ANALYSIS OF DOUBLE PIPE HEAT EXCHANGER WITH HELICAL FINS

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Abstract – In this present day double pipe heat exchanger is the most common type of heat exchanger widely use in oil refinery and other large chemical processes because it suits high pressure application. To determine the performance of double pipe heat exchanger, the hot fluid has made to flow through inner tubes and cold fluid is flow through the outer tubes. The main objective is to design the DPHE with different angles of fins. & to study the flow and temperature field inside the tubes. Also, attempts were made to investigate the effects and heat transfer characteristics of a DPHE for six different inclination of fins namely 0˚, 5˚, 10˚, 15˚, 20˚ and 25˚. The basic geometry of DPHE has made by using CATIA V5 and meshing is generated by using hyper mesh. The flow and temperature field inside the tube have studied using ANSYS FLUENT R18.0. The work determines with better enhancements in heat transfer rate and overall heat transfer coefficient using helical fins.

Key Words: Helical fins, overall heat transfer coefficient, heat transfer rate, mass flow rate, CFD.

1. INTRODUCTION

The heat exchanger is a device used to transfer the heat from the hot fluid to cold fluid with maximum rate and minimum investment. The heat exchanger is an important device in various thermal systems for e.g. condenser and evaporator in refrigeration systems, boiler & condenser in steam power plants etc. The heat exchanger has wide variety of industrial applications such as process industries, chemical industries, food industries etc. Now there is need of the compact heat exchangers to give required heat transfer rate with minimum space requirement. The helical fins on the inner tube increase the area available for the heat transfer and the helical fins on inner tube increases the turbulence. With helical fins at larger pitch, the efficiency of the heat transfer enhancement however is rather low when the total length of heat exchanger is fixed. At high Reynolds number, pressure drop will increase sharply if the helical pitch decreases. Due to this reason the heat transfer enhancement with helical fins is more suitable at low Reynolds number. The worldwide researchers are making hard efforts to find out suitable alternatives for heat exchangers with different geometry and varying parameters which effects on performance of heat exchanger. Now days helix fins has became blessings for researchers. Balarama Kundu et al. [1] had experimentation on beneficial design of shell and tube heat exchangers for attachment of longitudinal fins with trapezoidal profile. In this experimentation, the rectangular and trapezoidal fin shapes longitudinally attached to the fin tubes. The results show that the heat transfer rate was lesser than the rectangular cross section keeping the outer shell diameter is a constant along with all other constraints of a heat exchanger. N. Sathiya Narayanan et al. [2] had done modelling and simulation of helical fluid flow through double start screw type heat exchanger. In this experimentation efficient heat transfer is achieved by increasing the area of heat transfer by providing fin arrangement. The result shows that an efficient heat transfer is achieved as heat transfer coefficient is more. Shewale omkar M et.al. [3] have performed experimental investigation of double pipe heat exchanger with helical fins on the inner rotating tube. In this analysis the Nusselt Number obtained from the experimental results are higher than that of theoretical values obtained from Dittus-Boelter equation. The helical fins over the inner tube results into the increase in the heat transfer area and reduction in the hydraulic diameter of the flow channel. The result shows that the Nusselt number for the inner tube with helical fins is 4 times higher than that of the plain inner tube for stationary condition. The Nusselt number at the speed 50 rpm and 100 rpm are 36 % and 64% more than that of stationary inner tube. Vinous M Hameed et al. [4] have carried out an experimental study of turbulent flow heat transfer and pressure loss in a double pipe heat exchanger with triangular fins. The working fluids were air flowing in the annular pipe and water through the inner circular tube. The results shows that the heat dissipation 3.815 to 5.405times than that of smooth tube. . In the lowest space the average increment in nusselt number is about 98% over the smooth tube heat exchanger. Yu et al. [5] performed to compute the heat transfer and pressure drop characteristics of tubes with internal wave-like longitudinal fins. They conducted two cases for this work were carefully examined, using air as a working fluid. For the tube of type A, since the inner channel of the insertion is not blocked, its flow cross-section area only differs mildly from that without the insertion. While for the tube of type B the cross-section of the inner tube is totally blocked. The wave-like fins are within the annulus and span its full width. There are total 20 waves. The outer tube was electrically heated. Pressure taps were no uniformly distributed in 13 cross-sections along the test tube axis. Results showed that the wave-like fins enhance heat transfer significantly with the blocked case by 36% higher than that of unblocked tube. Sameer H. Ameen et al. [6] has constructed a model with parabolic fins fixed over the outer surfaces of its inner pipe with different inclination angles from copper alloy. They carried out the numerical work using ANSYS14.0 and conclude that local heat convection for parabolic fin heat exchangers is 2.42 times greater than pipes without fins.

1.1 Materials selection

Heat Exchanger

The selection of material is the first step while designing a heat exchanger. There are so many materials available at market for double pipe heat exchanger like copper, stainless steel, aluminum, etc. However, the process temperature and pressure dictates the choice of the material. As we are dealing with hot fluid there will be chances of development of thermal stresses, so copper and stainless steel are selected. As copper is having high thermal conductivity it is selected for inner tube and stainless steel for annulus. The brazing material used in stainless steel exchangers is a nickel based alloy with appropriate melting and welding characteristics.

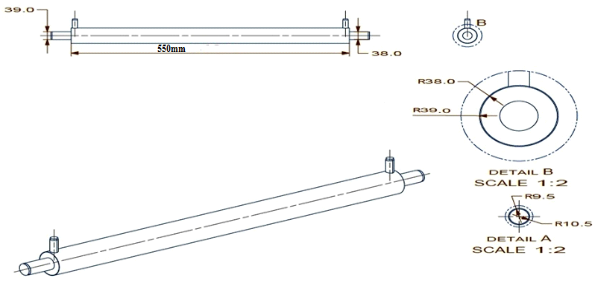
Table -1: Thermal Properties of water

Sr.no.	Property	Water(hot)	Water(cold)
1	C, J/kg K	4179	4179
2	ρ, kg/m³	997.1	997.1
3	k, W/m K	0.605	0.605
4	u, m²/s	0.001	0.001

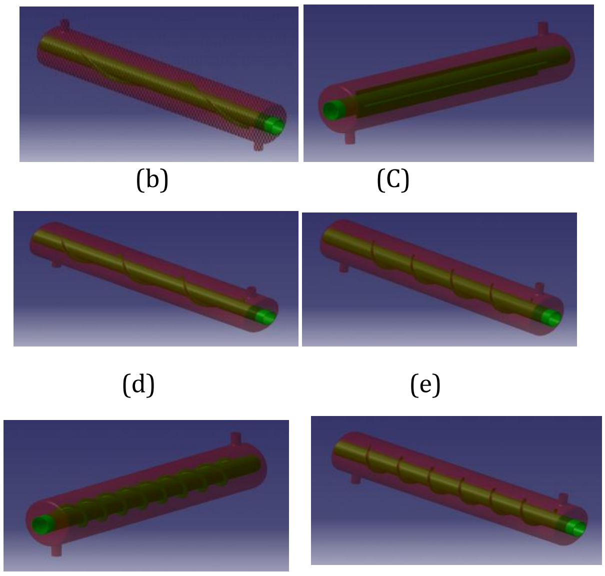
2. Computational fluid dynamic procedure

2.1 Geometry and computational fluid domain:

The schematic diagram of computational fluid domain is as shown in fig.1.



(a)



(f) (g)

Fig.1 (a) Geometry of Double pipe heat exchanger, (b) Computational fluid domain

2.2 Grid Generation

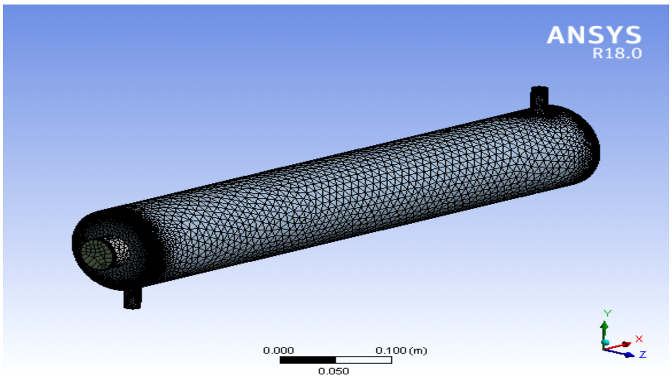


Fig. 2 Discretized computational domain

2.3 Setting of boundary condition and solving

The inlet boundary conditions are defined as cold fluid velocity flowing though outer pipe and hot fluid velocity flowing though inner pipe in counter flow.

Table2: Boundary Conditions

Quantities	Boundary Conditions	
Working fluid	Water	Water
Inner pipe (hot fluid)	Hot inlet (water)	
	Velocity	Temperature
	0.1472 m/s	55⁰C
Outer pipe (cold fluid)	Cold inlet (Water)	
	Velocity	Temperature
	0.05859 m/s to 0.5859 m/s	28⁰C

2.4 Post processing

The variables such as temperature, velocity, water are represented in the form of vectors, contours which are extracted from post processing tool.

3. Experimental set up

3.1 Fabrication:

The experimental set up fabricated as per design of heat exchanger. Four temperature indicators are used to measure inlet and outlet temperatures. Two pumps with two flow controlling valves each and a flow meter, two tanks to store the water. The system line diagram is shown in fig.3

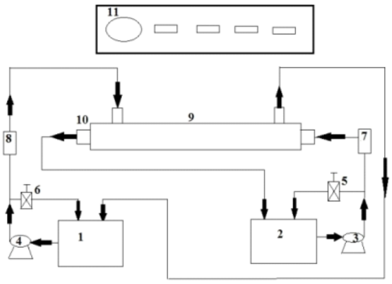


Fig. 3 Line diagram of set up

3.2 Actual set up photo

4. Data processing

4.1 Analysis of heat exchanger

1. According to first law of thermodynamics, heat transfer rate from hot fluid is equal to cold fluid. It is given by,

- Hot fluid heat transfer rate $Q_h = m_h*C_{ph}*(Th_i-Th_o)$
- Cold fluid heat transfer rate $Q_c = m_c*C_{pc}*(Tc_o-Tc_i)$

Where, m_h and m_c are the mass flow rates of hot and cold fluid respectively, C_{ph} and C_{pc} are the specific heats of hot and cold fluid respectively, Th_i and Tc_i are hot and cold inlet temperatures, Th_o and Tc_o are hot and cold outlet temperatures. Then average of both of them is taken for further calculation as shown below,

$$Q_{avg} = (Q_h + Q_c)/2$$

2. Logarithmic mean temperature difference (LMTD) is calculated by using formula,

$$\text{LMTD } (\Delta T_{lm}) = \frac{(Thi - Tco) - (Tho - Tci)}{ln(Thi - Tco)/(Tho - Tci)}$$

3. The surface area is calculated as

$$A_s = \Pi*Do*L+2LNH$$

The overall heat transfer coefficient is calculated by using formula,

$$Q_{avg} = U*A_s*\Delta T_{lm}$$

1, 2 - Storage tanks
3, 4 – Pumps
5, 6 - Ball valves
7, 8 – Rota meters
9 -Stainless steel tube
10 - Copper tube
11 - Control panel

5. Results and Discussion

Effects of helix angles of fin in the base fluid on thermophysical properties of water and different parameters like heat transfer rate, overall heat transfer coefficient are discussed in this chapter.

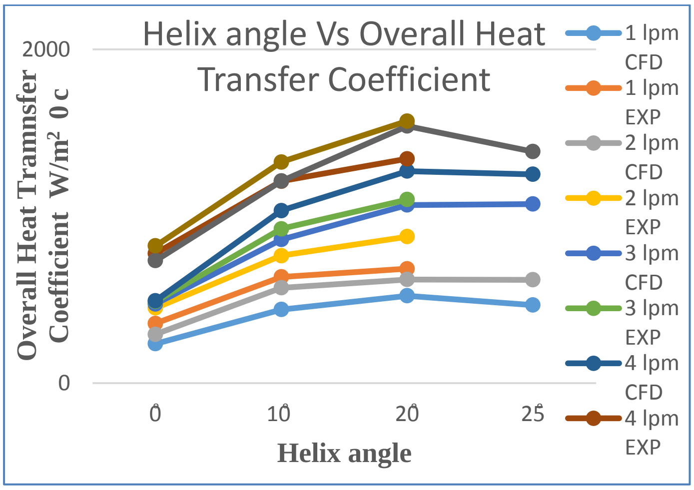
Table 3: For 0.017 Kg/sec

Fins inclination angle	T_{co} CFD	T_{co} EXP	Heat Transfer (W) CFD	Heat Transfer (W) EXP	Overall Heat Transfer Coefficient (W/m²⁰C) CFD	Overall Heat Transfer Coefficient (W/m²⁰C) EXP
0°	39.94	39	462.86	747.06	236.43	357.63
5°	39.97		500.74		390.88	
10°	40.02	40	563.02	818.55	441.70	636.82
15°	40.22		570.14		450.01	
20°	40.43	41	655.91	854.14	523.44	685.39
25°	40.78		582.95		467.99	

Table 4: For 0.034 Kg/sec

Fins inclination angle	T_{co} CFD	T_{co} EXP	Heat Transfer (W) CFD	Heat Transfer (W) EXP	Overall Heat Transfer Coefficient (W/m²⁰C) CFD	Overall Heat Transfer Coefficient (W/m²⁰C) EXP
0°	36.43	37	649.86	996.5	293.26	451.3
5°	36.89		696.84		511.26	
10°	36.94	37	775.13	1067.64	571.32	763.9
15°	37.14		800.05		593.79	
20°	37.35	39	829.83	1138.86	621.51	878.2
25°	37.70		825.67		619.84	

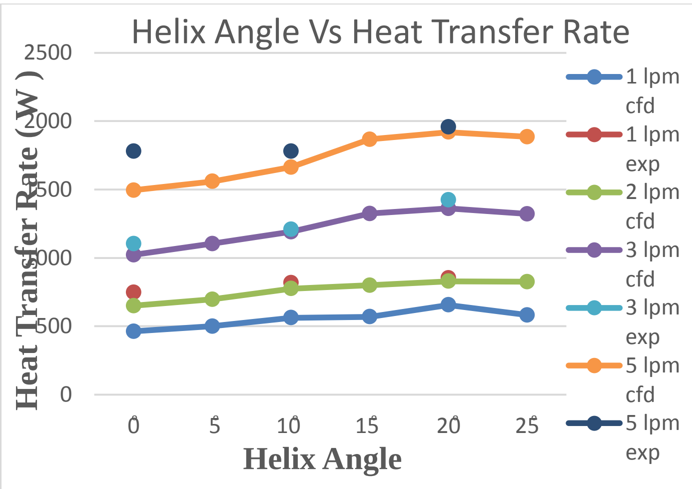
5.1 Effect on overall heat transfer coefficient



Graph 5.1 Helix angle Vs Overall Heat Transfer Coefficient (U)

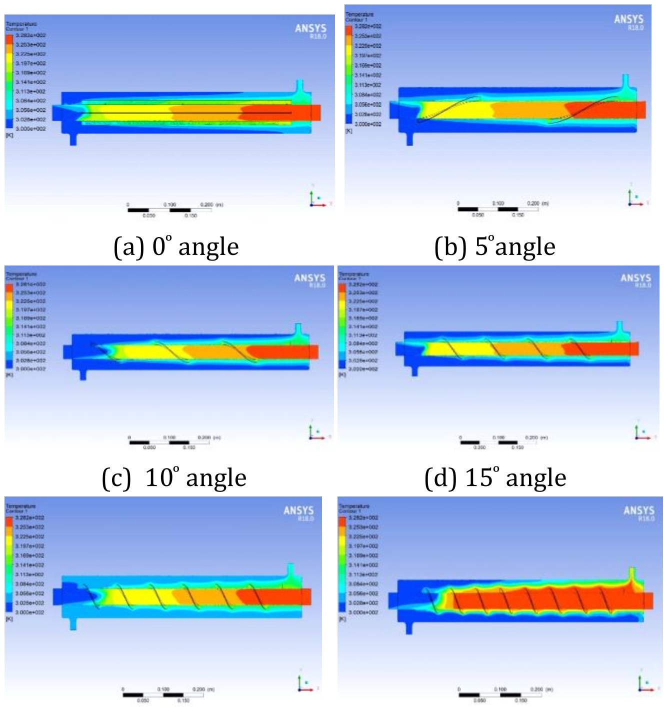
From CFD analysis, it shows that the mass flow rate increases then overall heat transfer coefficient increases. The graph shows the effect of helix angle on overall heat transfer coefficient for five flow rate

5.2 Effect on heat transfer rate



Graph 5.2 Helix angle Vs Heat Transfer Rate (Q)

From CFD analysis, it shows that the mass flow rate increases then heat transfer rate increases. The graph shows the effect of helix angle on heat transfer rate for five flow rate. From CFD analysis of different helix angle of fins it is found that increase in helix angle then increases the overall heat transfer coefficient. Also, the mass flow rate increases the values of U.



(a) 0° angle (b) 5° angle

(c) 10° angle (d) 15° angle

(e) 20° angle (f) 25° angle

Fig.5.3 Temperature distribution diagrams

The figure5.3 shows the temperature distribution diagrams for different helix angles explained in above graph (0°, 5°, 10°, 15°, and 20°and 25°). Diagrams are for the first reading of each helix angle. As hot flow rate is constant throughout and cold flow rate is varied from 1 LPM to 5 LPM.

6. Conclusions

Analysis of different helix angles of fins for a double pipe heat exchanger with the help of ANSYS FLUENT R18.0 is studied. From those angles experimental study on three angles (0°,10°,20°) is performed. The thermal performance parameter overall heat transfer coefficient has been determined. Some of main conclusions of the present work are noted below.

1. From CFD analysis it is observed that increase in heat transfer rate (1494.75 W to1920.05 W) and overall heat transfer coefficient (734.58 W/m² ⁰C to 1570.46 W/m² ⁰C) for 0° to 20° and above the 20̊ angle (1886.24 W) it decreases
2. From CFD analysis it is observed that increase in helix fins gives promising enhancement in heat transfer rate.
3. Experiment were conducted for the same flow rate and inlet conditions it shows that heat transfer rate increase from0° to 20° .

4. From these analysis it indicates that heat transfer rate is better for 20° helical fins in double pipe heat exchanger.

FUTURE SCOPE

The conventional method used for the design and development of double pipe heat exchanger are expensive .CFD provide alternative to cost effectiveness speedy solution to DPHE design and optimization. The extension of this work can be done by using Computational Fluid Dynamics (CFD) analysis for knowing heat transfer rate over the helical fins in DPHE.

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