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A Review on Heat Transfer Enhancement by Using Helical Coil Heat Exchanger

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ABSTRACT

This study gives comparison of helical coil heat exchanger with straight tube heat exchanger as well as analysis of helical coil heat exchanger and enhancement the heat transfer rate in helical coil heat exchangers. In this work, only heat transfer analysis was taken in to consideration excluding pressure drop analysis. The reason doing so is, we know pressure drop is an issue for these kinds of techniques. Many researchers worked and concluded that with some unavoidable penalty at pressure drop wire coils are best amongst all other. Thus only heat transfer was focused skipping pressure drop considerations.
Keywords : Helical Coil Heat Exchanger, Heat Transfer, Heat Exchanger.

I. INTRODUCTION

Helical coiled tubes are used in a variety of applications, helical coils offer advantageous due to their compactness and increased heat transfer coefficient. Increased heat transfer coefficients are a consequence of the curvature of the coil, which induces centrifugal forces to act on the moving fluid, resulting in the development of secondary flow. Fluid turn the inside of the tube is thrown through the centre of the tube towards the outer wall and then returns to the inner wall via the wall region. This secondary flow enhances heat transfer and temperature uniformity due to increased mix especially in laminar flow. However, the required pressure gradient to obtain a given mass flux is increased compared to a straight tube.

II. HELICAL COIL HEAT EXCHANGER

Heat transfer in helical coils are higher than as compared to straight coils. Because of its compact size, higher film coefficient, they are widely used in industrial applications like power generation, nuclear industry, process plant, heat recovery system, chemical process industries etc. These heat exchanger are used to control the temperature of the reactors for exothermic reactions. They have less expensive design. Helical geometry allows the effective handling at higher temperatures and extreme temperature differentials without any highly induced stress or expansion of joints. Helical coil heat exchanger consists of series of stacked helical coiled tubes and the tube ends are connected by manifolds, which also acts as fluid entry and exit locations.

III. CHARACTRISTICS OF HELICAL COIL

The pipe has an inner diameter 2r. The coil has a diameter of 2Rc (measured between the centers of the pipes), while the distance between two adjacent turns, called pitch is H. The coil diameter is also called pitch circle diameter (PCD). The ratio of pipe diameter to coil diameter (r/Rc) is called curvature ratio. The ratio of pitch to developed length of one turn (H/2_Rc) is termed non-dimensional pitch.

Consider the projection of the coil on a plane passing through the axis of the coil. The angle, which projection of one turn of the coil makes with a plane perpendicular to the axis, is called the helix angle, Similar to Reynolds number for flowing pipes; Dean Number is used to characterize the flow in a helical pipe.

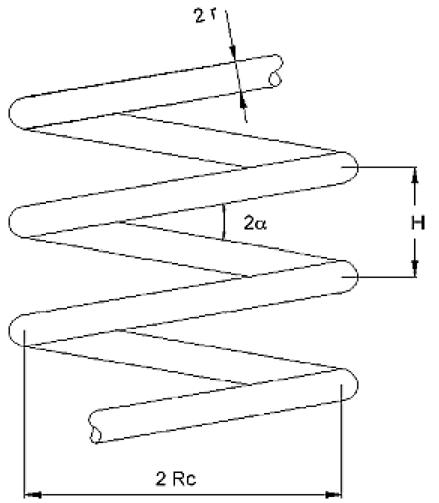

Figure 1: Basic Geometry of Helical Pipe

Many researchers have identified that a complex flow pattern exists inside a helical pipe due to which the enhancement in heat transfer is obtained. The curvature of the coil governs the centrifugal force while the pitch (or helix angle) influences the torsion to which the fluid is subjected to. The centrifugal force results in the development of secondary flow. [4]

IV. SECONDARY FLOW FORMATION

In the coiled tube, the flow modification is due to centrifugal forces. The centrifugal forces are acting on the moving fluid due to the curvature of the tube results in the development of secondary flow which enhances the heat transfer rate. This phenomenon can be beneficial especially in laminar flow. When a fluid flows through a straight tube, the fluid velocity is maximum at the tube center, zero at the tube wall & symmetrically distributed about the axis. However, when the fluid flows through a curved tube, the primary velocity profile is distorted by the addition of secondary flow pattern. Figure 2 shows the secondary flow pattern in coiled tube.

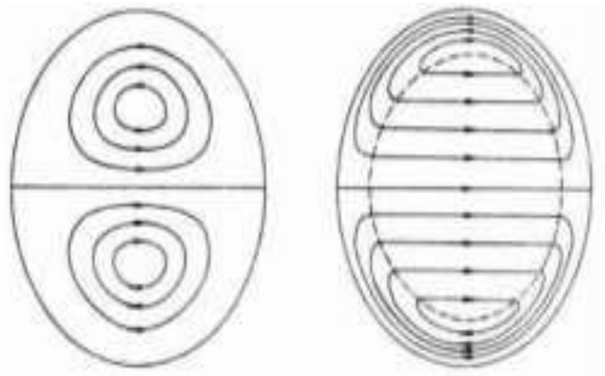

Figure 2: Secondary flow pattern in coiled tube

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 inward along the tube wall to replace the fluid ejected outwards. This results in the formation of two vortices symmetrical about a horizontal plane through the tube centre. [1]

V. ANALYSIS OF HELICAL COIL HEAT EXCHANGER

The effect of flow rate, temperature, number of turns, pitch diameter, coil diameter on overall heat transfer coefficient is analysing and comparing with linear copper pipe through the following figures.

A. Effect of flow rate on overall heat transfer coefficient

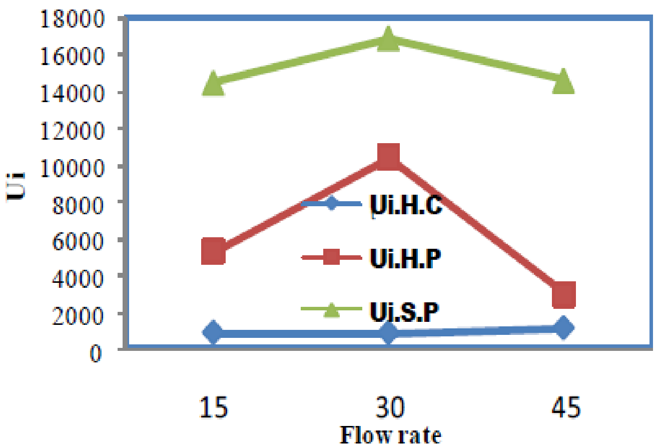

Figure 3: Flow rate Vs Overall Heat Transfer

As the flow rate increases in parallel configuration Ui rises slowly till 30^{o} and starts declining after 30^{o}. But in the straight it raises till 30^{o} (and starts declining after 30^{o}.In counter flow configuration as flow rate increases Ui is almost constant till 30^{o} and later its value raises slightly. Similar in a straight configuration as flow rate increases Ui decreases till 30^{o} and rises sharply after 30^{o}, as shown in Fig 3. [2]

B. Effect of temperature on overall heat transfer coefficient

In the parallel configuration of helical pipe as temperature increases Ui increases sharply and starts decreasing and finally maintains constant Ui after a certain period of time. But in counter also initially it starts decreasing and maintains constant Ui quickly. The overall heat transfer is more in case of parallel than the counter of helical arrangement. As temperature increases in straight pipe Ui start decreasing till 70° and rises sharply after 70 °. It follows a cycle i.e. periodic rise and fall of Ui .Similarly in counter arrangement as temperature increases Ui decreases gradually, as shown in Figure 4 [2]

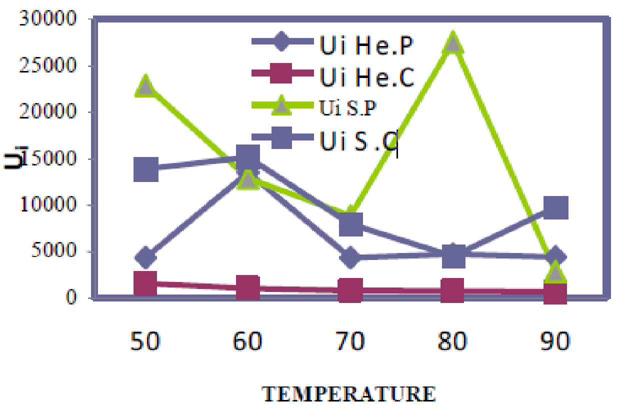

Figure 4: Temperature Vs Overall Heat Transfer

C. **Effect of number of turns on overall heat transfer coefficient**

In counter arrangement Overall Heat transfer is constant but in parallel arrangement it drops drastically with an increase in the number of turns as shown in Figure5 [2]

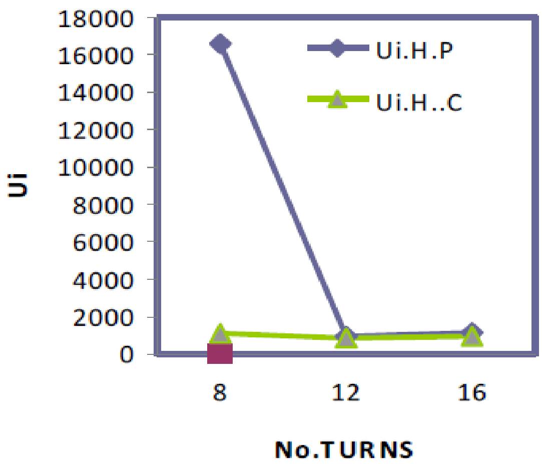

Figure 5 Number of turns Vs Overall Heat Transfer

D. Effect of coil pitches on overall heat transfer coefficient

It is revealed that increasing coil pitch increases overall heat transfer coefficient in coiled tube heat exchangers. By increasing the coil pitch, a better contact is obtained between tube and shell side flow rates, so the heat transfer rate between these fluids increases, as shown in Figure 6 [3]

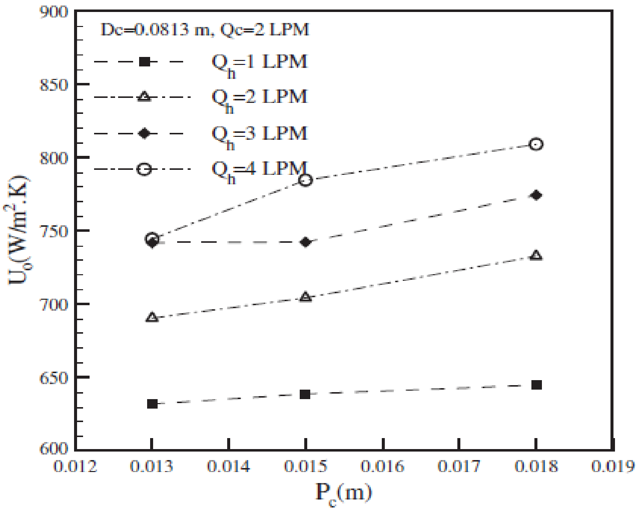

Figure 6. Coil pitches Vs overall heat transfer coefficient.

E. Effect of coil diameter on overall heat transfer coefficient

By increasing the coil diameter the length of tube increases and the residence time of hot fluid in heat exchanger increases, so the cold water can gain more energy from the hot water in the coil. Therefore the tube side Nusselt number and overall heat transfer coefficient increases by increasing the coil diameter, as shown in Figure 7

By increasing the coil diameter, coil pitches, hot and cold water flow rates, heat transfer rate can be enhanced considerably in coiled tube heat exchangers. [3]

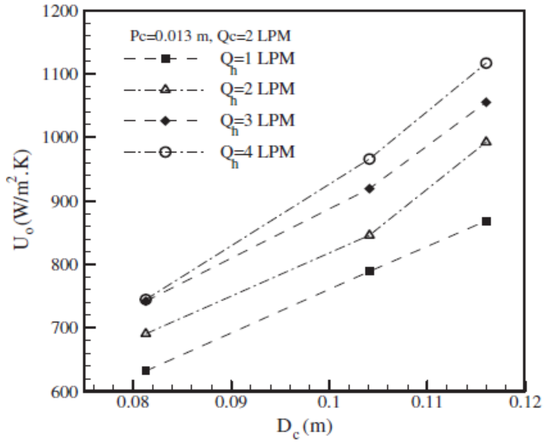

Figure 7. Coil diameter Vs overall heat transfer coefficient

VI. CONCLUSION

Heat transfer coefficient was affected by the geometry of the heat exchanger and the temperature of the water bath surrounding the heat exchanger. The helical coil had a greater increase of temperature compared to the straight tube and the increase of flow rate resulted in a decrease of the temperature rise. The larger temperature rise in the helical coil compared to the straight tube would be due to the secondary flow developed in the coil, as this is the only difference between the two coils. The decrease in the temperature rise due to increased flow is a result of the decreased residence time of the fluid. For low Re, the graphs of Nu Vs Re and hi Vs Re is steeper than that at high Re. It indicates that helical coils are efficient in low Re. As well as the graph shows as coolant velocity increases the slope of the graph increases. This implies that if the flow rate of coolant is increased, the rate of increase of heat transfer coefficient with Reynolds number increases. Maximum effectiveness in parallel configuration of helical type is 0.631. Maximum effectiveness in counter configuration of helical type is 0.671. Maximum effectiveness in parallel configuration of straight type is 0.316. Maximum effectiveness in counter configuration of straight type is 0.498. By increasing the coil diameter, coil pitches, hot and cold water flow rates, heat transfer rate can be enhanced considerably in coiled tube heat exchangers.

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