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A review on Experimental Investigation of Double Pipe Helical Coil Heat Exchanger with and without Micro-fins

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ABSTRACT

The helical coil heat exchangers are used to improve heat transfer performance. Helically coiled heat exchanger offers compact size which provides a distinct benefit. Also offers Higher film coefficients- the rate at which heat is transferred through a wall from one fluid to another and more effective use of available pressure drop result in efficient and less expensive designs. Helical coils are extensively used as heat exchanger and reactors due to higher heat transfer coefficient, narrow residence time distributions and compact structure. Specifically coiled tube heat exchanger effective for laminar flow region heat transfer rate of helical tube is significantly higher because of the secondary flow caused by the centrifugal force. Many different methods have been considered to increase the rate of heat transfer on forced convection while reducing the size of heat exchanger and encompass energy savings.

Keywords : Double pipe, Heat Exchanger, Counter Flow, Heat transfer coefficient

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I. INTRODUCTION

Heat exchangers are devices that facilitate the exchange of heat energy between two fluids that are at different temperatures while keeping them from mixing with each other. Heat exchangers are used in different processes ranging from conversion, utilization & recovery of thermal energy in various industrial, commercial & domestic applications. Some common examples include steam generation & condensation in power & cogeneration plants; sensible heating & cooling in thermal processing of chemical, pharmaceutical & agricultural products; fluid heating in manufacturing & waste heat recovery etc.

II. LITERATURE REVIEW

There are tremendous techniques and research carried out by designers and researcher to increase heat transfer rate. The purpose of this literature survey is to go through the main topics of interest.

Zimparov et. al. [1] Heat transfer and isothermal friction pressure drop results have been obtained experimentally for two three-start spirally corrugated tubes combined with five twisted tape inserts with different relative pitches in the range of Reynolds number. The characteristic parameters of the tubes are: height to diameter ratio, and relative pitch. Significantly, higher friction factor and inside heat-transfer coefficients than those of the smooth tube under the same operating conditions have been observed. Extended performance evaluation criteria (PEC) equations for enhanced heat transfer surfaces have been used to assess the multiplicative effect. Thermodynamic optimum can be defined by minimizing the entropy generation number compared with the relative increase of heat transfer rate or relative reduction of heat transfer area.

Prabhanjan et. al. [2] The purpose of this study was to determine the relative advantage of using a helically coiled heat exchanger verses 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.

Akpinar et. al [3] The effect of heat transfer rates of swirl generators with holes for the entrance of fluid were investigated by placing them at the entrance section of inner pipe of heat exchanger. Various swirl generators having different arrangements of whole where used. Hot and cold water were passed through the inner pipe annulus respectively. Experiments were carried out for both parallel and counter flow models of the fluid at the Reynolds numbers between 8500-17500.

With the values obtained from the experimental data in inner pipe, the changes in the Nusselt numbers with the

Reynolds numbers were drawn for various swirl generators containing circular holes at different diameter and number. The experiments were performed for both counter and parallel flow mode, and results were compared to those obtained from the empty tube and Dittus–Boelter correlation Nu = 0.023Re0.8Pr0.4 (describes non-swirling flow in the smooth-tube). Indeed, the empty tube has the tangential inlet, which generates the swirl flow. The swirl flow induced by the step-shape distribution of the vorticity has a set of axial velocity profiles under the same Reynolds and swirl numbers. This is the main distinction between flows with and without swirling.

Rennie et. al. [4] studied the double-pipe helical heat exchangers numerically and experimentally neglecting the effect of coiled tube pitch. Though the boundary condition of his work was different from the conventional boundary conditions of constant wall temperature and constant heat flux, however, it is obvious that the geometry of the double-pipe coiled tube heat exchanger is completely different from that of shell and coiled tube heat exchanger of present work. The purpose of the study was to determine the relative advantage of using a helically coiled heat exchanger versus a straight tube heat exchanger for heating liquids.

A double-pipe helical heat exchanger was numerically modeled for laminar fluid flow and heat transfer characteristics under different fluid flow rates and tube sizes. Two different tube diameters were used. The overall heat transfer coefficients were calculated for both parallel flow and counter flow. Validation of the simulations was conducted by comparing the Nusselt numbers in the inner tube with those found in literature; the results fell within the range found in the literature.

Kumar et. al.[5] investigated a tube-in-tube helically coiled heat exchanger for turbulent flow regime numerically. 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. In results shown that low Reynolds numbers, heat-transfer is 25% higher as compared to coiled tubes. At high Reynolds numbers, the configuration has less influence on heat transfer. New empirical correlations are developed for hydrodynamic and heat transfer predictions in the coiled flow inverter.

In the present study a tube-in-tube helically coiled (TTHC) heat exchanger has been numerically modeled for fluid flow and heat transfer characteristics for different fluid flow rates in the inner as well as outer tube. The three-dimensional governing equations for mass, momentum and heat transfer have been solved using a control volume finite difference method (CVFDM). The renormalization group (RNG) k–ε model is used to model the turbulent flow and heat transfer in the TTHC heat exchanger.

Eiamsa et. al. [6] in its present work experimentally investigates the heat transfer and friction characteristics in double pipe heat exchanger by inserting louvered strips. The louvered strip was inserted into the tube to generate turbulent flow which helped to increase the heat transfer rate of the tube. The turbulent flow devices consist of the louvered strips with forward or backward arrangements, and the louvered strip with various inclined angles (θ=15°, 25° and 30°), inserted in the inner tube of the heat exchanger. In the experiment, hot water was flowed through the inner tube whereas cold water was flowed in the annulus. The experimental data obtained were compared with those from plain tubes of published data. Experimental results confirmed that the use of louvered strips leads to a higher heat transfer rate over the plain tube. The increases in average Nusselt number and friction loss for the inclined forward louvered strip were 284% and 413% while those for the backward louvered strip were 263% and 233% over the plain tube, respectively. It is seen that the Nusselt number ratio value was high at lower Reynolds number and then rapidly decreased for the rise of Reynolds number. The Nusselt number ratios of all cases are higher than unity. This indicates to an advantageous gain of using the louvered strips over the plain tube, especially at low Reynolds number.

Swamee [7] presents the optimal design of the exchanger has been formulated as a geometric programming with a single degree of difficulty. The solution of the problem yields the optimum values of inner pipe diameter, outer pipe diameter and utility flow rate to be used for a double pipe heat exchanger of a given length, when a specified flow rate of process stream is to be treated for a given inlet to outlet temperature. Author has explained the optimal design procedure.

In the current literature the focus is on optimizing the area of the heat exchanger irrespective of the different flow rates of the utility that can be used. Using this pressure drop is not minimized to the fullest extent. This fact can be avoided through the design method discussed in the paper. For the optimal design of the exchanger, it is considered that its cost is optimized by considering three main parameters – the inner and outer diameter of the heat exchanger and the flow rate of the utility.

Mansoor Siddique [8] presents the experimental investigation of double pipe heat exchanger with water as the cooling as well as the heating fluid for six sets of runs. The pressure drop data is collected under isothermal conditions. Data were taken for turbulent flow with $3300 \leqslant Re \leqslant 22{,}500$ and $2.9 \leqslant Pr \leqslant 4.7$. The main focus of the present study is to experimentally investigate the heat transfer and the pressure drop characteristics of a typical micro-fin tube and to develop accurate, simple and easy to use empirical design correlations for turbulent flow conditions in the range $3300 \leqslant Re \leqslant 22{,}500$. Heat transfer and pressure drop characteristics for turbulent flow inside a micro-finned tube were studied. It was observed that the micro-fins have a significant effect on the both the heat transfer rate and the pressure drop in such tubes. It was observed that, the friction factor it decreases with Reynolds number for Re < 6000, approximately constant for up to 6000< Re < 11,800 then resume decreasing for Re > 11,800. Beyond Rez11,800 the KAU correlation predicted friction factors are higher than the smooth tube Blasius equation predicted friction factors

Shahiti et.al [9] presents the experimental study of heat transfer and pressure drop characteristics of a double-pipe pin fin heat exchanger. Pin fins are used in heat exchangers as very effective elements for heat transfer enhancement. Extensive work is being carried out to select and optimize pin fins for various applications.

The author develops the mathematical model of the entropy generation minimization for different heat exchanger flow lengths and different pin length. The reported conclusions are derived on the basis of the behaviour of the entropy generation Nu number as a function of Re. It could be demonstrated that for all the investigated flow length, an optimal region Re, which ensures a minimal NS, could be found.

Behabadi et.al [10] presents the experimental investigation has been carried out to study the enhancement in heat transfer coefficient by coiled wire inserts during heating of engine oil inside a horizontal tube in a laminar flow heat exchanger. In present experimentation two different coiled wire insert of 2.0 mm and 3.5 mm wire thickness are used and results are carried out. The test-section was a double pipe counter-flow heat exchanger. The engine oil flowed inside the internal copper tube; while saturated steam, used for heating the oil, flowed in the annulus. The effects of Reynolds number and coiled wire geometry on the heat transfer augmentation and fanning friction factor were studied.

The present study leads to conclusion that, coiled wire insert of 2.0 mm wire thickness enhances the oil side Nusselt number, while the coiled wire pitch has a little effect on the Nusselt number. The insert enhances the Nusselt number by 2.2 times than that of the plain tube. However, for the coiled insert of 3.5 mm wire thickness, the enhancement in Nusselt number can be attained up to 3.2 times. According to the performance evaluation factor, it was seen that wire coil inserts with lower wire diameters have better performance, especially at low Reynolds numbers. Also, the increase in the coil pitch made a moderate decrease in performance parameter. The experimental fanning friction factor, f for plain tube is in a range of -7 to +16 percent of that predicted by the theoretical model. The experimental Nusselt number in an error band of +10 percent. Coiled wire insert of 2.0 mm wire thickness enhances the oil side Nusselt number, while the coiled wire pitch has a little effect on the Nusselt number. Finally, two empirical correlations have been developed for predicting the heat transfer enhancement of these coiled wire inserts.

Naphon et. al. [11] the experiments setup were designed and constructed for the measured data by using hot water and cold water as working fluids. The micro-fin tube is fabricated from the copper tube with an inner diameter of 8.92 mm. The experiments are performed for the hot and cold water mass flow rates in the range of 0.02–0.10 kg/s. The inlet hot water and inlet cold water temperatures are between 40 and 50 °C, and between 15 and 20 °C, respectively. The effects of relevant parameters on the entropy generation and exergy loss are discussed. A central finite difference method is employed to solve the model for obtaining temperature distribution, entropy generation, and exergy loss of the micro-fin tube heat exchanger. The predicted results obtained from the model are verified by comparing with the present measured data. Reasonable agreement is obtained from the comparison between predicted results and those from the measured data. The variations of the outlet cold water temperature with hot water mass flow rate for different inlet hot water temperatures. As expected, the outlet cold water temperature tends to increase with increasing hot water mass flow rate. However, at higher hot water mass flow rate, this effect tends to decrease. It should be noted that when the cold and hot water mass flow rates are kept constant, the outlet cold water temperatures at lower inlet hot water temperature are lower than those from higher ones. Also compares the results obtained from the present experiment and those from the model. It can be clearly seen from the figure that the results obtained from the model slightly under predict the measured data.

The variations of the average heat transfer rate with hot water mass flow rate. As expected, the heat transfer rate depends on the heating capacity rate of the hot water. It shows effect of cold water mass flow rate on the average heat transfer rate. It can be seen that the average heat transfer rate increases as the cold water mass flow rate increases. This is because the heat transferred from the hot water to cold water depends on the cooling capacity of cold water mass flow rate. Therefore, the average heat transfer rate tends to increase as cold water mass flow rate increases.

Promvonge et. al [12] presented the insertion of the double twisted tapes with twist ratio, in the range of 2.17 to 9.39 is to create vortex flows inside the tube. The inserted ribbed tube was arranged in similar directions of the helical swirl of the twisted tape and the helical rib motion of the tube (called co-swirl). Effects of the co-swirl motion of the ribbed tube and the double twisted tapes with various twist ratios on heat transfer and friction characteristics were examined. The results obtained from the ribbed tube and the twin twisted tape insert are compared with those from the smooth tube and the ribbed tube acting alone. The experimental results reveal that the co-swirling inserted tube performs much better than the ribbed/smooth tube alone at a similar operating condition. In addition, the correlations of Nusselt number and friction factor as functions of Re, Pr and Y are also proposed.

Thermal characteristics in a helical-ribbed tube fitted with twin twisted-tapes in co-swirl arrangement are presented in the present study. The work has been conducted in the turbulent flow regime, Re from 6000 to 60,000 using water as the test fluid. The findings of the work can be drawn as follows:

1. For the inserted ribbed tube, the Nu tends to increase with the rise in Re while the f and TEF give the opposite trends.
2. The TEF obtained from the inserted ribbed tube is found to be much higher than unity.
3. The compound enhancement devices of the helical-ribbed tube and the twin twisted tapes show a considerable improvement of heat transfer rate and thermal performance relative to the smooth tube and the helical-ribbed tube acting alone, depending on twist ratios.
4. The co-swirl tube yields higher Nu and f than the ribbed tube a higher twist ratio. The maximum TEF is obtained for the co-swirl tube at $Y \approx 8$.

III. CONCLUDING REMARK

1. The various studies indicate that helically coiled tubes are superior to straight tubes. The centrifugal force due to curvature of tubes results in secondary flow development which enhance heat transfer rate. Most of researchers have done numerical and experimental studies on helical coil heat exchanger in circular.
2. The proposed study is concern with experimental investigation of convective heat transfer from tube in tube helical coil exchanger with and without micro fins.
3. From literature review it was clear that most of the researcher studied, helically tubes as one of the passive heat transfer enhancement techniques and widely used in various industrial applications.

IV. CONCLUSION

Experimental study of Double pipe heat exchanger was performed using with and without micro fin. The results will show comparison between with and without micro-fin helical coil heat exchanger. The plain heat exchanger and finned heat exchanger were tested for counter flow configuration using water as working fluid with single phase heat transfer was studied.

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