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THEORETICAL AND EXPERIMENTAL ANALYSIS OF HELICAL DOUBLE TUBE IN TUBE HELICAL COIL HEAT EXCHANGER

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Abstract-*Helical double tubes are mostly used in various heat transfer progressions related to heat exchangers. Heat transfer characteristics of helical double tube heat exchanger are efficient than the straight tube due to elevated turbulence as well as enhancement of the secondary flow of planes which isNormal to primary flow in the helical pipe. Helical pipes inherent good performance in heat transferEnhancement, while the homogenous curvature of coil construction is impossible in tube fitting in heatExchangers. Due to its compact arrangements, effectiveness and higher heat transfer coefficient then other. For that reasons, these heat exchangers have wide applications. It also enlarges the area of surface in the defined arrangement, the configuration of helixes or arrangement to attain maximal area of surface. The orientation of the tubes is achieved maximum surface area would be to develop a helical double tube in coil Heat exchanger in the cross-section of tube arrangement. System design and theoretical derivationdimension of exterior tube, interior tube, coils number for estimated temperature design and fabrication ofdouble tube helical coil heat exchanger of clogged helix arrangement. The computational fluid dynamics (CFD) method ANSYS FLUENT 18.1 is using to investigate effects of the various temperature of the characteristics heat transfer of a helically double tube. Most of the considered cases in this project such as Nusselt number, heat transfer coefficient, Reynolds number are calculated and studied for evaluating the characteristics heat transfers of the helical coil double tube.*

Keywords: Helical double tube in tube, heat exchanger, computational fluid dynamics/finite element method

1. INTRODUCTION

Heat exchanger is generally used to transfer heat between two and more fluids for several applications such as refrigeration, power plants, nuclear reactors, automotive industries, air conditioning system, heat repossession system, food industry and chemical processing. Numerous types of techniques applied to enhance heat transfer. Types are categorized into two main groups. First one, active techniques are required for heat transfer of external power amplification and second one is passive techniques, which are not needed such augmentation for external power. The second technique use in helically double tubes. Several papers researched and studied that double helical tubes are preferable than straight tube for their compactness and amplification in heat transfer coefficient. The helical tube heat exchanger is used by choice due to their structure allow a large surface area of heat transfer in a lesser accommodation and has higher heat transfer coefficient. Forces like centrifugal are developed on moving fluid because of the structure of the pipe, which results in the heat transfer enhancement. Heat Exchangers are usually used for transmission of heat from one side to other side. There are numerous types of heat exchanger but among them double tube helical type heat exchanger displays greater result. In double tube helical coil heat exchanger two types of flow mostly use. One is parallel flow and other one is counter flow. In this paper parallel flow used for analysis. The tube temperature contour was designed and calculated by ANSYS FLUENT 18.1. Here steel was taken as metal for the structure of the helical tube. Water was taken as fluid flowing through the tube. Frist law of thermodynamics is played important role in double tube helical tube heat exchanger.

The primary objective of this project is to determine the characteristics of heat transfer of helical double-pipe heat exchanger by changing temperature of a same fluid in both the outer and inner tubes for parallel flow configuration. As well comparison of numerical data with experimental data and Relationship between Reynolds number and Nusselt Number of the heat exchanger. The problem is well-defined for the temperature contours of the heat exchanger. Another objective of the study is presentation of helical double tube in Helical Tube heat exchanger, using experimental setup. Further this project is studying the temperature drops in helical coil double tube helical heat exchanger.

2. EXPERIMENTAL SETUP

Materials selection involves in kind of their source, lead time, availability, size and product form. This is essential because the material needed to be moderately ductile for flexible method and smooth materialization of helical tubes. Processing of metal needed to be less roughness and having less friction factor which is causing in least depending on values of relative roughness in the Moody’s chart. Materials such as mild steel, copper, stainless steel or others metal can be used. The helical double pipe of heat exchanger is made of stainless steel. Stainless steel also used for making the pipes. Two knobs that is the input knobs are used for cold and the hot water input and output knobs are used for cold and hot water output. Stainless steel is used in making two knobs for cost reduction.

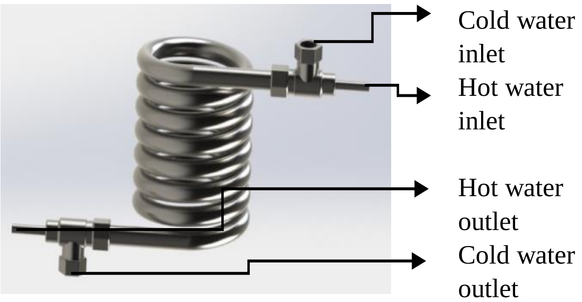

Fig.1: Assembly of Heat Exchanger (CAD model).

Stainless steel was used for fabricating the heat exchanger. Outside diameter of internal tube 12mm and inside 10mm also made of stainless steel. Outside diameter of external tube 25mm and inside diameter 23mm too built from stainless steel. The coil circular diameter is 150 mm and elevation is 210 mm. The twisting of tubes is acceptable and occupied in the tube to continue smoothness of innermost area of the surface and splashed by compressed air. The circular cross segment was taken attention to reservation of the coil through the bending manner. Finish associates joined for tube finishes and the two finishes tired from coiled tube end situation. An experiment was run after completion of the apparatus. Following the apparatuses were in place and check for any leakages. After fixing leakages, Apparatus was prepared to taking value of experiment. Test ran with keeping setup and surroundings in laboratory conditions. Collection of data delayed five minutes for waiting to reached the setup in steady state position. The experimental data was collected after reaching in steady state position.

After the setup is completed, it was tested systematically. Hot temperatures were in predictable condition but the cold temperature was in more irregular. In one situation it was rising seven degrees within six minutes and at that moment the next analysis fell four degrees. Setup took six minutes to reach steady state position which can differ on built functional circumstances. Take the reading until it reached two-hour mark. Though, Data was become unreliable, so determining steady state conventional founded proximity of readings. Very possible arrangements for constant flow rates in together the inner tube and the outer tube were verified. That were prepared for parallel flow conformations in all the tubes. Additionally, four repeats were accepted in same flow rate, configuration and coil size. That bring about in a whole of 40 trials. The data of temperature was verified after each 20 seconds. Data used in the calculations after the system reached steady state condition. Measuring temperature in the 2 minute of the steady system were used, temperature reading fluctuated within ±1.10C.

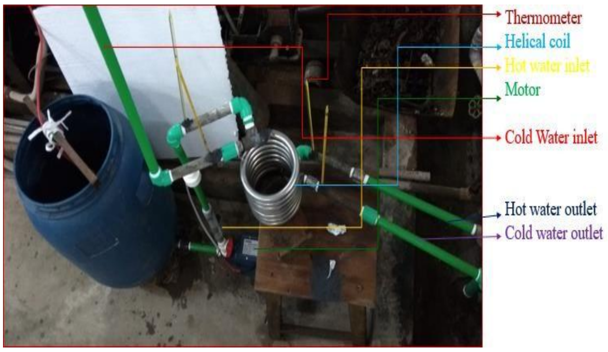

Fig.2: Setup of helical tube Heat Exchanger.

3. SIMULATION

Computational fluid dynamics (CFD) which is a branch of fluid mechanics that use mathematical data constructions and analysis to investigate and solving problems where fluid flows included. Calculation is achieved by computer where is required to calculate the fluid of free-stream flow, and fluid interaction (liquids and gases) through surfaces distinct by the means of boundary conditions.

3.1 Design Methodology

Helical double tube heat exchanger is made in the design section of ANSYS workbench. For, a parallel flow in heat exchanger. For that the first sketch Out of 3 planes, YZ, XY and ZX-plane, In the YZ-plane is designated. Two circles were drawn in 1 which diameter was 10mm and 12mm. In drawing 2, two circles of diameters 23mm and 25mm are made which was concentric to earlier circle. Then in drawing 3, drawn a line which was 210mm away from horizontal and away from 75mm vertical distance from concentric origin. Drawing 1, 2 are swept sideward the line complete in drawing ready in drawing 3 where “add frozen” process was used to build the 3D model with other parts. The helical curve had of 7 turns. Quantity of twist was defined by the turn requirement. After that sweep process, the model shown in 4 parts and 4 bodies after that by means of control and merged as 1 part.

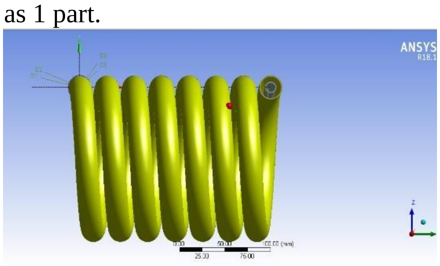

Fig.3: Original Geometry

3.2 Analysis of CFD

Primarily a coarser mesh was generated. That mesh consists mixed cells such as Tetra and Hexahedral cells taking both quadrilateral and triangular faces at boundaries. Taking care of using structured hexahedral cells as considerably. It means that to reduce numerical circulation as possible by the means of structuring of the mesh with good manner, mainly nearby the wall region. After that, a fine mesh was produced. For this fine mesh, regions of high temperature and pressure and edge gradients are finely meshed. In figure 4mesh particulars view provided us the ensuing information:

- Size: 4.033e-005m to 8.066e-005m
- Relevance center: fine meshing
- Smoothing: high
- Pinch tolerance: 3.6297e-005m
- Elements: 531700
- Nodes: 586300

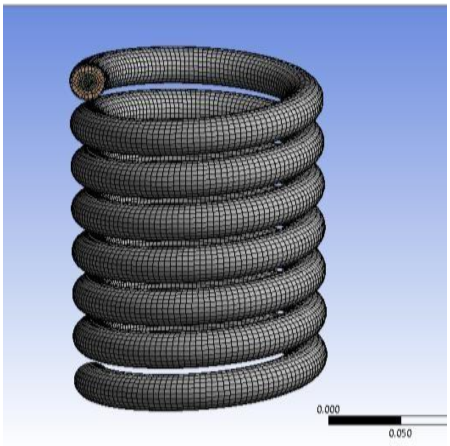

Fig.4: Mesh

Naming of different part as per essential outlets and inlets for outer and inner fluids. Here the outer wall was named as adiabatic surface.

3.3 Solution

Checking the mesh quality is obtained. The type was changed according to temperature. Changing velocity formation and time of steady state. Z = -9.81 m/s^2 was define as gravity. Energy was usual ON position. “k-ε model (2 equation) was used as Viscous model which is connected to add water-liquid and steel to the incline of fluid and solid correspondingly. Boundary conditions were using according to the essential of the model. The internal inlet is designated from the drop down list of “compute from”. The standards temperature 323 K, density 998.2 kg/m^3, 1 m2 area, 1050mm length, 0.001003 kg/m-s viscosity, 1.4 rate of specific heat are taken.

4. DATA REDUCTION

Coefficient of heat transfer and rates of heat transfer are determined built on the dignified temperature records. The heat is flowing hot water side of internal tube to cold water side of outside tube.

- Hot water mass flow rate (Kg/sec):

$$m_h = q_{wh}/t \quad \text{......i}$$

t = Water collection require time (s)
q = Water volume (L)

- Cold water mass flow rate (Kg/sec):

$$m_c = q_{wc}/t \quad \text{......ii}$$

- Hot heat transfer rate of water (J/sec):

$$Q_h = m_h \times C_P \times \Delta t_{hot} \quad \text{......iii}$$

m_h = Rate of mass flow hot water (Kg/m^3)
Q_h = The rate of heat transfers of hot water (J/s)
Δt_{hot}= Hot water Temperature difference (K)
C_p = pressure coefficient

- Cold water heat transfer rate of (J/sec):

$$Q_c = mc \times C_P \times \Delta t_{cold} \quad \text{......iv}$$

Q_c = The rate of heat transfers of cold water (J/s)
m_c = The cold water Mass flow rate (Kg/m^3)
Δt_{cold}= Cold water Temperature difference (K)

- Heat transfer rate average,

$$Q_{avg} = (Q_h + Q_c)/2 \quad \text{......v}$$

- The coefficient of heat transfer was calculated with:

$$H = \frac{Q}{A \times LMTD} \quad \text{......vi}$$

A = Area of the surface of the tube (m^2)

- LMTD = Log mean temperature difference

$$LMTD = \frac{\Delta T1 - \Delta T2}{\ln\frac{\Delta T1}{\Delta T2}} \quad \text{......vii}$$

where d_i and d_o are correspondingly inner and outer diameters of the pipe.

- Hot water velocity (m/sec):

$$V_{hot} = \frac{mh}{1000 \times area} \quad \text{......viii}$$

- Cold water velocity (m/sec):

$$V_{cold} = \frac{mc}{1000 \times area} \quad \text{......ix}$$

- The Reynolds number:

$$Re = \frac{\rho VD}{\mu} \quad \text{......x}$$

D= Diameter of annulus (m)

- Prandtl number for water:

$$Pr = \frac{\mu \times c}{k} \quad \text{......xi}$$

- Nusselt number water:

$$Nu = \frac{h \times d}{K} \quad \text{......xii}$$

d = Diameter of hot water pipe (m)

5. RESULT AND DISSCUSION

The research is showed heat transfer presentation for single-phase water to water. Investigational study of a cable twisted tube-in-tube helical looped heat exchanger was completed considering cold water flow in outer wall and hot water in the inner tube at continuous flow rate conditions. The contours of temperature for the coil which consist of 7 turns is shown in Figure 5

5.1 Temperature Contour

The contour temperature is shown in above figure 5 which is displayed that the inner tube contained hot water temperature reductions and outer tube contain cold water temperature rises. In excess of the whole length of helical pipe in tube heat exchanger is shown that how thedifference of temperature drops.

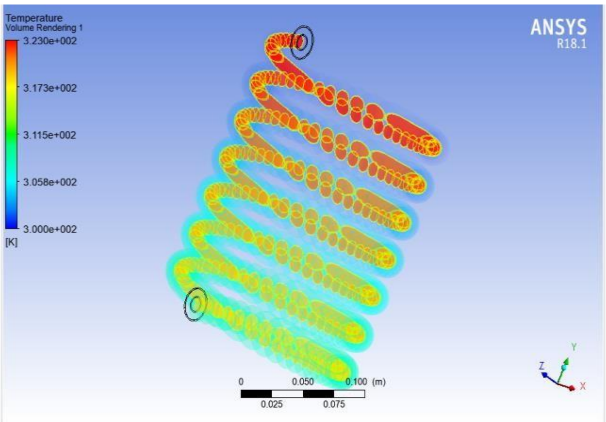

Fig.5: Temperature contour

5.2 Iteration Curve

Figure 6 is shown the iteration curve. In the curve is converged in 100 iterations which is displayed convergence of numerous mounted residuals include x velocity, continuity, swirl y velocity, epsilon, K and energy.

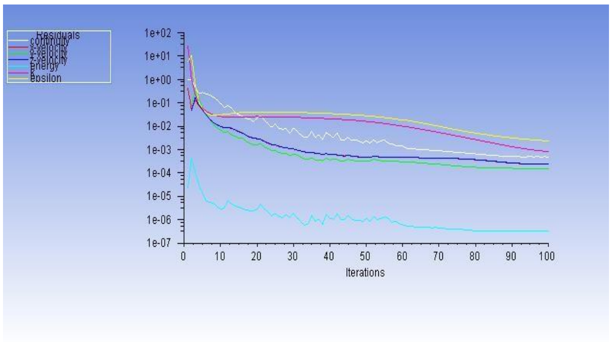

Fig.6: Iteration Curve

5.3 Nusselt Number VS Reynolds Number (hot water)

As figure 7 shown that if the Reynolds number rises there Nusselt number also increases. Larger Nusselt number relates to more vigorous convection in the 10 mm. Inner Nusselt number for the inner tube continues flow of inner hot water. Flow rate is constant for hot water flow in the inner tube.

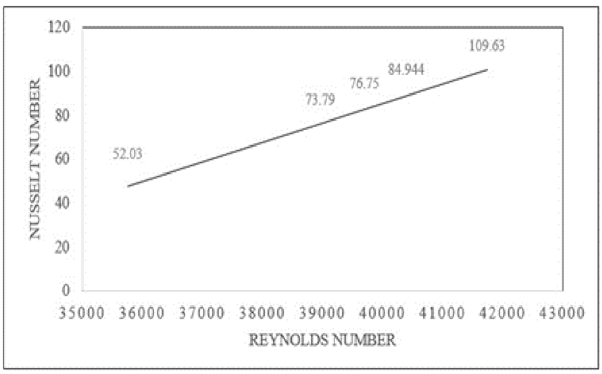

Fig.7: Nusselt Number vs Reynolds Number in inner tube.

5.4 Nusselt Number VS Reynolds Number (cold water):

There are five different selected correlations of Nu for tube-in-tube helical coil heat exchanger Which is taken from the literature for the study, as these correlations fulfill the conditional requirements of the data selected for the analysis. The constant of mass flow rate considered for analysis pertains to turbulence range. As the following graph is shown that the Reynolds number is increased Nusselt number also increased. A greater Nusselt number obtained at 23 mm inner diameter outer pipe. Outer tube Nusselt number vs Reynolds number is given below in figure 8. For that reasons some error was found after compering between experimental and theoretical data. The error calculated 26% in the hot water tube was and 28% error was calculated in cold water pipe.

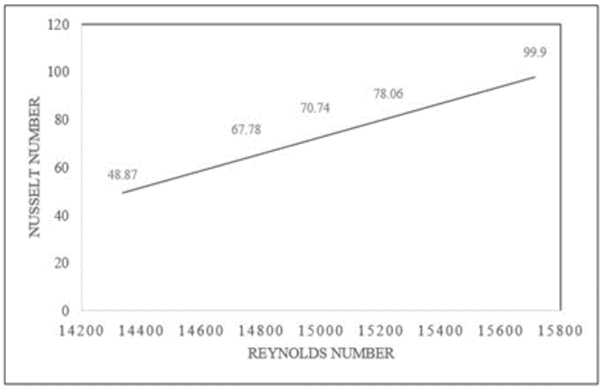

Fig.8: Nusselt Number vs Reynolds Number Outer tube.

7. CONCLUSION

The results CFD are valid with the literature work, the results which were well within error limits. The result of heat transfer simulation is showed that, heat transfer coefficient and Nusselt number are greater in circumstance of helical double tube in comparison with straight tube heat exchanger. Helical double tube helical coil heat exchanger comparative study in discussion and simulation are quite similar and acceptable percentage of error.

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8. NOMENCLATURE

Symbol	Meaning	Unit
Q	Heat transfer rate	(J/s)
V	Velocity	(m/s)
μ	Dynamic viscosity	(Kg/m.s)
ρ	Water Density	(kg/m^3)
K	Thermal conductivity	(Wm^{-1} k^{-1})
C	Specific heat	(J/Kg. K)
h	Heat transfer coefficient	(W/m^{2}k)