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Review on Comparative Study between Helical Coil and Straight Tube Heat Exchanger

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Abstract: *The purpose of this study is to determine the relative advantage of using a helically coiled heat exchanger against a straight tube heat exchanger. It is found that the heat transfer in helical circular tubes is higher as compared to Straight tube due to their shape. Helical coils offer advantageous over straight tubes due to their compactness and increased heat transfer coefficient. The 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. 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. Due to the curvature effect, the fluid streams in the outer side of the pipe moves faster than the fluid streams in the inner side of the pipe. The difference in velocity sets-in secondary flows, whose pattern changes with the Dean number of the flow.*

In current work the fluid to fluid heat exchange is taken into consideration, Most of the investigations on heat transfer coefficients are for constant wall temperature or constant heat flux. The effectiveness, overall heat transfer coefficient, effect of coldwater flow rate on effectiveness of heat exchanger when hot water mass flow rate is kept constant and effect of hot water flow rate on effectiveness when cold water flow rate kept constant studied and compared for parallel flow, counter flow arrangement of Helical coil and Straight tube heat exchangers. The inner heat transfer coefficient calculated from Wilson plot method. Then Nusselt no and correlation obtained on the basis of inner heat transfer coefficient. All readings were taken at steady state condition of heat exchanger.

The result shows that the heat transfer coefficient is affected by the geometry of the heat exchanger. Helical coil heat exchanger are superior in all aspect studied here.

Key Words*: Helical coil heat exchanger, Straight tube heat exchanger, overall heat transfer coefficient.*

I. INTRODUCTION

Heat exchangers are used in a wide variety of applications including power plants, nuclear reactors, refrigeration and air-conditioning systems, automotive industries, heat recovery systems,chemical processing, and food industries .Besides the performance of the heat exchanger being improved, the heat transfer enhancement enables the size of the heat exchanger to be considerably decreased. In general, the enhancement techniques can be divided into two groups: active and passive techniques. The active techniques require external forces like fluid vibration, electric field, and surface vibration. The passive techniques require special surface geometries or fluid additives like various tube inserts. Both techniques have been widely used to improve heat transfer performance of heat exchangers. Due to their compact structure and high heat transfer coefficient, helically coiled tubes have been introduced as one of the passive heat transfer enhancement techniques and are widely used in various industrial applications. Several studies have indicated that helically coiled tubes are superior to straight tubes when employed in heat transfer applications .The centrifugal force due to the curvature of the tube results in the secondary flow development which enhances the heat transfer rate. This phenomenon can be beneficial especially in laminar flow regime. Thermal performance and pressure drop of a shell and helically coiled tube heat exchanger with and without helical crimped fins have been investigated by Naphon one of the most frequent uses of helically coiled tubes is in shell and coiled tube heat exchangers. Going through the existing literature, it was revealed that there are a few investigations on the heat transfer coefficients of this kind of heat exchangers considering the geometrical effects like coil pitch. Also, this scarcity is more prominent for shell-side heat transfer coefficients.

II. Literature Survey

The following research papers are studied in detail and the abstract of the work is presented here:
Timothy J. Rennie, Vijaya G.S. Raghavan [1] Have done An experimental study of a double-pipe helical heat exchanger. Two heat exchanger sizes and both parallel flow and counter flow configurations were tested. Flow rates in the inner tube and in the annulus were varied and temperature data recorded. Overall heat transfer coefficients were calculated and heat transfer coefficients in the inner tube and the annulus were determined

using Wilson plots. Nusselt numbers were calculated for the inner tube and the annulus. The inner Nusselt number was compared to the literature values. Though the boundary conditions were different, a reasonable comparison was found. The Nusselt number in the annulus was compared to the numerical data. D. G. Prabhanjan, G. S. V. Ragbavan and T. J. Kennic [2] Have done experimental study to determine the relative advantage of using a helically coiled heat exchanger versus a straight tube heat exchanger for heating liquids. The particular difference in this study compared to other similar studies was the boundary conditions for the helical coil. Most studies focus on constant wall temperature or constant heat flux, whereas in this study it was a fluid-to-fluid heat exchanger. All tests were performed in the transitional and turbulent regimes. H. Shokouhmand, M.R. Salimpour, M.A. Akhavan-Behabadi [3] Have done an experimental investigation of the shell and helically coiled tube heat exchangers. Three heat exchangers with different coil pitches and curvature ratios were tested for both parallel-flow and counter-flow configurations. All the required parameters like inlet and outlet temperatures of tube-side and shell-side fluids, flow rate of fluids, etc. were measured using appropriate instruments. Overall heat transfer coefficients of the heat exchangers were calculated using Wilson plots. The inner Nusselt numbers were compared to the values existed in open literature. Nasser Ghorbani, Hessam Taherian, Mofid Gorji, Hessam Mirgolbabaei [4], Have done an experimental investigation of the mixed convection heat transfer in a coil-in-shell heat exchanger is reported for various Reynolds and Rayleigh numbers, various tube-to-coil diameter ratios and dimensionless coil pitch. The purpose of this article is to check the influence of the tube diameter, coil pitch, shell-side and tube-side mass flow rate over the performance coefficient and modified effectiveness of vertical helical coiled tube heat exchangers. The calculations have been performed for the steady-state and the experiments were conducted for both laminar and turbulent flow inside coil. It was found that the mass flow rate of tube-side to shell-side ratio was effective on the axial temperature profiles of heat exchanger -Nian Chen, Ji-Tian Han, Tien-Chien Jen, Li Shao , Wen-wen Chen [5] Have done an experimental investigation on condensation heat transfer of R-134a in horizontal straight and helically coiled tube-in-tube heat exchangers. The experiments were carried out at three saturation temperatures(35^0 , 40^0 and 45^0) with the refrigerant mass flux varying from 100 kg/m2 s to 400 kg/m2 s and the vapor quality ranging from 0.1 to 0.8. The effects of vapor quality and mass flux of R-134a on the condensation heat transfer coefficient were investigated. The results indicate that the condensation heat transfer coefficients of the helical section are 4%-13.8% higher than that of the straight section. J.S. Jayakumar, S.M. Mahajani, J.C. Mandal, P.K. Vijayan, Rohidas Bhoi [6], An analysed heat exchanger considering conjugate heat transfer and temperature dependent properties of heat transport media. because constant temperature or constant heat flux boundary condition for an actual heat exchanger does not yield practical condition for heat exchangers. An experimental setup is fabricated for the estimation of the heat transfer characteristics. The experimental results compared with the CFD calculated results using the CFD package FLUENT 6.2. Based on the experimental results a correlation is developed to calculate the inner heat transfer coefficient of the helical coil. Nasser Ghorbani, Hessam Taherian, Mofid Gorji, Hessam Mirgolbabaei [7], The mixed convection heat transfer is reported for various Reynolds and Raylighs numbers, various tube-to-coil diameter ratios And dimensionless coil pitch. Shell-side and mass flow rate over the performance coefficient and modified effectiveness of vertical coiled tube heat exchangers. The calculations have been performed for the steady state and the experiments were conducted for both Laminar and turbulent flow inside coil. The results also indicate the –NTU relation of the mixed convection heat exchangers was the same as that of a pure counterflow flow heat exchanger. Paisarn Naphon, Somchai Wongwises[8], The performance of a spiral coil heat exchanger under cooling and dehumidifying conditions are investigated. The heat exchanger consist of a steel shell and A spirally coiled tube unit. The spiral coil-unit consist of six layers of concentric spirally coiled tubes. Air and water are used as working fluids. The chilled water entering the outermost turn flows along the spirally coiled tube, and flows out at the innermost turn. The hot air enters the heat exchanger at the centre of shell and flows radially across spiral tubes to the periphery. A mathematical model based on mass and energy conservation is developed and solved by using the Newton-Raphson iterative method to determine the heat transfer characteristics. M.R. Salimpour, [9], The heat transfer coefficient of shell and helically coiled tube heat exchangers were investigated experimentally. The heat exchangers with different coil pitches were selected as test section for both parallel-flow and counter-flow configurations . All the required parameters like inlet and outlet temperatures of tube-side and shell-side fluids, flow rate of fluids,etc.were measured using appropriate instruments. Empirical correlations were proposed for shell-side and tube –side. The calculated heat transfer coefficients of tube side were also compared to the existing correlations for other boundry conditions. M.R. Salimpour, [10], The heat characteristics of temperature-dependent-property engine oil inside coil and tube heat exchangers. Three heat exchangers with different coil pitches were selected as the test section for counter flow configuration. Engine oil was circulated inside the inner coiled tube, while coolant water flowed in the shell. All the required parameters like inlet and outlet temperatures of tube side and shell side fluids, and flow rates of fluids, etc were measured using appropriate instruments. Paisarn Naphon,[11], Numerical and experimental results of the heat transfer and flow characteristics of the horizontal spiral-coil tube are investigated. The spiral-coil tube is fabricated by bending a 8.00mm diameter straight copper-tube into a spiral-coil of five turns. The innermost and outermost diameters of the spiral-coil are 270.00 and 406.00 mm, hot water and cold water are used as a working fluid.

Experiments are performed to obtain the heat transfer and flow characteristics for verifying the numerical results. Paisarn Naphon, Jamnean Suwgrai,[12], Effect of curvature ratios on the heat transfer and flow developments in the horizontal spirally coiled tubes are investigated. The spiral-coil tube is fabricated by bending a 8.00mm diameter straight copper-tube into a spiral-coil of five turns. The spirally coiled tube with three different curvature ratios of 0.02, 0.04, 0.05 under constant wall temperature are tested. A finite volume method with an unstructured nonuniform grid system is employed for solving the model. The centrifugal force has asignificant effect on the enhancements of heat transfer and pressure drop. Due to this force, the heat transfer and pressure drop obtained from the spirally coiled tube are higher than those from the straight tube..Piroz Zamankhan,[13]**,** A 3D mathematical model has been developed to investigate the heat transfer augmentation in a circular tube with a helical tabulator. Glycol water blends of various concentrations were used in the inner tube, and pure water was used in the outer tube. Changes in fluid physical properties with temperatures were taken into account. And k-έ, k-ώ, and large eddy simulations were developed for turbulence modeling. The simulation results showed a nonlinear variation in Reynolds and prandtl numbers for a long model of heat exchanger even in the absence of a turbulator, and was found to increase the heat transfer. Rahul Kharat, Nitin Bhardwaj, R.S. Jha[14]**,** Experimental data and CFD simulations using fluent 6.3.26 are used to developed improved heat transfer coefficient correlation for the flue gas side of heat exchanger. Mathematical model is developed to analyze the data obtained from CFD and experimental results to account for the effects of different functional dependent variables, tube diameter and coil diameter which effect the heat transfer.

Optimization is done using numerical techniques. Paisarn Naphon [15]**,** has studied the thermal performance and pressure drop of the helical-coil heat exchanger with and without helical crimped fins. The heat exchanger consists of a shell and helically coiled tube unit with two different coil diameters. Each coil is fabricated by bending a 9.50 mm diameter straight copper tube into a helical-coil tube of thirteen turns. Cold and hot water are used as working fluids in shell side and tube side, respectively. The experiment done at the cold and hot water mass flow rates ranging between 0.10 and 0.22 kg/s, and between 0.02 and 0.12 kg/s, respectively. The inlet temperatures of cold and hot water are between 15 and 25 °C, and between 35 and 45 °C, respectively. The effects of the inlet conditions of both working fluids flowing through the test section on the heat transfer characteristics discussed.

III. Helical Coil Heat Exchanger

The helical coil heat exchanger is fabricated in heat transfer lab. The schematic of the experimental set-up used for the present investigation is shown figure1. The set-up consisted of the following components;

Helical coil [Copper], Shell [G.I], Heater, Flow measuring devices, Cold water source.

Hot water from hater flows inside the tube where it loses heat to cold water flowing through shell. The entry and exit of cold water in shell kept at top so shell should be filled completely and complete coil must be immersed in water. The flow of cold water is controlled by rotameter at the entry in shell, this cold water then carries heat to drainage. Hot water mass flow rate controlled after the exit of helical coil. This is done to get parallel flow and counter flow configurations. Four thermocouples are used to note down temperature at entry and exit of hot can cold water flows respectively. Following fig. shows the experimental setup.

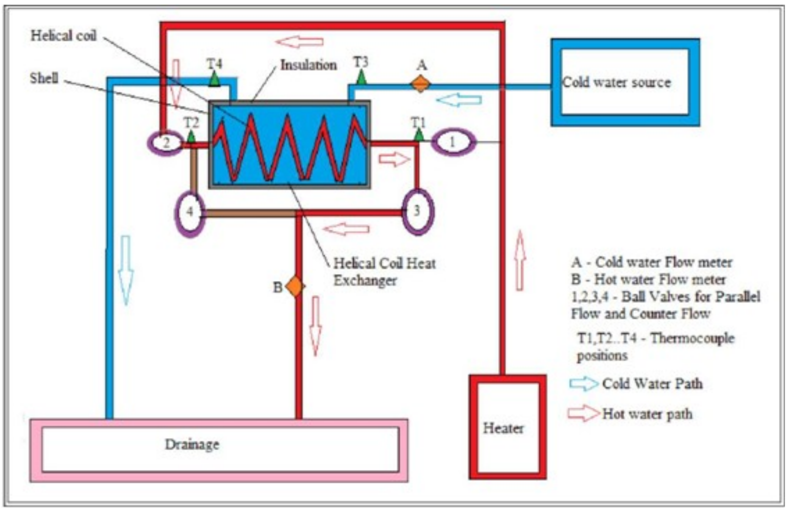

Fig.1: Schematic of Helical Coil Heat Exchanger

IV. Results and Discussion

Comparison Of Overall Heattransfer Coefficient For Helical Coil And Straight Tube Heat Exchanger.

Fig 2.0, 3.0,4.0 shows the variation of overall heat transfer coefficient for straight tube parallel flow, straight tube counter flow, helical coil parallel flow and helical coil counter flow, when hot water mass flow rate is constant and cold water mass flow rate varied.

As the mass flow rate through the shell increases the overall heat transfer coefficient increases, and it is observed that hot mass flow rate inside tube increases the overall heat transfer coefficient also increases. Overall heat transfer coefficient of counter flow heat exchanger is high compared to corresponding exchanger parallel flow. Helical coil counter flow has max. Overall heat transfer coefficient and straight tube parallel flow has lowest overall heat transfer coefficient for corresponding readings.

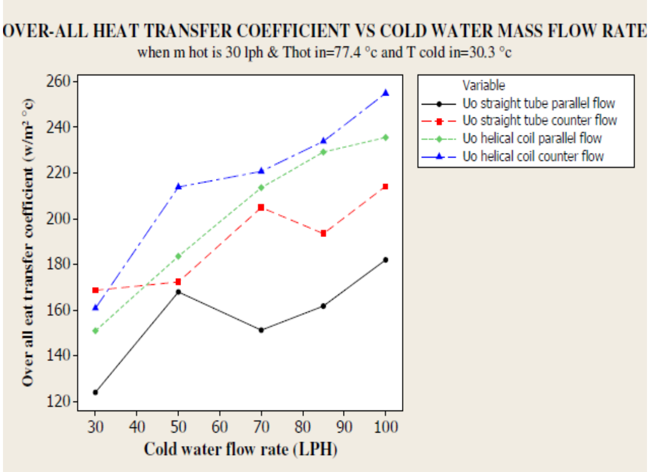

Fig.2.0 variation of overall heat transfer coefficient when mass flow rate inside the tube is 30 LPH.

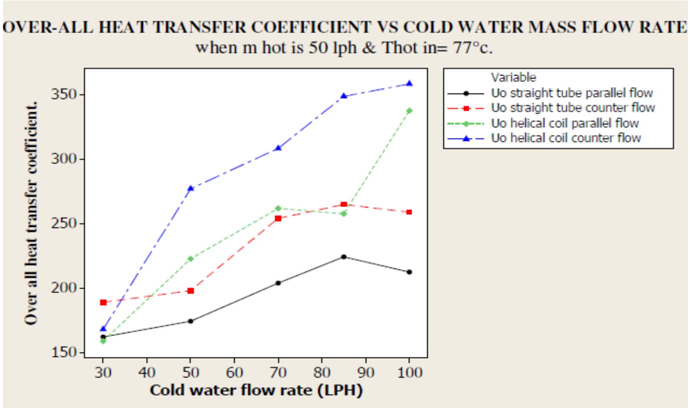

Fig.3.0 variation of overall heat transfer coefficient when mass flow rate inside the tube is 50 LPH.

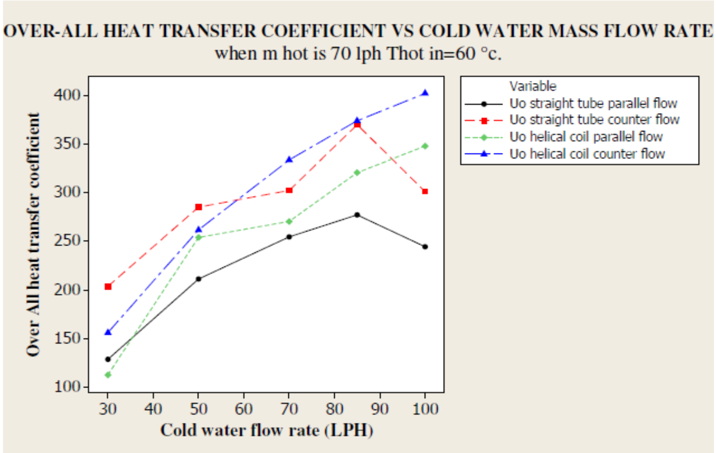

Fig.4.0 variation of overall heat transfer coefficient when mass flow rate inside the tube is 70 LPH

V. Conclusion

Comparative study is carried out between helical coil heat exchanger and straight tube heat exchanger, The effectiveness of heat exchanger greatly affected by hot water mass flow rate and cold water flow rate. When cold water mass flow rate is constant and hot water mass flow rate increased the effectiveness decreases.

Increase in cold water mass flow rate for constant hot water mass flow rate resulted in increase in effectiveness. For both helical coil and straight tube heat exchangers with parallel and counter flow configuration this result obtained. Helical coil counter flow is most effective in all these conditions and straight tube parallel flow heat exchanger is least effective.

Overall heat transfer coefficient on other hand increases with increase in hot water mass flow rate and cold water mass flow rate. The highest overall heat transfer coefficient is noted for cold water mass flow rate 100 LPH and hot water mass flow rate 100 LPH, in helical coil counter flow. Use of a helical coil heat exchanger was seen to increase the heat transfer coefficient compared to a similarly dimensioned straight tube heat exchanger.

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