A Study of the Literature Review on Heat Transfer in A Helically Coiled Heat Exchanger

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***Abstract*— The article gives a detailed discussion on the literature study of heat transfer in a helically coiled heat exchanger. Heat transfer characteristics inside a helical coil for various boundary conditions are studied. The effects of different flow parameters are analysed An experimental setup is done for estimating the characteristics of heat transfer. The inner heat transfer coefficient is calculated by the numerical method.**

Keywords—: Heat Transfer, Helically coil, Heat Exchanger, Boundary Conditions.

1 INTRODUCTION

The literature states that the heat transfer rates in helical coils are higher as compared to straight tubes. Because of the compact structure and high heat transfer coefficient, helical coil heat exchangers has its wide variety of applications in power generation, nuclear reactors, air-conditioning, automotive industries, electronics, cryogenic processes heat recovery systems, chemical processing steam power plants, food industry, cryogenic processes, transportation power systems, refrigeration units etc., The size of the heat exchanger is decreased considerably by heat transfer enhancement techniques. The enhancement techniques is divided into two groups active and passive The active techniques require external forces like vibration of fluid, surface vibration and electric field. The passive techniques use the surface geometries. The combination of two techniques are used to improve the heat transfer performance in heat exchangers

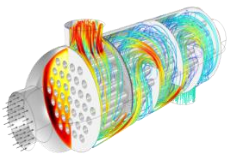

Fig 1

The helically coiled tubes are considered as the passive heat transfer enhancement techniques areused in many applications related to industries.

Helically coiled are considered superior to the straight tubes due to secondary flow development by the centrifugal force caused by the curvature of the tube. Thermal performance and pressure drop of the shell have been studied by Naphon[1]. The literature reveals the investigation on the heat transfer coefficient mostly based on the geometrical effects. Heat exchangers have started with transportation from large ones like trucks, airplanes to small ones which is fit into our palms. The fabrication cost, installation, size and weight contribute to the design. Heat exchangers can be classified according to transfer process, construction, number of fluids, surface compactness, flow arrangement and heat transfer mechanisms

11 Helically coiled pipes Terminology

The figure 1 gives the structure of helical coil with the inner diameter 2r. The coil diameter is given by 2RC which is the measurement between the centers of the pipes. The distance between two adjacent turns is called pitch denoted by H. The curvature ratio is defined as the ratio of the pipe diameter to coil diameter(r/Rc). Consider a cross section of the pipe created by a plane axis is called the helix angle passing through the coil axis. The side of pipe which is nearest to the axis of the coil is called inner side of the coil and the side farthest is called outer side of the coil. Dean number is used to study the flow characterization in the helical pipe.

111 Heat transfer in Laminar and Turbulent flow

- An additional mechanism of heat transfer in the radial and azimuthal directions is possible in turbulent flow. This is called as eddy transport and it provides energy across the flow at a given axial position than in the laminar flow. The conduction is the mechanism that operates in the transverse directions.
- The thermal entrance region is short in turbulent flow because of the intense transverse transport of energy wand long in laminar flow.
- Heat transfer correlation are based on the experimental results applicable in the thermal entrance region and in fully developed region whereas in the laminar flow it is designed to be short to account the high heat transfer rates that is possible in the thermal entrance region. This is the typical heat transfer occurs in the fully developed region on turbulent flow.

IV. SINGLE PHASE FLOW

The centrifugal force is generated when the fluid flows through the curved tubes because of its curvature. This secondary flow induced by the centrifugal force enhance the rate of heat transfer The characteristics of single phase heat transfer in helically coiled tubes has been studied experimentally and theoretically by the researchers. The large volume of results obtained by numerical method at low cost. Dravid et al. [2] investigated numerically the effect of secondary laminar flow heat transfer in helically coiled tubes in the fully developed region as well as and in the thermal entrance region. The value of the Reynolds number helps to determine the flow is laminar or turbulent.’where D is the inside diameter of the tube or pipe,V is the average velocity of the fluid, ρ is the density of the fluid, and µ is the dynamic viscosity. Kinematic viscosity . The mass flow rate is related to volumetric flow rate Q, where m=Q*ρ.For the range of Re in the range if $Re < 2300$ $the\ flow\ is\ laminar$ $2300 < Re < 4000$ $the\ flow\ is\ in\ transitioin$ $and\ if\ Re > 4000, the flow\ is\ turbulent.$ The turbulent flow is unsteady and time dependent fluctuations in pressure and velocity. The general schematic diagram is given by fig2. The extent of centrifugal force depends on the axial velocity of the particle and coil radius of curvature. The fluid particles flows at the core of the pipe have high velocity than that of near to the wall of the pipe. The stream drives the fluid towards the inner wall of the tube causes counter-rotating vortices called as secondary flow. It provides the transport of the fluid over the pipe’s cross section. This convective transport increases the heat transfer when compared to straight tube. The effect of the curvature of the coil decreases the turbulent fluctuations. Heat transfer augmentation technique is adopted to enhance theat transfer in single phase. Helical coils provide more surface area for a given volume. The movement of fluid particles in helical coils increases the pumping power requirement compared to the straight tube. Vaishisth et al [3] has given a review of fluid flow transfer in curved tube with their application in process industry. Fundamental studies explains clearly explains the secondary flow mechanism with the geometric parameters like diameter of the pipe. Coil diameter and pitch. The collection of published single phase friction factors, Reynolds number for the laminar and turbulent flow. Curvature ratio changes the secondary flow’s strength which stabilizes the flow and causes delay in turbulence inception. Seban and Mclanghlin [4] estimated the correlation based on the measurement of temperature by the thermocouples at axial location followed by Rogers and Mayhew[5]. Several papers on it report that correlation of heat transfer for their own range of Dean and Reynolds number which is more than the critical value. Torsion reduces the efficiency of Reynolds number which in turn emerges turbulence. This increases as torsion increases and it attains maximum and then decreases with the increase in torsion. Jamshidi et al [6] studied the geometric parameters to enhance the heat transfer rate. The paper explains the coil geometry and pressure drop in a single phase flow. Yang et. al [7] presented a numerical method; to study the laminar convective heat transfer in a helical coil pipe having fine pitch.

V.. LOG MEAN TEMPERATURE DIFFERENCE

Due to the difference in the temperature between two sides heat flows between hold and cold streams. The effective temperature distribution calculated from the heat exchangers equation is called LMTD which is defined as $\Delta\theta = \frac{\theta_1 - \theta_2}{\ln\frac{\theta_1}{\theta_2}}$

Fig 2 represents the secondary flow developed due to curvature

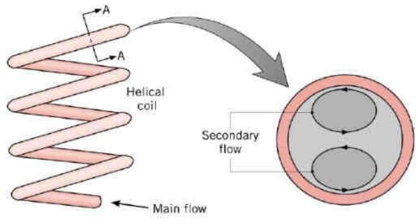

Fig 2

VI. Helical coil heat exchanger parameters:

The length of coil is defined as $L_{coil} = N_{coil}\sqrt{\pi d_0{}^2 + ptich^2}$

Volume occupied by the coil = $\frac{\pi}{4} d_0{}^2 L_{coil}$

$$\frac{\pi}{4} d_0{}^2 L_{coil}$$

Annulus volume = $\frac{\pi}{4}(D^2{}_{in} - D^2{}_{out})pitch * L_{coil}$

Volume of the fluid flow = Annuls volume - coil volume.

(i)Heat Transfer Coefficient

The vicinity of the fluid’s surface and film which is turbulence free covers the surface in the convective heat transfer from surface to fluid. It takes place by thermal conduction and improves the heat transfer by increasing the velocity of the fluid over the surface and reducing the film thickness.

(ii) Dean number:

The Dean number is defined as the ratio of the viscous force acting on a fluid flows in a curved pipe to the centrifugal force. It characterizes the flow in a helical pipe. For the same flow the dean number cannot be more than the Reynolds number. The effects of centrifugal force dominate the flow as the Dean number approaches to the Reynolds number. Due to the geometry of the helical coil the heat transfer coefficient is large. The Dean number is given by

$$De = Re\sqrt{\frac{d}{D}}$$

Where d is the diameter of tube and D is coil’s diameter. Dean is the first person to study the flow patterns using toroidal coordinate system. He studied that the secondary flow divides along tube diameter into two distinct re-circulating vortices. Rennie [8] studied the characteristics of heat transfer in a helical heat exchanger for parallel and counter flow with the dean numbers from 38 to 350.

(iii) Effect of Nu Nusselt number:

Dravid et al.[2] investigated the secondary flow on laminar with the helically coiled in the fully developed and thermal entrance region. The results are validated with experimental values. The Nu value given by $Nu = \left(0.65\sqrt{De} + 0.76\right)Pr^{0.175}$.

Patankar et al[9] explained the effect caused by Dean number an friction factor and transfer of heat in the developing and fully developed region of a helically m pipe. He has considered the velocity profiles, the temperature of the wall

for uniform heat flux in the axial direction with the isothermal property transfer is studied. The results on the study of the incompressible Newtonian fluid laminar flow gives the conclusion as he increase in the temperature gradient in one side of wall pipe and decreased in the other side of wall's pipe increases the torsion with the large Prandtl number and decreased Nusselt number but the fluid with a small Prandtl number, the Nusselt number declined slightly as the torsion increased. Zheng et al[10] solved the three dimensional governing equations using control-volume finite difference method with second order accuracy. The paper focused on the laminar forced convection and thermal radiation inside a helical pipe with the effects of thermal radiation which enhances the heat transfer.Many researchers studied the different parameters of
the helical coil heat exchangers. Purandere et al. [11] discussed the parametric analyses of Helical coil heat exchanger. Re range is considered as 100 to 6000 for laminar and turbulent region. The studied is further modified by Kshirsagar et al.[16] examined the variation in pitch for the overall heat transfer coefficient.Wilson pilot method was applied to find the inner heat transfer coefficient by Shirgire et al.[17] and proved that the geometry of heat exchangers affect the heat transfer coefficient Jayakumar [13] studied the numerical experiments to find the coil parameters influence on heat transfer. They summarised with the advantages of the helical coil exchangers with its applications. Chen and Zhang [16] studied the effects of rotation , curvature (centrifugal force), and heating/cooling (buoyancy force) on the flow pattern, friction factor, temperature distribution, and Nusselt number. Lin Ebadian [15] applied the standard k-ϵ model to investigate three-dimensional turbulent heat transfer in helical pipes with finite pitches. The effects of pitch, curvature ratio and Reynolds number on thermal conductivity and temperature fields, and local and average Nusselt numbers were discussed.

VII. CONCLUSION:

This paper gives a broad review of the study of the helical coil heat exchangers effectiveness with the other exchangers. Because of the secondary flow inside the helical tube, the heat transfer is more and it increases the rate at which heat transfer takes place. This increases the friction factor which increases the effectiveness if the helical coil heat exchanger. The curvature of the coil affects the turbulent fluctuation within the fluid. The overall heat transfer coefficient increases with the De, Nu, Re values accordingly.

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