet, outlet and wall.

(2) Mesh:

Firstly a relatively coarser mesh is generated. This mesh contains mixture of Tetrahedral and Hexahedral cells having both triangular and quadrilateral faces at the cell boundaries. Care is to be taken to use structured hexahedral cells as much as possible. This will reduce numerical diffusion as much as possible by structuring the mesh in a well manner, specifically near the wall region. Secondly, a fine mesh is generated.

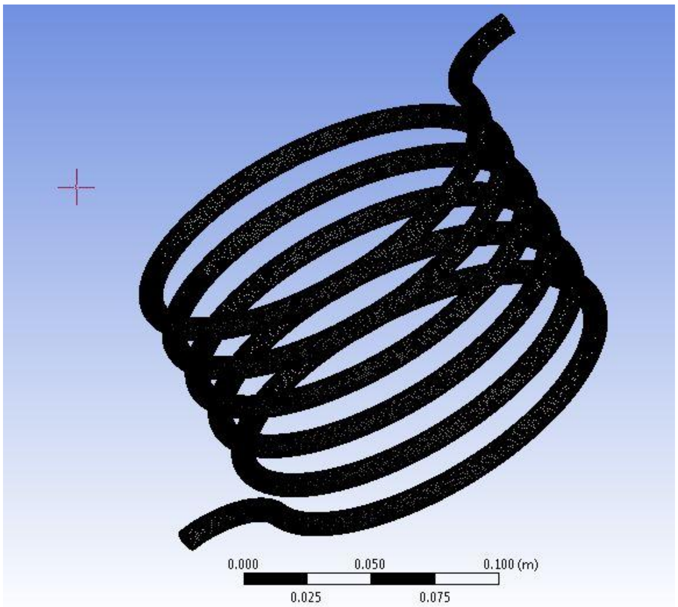

Fig -2: Mesh

(3) Solution:

It is achieved in following steps:

General: Type- Density based, Velocity formulation- Absolute, Time- Steady

Model: Multiphase model- Wet steam, Energy equation- ON, viscous model- Standard k-ε model standard wall function

Cell zone conditions: Fluid

Boundary conditions: inlet- pressure inlet, outlet- pressure outlet, wall- constant temperature

Solution methods: Formulation-implicit, flux type- Roe FDS, Gradient- least square cell based, flow-first order upwind, turbulent KE- flow-first order upwind, turbulent dissipation rate- first order upwind, wet steam- first order upwind.

Solution initialization: initialization methods- hybrid initialization.

Run Calculation: number of iteration- 50000, reporting interval- 1, profile update interval- 1

Results: graphics and animation- contours of-wall fluxes-surface heat transfer coefficient. Reports- mass flow rate-outlet.

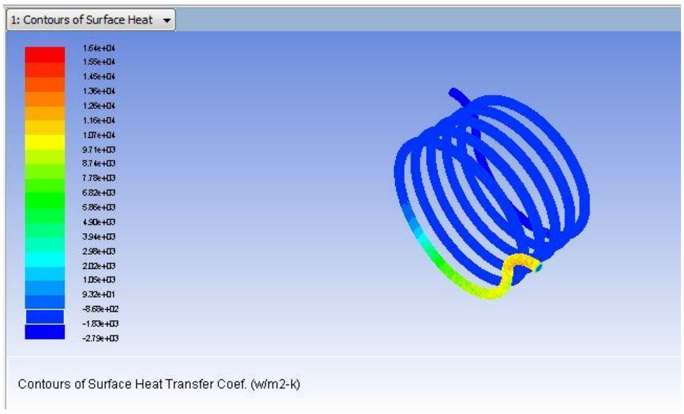

Fig -3: Contours of surface heat transfer coefficient

6. RESULTS AND DISSCUSSION

(A) Effect of inlet temperature of steam on heat transfer co-efficient for 125mm, 150mm and 175mm helical coil at 5 lpm of water flow rate:

Variation in heat transfer co-efficient for various inlet temperatures of steam is shown in figure.

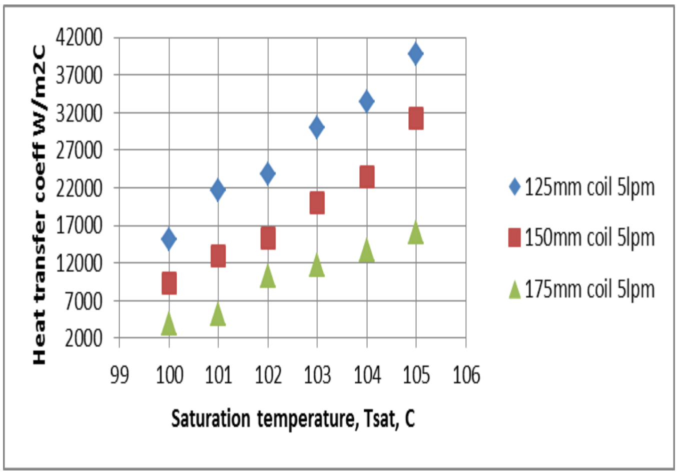

Chart -1: Variation in Heat transfer co- efficient for different inlet temperature of steam at 5 lpm of water flow rate.

From the above chart it is very clear that as inlet temperature of steam increasing the heat transfer co-efficient also increases.

(B)Effect of inlet temperature of steam on heat transfer co-efficient for 125mm helical coil at 2 lpm of water flow rate:

Variation in heat transfer co-efficient for various inlet temperatures of steam is shown in figure.

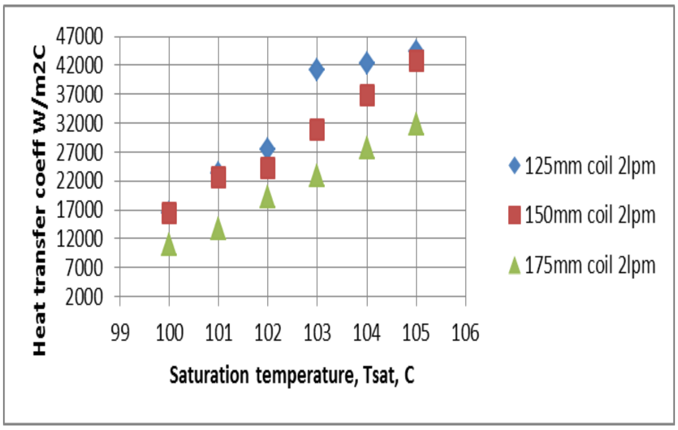

Chart -2: Variation in Heat transfer co- efficient for different inlet temperature of steam at 2 lpm of water flow rate.

From the above chart it is very clear that as inlet temperature of steam increasing the heat transfer co-efficient also increases.

7. CONCLUSIONS

From the above charts it is very clear that heat transfer co-efficient increase with increasing inlet temperatures of steam for both 5lpm and 2lpm of water flow rate. After comparing above two graphs it was observed that (i) Condensation heat transfer coefficient is more for 2lpm as compared to 5lpm. (ii) Condensation heat transfer coefficient increases with decrease in coil curvature ratio for both 2lpm and 5lpm.

REFERENCES

[1]. Thundil Karuppa Raj, Numerical Analysis of Helically Coiled Heat Exchanger Using CFD Technique, 2014, ARPN Journal of Engineering and Applied Sciences.

[2]. Ferng, Numerically investigated effects of different Dean Number and pitch size on flow and heat transfer characteristics in a helically coil-tube heat exchanger, 2012, Applied Thermal Engineering.

[3] Raghavan, Numerical Studies of a Double-Pipe Helical Heat Exchanger, 2006, Applied Thermal Engineering.

[4] Jayakumar, Experimental and CFD Estimation of Heat Transfer in Helically Coiled Heat Exchangers, 2008, Chemical Engineering Research and Design.

[5] Bhardwaj, Development of Heat Transfer Coefficient Correlation for Concentric Helical Coil Heat Exchanger, 2009, International Journal of Thermal Sciences.

[6] Jayakumar, Thermal hydraulic characteristics of air–water two-phase flows in helical pipes, 2010, Chemical Engineering Research and Design.

[7] Imran, CFD Analysis of Heat Transfer Rate in Tube in Tube Helical Coil Heat Exchanger, 2015, International Journal of Innovative Science, Engineering & Technology, Vol. 2 Issue 8.

[8] Triloki Nath Mishra, Modeling and CFD Analysis of Tube in Tube Helical Coil Heat Exchanger, 2015, International Journal of Science and Research.