" EXPERIMENTAL AND CFD ANALYSIS OF TUBE IN TUBE HELICAL COIL HEAT EXCHANGER"

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ABSTRCT

Heat exchangers are the important engineering systems with wide variety of applications including power plants, nuclear reactors, refrigeration and air- conditioning systems, heat recovery systems, chemical processing and food industries. Helical coil configuration is very effective for heat exchangers and chemical reactors because they can accommodate a large heat transfer area in a small space, with high heat transfer coefficients. Working towards the goal of saving energies and to make concise design for mechanical and chemical devices and plants, heat transfer play major role in design of heat exchangers. 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, heat transfer rate and reduce power consumption, D/d geometrical parameter will be varied for different boundary conditions. The impact of this modification on Nusselt number, friction factor, pumping power required and LMTD variation of inner fluid with respect to Reynolds number was studied.

Keywords:- *Tube in tube helical coil, Heat transfer, LMTD, Reynolds number*

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1 INTRODUCTION

The heat exchanger is a device which is used to transfer heat between two fluids which may be in direct contact or may flow separately in two tubes or channels. We find numerous applications of heat exchangers in day to day life. A heat exchanger may be defined as equipment which transfers the energy from a hot fluid in a cold fluid, with maximum rate and minimum investment and running cost. The rate of transfer of heat depends on the conductivity of the dividing wall and convective heat transfer coefficient between the wall and fluids. In thermal power plant heat exchangers are used in boilers, condensers, air coolers and chilling towers etc. Similarly the heat exchangers used in automobile industries are in the form of radiators and oil coolers in engines.

The purpose of constructing a heat exchanger is to get an efficient method of heat transfer from one fluid to another, by direct contact or by indirect contact. The heat transfer occurs by three principles: conduction, convection and radiation.

1.1 Type of heat exchangers

According to Heat transfer process:-

Direct Contact Type: Direct contact type Heat exchangers are the heat exchanger in which two immiscible fluids are directly mixed with each other to transfer heat between two fluids.

Transfer Type Heat Exchanger: Transfer type or recuperater type heat exchanger in which two fluid flows simultaneously through two tubes separated by walls.

Regenerators Type Heat Exchanger: Regenerator type heat exchanger the hot and cold fluid flow alternatively on same surface.

According to Constructional Features:-
Tubular Heat Exchanger: Tubular heat exchangers are placed concentric to each other and two fluids flows in two tubes separated by wall
Shell and Tube type Heat Exchanger: Shell and tube type heat exchanger consists of shell and large number of parallel tubes.
Finned Tube Heat Exchanger: For improving the heat transfer rate fins are provided on the outer surface of the heat exchangers.
According to flow arrangement:-
Parallel Flow: Parallel flow type heat exchanger two fluids flow parallel to each other that is they flow in same direction.

Counter Flow: Counter flow heat exchanger two fluid flow in opposite direction.

Cross Flow: Cross flow type heat exchanger two fluids flow perpendicular to each other.

1.2 Helical coil heat exchanger

Recent developments in design of heat exchangers to full fill the demand of industries has led to the evolution of helical coil heat exchanger as helical coil has many advantages over a straight tube. The double pipe or the tube in tube type heat exchanger consists of one pipe placed concentrically inside another pipe having a greater diameter. The flow in this configuration can be of two types: parallel flow and counter-flow.

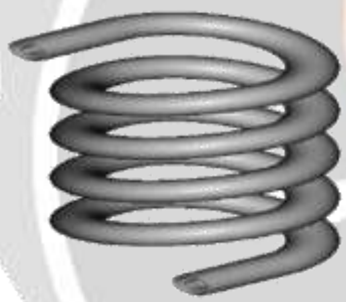

Fig 1 Double pipe helical coil

Fig 2 Close-up of double pipe coil

2 LITERATURE REVIEW

J. S. Jayakumar, S. M. Mahajani, J. C. Mandal, Rohidas Bhoi [1]studied the constant thermal and transport properties of the heat transfer medium and their effect on the prediction of heat transfer coefficients. Arbitrary boundary conditions were not applicable for the determination of heat transfer for a fluid-to-fluid heat exchanger. An experimental setup was made for studying the heat transfer and also CFD was used for the simulation of the heat transfer. The CFD simulation results were reasonably well within the range of the experimental results. Based on both the experimental and simulation results a correlation was established for the inner heat transfer coefficient.

Mrunal p.kshirsagar,trupti j. kansara, swapnil m. aher[2]has observed on fabrication and analysis of tube-in-tube helical coil heat exchanger. Experimental study of a wire wound tube-in-tube helical coiled heat exchanger was performed considering hot water in the inner tube at various flow rate conditions and with cooling water in the outer tube. The mass flow rates in the inner tube and in the annulus were both varied and the counter-current flow configurations were tested. The experimentally obtained overall heat transfer coefficient (U_o) for different values of flow rate in the inner-coiled tube and in the annulus region were reported. It was observed that the overall heat transfer coefficient increases with increase in the inner-coiled tube flow rate, for a constant flow rate in the annulus region. Similar trends in the variation of overall heat transfer coefficient were observed for different flow rates in the annulus region for a constant flow rate in the inner-coiled tube. It was also observed that when wire coils are compared with a smooth tube, it was also observed that overall heat transfer coefficient is increases with minimum pitch distance of wire coils. The efficiency of the tube-in-tube helical coil heat exchanger is 15-20% more as compared to the convention heat exchanger and the experimentally calculated efficiency is 93.33%.

Ganesh Mhaske and Prof D. D. Palande [3] study on Experimental and CFD Analysis of Tube in Tube Helical Coil Heat Exchanger. They compare Experimental and CFD results. By comparing Experimental and CFD results of wire wounded Tube in Tube Helical Coil Heat Exchanger, they had observed that inner tube flow rate (LPH) increases so inner heat transfer coefficient was improve. They study and proved that Nusselt Number is directly proportional to inner heat transfer coefficient. For constant Cold Water Flow Rate, They study improve Nusselt Number so increasing inner tube flow rate, They also found that inner tube flow rate (LPH) directly proportional to temperature difference. For constant Cold Water Flow Rate, Log mean temperature difference (LMTD) is directly proportional to inner tube flow rate. They found that inner tube flow rate (LPH) increases with increase heat gain by cold water.

Timothy J. Rennie [4] 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. For dean numbers ranging from 38 to 350 the overall heat transfer coefficients were determined. The results showed that the overall heat transfer coefficients varied directly with the inner dean number but the fluid flow conditions in the outer pipe had a major contribution on the overall heat transfer coefficient. The study showed that during the design of a double pipe helical heat exchanger the design of the outré pipe should get the highest priority in order to get a higher overall heat transfer coefficient.

Sadashiv and Madhukeshwara.N [5]have worked on Numerical simulation of enhancement of heat transfer in a tube with and without rod helical tape swirl generators .The study show A CFD analysis has been conducted to investigate heat transfer enhancement by means of helical tape inserts in a double pipe heat exchanger using cold water and hot air as the test fluids. The flow rate of the tube is considered in a range of Reynolds number between 2300 and8800. The swirling flow devices consisting of: the full length helical tape with or without center rod of a concentric tube heat exchanger. The data obtained by simulation are matching with the literature value for a plain tube with the discrepancy of less than plus or minus 5% for Nussult number and for the friction factor. Enhanced heat transfer with decreasing twist ratio has been observed. Heat flux is more uniform all along the tube and decreases uniformly towards the center. From the experimental results, it can be found that enhancing heat transfer with passive method using different types of helical tape construction in the inner tube of a concentric double pipe heat exchanger can improve the heat transfer rate efficiently.

Jayakumar et al.[6] had done numerical and experimental work on helical coil heat exchanger considering fluid to fluid heat transfer. They had taken different boundary conditions for example constant heat flux, constant wall temperature and constant heat transfer coefficient.

Jayakumar et al.[7] had done the numerical and experimental analysis to find out the variation of local Nusselt number along the length and circumference of a helical tube. They had changed the pitch circle diameter, tube pitch and pipe diameter and their influence on heat.

Kumar et al. [8] had investigated hydrodynamic and heat transfer characteristic of tube in tube helical heat exchanger at pilot plant scale. They had done the experiment in a counter flow heat exchanger.

3 EXPERIMENTAL SETUP

Experimental-Setup consists of following parts:-
1. Tube-In-Tube Helical Coil Heat Exchanger
2. Tank with thermostatic heater
3. Water Reservoir
4. Flow Control valve
5. Pressure Indicator
6. J-Type thermocouples

Fig.3 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 60^0C. 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. Flexible PVC tubing will use for all the connections. J-Type thermocouples will insert into the flexible PVC tubing to measure the inlet and outlet temperatures for both fluids. Temperature data will be recorded using a creative temperature indicator. The fluid properties of the working fluid (water) was assumed to be constant throughout the analysis with respect to temperature and presented in the table

Table 1 Fluid properties of the working fluid (water)

Description	Value	Units
Viscosity	0.001003	kg/m-s
Density	998.2	kg/m^3
Specific Heat Capacity	4182	J/kg-K
Thermal Conductivity	0.6	W/m-K

3.1 Construction of Tube-in-Tube Helical Coil Heat Exchanger

The tube of the heat exchanger is made up of copper for maximize the heat transfer, because copper has good thermal conductivity. Also the properties of the copper were also remains constant throughout the analysis. It is represented in table below

Table 2 Properties of copper

Description	Value	Units
Density	8978	kg/m^3
Specific Heat Capacity	381	J/kg-K
Thermal Conductivity	387.6	W/m-K

During Construction of Tube-in Tube Helical coil Heat Exchanger following parameters are taken into considerations

- Effect of curvature ratio on heat transfer
- The Influence of pitch of coil on heat transfer
- Influence of the tube diameter change on heat transfer characteristics
- Influence of the number of coils on the overall heat transfer coefficient

Actual dimensions of tube-in-tube helical coil heat exchanger

Table 3 Dimensional Parameters of Heat Exchanger

Dimensional parameters	Heat Exchanger
di, mm	10
do, mm	12
Di, mm	23
Do, mm	25
Curvature Radius, mm	125
Stretch Length, mm	3992
Wire diameter, mm	1.5
Curvature ratio	0.1
No. of Turns	4

4 SIMULATION OF TUBE IN TUBE HELICAL COIL HEAT EXCHANGER

4.1 Cfd Methodology

For simulation of tube in tube Helical coil heat exchanger, First we have to creat a heat exchanger model using creo software. After creating the geometry and doing the meshing in ANSYS 14.5 the problem is analysed in ANSYS 14.5 .As this is counter flow of inner hot fluid flow and outer cold fluid flow so there is two inlet and outlet respectively. There is a pipe which separate the two flow which is made by copper. Inner fluid is take as hot water and outer fluid is take cold water.

- Import CAD geometry to ANSYS environment
- Extract fluid domain
- Apply boundary conditions (Pressure, Velocity, Mass flow rate, Temperature)
- Selecting CFD model (energy, turbulence)
- Processing simulation
- Monitoring residuals
- Plotting results

Creo model of tube in tube helical coil heat exchanger are

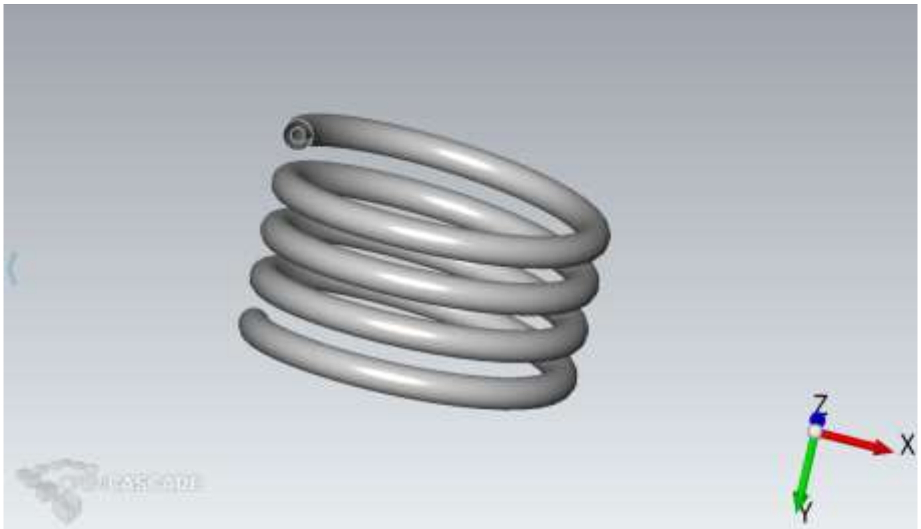

Fig.4 Creo model of tube in tube helical coil heat exchanger

Boundary condition for CFD Analysis

Table 4 Boundary condition for CFD Analysis

Sr.No.	Parameters	Range
1.	Inner tube flow rate	120-480 LPH
2.	Outer tube flow rate	480 LPH
3.	Inner tube inlet temperature (℃)	60
4.	Inner tube outlet temperature (℃)	40-52
5.	Outer tube inlet temperature (℃)	30
6.	Outer tube outlet temperature (℃)	30-42

5 RESULT & DISCUSSION

5.1 Experimental Results

Table 5 Observations for Cold Water Flow Rate = 480 LPH

Sr. No.	Hot water flow rate (LPH)	Cold Water Temperature(^{0}C)		Hot Water Temperature(^{0}C)		Δt_1(^{0}C)	Δt_2(^{0}C)	LMTD(^{0}C)
		T_{inlet}	T_{outlet}	T_{inlet}	T_{outlet}			
COLD WATER FLOW RATE = 480 LPH								
1	120	30	36	60	40.1	24	10.1	16.06
2	240	30	38	60	42.2	22	12.2	16.62
3	360	30	40	60	45.4	20	15.4	17.14
4	480	30	42	60	47	18	17	17.49

5.2 CFD RESULT

For CFD analysis, we were taken constant cold water flow rate =480 LPH and different hot water flow rate i.e. 120LPH,240LPH,360LPH,480LPH for validation of above experimental results.

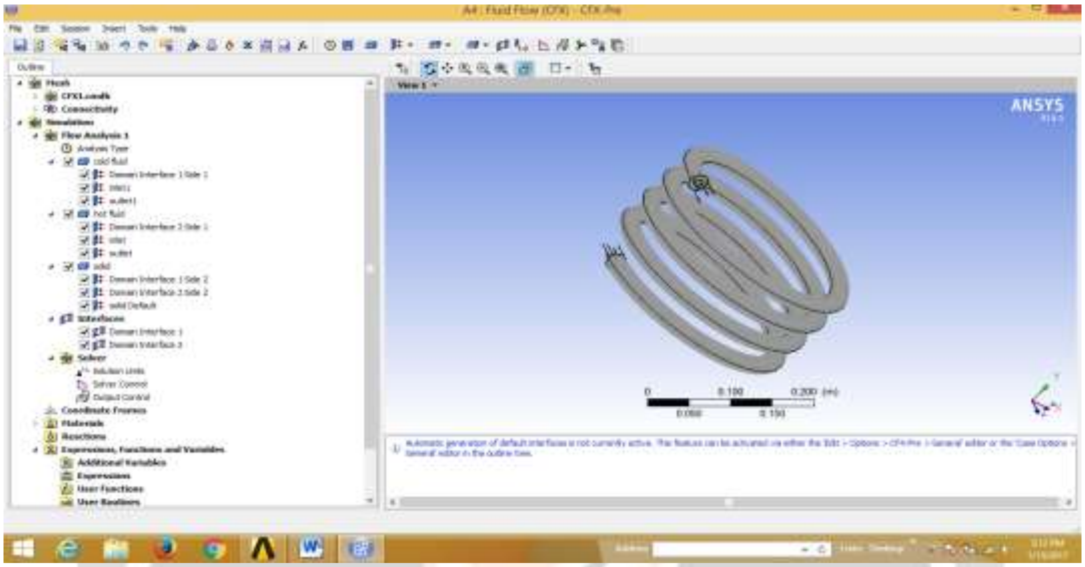

Fig. 5 Fluid domain for helical coil heat exchanger

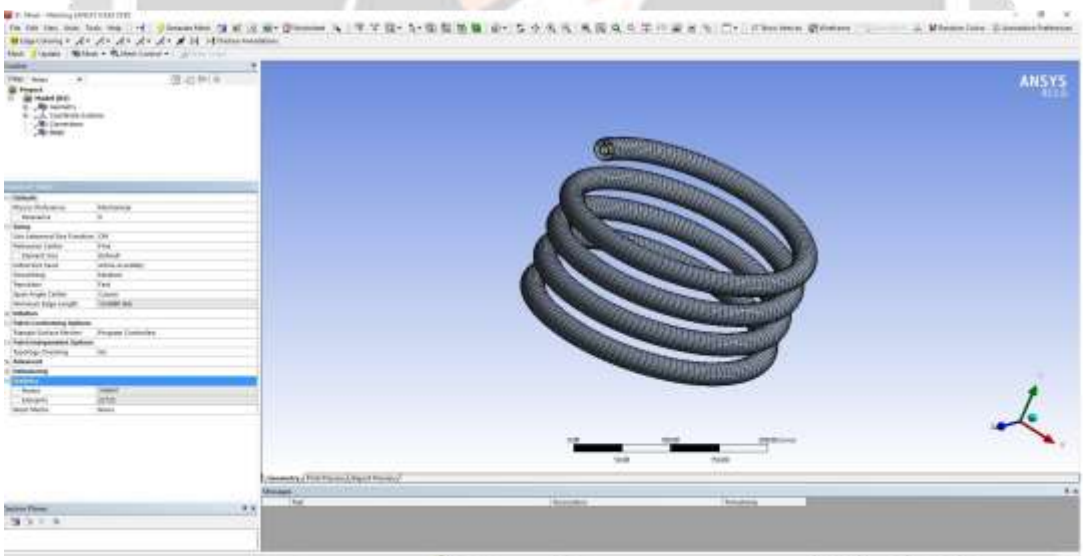

Fig.6 Meshing applied on helical coil heat exchanger fluid domain

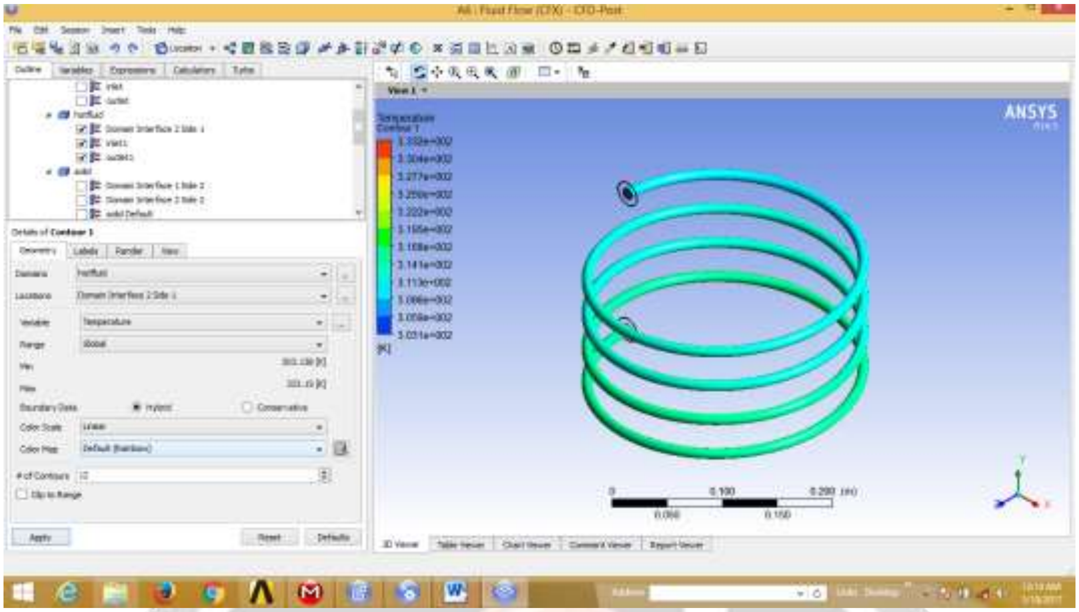

Fig 7 Temperature distribution in inner tube at mass flow rate of 120 LPH (hot fluid)

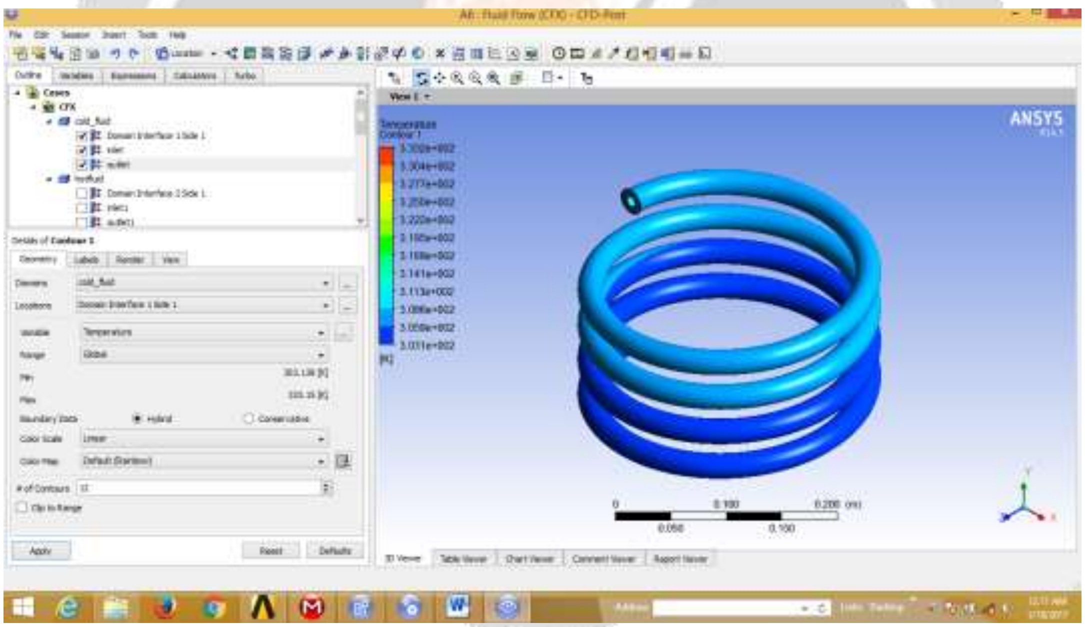

Fig 8 Temperature distribution for outer tube at mass flow rate of 480 LPH (cold fluid)

5.3 COMPARE EXPERIMENTAL AND CFD RESULT OF TUBE IN TUBE HELICAL COIL HEAT EXCHANGER

Table 6 Experimental Vs CFD Results

Sr. No.	Hot water flow rate (LPH)	Cold Water Temperature(^{0}C)				Hot Water Temperature(^{0}C)				Δt_1(^{0}C)		Δt_2(^{0}C)		LMTD(^{0}C)	
		T_{inlet}		T_{outlet}		T_{inlet}		T_{outlet}							
COLD WATER FLOW RATE = 480 LPH															
		Exp	CFD	Exp	CFD	Exp	CFD	Exp	CFD	Exp.	CFD	Exp.	CFD	Exp.	CFD
1	120	30	30	36	35	60	60	40.1	42	24	23	10.1	12	16.06	16.90
2	240	30	30	38	41	60	60	42.2	46	22	19	12.2	16	16.62	17.45
3	360	30	30	40	41	60	60	45.4	49	20	19	15.4	16	17.14	17.45
4	480	30	30	42	43	60	60	47	52	18	17	17	16	17.49	16.49

From above Experimental and CFD result, We obtained graph for cold water outlet, Hot water outlet, and LMTD.

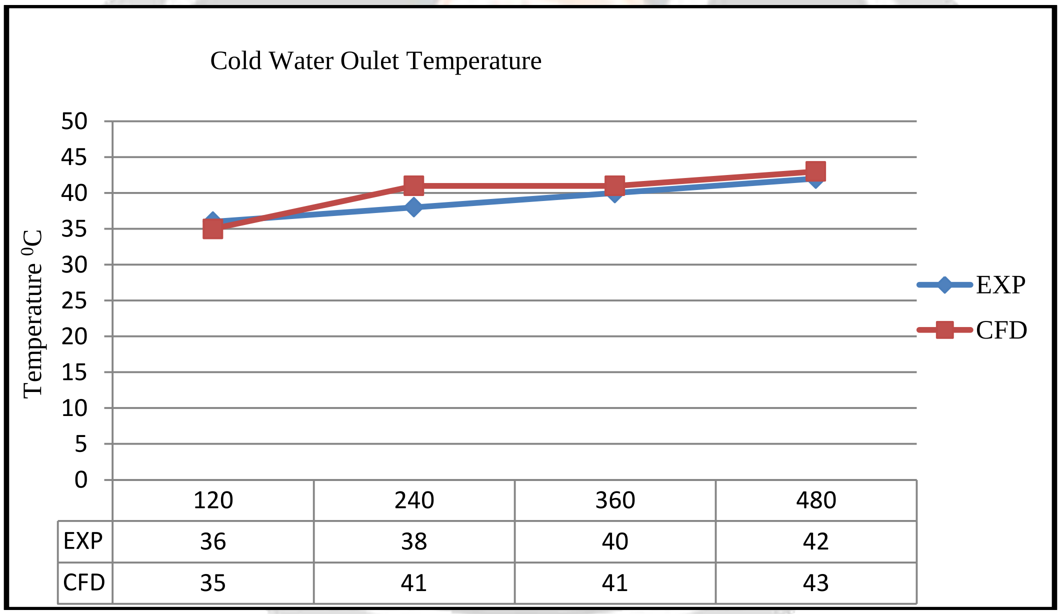

Chart 1 Experiment Vs CFD results for cold water outlet temperature

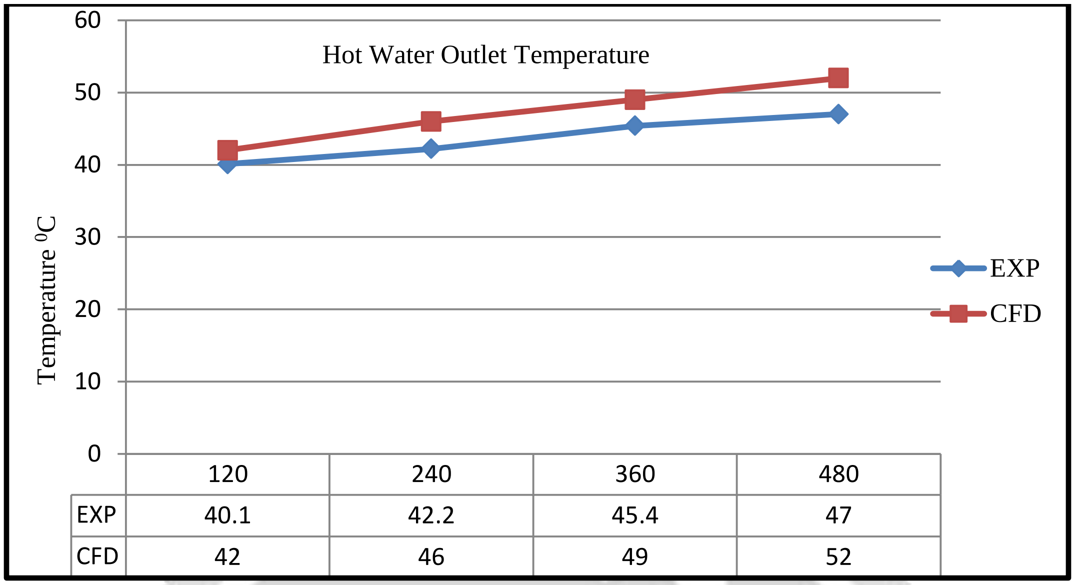

Chart 2 Experiment Vs CFD results for hot water outlet temperature

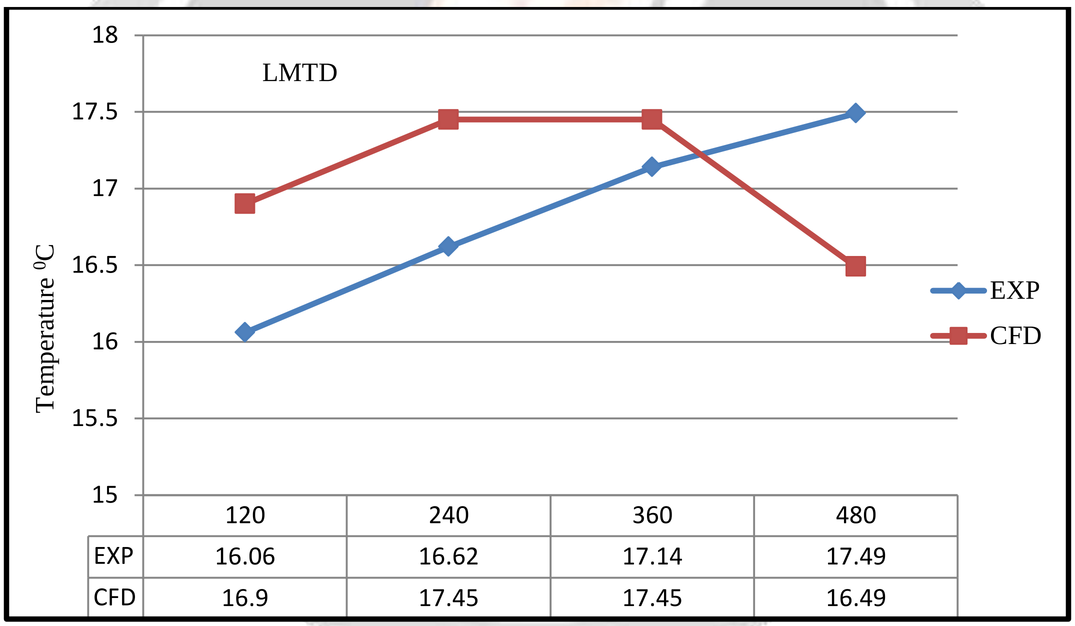

Chart 3 Experiment Vs CFD results for Logarithmic Mean Temperature Difference (LMTD)

6 CONCLUSION

1. Heat transfer analysis of a helically coil heat exchanger using CFD code ANSYS 14.5 has been present in the thesis.
2. As per the results obtained through simulation, it is observed that the data is in good agreement with experimental results. Hence, the CFD model can be considered valid to be utilized for performing modifications in the geometry.
3. By comparing these Experimental and CFD results of wire wounded Tube in Tube Helical Coil Heat Exchanger, we observed that as the inner tube flow rate (LPH) increases Temperature difference also increases, So Log mean temperature difference (LMTD) is increases with increasing inner tube flow rate, for constant Cold Water Flow Rate.

4. We know that Nusselt Number is directly proportional to inner heat transfer coefficient (hi), So that Nusselt Number is increases with increasing inner tube flow rate, for constant Cold Water Flow Rate.

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