

| e-ISSN: 2319-8753, p-ISSN: 2320-6710| <u>www.ijirset.com</u> | Impact Factor: 7.512|

|| Volume 10, Issue 4, April 2021 ||

DOI:10.15680/IJIRSET.2021.1004019

Design and Analysis of Helical Coil Heat Exchanger for Heat Transfer Improvement

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ABSTRACT: Helical coil heat exchanger (HCHE) is widely used in industrial applications because it can accommodate greater heat transfer area in a less space, with higher heat transfer coefficients. At present, work attempts are made to enhance the overall heat transfer coefficient in HCHE by varying helix angle. Hot water flows in helical coil and cold water flows in shell side. The heat transfer can be improved by varying helix angle. Different angles are analyzed for that. In this work all numerical data are tabulated and compared to get the optimum helix angle by CFD analysis.

KEYWORDS: Helical Coil Heat Exchanger, Helix Angle, Computational Fluid Dynamics (CFD)

I. INTRODUCTION

Heat exchanger are the important engineering equipments which are used for transferring heat between a solid object and a fluid, or also between two or more fluids. The fluids are separated by a solid wall to prevent mixing or they are in direct contact. Heat exchanger between flowing fluids is one of the important physical process of concern and variety of heat exchanger are used in different type of installations, as in process industries, compact heat exchanger nuclear power plant, HVAC systems, food processing, refrigeration, air conditioning etc. The purpose of constructing heat exchanger is to get efficient way of heat transfer from one fluids to another, by direct contact or indirect contact. Heat exchanger are the important engineering systems with wide variety of applications including power plants, nuclear reactors, refrigeration, heat recovery systems, chemical processing and food industries. Besides the performance of the heat exchanger being improved, the heat transfer enhancement enables the sizes of heat exchanger is considerably reduced. The enhancement in heat exchanger can be classified into three techniques, which are active, passive and compound techniques. The active techniques require external forces, e.g. electric field, acoustic and surface vibration. The passive techniques require special surface geometries or fluid additives. Compound heat transfer techniques is the combination of any two or three above mentioned techniques simultaneously.

II. HELICAL COIL HEAT EXCHANGER

Helically coiled tubes can be found in many applications including food processing, nuclear reactors, compact heat exchanger, heat recovery systems, chemical processing, low value heat exchanger, and medical equipment. Curved tubes are of interest to the medical community as flowing of blood occurs in many arteries that are curved. Helical coils are very famous for different process such as heat exchanger due to extensive use of helical coils in these applications, knowledge about the pressure drop, flow patterns and heat transfer characteristics are very important. Pressure drop characteristics are required for evaluating pump power required to overcome pressure drops for providing necessary flow rates. These pressure drops are also functions of curvature of tubes. The curvature induces secondary flow patterns which is perpendicular to the main axial flow direction. There are various research on heat transfer in curved and helical circular tubes and it has been widely reported in literature that heat transfer rates in helical coils are higher as compare with straight coils. The main important characteristics of coiled pipes is they are compactness and high heat transfer performance. In spite of lot of research on numerical and experimental studies that have been done in relation to tube side heat transfer coefficient, there are not many investigations on heat exchanger performance by changing taper helix angle. The most important characteristics of coiled pipes are the compactness and high heat transfer performance.



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III. TERMINOLOGY OF HELICAL COIL HEAT EXCHANGER

Figure.1 shows the schematic view of the helical coil. The pipe has an inner diameter donated by 2r. the coil diameter is represented by 2Rc which is distances between the centre of the pipes. The distance between two turns is called as pitch H. the coil diameter is also terms as pitch circle diameter (PCD). The ratio of pipe diameter to coil diameter (r/R_c) is called curvature ratio. The ratio of pitch to length of one turn ($H/2\pi R_c$) is termed non-dimension pitch, λ . Consider the projection of the coil on a plane passing through the axial of the coil. The angle, which projection of one turn off the coil makes with a plane which is perpendicular to the axis, is called the helix angle, α . Consider any cross section of the pipe created by a plane passing through the coil axis. The side of pipe wall nearest to the coil axis is termed inner side of the coil and the farthest side is termed as outer side of the coil.



- 1. Helical coils are used for transferring heat in chemical reactors because the heat transfer coefficients are greater in these type of coils as compared to other configurations. This phenomenon is especially important when chemical reactions have high heats of reaction are carried out and the heat generated (or consumed) has to be transferred rapidly to maintain the temperature of the reaction. They are widely used in petroleum industries for different applications.
- 2. The helical coils have a compact configuration, and because of that advantage they can be readily used in heat transfer applications with space limitations, for example marine cooling systems, central cooling, cooling of lubrications oil, steam generations in marine and industrial applications.
- 3. The helical coil heat exchangers are widely used in food and beverage industries, for example in food processing and preheating, pasteurization of liquid food items, and for storing food at desired temperatures.
- 4. In cryogenic industry for liquefaction of gases helical coiled tubes are used extensively.

IV. LITERATURE REVIEW

S.D.Sancheti & Dr.P.R.Suresh[1] have worked on the Experimental and CFD estimation of the heat transfer in helically coiled heat exchanger. Use of constant values for the basic thermal and transport properties in the heat exchanger resulted in prediction of inaccurate heat transfer coefficients. From the results obtained from experiment a correlation was developed for the calculation of inner heat transfer coefficient in a helical coil heat exchanger.

J.S.Jayakumar[2] observed that the use of constant values for the transfer and thermal properties of the fluid resulted in inaccurate heat transfer coefficients. In this study, analysis was done for both the constant wall temperature and constant wall heat flux boundary conditions. The Nusselt numbers that were obtained were found to be highest on the outer coil and lowest in the inner side. Various numerical analyses were done so as to relate the coil parameters to heat transfer.

Rahul Kharat, Nitin Bhardwaj and R.S.Jha[3] worked on the Development of heat transfer coefficient correlation for concentric helical coil heat exchanger. Mathematical model was also developed for analyzing the data, which were obtained from experimental results and CFD to accounts for the effects, by different parameters and functional variables like coil gap, coil diameter and tube diameter. Using numerical technique Optimization was done for the heat transfer.

Jamshidi et al. [4] experimented of heat transfer rate in shell and coiled tube heat exchanger. In his work different pitch of helical coil was experimentally analysis with varying flow rate. In the experiment helical coils were made by copper 12.7mm outer diameter and 9mm inner diameter. All the graph showed that increasing shell side flow rate increase nusselt number. Increasing coil pitch will also increase overall heat transfer coefficient.

Jay Chandraiah[5] focus his work on CFD analysis of HCHE by varying different volume flow rates at coil side with constant flow rate at shell side. various flow rate values are 40, 60, 80, 100 and 140 LPH. Result shows that dean



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number increase in coil side flow rate and the overall heat transfer coefficient increase with increase in flow rate at coil side. The greater effectiveness of 0.80 was obtained at 40 LPH.

Asif Afzal, Mohammed Samee A. D. and Abdul Razak R. K.[6] conducted the experimental study is carried out in parallel and counter flow conditions with laminar flow of the fluids for different fluid flow rates of 0.25 lpm (litre per minute), 0.5 lpm, and 0.75 lpm. Finally it is concluded that in helical tube and shell type of heat exchanger the counter flow with coolant oil as a coolant is more effective.

V. DATA COLLECTION

An attempt is made in the paper to design and perform the analysis of helical coil heat exchanger. The model is created by using CREO 3.0. By applying boundary conditions, CFD analysis is carried out in ANSYS FLUENT 15.0. Design data which is used for the design of HCHE is tabulated below.

Table 1 Geometric dimensions for HCHE

No.	Parameters	Value(mm)
1.	Outer diameter of coil	12.7
2.	Inner diameter of coil	9
3.	Coil diameter	81.3
4.	No of coil turns	10
5.	Pitch of coil	18
6.	Shell outer diameter	200
7.	Shell inner diameter	190
8.	Length of the shell	350

Table 2 Boundary conditions

Parameters	Cold water	Hot water
Mass flow rate(kg/s)	0.051	0.051
Inlet temperature(k)	293	323
Pressure outlet(Pa)	0	0

VI. MODELING



Figure.2 Design of helical coil



Figure.3 Design of shell



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VII. MESHING

The meshing of helical coil heat exchanger is done using steady state solution and turbulence model K-e equation.



Figure.4 Meshing of Helical Coil Heat Exchanger



The below table shows the CFD temperature results in coil and shell sides for various helix angles.

S.No.	Helix angle	Coil side temperature(K)		Shell side ten	nperature(K)
		Inlet	Outlet	Inlet	Outlet
1.	1°	323	312.972	293	303.130
2.	2°	323	311.702	293	303.921
3.	3°	323	314.680	293	301.630
	0.75e-04 0.13e-04 0.53e-04 0.53e-04 7.87e-04 7.87e-04 7.87e-04 6.32e-04 6.32e-04 6.32e-04 4.71e-04 4.71e-04 4.71e-04 2.32e-04 1.50e+04 0.73e+03 3.45e+03 2.25e+04 1.54e+04 -2.16e+04 -2.16e+04	d By Tolal Energy (J/kg)		Mer 15, 2021 ent 16.0 (34, pbns, ske)	

 Table 3 Temperature Results of HCHE Considering Helix Angle

Figure. 5 Temperature Contour of HCHE Containing 2° Helix Angle

Figure.5 shows temperature streamlines of shell side flowing fluid and temperature contour of coil for HCHE containing 2^o helix angle. As the helix angle increases the coil side design is improving and area of coil is also increases. So more contact between hot fluid and coil fluid is increases with increase in helix angle. By that transfer of heat is also increases.



Figure. 6 Pressure Contour of HCHE Containing 2º Helix Angle



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Table 4 Result for Shell Side Pressure Drop and Wall Heat Transfer Coefficient

S.No.	Helix angle	Pressure Drop(Pa)	Wall heat transfer coefficient(W/m ² .K)
1.	10	193.38	1879.77
2.	2°	143.014	2334.51
3.	30	140.921	3632.03

It is observed that by increasing the helix angle the pressure drop is decrease. At the helix angle 1°, 2° and 3° the shell side pressure drop obtained from CFD is 193.38 Pa, 143.014 Pa and 140.921 Pa respectively, and inlet temperature of shell side fluid is 293K, by using all this boundary conditions shell side pressure drop and wall heat transfer coefficient is observed. Pressure drop between 2 and 3 helix angle is around 1.46% which is less compare to 26.04% of pressure drop between 1 and 2 helix angle.

IX. CONCLUSION

In the present study, CFD analysis is carried out to study the heat exchanger characteristics in helical coil heat exchanger. The design and CFD analysis of study under consideration is done and has following conclusions.

- By increasing the helix angle coil side and shell side heat transfer rate is increases.
- The static pressure is more at helix angle 3° and velocity is also more in helix angle 3°.
- The net heat transfer increases from helix angle 1° to 2° and reduces at 3°.

Table 5 Net heat transfer result

Parameters	Helix angle 1°	Helix angle 2º	Helix angle 3 ^o
Static Pressure(Pa)	1.06e4	6.17e3	6.94e3
Velocity(m/s)	1.09	1.04	1.73
Total Energy(J/Kg)	1.04e5	1.04e5	1.04e5
Net heat transfer(W)	24	342	214

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