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Experimental Investigation of tube in tube helically coiled heat exchanger with single phase heat transfer for micro-finned tube and plain tube

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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 laminarflow 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. The main focus of present study to find out the heat transfer and pressure drop characteristics of a typical micro-fin tube.

***Keywords* – Tube in tube, Heat exchanger, Micro-fin, Heat transfer coefficient, counter flow.**

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I. INTRODUCTION

The Helical coil heat exchanger are used for enhance the heat transfer in various industrial processes. Because of secondary flow developed inside the pipe the fluid particle mixes with original flow pattern and disturb the flow. Hence fluid particle comes in contact with outer surface of tube. Because of geometry of tube the fluid particles strike at the outer surface of inner tube this is because centrifugal force. 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. Ranging from chemical and food industries, power production, electronics, environmental engineering, manufacturing industry, air conditioning, waste heat recovery, cryogenic processes and space application. The development of the flow in the helical coiled tubes is due to the centrifugal forces. The curvature of the tube produces a secondary flow field with a circulatory motion, which causes the fluid particles to move toward the core region of the tube. The secondary flow increases heat transfer rates and it reduces the temperature gradient across the cross-section of the tube. There is additional convective heat transfer mechanism, perpendicular to the main flow, which does not exist in conventional heat exchangers. [5,9].

II. LIETRATURE REVIEW

Pongjet Promvonge [1] 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. LI Ya-xia[2] presented the numerical simulation 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. The results shows that the spiral corrugation can further enhance heat transfer of the smooth helical tube due to the additional swirling motion. Decrease of the pith of spiral corrugation can enhance heat transfer in the tube. Within the research scope, helical tubes cooperating with spiral corrugation show 50-80% increase of heat transfer while the flow resistance is 50-300% larger than that in the smooth helical tube. Paisarn Naphon [3] 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. Kumar et. al. [4&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 impudence on heat transfer. New empirical correlations are developed for hydrodynamic and heat transfer predictions in the coiled flow inverter. Rennie et. al. [6, 7 & 8] 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 coiledheat exchanger versus a straight tube heat exchanger for heating liquids. Prabhanjan et. al. [9] 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. Mansoor Siddique [10] 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 $3300 \leqslant Re \leqslant 22{,}500$.

III. EXPERIMENTAL SETUP

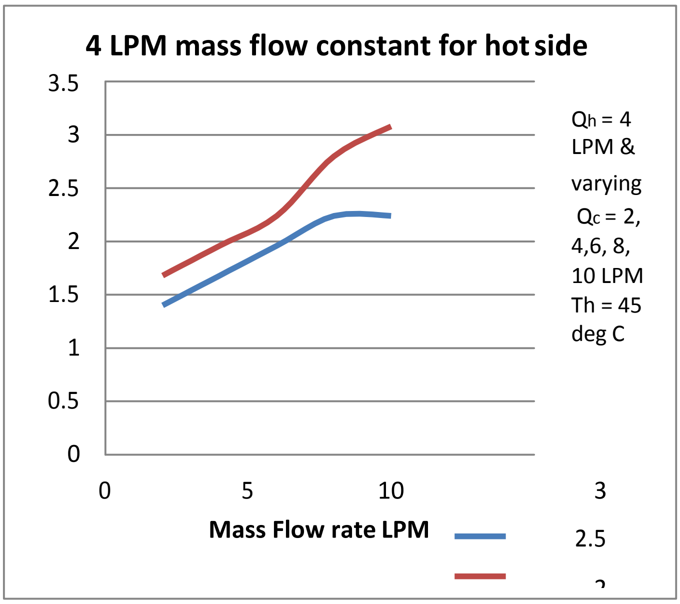
Convective heat transfer through pipe is studied by inserting surfaces roughness parameter such as twisted tapes, internal fins etc. It is seen from literature review that helical coil is of prime importance which affects the heat transfer. To achieve high heat transfer rate in an existing heat exchanger passive type heat transfer have shown good results in past studies. For experimental work copper tube is used at inner side of test section having 2500 mm length and 11 mm ID. Inside copper tube is internally threaded. 4 thermocouples fitted on inner side pipe to measure the surface temperature. Outer shell made of mild steel having 23 mm ID and having 1mm wall thickness. Water is used as hot and cold working fluid. Eight brass connecters are brazed in inner and outer tube. Two connecters are placed at the end inlet and exit ofinner tube for hot water flow. Two connecters are placed over outer surface of outer pipe for cold water flow. Remaining four connecters, two are placed into the inlet and other two are at the outlet of inner pipe for pressure measurement. PT100,k-type temperature sensors are directly inserted into brass connector at inner and outer tube to measure inlet and outlet temperatures of both the fluids. Temperature data was recorded using data acquisition/switch unit.

Figure no.1: Experimental setup

Figure no.2: Micro-Finned copper tube

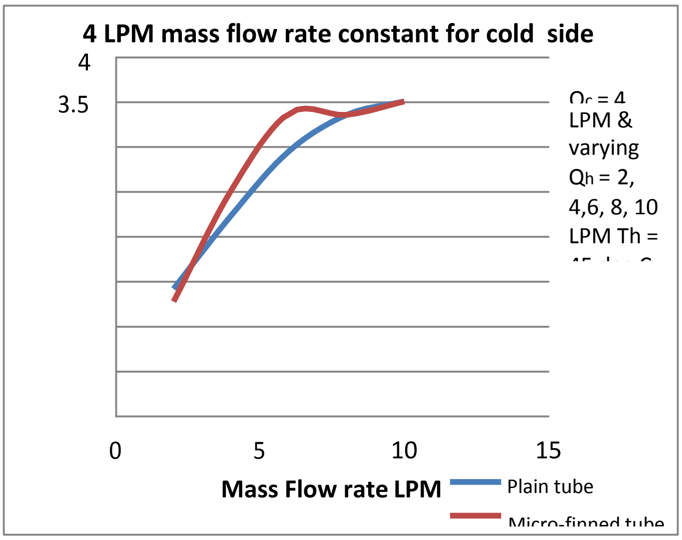
IV. RESULTS AND DISCUSSION

In present study, experimental studies are conducted for single-phase water to water heat transfer application. The double pipe heat exchanger has been analyzed in terms of temperature variation for micro fins. The results obtained from the experimental investigation of heat exchanger operated at various operating conditions are studied in detail and presented.In the first graph of Mass flows rate (LPM) Vs Heat transfer rate (Q), we take 4 lpm mass flow rate constant for hot water side and varying mass flow rate of cold water side by 2 lpm,4 lpm,6 lpm,8 lpm,10 lpm for both plain tube and finned tube. Graph 1 shows comparison of tube in tube helical coiled heat exchanger with plain tube and micro-finned tube. The results clearly show increase in heat transfer rate for micro-finned tube by 25-30% more than the plain tube.



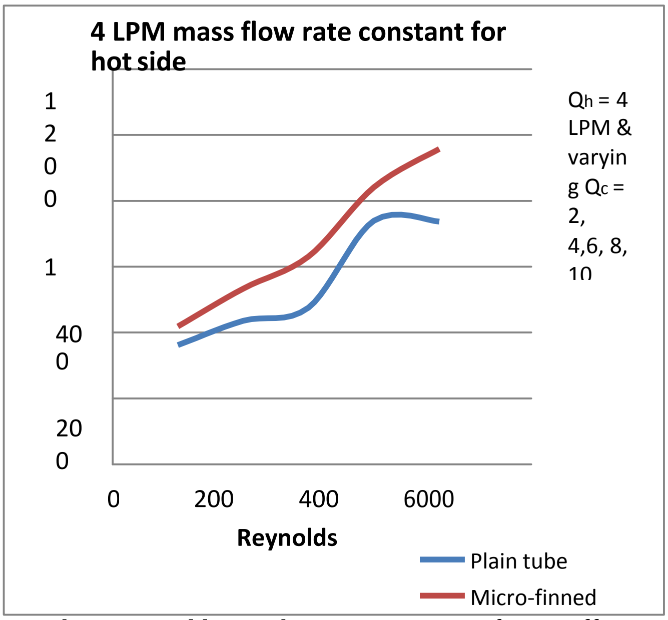
Graph 1 Mass flow rate (LPM) Vs Heat transfer rate (Kw) of 4 lpm constant flow for hot side and varying cold side mass flow by 2 lpm,4 lpm,6 lpm,8 lpm,10 lpm

Similarly, In second graph of mass flow rate Vs heat transfer rate, 4 lpm mass flow rate constant for cold water side and varying mass flow rate of hot water side. But results of 2nd graph show drastic change in its curve. It shows, for finned tube heat transfer rate increases as mass flow rate increases but suddenly falls equal to plain tube for mass flow of 8 lpm, 10 lpm.



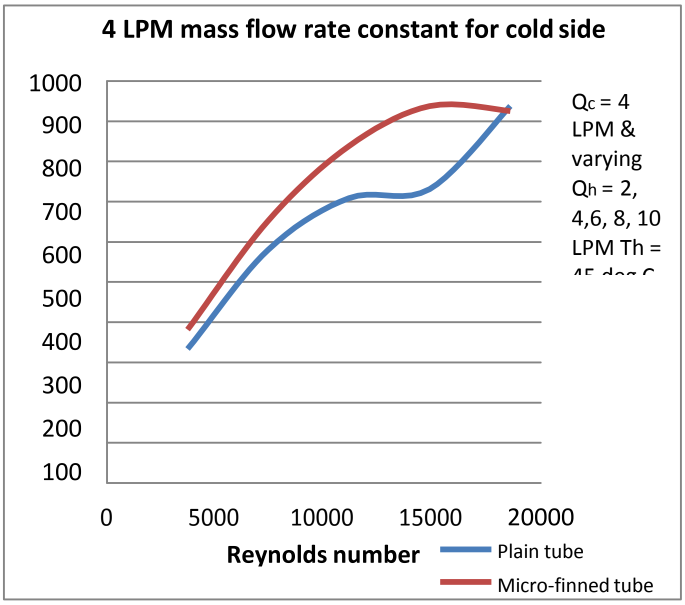
Graph 2 Mass flow rate (LPM) Vs Heat transfer rate (Kw) of 4 lpm constant flow for cold side and varying hot side mass flow by 2 lpm,4 lpm,6 lpm,8 lpm,10 lpm

Now, we consider Reynolds number Vs Heat transfer coefficient for comparison of finned tube and plain tube. Graph 3 plotted Reynolds number Vs Heat transfer coefficient for condition, 4 lpm mass flow rate constant for hot water side and varying mass flow rate of cold side water by 2 lpm,4 lpm, 6 lpm, 8 lpm,10 lpm with constant Reynolds number for hot side and varying Reynolds number for cold side.Results shows that Micro-finned heat exchanger has 20 % more heat transfer coefficient than plain tube heat exchanger. Graph clearly shows variation of heat transfer coefficient for plain and finned tube.



Graph 3 Reynolds number Vs Heat transfer Coefficient (w/m^2k) of 4 lpmconstant flow for hot side and varying cold side mass flow by 2 lpm,4 lpm,6 lpm,8 lpm,10 lpm.

Graph 4 plotted Reynolds number Vs Heat transfer coefficient for condition, 4 lpm mass flow rate constant for Cold water side and varying mass flow rate of hot side water by 2 lpm,4 lpm, 6 lpm, 8 lpm,10 lpm with constant Reynolds number for cold side and varying Reynolds number for hot side.A result shows that Micro-finned heat exchanger has more heat transfer coefficient than plain tube heat exchanger. Graph clearly shows variation of heat transfer coefficient for plain and finned tube.



Graph 4 Reynolds number Vs Heat transfer Coefficient (w/m^2k) of 4 lpm constant flow for cold side and varying hot side mass flow by 2 lpm,4 lpm,6 lpm,8 lpm,10 lpm.

V. CONCLUSION

Most of researchers performed their work on helically coiled heat exchanger with Constant heat flux and Constant wall temperature as major boundary conditions. But this paper focused on fluid to fluid heat exchange. In this paper, results show comparison between helically coiled heat exchanger with and without micro fin. This objective carried for counter flow heat exchanger using water as hot and cold working fluid. The conclusions are drawn as follows:

1. From the experimental results we find out Micro-finned tube gives better heat transfer as compared to plain tube.

2. In heat exchanger, various types of inserts can be used to enhance maximum heat transfer rate, but they results increase in the pressure drop and also dependant factor pumping cost increases, thereby increasing the operating cost. So as per requirement above method can be used for heat transfer augmentation.

3. Micro-finned heat exchanger has 20 % more heat transfer coefficient than plain tube heat exchanger.

4. Increase in heat transfer rate for micro-finned tube by 25-30% more than the plain tube.

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