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# Helically Coiled Tube with Different Geometry and Curvature Ratio on Convective Heat Transfer: A Review

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***Abstract— A helically coil-tube heat exchanger is generally applied in industry applications due to its compact structure, larger heat transfer area and higher heat transfer capability. Several studies from literature have also indicated that heat transfer rate in helically coiled tube are superior to straight tube due to complex flow pattern exist inside helical pipe. The concept behind compact heat exchanger is to decrease size and increase heat load which is the typical feature of modern helical tube heat exchanger. While the heat transfer characteristics of helical coil heat exchangers are available in the literature, This paper elaborates a brief review on different curvature ratio and geometry of tubes in heat transfer through heat exchangers.***

***Keywords—Helical coil Heat exchanger, Conjugate heat transfer, Heat transfer correlation, Dean number, curvature ratio***

## I. INTRODUCTION

It has been widely reported in literature that heat transfer rates in helical coils are higher as compared to that in straight tubes. Due to the compact structure and high heat transfer coefficient, helical coil heat exchangers are widely used in industrial applications such as power generation, nuclear industry, process plants, heat recovery systems, refrigeration, food industry, etc.[1] They are used also in steam generator and condenser design in power plant because of their large surface area per unit volume. These centrifugal forces generate a secondary flow, normal to the primary direction of flow with circulatory effects that increases both the friction factor and rate of heat transfer [2]. The intensity of secondary flow developed in the tube is the function of tube diameter and coil diameter. A lot of work done on straight helical coil heat exchanger but very few author works on conical and spiral heat exchanger .

## II. LITERATURE REVIEW

It has been widely reported in literature, the heat transfer and pressure drop characteristics of the conical coil heat exchanger with different cone angles, tube diameter and flow rates shows considerable effects in performance. In this conical coil with cone angle of 0˚(helical), 45˚, 90˚, 135˚, and 180˚ (spiral) coils are analysed experimentally[1]. It is observed that, maximum velocity is located in central region of the inner tube because this region has maximum distance from the boundary layer. Dean number is an important and effective parameter in helical double tube heat exchanger. By increasing of inner tube diameter, overall heat transfer coefficient of heat exchanger increases. With increase of annulus mass flow rate (that leads to Dean number increase in annulus) rate of heat transfer will increase, is observed.[2]. Experimental studies on steady-state natural convection heat transfer in helical coil in water bath were performed. It is found that the overall heat transfer coefficient and Nusselt number are increases as the flow rate of coolant increase. As per the experimental results the curvature ratio di/D = 0.1101 gives a higher values of overall heat transfer coefficient than the ratio di/D = 0.0942, in addition when the curvature ratio of coil increase the Nusselt number values also increase; [3]. Experimental results for forced convection heat transfer and friction factors, obtained with water flowing through steam heated coils, are reported and compared with the limited results available to date. Existing equations for isothermal friction factors in smooth coils are deemed satisfactory. Non-isothermal friction factors and heat-transfer coefficients can be estimated from proposed equations for design purposes, but results cannot yet claim the same validity as those for straight pipes [4]. Characteristics of heat transfer under turbulent flow of single phase water through helical coils of vertical axis are presented in the article.

Necessary Python codes, which run in the framework of visualization package, have been developed for accurate estimation of Nusselt number at any point on the heat transfer surface. Analysis has been carried out both for the constant wall temperature and constant wall heat flux boundary conditions. Fluid particles are found to undergo oscillatory motion inside the pipe and this causes fluctuations in heat transfer rates[5]. Cooperating with spiral corrugation on the inner wall is a passive, further heat transfer enhancement method for the smooth helical tube. Numerical simulation was performed to give the turbulent flow and temperature fields in helical tubes cooperating with spiral corrugation. The effects of the spiral corrugation parameters and Reynolds number on the flow and heat transfer were studied. Within the research scope, helical tubes cooperating with spiral corrugation show50-80% increase of heat transfer while the flow resistance is 50-300% larger than that in the smooth helical tube this is validate by LI Ya-xia,[6]. This paper focus on an increase in the effectiveness of a heat exchanger and analysis of various parameters that affect the effectiveness of a heat exchanger and also deals with the performance analysis of heat exchanger by varying various parameters like number of coils, flow rate and temperature. The results of the helical tube heat exchanger are compared with the straight tube heat exchanger in both parallel and counter flow by varying parameters like temperature, flow rate of cold water and number of turns of helical coil. 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.[7]. This Numerical research is introducing the concept of helical cone coils and comparing the performance of helical cone coils as heat exchangers to the ordinary helical coils. Helical and spiral coils are known to have better heat and mass transfer than straight tubes, that's attributed to the generation of a vortex at the helical coil known as Dean Vortex, this vortex is a secondary flow superimposed on the primary flow. The Dean Number which is a dimensionless number used in describing the dean vortex is a function of Reynolds Number and the square root of the curvature ratio, so varying the curvature ratio for the same coil would vary the Dean Number; is founded,[8]. The parametric study has been done using a computational fluid dynamics (CFD) program named FLUENT to estimate the performance of the heat exchanger with different fin shapes, sizes and numbers. The results obtained from the study for a steady and laminar flow of fluid under mixed flow convection heat transfer condition shows that there exists an optimum number for fins to keep the pipe wall temperature at a minimum. The wall temperature optimises at a definite fin height beyond which it is insensitive to any height variation. Moreover, amongst the three different shapes considered for fin, results show that wall temperature is least for triangular shaped fins, compared to rectangular and T-shaped fins. In addition to study of thermal characteristics, the pressure drop caused by presence of fins has also been studied;[9].

## III. CHARACTERISTICS OF HELICAL COIL.

Fig. 1 gives the schematic of a helical coil. The pipe has an inner diameter *2r*. The coil has a diameter of $2R_c$ (measured between the centres 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 ($r/R_c$) is called curvature ratio, δ. The ratio of pitch to developed length of one turn ($H/2\pi R_c$) is termed non-dimensional pitch, λ. 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, α. Similar to Reynolds number for flow in pipes, Dean Number is used to characteristics the flow in a helical pipe. The Dean number, *De* is defined as,

$$De = R_e \cdot \sqrt{\frac{r}{R_c}} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, *Re* is the Reynolds number = $2ru_{av}\rho/\mu$.

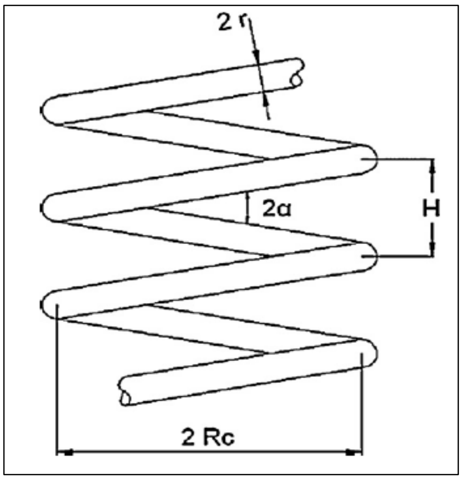



*Fig. 1 A Geometry of helical coil*

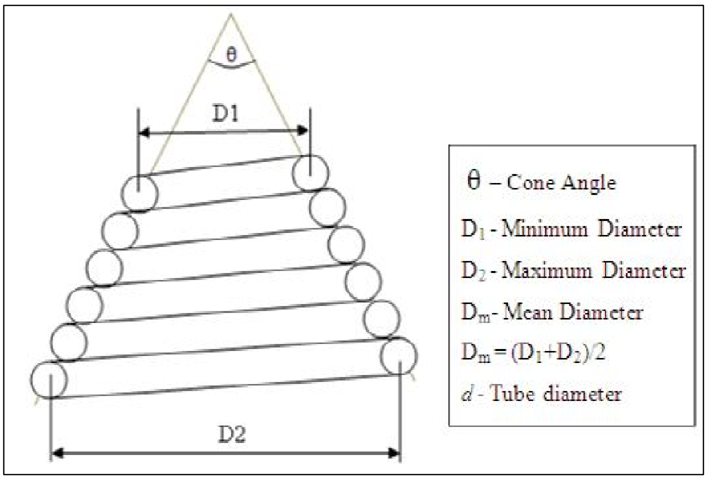



*Fig.2 A Geometry of conical coil*

## IV. EFFECT OF CURVATURE RATIO ON THE HEAT TRANSFER AND PRESSURE DROP IN COILEDTUBE[3]

Experimental set up is shown in the figure, the coils of two different curvature ratios (di/D = 0.1101 and 0.0942) used in these experiments are fabricated by bending a copper pipe of 13mm ID and 3m long. The test coil are curried out in a different ambient temperatures bath (30×50×20 cm$^3$), which serves as a heating medium. Air was pumped in the tube coil as a coolant with different volumetric flow rates (2-5m$^3$/hr) were measured by flow meter having a range of (1.5 - 16 m$^3$/hr).

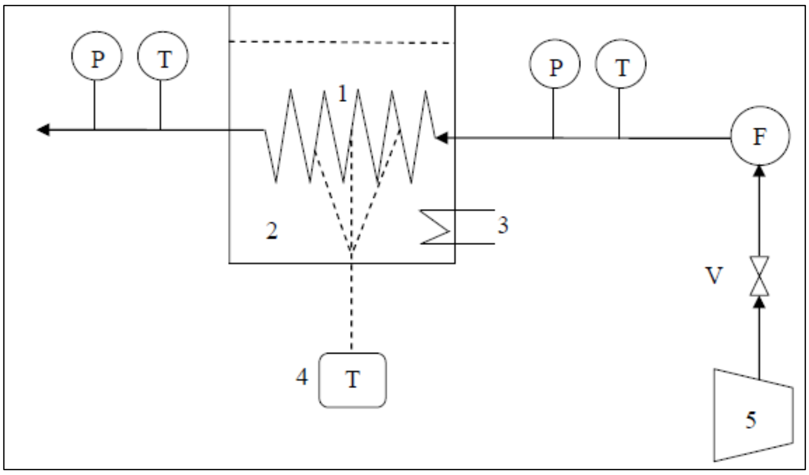



*Fig.3 Flow diagram of the experimental set-up*

*1-coil*
*2- Water bath*
*3- Electrical heater*
*4- Digital temperature indicator*
*5- Compressor*

*P- pressure manometer*
*T- mercury thermometer*
*F- flow meter*
*V- gate valve*

The experiments were conducted for seven different flow rates.

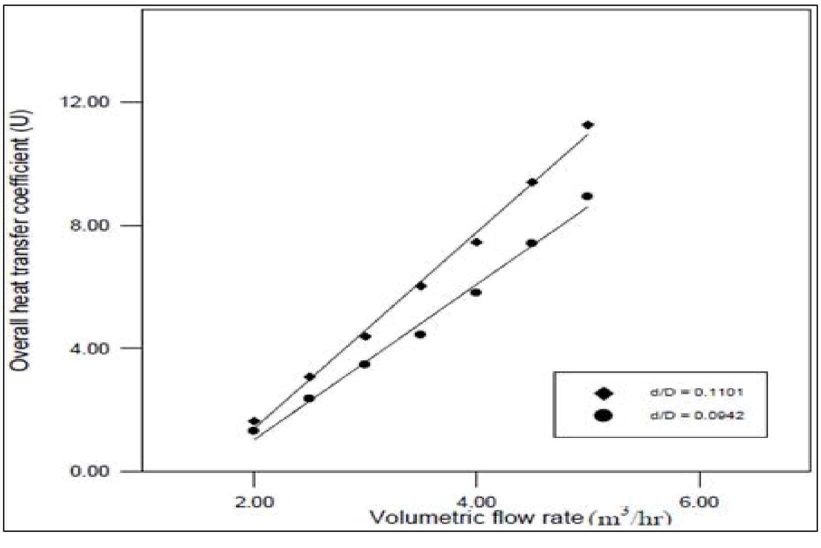
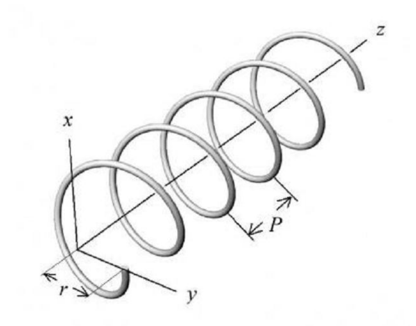
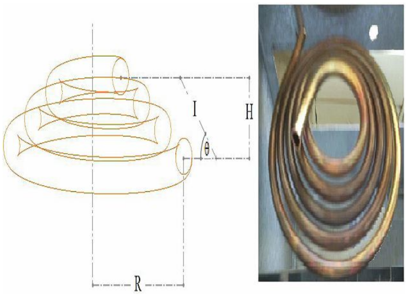
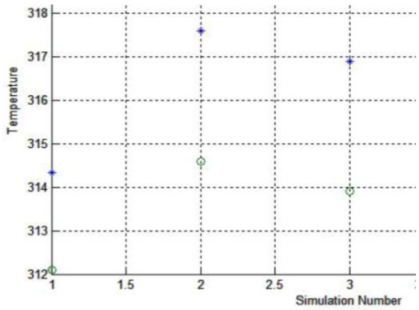
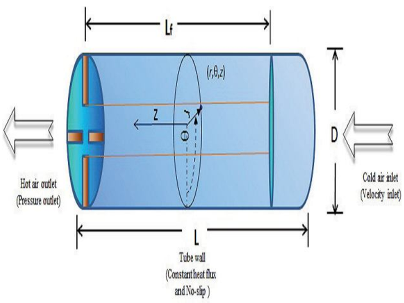



*Fig.4:The effect of the curvature ratio of coil on the overall heat transfer coefficient*

fig 4 shows that the curvature ratio have significant effect on the overall heat transfer coefficient which can be seen in figure 3. It illustrate that the curvature ratio (di/D = 0.1101) gives a higher values of overall heat transfer coefficient than the ratio (di/D = 0.0942), i.e. the overall heat transfer coefficient was increase when the curvature ratio of coil increase.

## V. VARIOUS GEOMETRY USED

| S.NO | GEOMETRY | FEATURE | CURVATURE RATIO | MASS FLOW RATE | OVERALL HEAT TRANSFER COEFFICIENT |
|---|---|---|---|---|---|
| 1 | Helical |  | 0.1101 | Increases | Increases |
| | | | 0.0942 | Increases | Increases |
| 2 | Conical |  | The taper angle of the helical cone coil has a significant effect on its heat transfer characteristics. | |  |
| 3 | Helical With Fins |  | - | - | The wall temperature distribution is minimum for triangular shaped fin as compared to rectangular and T- shaped fin. |

## VI.CONCLUSION

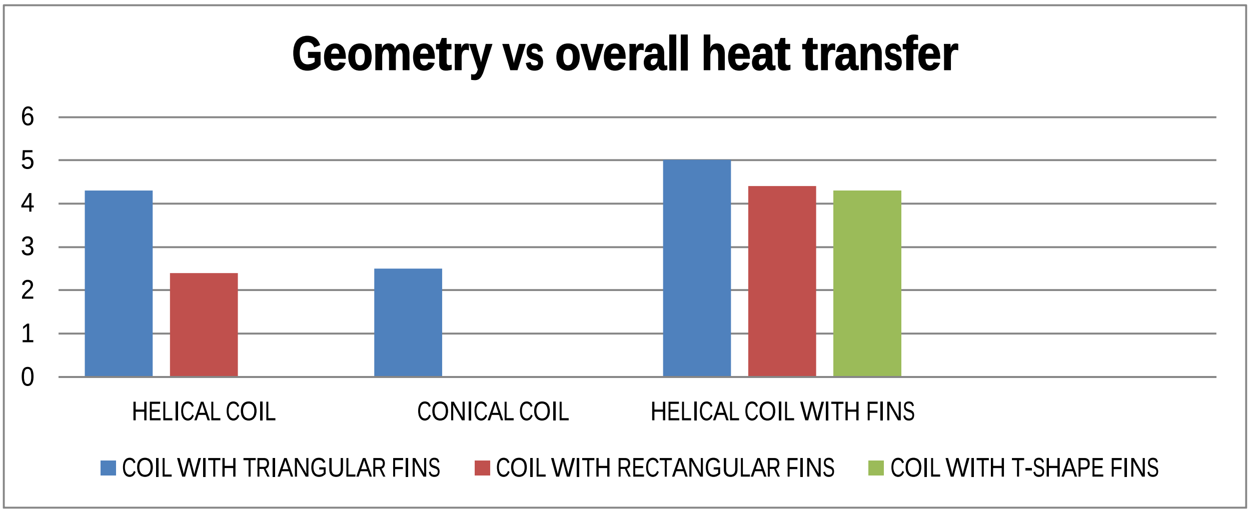



*Fig.5 Geometry vs overall heat transfer*

The chart shows that as the curvature ratio increases overall heat transfer coefficient also increases There exists an optimum fin number for which the wall temperature is minimum and the heat transfer is maximum and in the present case the optimum number of fin is found to be 10.It is also seen that the top wall temperature distribution is higher compared to the bottom wall due to buoyancy effect. There exists an optimum fin height of where the wall temperature is found to be minimum and the rate of heat transfer is maximum after which the rate of heat transfer remains unchanged. For same volume it is seen that the wall temperature distribution is minimum for triangular shaped fin as compared to rectangular and T- shaped fin.

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