PERFORMANCE ANALYSIS OF CONICAL HELICAL TUBE HEAT EXCHANGER WITH STRAIGHT AND CONICAL SHELL USING CFD

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Abstract - In the present study performance of conical Helical coil Heat exchanger is studied by using computational Fluid dynamics, for this we use two shell geometry such as straight shell and conical shell. As we know conical helical coil has more heat transfer rate when compare to traditional shell and tube heat exchanger, as there is development of secondary flow we can say it as vortex In addition to above advantage we can get more benefit if we use conical shell instead of straight shell. The above type of heat exchanger is having tremendous application in helically coiled tubes are used frequently in HVAC applications, condenser, boiler and evaporator. For the CFD analysis solid modelling is done in the CATIA, Grid creation is done in ICEM-CFD and hyper mesh and finally Simulation is done in ANSYS-FLUENT. Two different cases were studied with straight tube and conical tube and results were presented in the research paper.

Index Terms - Conical Helical Coil, Conical shell, CFD

NOMENCLATURE		**SUBSCRIPTS**	
d_i	Inner Diameter of Tube	C	Cold water
d_o	Outer diameter of Tube	H	Hot water
D_o	Outer diameter of Shell	I	Inner, tube side
D_i	Inner diameter of Shell	S	Shell
L	Total Length of coil	T	Tube
P	Pitch of coil	C	Coil
N	Number of turns	O	Outer, outside
k_t	Thermal conductivity of tube		
k_c	Thermal conductivity of tube fluid		
k_s	Thermal conductivity of shell fluid		
$T_{c,i}$	Inlet temperature of tube fluid in °K		
$T_{c,o}$	Outlet temperature of tube fluid in °K		
$T_{s,i}$	Inlet temperature of shell fluid in °K		
$T_{s,o}$	Outlet temperature of tube fluid in °K		

I. INTRODUCTION

Straight helical coil heat exchanger

"Heat exchanger is a device which is use to transfer the heat from one fluid to another fluid through the same device". In helical coil heat exchanger the helical coils are used for the heat transfer. Helically coiled tubes are used frequently in heating, refrigerating, HVAC applications, steam generator, condenser and power plants because of their large surface area per unit volume. In spite of their widespread use there in no information available on natural convection from such coils however correlation in the literature for natural convection from vertical and horizontal plates are available. The foregoing consideration provided motivation for the present research to fill the gap in the literature. [1]

It has been long recognized that heat transfer characteristics of helical tubes is much better than straight one because of the occurrence of secondary and fluid flow in planes normal to the main flow inside helical tubes show great performance in heat transfer enhancement while the uniform curvature of spiral conical structure inconvenient in pipe installation in heat exchanger.[2]

In this type of heat exchanger, the secondary flow is generated by centrifugal action and acts in a plane perpendicular to the primary flow. Since the velocity is maximum at the centre, the fluid at the centre is subjected to the maximum centrifugal action, which pushes the fluid towards the outer wall. The fluid at the outer wall moves in ward along the tube wall to replaces the fluid ejected outwards. This results in the formation of two vortices symmetrical about a horizontal plane through the tube center.

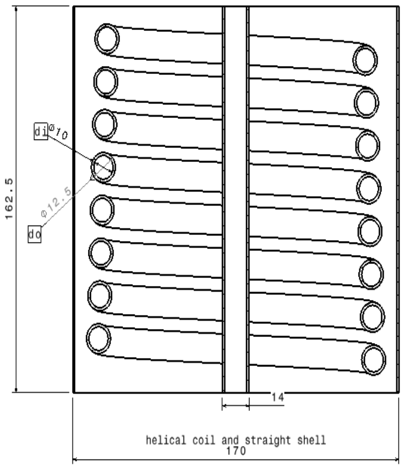


Fig 1.1 Straight Helical Coil Heat Exchanger

Inside heat transfer coefficient for helical coil and curved tube are greater than inside heat transfer coefficient of straight tube because of secondary flow (Dean Vortex) in curved tube and it is characterized by Dean Number which is equal to

$De = Re \times ((d_i/D)^{0.5})$ (1.1)

In this type the curvature ratio is constant. Secondary flow become intensive, which in turn increases (hi).

For calculation of outside heat transfer coefficient (h_0) correlations are found only for typical applications and specified ranges of Re, Ra study by researchers.

Generally correlations for h_0, covering entire range of Re, di/D is not found due to this we have used the available correlations of straight tube.

It has been widely observed that the flow inside coiled tube remains in the viscous regime up to much higher Reynolds number than that for straight tubes. Helical coils are known to have better heat and mass transfer compared to straight tube the reason for that is the formation of a secondary flow superimposed on the primary flow. [3]

II. LITERATURE SURVEY

The Mohamed Ali [1] was performed the experimental investigation of Natural convection made to study, steady type Natural Convection was obtained from turbulent natural convection to water. The experiment have been carried for four coil diameter to tube diameter ratio for five and ten coil tubes and for five pitch outer diameter ratio.

He correlated Rayleigh Number for two different coil sets and the heat transfer coefficient decreases with coil length for tube diameter do =0.012m but increases with coil length for do=0.008m. For tube diameter of 0.012 m with either five or ten coil turns, critical D/d_0 is obtained for a maximum heat transfer coefficient.

Yan ke [2] investigated numerical simulation of conical tube bundles. He observed the effect of structural parameters on heat transfer characteristics. fluid flow characteristics inside tube of different cross section also investigated result shows that cone angle cross section have been significant effect inside heat transfer. Also helical pitch has little influence on heat transfer enhancement. He also includes that the secondary fluid become intensive along the tube due to increase of tube curvature. Secondary fluid flow contains four contours and flow direction of each contour are different due to this heat transfer rate increases.

J.S Jaykumar[3] after validating the methodology of CFD analysis of a heat exchanger, the effect of considering the actual fluid properties instead of a constant value is established. Various boundary conditions are compared to calculate heat transfer characteristics inside a helical coil. It is found that the specification of a constant temperature or constant heat flux boundary condition for an actual heat exchanger does not give satisfactory result through modelling. For this problem the heat exchanger is analysed with considering conjugate heat transfer and properties of heat transport fluid which are temperature dependent. An experimentation was carried out for the calculation of the heat transfer characteristics. Experimental results and CFD calculation results using the CFD package FLUENT 6.2 are compared. Finally the correlation is developed by using the experimental result obtained. The inner heat transfer coefficient of the helical coil is thus obtained. CFD code FLUENT is used for finding Heat transfer characteristics of the heat exchanger with helical coil. The CFD predictions are in good agreement with the experimental results within experimental error limits.

N. Ghorbani[4] conducted experimental study of thermal performance shell and coil heat exchanger in the purpose of this article is to access the influence of tube diameter , coil pitch , shell side and tube side mass flow rate on the modified effectiveness and performance coefficient of vertical helical coiled tube heat exchanger. The calculation has been performed for the steady state and the experiment was conducted for both laminar and turbulent flow inside coil. It was found that the mass flow rate of tube side to shell ratio was effective on the axial temperature profiles of heat exchanger. He concluded that with increasing mass flow rate ratio the logarithmic mean temperature difference was decreased and the modified effective's decreases with increasing mass flow rate.

R. Patil [5] suggested design methodology for helical coil heat exchanger. heat transfer coefficient based on the inside coil diameter hi, is obtained using method for a straight tube either one of Sieder –Tate relationships or plot of the Colburn factor ,JH vs Re. outside heat transfer coefficient is calculated using correlation for different range of Reynolds number. Helical coil heat exchanger is the better choice where space is limited and under the conditions of low flow rates or laminar flow.

III. SIMULATION

3.1 Geometry and Meshing

Geometry is created in the CATIA V5 for both HE with straight shell and conical shell. Meshing of geometry is completed in ICEM CFD Both volume and surface mesh is done for the geometry.

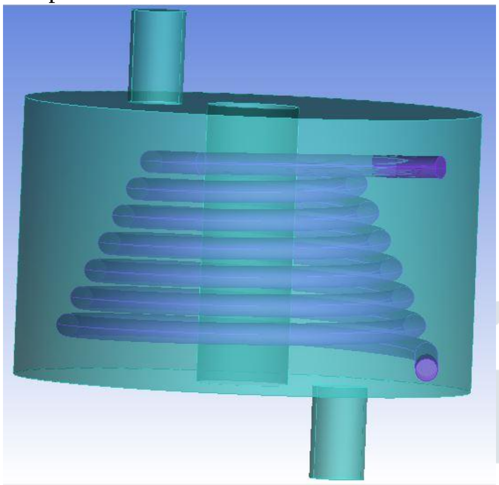


Fig.3.1 (a) Geometry of HE with straight shell

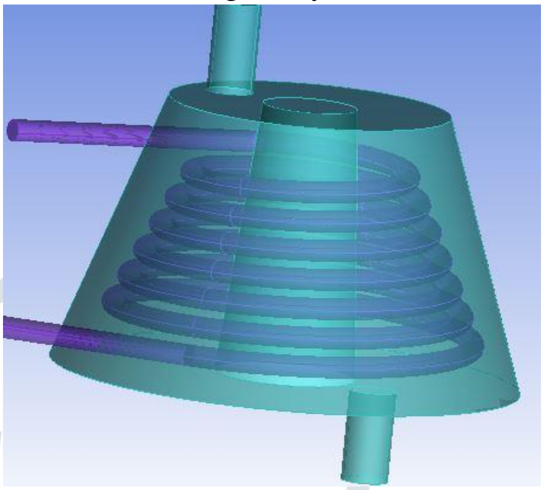


Fig.3.1 (b) Geometry of HE with conical shell

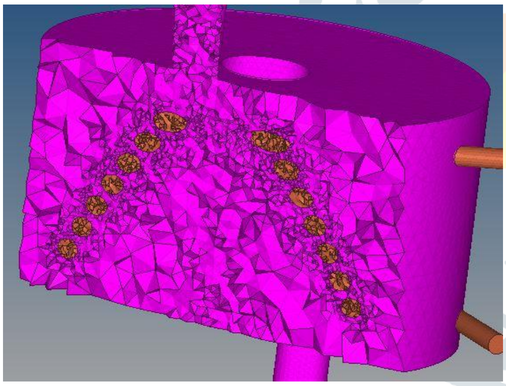


Fig.3.2 (a) Meshing of HE with straight shell

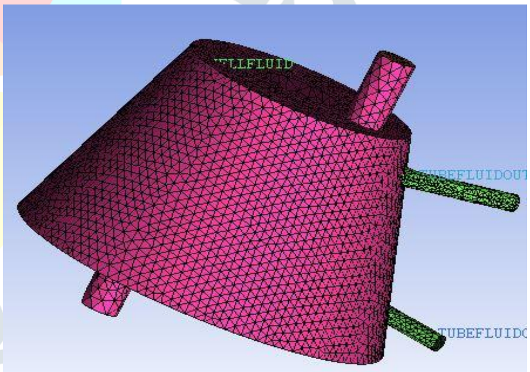


Fig.3.2 (b) Meshing of HE with Conical shell

3.2 Boundary Conditions & Assumptions:

- **Solver type :** Pressure based Steady State
- **Turbulence Model***:* K-epsilon Realizable Standard Wall Function
- **Boundary/ Zone Conditions:**
  - Fluid: water-liquid
  - Tube/Coil inlet= mass flow inlet type with Temp Tci
  - Shell inlet= mass flow inlet type with Tsi
  - Tube/ Coil outlet= Pressure outlet
  - Shell outlet= Pressure outlet
  - Wall-coil= Copper, coupled wall
  - All other walls= stationary no slip

IV. RESULTS

A) For Straight shell

Temperature contours:

Shell outlet temperature comes 312 k and tube outlet temperature comes 338 k.

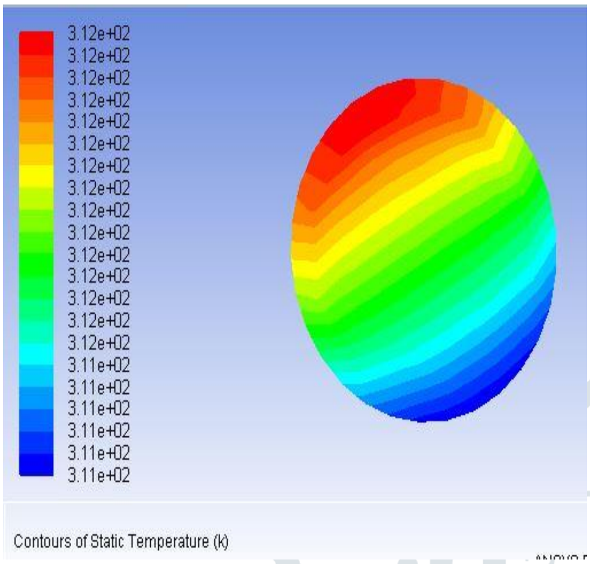


Fig. 4.1(a) Contours of shell outlet temperature

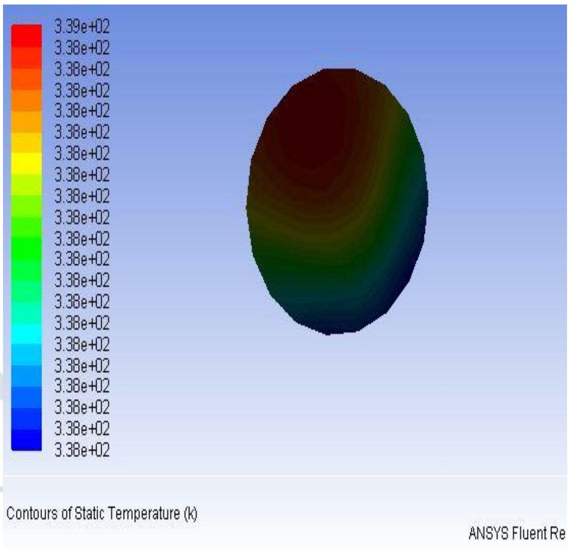
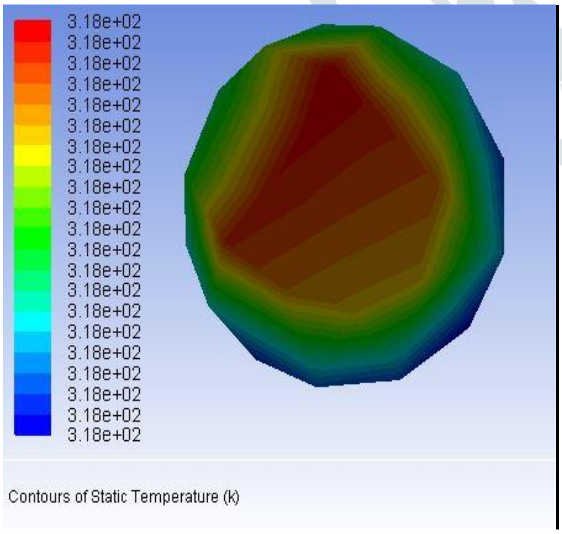


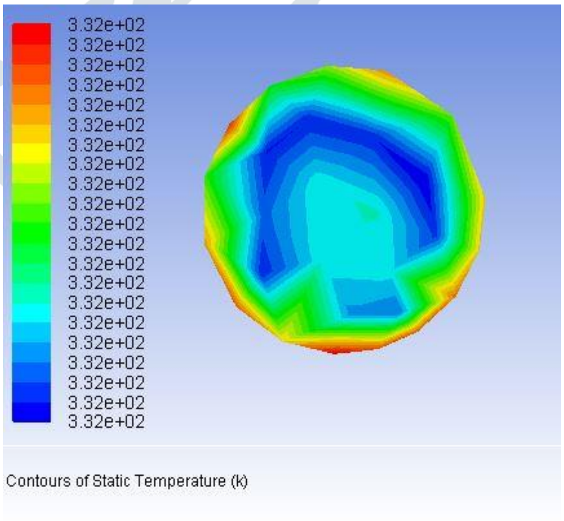
Fig. 4.1(b) Contours of shell outlet temperature

B) For Helical shell

Temperature contours:

Shell outlet temperature comes 318 k and tube outlet temperature comes 332 k. There is much improvement in heat transfer as the more shell fluid comes in contact with the tube fluid.





V. CONCLUSION

The analysis of conical helical tube heat exchanger is carried out using computational fluid dynamics. There is much improvement in heat transfer as the more shell fluid comes in contact with the tube fluid when we use conical shell instead of helical shell. The pressure drop will increase with conical shell arrangement. We can still increase heat transfer if we use baffles. CFD finds best tool for such new concepts design.

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