Experimental Design, Development and analysis of Helical Coil Tube in Tube Heat Exchanger

Pramod Deshmukh[1], D. D. Baviskar[2], Avinash Chavan[3], Amit Chorghe[4]
[1]Dept. Of Mechanical Engineering
[1, 2, 3] Asst. Prof. Dept.Of Mechanical Engineering
[1, 2, 3, 4] SCOE Kharghar, Navi Mumbai

Abstract- *The Heat exchanger system are the important engineering systems with broad variety of applications involving many power sectors, refrigeration and air-conditioning systems, waste heat recovery systems, chemical, nuclear reactors, and food industries. Natural convection is a process of heat transfer, in which the flow of fluid is caused by density differences in the fluid occurring due to various temperature conditions. The fluid in contact with the source of heat gains heat, causing to lessen density and goes up. High temperature fluid causes to cool the working fluid and then working fluid take place of high temperature fluid. The continuation of the process of heating cooler fluid caused to create current of convection. Exchange of heat between streams through the pipe wall is the forced convection. The fluid with low temperature gain heat from the fluid with high temperature due to across or along flows to each other. The Parallel flow can be named when flows will be parallel to each other, on other hand The Counter flow can be named when flows are across to each other. Simply the tube in tube helical coil heat exchanger is compared with straight tube of same length and diameter. Variation in different parameters are the key factors in the analysis.*

Keywords- Heat Exchanger, Parallel Flow, Counter Flow, HVAC, Refrigeration and Air-Conditioning systems.

I. INTRODUCTION

A heat exchanger is a piece of equipment built for efficient heat transfer from one medium to another. While heat transfer fluids may be having direct heat transfer of indirect heat transfer. The separating wall with high thermal conductivity is used in indirect heat transfer and directly mixed in direct heat transfer. A broad range of applications are there like sewage treatment, chemical plants, natural gas processing, petrochemical plants, petroleum refineries, space heating, refrigeration, air conditioning, power plants.

The classic example of a heat exchanger is found in an internal combustion engine in which a circulating fluid known as engine coolant flows through radiator coils and air flows past the coils, which cools the coolant and heats the incoming air.

Heat exchange between flowing fluids is one of the most important physical process of concern, and a variety of heat exchangers are used in different type of installations, as in process industries, compact heat exchangers nuclear power plant, HVACs, food processing, refrigeration, etc. The construction of Heat Exchanger is for satisfying the purpose of efficient heat transfer between fluids may be direct way or indirect way. There are three ways of heat transfer first is conduction, second is convection and third is radiation. Negligible amount of heat is radiated through heat exchanger hence only heat conduction and convection are accounted during study and analysis. Heat conductive walls are responsible for exchanging heat from fluid with high temperature fluid to low temperature fluid. The rate of heat transfer through conduction is dependent on as well as manipulated by material with high conductivity and vital role in the Heat exchange is played by the convection and rate of heat transfer can be improved by implementation of Forced convection through pipe wall. One of the most effective heat transfer coefficient are observed in helical coil configuration, along with that they perform better. The larger heat transfer area in small space achieved due to spiral coil configuration with better flow.

II. PREVIOUS WORK

1. Chinna Ankanna (2014)

In these days in a broad variety of applications like food industries, chemical processing, refrigeration and air-conditioning systems, heat recovery systems, power plants and even in nuclear reactors vital role is played by the Heat Exchanger. The processes where chemical reaction happen or chemical reaction happen along with heat transfer Helical coil can performed very well. The helical coil can provide larger area for heat transfer in less space and can be achieve high heat transfer coefficients. This technical article have put emphasis on enhancing effectiveness of heat exchanger and performance analysis accounting variation in different parameters of the helical coil. How the result variation is happened along with the change in input parameters like flow rate of fluid or fluids, temperature of fluid, temperature difference in heat exchanging fluids, rate of flow of fluid or fluids. A certain set of results are expected with this focus and such results of helical coil is compared with straight tube heat exchanger. Both the parallel and counter flow type arrangements of straight tube are put for comparison with helical coil.

2. Pramod S. Purandare(2012)

In world of engineering process of heat transfer is really significant role in food industries, heat recovery systems, chemical processing, , power plants, nuclear reactors and even in refrigeration and air-conditioning systems. For acquiring higher amount of heat transfer coefficients helical coils came in picture of heat exchanger having higher ratio of amount of heat transfer to space available for heat transfer. Here the technical paper elaborates the analysis of correlations presented by different researchers who have their own set of results based on certain input parameters like coil diameter, coin length, flow rate etc. individually and identically.

3. Kapil Dev(2014)

helical coil have compact size and higher heat transfer coefficient they are widely used in industrial applications such as food preservation, refrigeration, process plant, power generation, etc. An attempt has been made to study the parallel flow and counter flow of inner higher temperature fluid flow and lower temperature fluid flow, which are separated by copper surface in a helical coil heat exchanger. Helical geometry allows the effective handling at higher temperatures and extreme temperature differentials without any highly induced stress or expansion of joints. This type of 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. In this paper, we focus on design parameters and heat transfer conditions of a vaporizer or generator of a simple vapor absorption refrigeration system having flow condition of refrigerant taken as laminar flow.

4. Shiva Kumar(2013)

Heat exchangers are the important equipments with a variety of industrial applications including power plants, chemical, refrigeration and air conditioning industries. Helically coiled heat exchangers are used in order to obtain a large heat transfer area per unit volume and to enhance the heat transfer coefficient on the inside surface. This paper deals with the CFD simulation of helical coiled tubular heat exchanger used for cooling water under constant wall temperature conditions. The results are validated by the results obtained by the numerical correlations used by different researchers. CFD results are also compared with the results obtained by the simulation of straight tubular heat exchanger of the same length under identical operating conditions. Results indicated that helical heat exchangers showed 11% increase in the heat transfer rate over the straight tube. Simulation results also showed 10% increase in nusselt number for the helical coils whereas pressure drop in case of helical coils is higher when compared to the straight tube.

III. EXPERIMENTALSET-UP

Figure is showing actual diagram of Setup of helical coil heat exchanger. The set-up is a good designed and instrumented as single phase heat exchanger system which includes a stream of hot water flowing inside of the tube-side is cooled by a stream of cold water flowing in the tube at outside. The main parts of the set up used in cycle are heater, centrifugal pump, storage tank and coiled tube heat exchanger. The specialty of tube used in heat exchangers is it includes a coiled tube of copper and a shell with insulation. The dimensional parameter associated with heat exchangers are mentioned in detailed report. An electric heater is used to supply heat to the water in storage tank. Reaching to a prescribed temperature, The pump is scheduled to circulate the cold water in the cycle as about reaching to a prescribed temperature.

A valve is used for controlling the rate of flow of coolant water stream as well as hot water stream, respectively. The inlet and outlet streams temperatures of hot and cold water have recorded by means of thermostat incorporated thermocouples in the inlet and outlet tubes of each heat exchanger and proper sealing introduced to prevent any leak in system for all the pipes and connections.

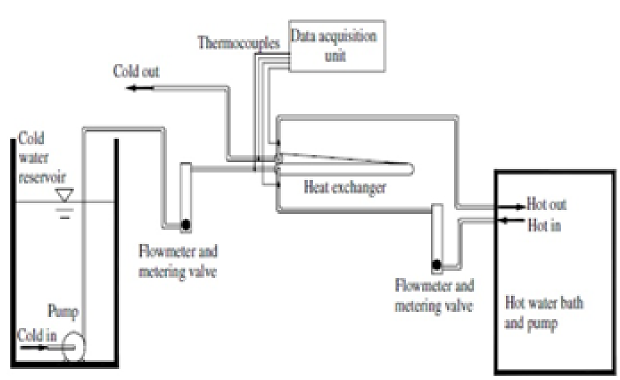

Fig.1 Schematic of Proposed Experimental Setup

Fig 2.Actual Project Setup

IV. RESULTS AND DISCUSSION

For Varying Mass Flow Rate:

Figure 4.1 illustrates about the variation of drop in water outlet temperatures with the rates of mass flow. It can be easily understood that temperature difference for helical coil tube is much higher than the temperature difference for straight tube. The curvature effect of the helical coil results in higher temperature difference. Fluid streams in the outer layer of the pipe moves with more speed than the fluid streams in the inner layer. This difference in the velocity will trigger for a secondary flow by rate which results that rate of heat transfer will be increased. It can be easily understood that the average temperature drop for the helical coil was increased by about 36% as compared to the straight coil when the rate of mass flow varied from 0.009 kg/s to 0.0113kg/s. As the mass flow rate increases the temperature drop decreases in both cases. At higher mass flow rates due to the increased velocity resident time for the fluid decreases thus reducing the temperature drop. The difference in temperature drops between straight and helical coil increases with the mass flow rate as depicted by fig 4.1 showing the better performance of the helical coil. This may be due to the increased turbulence and secondary flows at higher mass flow rates in the helical coils than the straight tube.

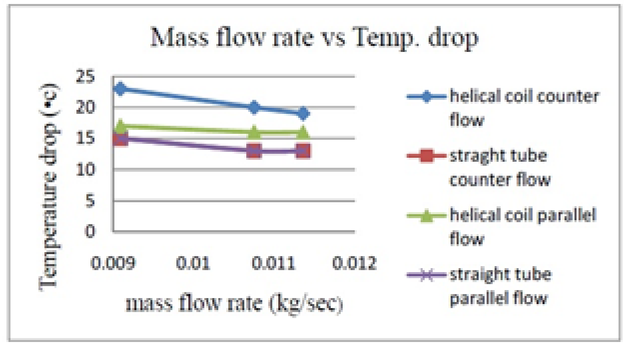

Fig.3variation of temperature drop with mass flow rate

Variation of Heat Transfer Rate with Mass Flow Rate for Straight and Helical Tube:

Figure 4.2 shows the variation of heat transfer rate through the water for straight and helical coil with mass flow rate. Heat transfer rate increases with mass flow rate for both cases, in the second case being higher than the initial showing the improvement in heat transfer through helical coils. On an average heat transfer rate for the helical coil increases by 51.29% when the mass flow rate was increased from 0.00909 to 0.011363.

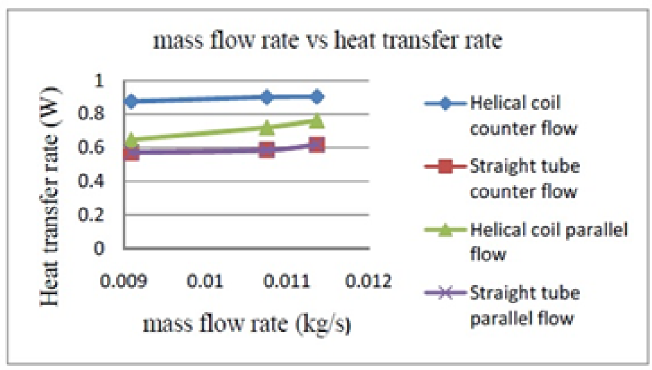

Fig.4variation of heat transfer rate with mass flow rate for straight and helical tube

Variation of Heat Transfer Coefficient with Mass Flow Rate for Straight and Helical Tube:

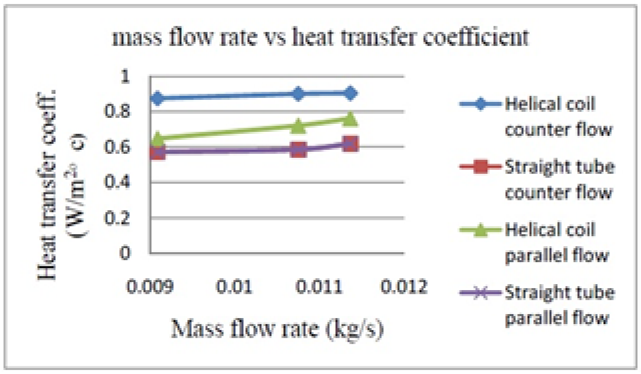

Fig.5variation of heat transfer coefficient with mass flow rate for straight and helical tube

Figure 4.3 depicts the variation of heat transfer coefficient for both the helical and straight tube heat exchanger for various mass flow rates which shows a remarkable increase of heat transfer coefficient for the helical tube heat exchanger when compared to the straight tube heat exchanger, indicating that a helical tube heat exchanger is efficient than a straight tube heat exchanger. Further for helical coils heat transfer coefficient has increased by 8.5% when the mass flow rate is increased from 0.00909 to 0.011363 kg/s.

V. CONCLUSION

Based on the results obtained by conducting the experiments on helical (parallel and counter flow) and straight (parallel and counter flow) tube, the following are the conclusions drawn:

1. The helical pipe is having the greater surface area which allows the fluid to be in contact for greater period of time period so that that there is an enhanced heat transfer compared to that of straight pipe.

2. The inside over all heat transfer coefficient for helical pipe is approximately 0.35 of that straight pipes.

3. The temperature of cold water coming from the helical tube in counter flow arrangement is (38oC - 52 oC) i.e. a rise in the temperature of water is between 7 oC to 21 oC. It implies that for the same surrounding area the helical pipe absorbed is more than that of straight copper tube.

4. The effectiveness of pipes either helical or straight in counter flow is greater than parallel configuration.

5. From the above one can realize the fact that for the same space or volume in industry the helical heat exchangers are more efficient than normal straight heat exchangers.

REFERENCES

[1] Andras Zachar (2013), “Investigation of a new tube-in-tube helical flow distributor design to improve temperature stratification inside hot water storage tanks operated with coiled-tube heat exchangers”, International Journal of Heat and Mass Transfer, Vol-63, pp. 150–161.

[2] Angelo Zarrella, Antonio Capozza, Michele De Carli (2013), “Analysis of short helical and double U-tube borehole heat exchangers: A simulation-based comparison”, Journal of Applied Energy, Vol-112, pp. 358–370.

[3] Bibin Prasad, Sujit V, Mohammed Shaban K, SajuHaneef, Vishnu Raj (2013), “Comparison of Heat Transfer between a Helical and Straight Tube Heat Exchanger”, International Journal Of Engineering Research &Technology, Vol.6, Pp.33-40.

[4] Gabriela Huminic, Angel Huminic (2011), “Heat transfer characteristics in double tube helical heat exchangers using nanofluids”, International Journal of Heat and Mass Transfer, Vol-54, pp. 4280–4287.

[5] M. R. Salimpure (2009), “Heat transfer coefficients of shell and coiled tube heat exchangers”, Experimental Thermal and Fluid Science, Vol.33, pp.203-207.

[6] PaisarnNaphon (2007) “Thermal performance and pressure drop of the helical-coil heat exchangers with and without helically crimped fins”, International Communications in Heat and Mass Transfer, Vol-34, pp. 321–330.

[7] Rahul Kharat, Nitin Bhardwaj, R.S. Jha (2009), “Development of heat transfer coefficient correlation for concentric helical coil heat exchanger”, International Journal of Thermal Sciences, Vol-48, pp. 2300–2308.

[8] Srbislav B. Genic, Branislav M. Jacimovic, Marko S. Jaric, Nikola J. Budimir, Mirko M. Dobrnjac (2012), “Research on the shell-side thermal performances of heat exchangers”, International Journal of Heat and Mass Transfer, Vol-55, pp. 4295–4300.

[9] Srbislav B. Genic, Branislav M. Jacimovic, Marko S. Jaric, Nikola J. Budimir (2013), “Analysis of fouling factor in district heating heat exchangers with parallel helical tube coils”, International Journal of Heat and Mass Transfer, Vol-57, pp. 9-15.