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Performance Analysis of Spiral Tube Heat Exchanger

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Abstract— ***In the present study, the performance of the spiral tube heat exchanger can be carried out. The heat exchanger consists of a shell and tube unit. Each coil is fabricated by bending a 12 mm diameter straight copper tube into a spiral coil tube of four turns. Cold water and hot oil are used as working fluids in shell side and tube side, respectively. The experiments are done at the cold water and hot oil mass flow rates ranging between 0.075 and 0.25 kg/s, and between 0.008 and 0.04 kg/s, respectively. The inlet temperatures of cold and hot water are between 29 and 37 °C, and between 70 and 56 °C, respectively. The cold water entering the heat exchanger at the shell inlet side and outer from the shell outside. The hot water enters the heat exchanger at the inner tube side and flows along the outside of the tube. The effects of the inlet conditions of both working fluids flowing through the test section on the heat transfer characteristics are discussed..***

Index Terms—***A spiral tube heat exchangers, Result and Discussion***

I. INTRODUCTION

Due to their high heat transfer coefficient and smaller space requirement compared with straight tubes, curved-tubes are the most widely used tubes in several heat transfer applications, for example, heat recovery processes, air conditioning and refrigeration systems, chemical reactors, food and dairy processes. The spiral coils are well known types of curved-tubes which have been used in a wide variety of applications. For spiral tube heat exchanger, few amount of theoretical and experimental works have been reported on heat transfer and flow characteristics.

1) Heat Exchanger

One of the important processes in engineering is the heat exchange. The means of heat exchanger that to transfer the heat between flowing fluids. A heat exchanger is the process to transfer heat from one fluid to another fluid. The heat exchanger is devise that used for transfer of internal thermal energy between two or more fluids at different temperatures. In most heat exchangers, the fluids are separated by a heat transfer surface, and ideally they do not mix. Heat exchangers are used in the process, power, petroleum, transportation, air conditioning, refrigeration,

Cryogenic, heat recovery, alternate fuels, and other industries. Common examples of heat exchangers familiar to us in day-to-day use are automobile radiators, condensers, evaporators, and oil coolers. Heat exchangers could be classified in many different ways.

2) Classification of Heat Exchangers

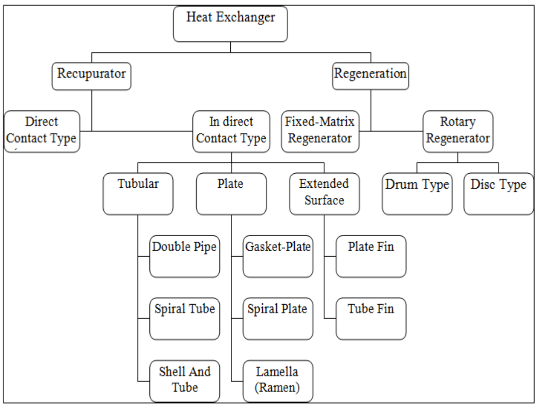

Fig. 1 Classification of Heat Exchangers

3) Tubular Heat Exchanger

Tubular heat exchangers are generally built of circular tubes ,although elliptical, rectangular or round/flat twisted tubes have also been used in some applications. There is considerable flexibility in design because the core geometry can be varied easily by changing the tube diameter, length, and arrangement. Tubular exchangers can be designed for high pressures relative to environment and high pressure differences between the fluids.

Tubular exchangers are used primarily for liquid to liquid and liquid to phase change (condensing or evaporating) heat transfer applications. There are also used for gas to liquid and gas to gas heat transfer applications primarily when the operating temperature and pressure is very high or fouling is a severe problem on at least one fluid side and no other types of exchangers work. These tubular exchangers may be classified as shell-and-tube, double-pipe, and spiral tube heat exchangers.

3.1) Spiral Tube Heat Exchanger

Spiral tube heat exchanger has excellent heat exchanger because of far compact and high heat transfer efficiency. Spiral-tube heat exchangers consist of one or more spirally wound coils which are, in circular pattern, connected to header from which fluid is flowed. This spiral coil is installed in a shell another fluid is circulated around outside of the tube, leads to transfer the heat between the two fluids.

Heat transfer rate associated with a spiral tube is higher than that for a straight tube. In addition, a considerable amount of surface can be accommodating in a given space by spiraling. In spiral tube heat exchanger, problem of thermal expansion is not probably occurring and self cleaning is also possible. A spiral tube heat exchanger is a coil assembly fitted in a compact shell that to optimizes heat transfer efficiency and space. Every spiral coil assembly has welded tube to manifold joints and uses minimum material requirement for durability and strength.

Spiral tube heat exchanger uses multiple parallel tubes connected to pipe or header to create a tube side flow. The spaces or gaps between the coils of the spiral tube bundle

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become the shell side flow path when the bundle is placed in the shell. Tube side and shell side connections on the bottom or top of the assembly allow for different flow path configurations. The spiral shape of the flow for the tube side and shell side fluids create centrifugal force and secondary flow induced, by centrifugal force that enhances the heat transfer on both sides in a true counter flow arrangement. Since there are no baffles are provided in to the system, therefore to lower velocities and heat transfer performance is optimized. Additionally, since there are varieties of multiple parallel tube configurations are not compromised by limited shell diameter sizes as it is in shell and tube designs.

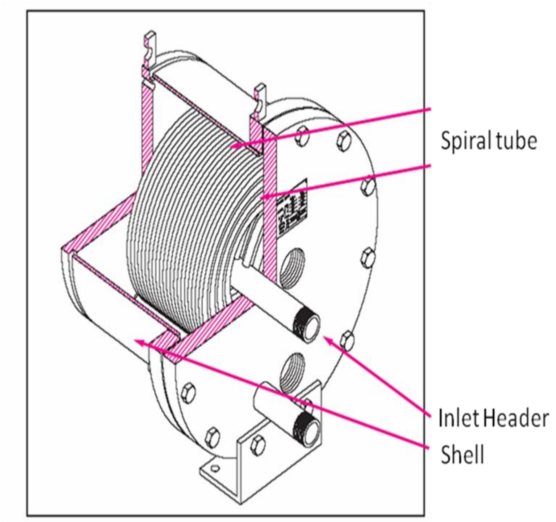

Fig. 2 Spiral Tube Heat Exchanger

Spiral tube heat exchanger uses single channel technology, which means that both fluids occupy a single channel, which allows fully counter-current flow. One fluid (hot fluid) enters the centre of the unit and flows towards the periphery. The other fluid (cold fluid) enters the unit at the periphery and moves towards the centre. The channels are curved and have a uniform cross section, which creates spiraling motion within the fluid. The fluid is fully turbulent at much lower velocity than straight tube heat exchangers, and fluid travels at constant velocity throughout the whole unit.

In the countercurrent flow where both of the fluids will flow in opposite directions and are used for liquid-to-liquid applications. The spiral tube heat exchanger is excellent for pasteurization, heat recovery, digester heating, effluent cooling, and pre-heating. Spiral tube heat exchangers can provide a good choice to shell-and-tube and other types of heat exchanger.

II. LITERATURE REVIEW

G. E. KONDHALKAR & V. N. KAPATKAT [4] Gives the performance analysis of spiral tube heat exchanger over the shell and tube type heat exchanger. The process at higher velocity was not suitable. So it is decided to keep the low velocity with more turbulence which is reduced fouling and increases the heat transfer rate as well as oil will not stick to the inner surface of the tubes. J. P. HARTNETT & W. J. MINKOWYCZ [5] They are investigate the average in tube heat transfer co-efficient in spiral coil heat exchanger. . They obtain the experiment result of tube heat transfer coefficient in spiral coil heat exchanger under dehumidifying conditions. They give the experimental equation and compare with the present correlation and to obtain new correlation. P. NAPHON [6] Proposed that the heat exchanger consists of a shell and helically coiled tube unit with two different coil diameters. The friction factor decreases with increasing hot water mass flow rate. Inlet hot and cold water mass flow rates and inlet hot water temperature have significant effect on the heat exchanger effectiveness. P. M. DESHPANDE & DR. S. DAWANDE [7] Studied horizontal spiral coil tube (HSTC) for various forces (viscous, buoyancy and centrifugal force) acting on fluid element in coil of which the centrifugal force is predominant and results in secondary flow. They also concluded that as the coil diameter reduces the curvature ratio increase that increases the pressure drop. DR. M. S. TANDALE & S. M. JOSHI [8] Provided analytical model to design of spiral tube heat exchanger and experiments were performed. The pressure drop estimated is also compared with actual values observed during experimentation which is found in acceptable range. Y. KE et al. [9] They had analyzes transverse vibration of conical spiral tube bundle. The effect of the external fluid flow on the transverse vibration of tube bundle is studied with the combination of experimental data, empirical correlations and FEM. M. P. NUNEZ, & G. T. POLLEY [10] Present method for the sizing of spiral plate heat exchangers. From this method given physical dimensions like width, thickness to achieve pressure drop and heat duty meet the required specifications of the design. R. K. PATIL et al. [11] Proposed that heat transfer rate of helical coil heat exchanger is better to compare other types of heat exchanger. In the helical coil heat exchanger space is limited so not enough straight pipes should be laid. A. M. FUENTES et.al. [12] Present an alternative design approach for the sizing of spiral heat exchangers in single phase counter-current applications. M. P. NUEZA , & G.T. POLLEY [13] Provides the design space where the available options that meet the heat duty and allowable pressure drops are displayed for the various geometrical parameters. They refer to the selection of the exchanger dimensions that will meet the heat duty within the limitations of pressure drop and the space between the streams is same. PAISARN NAPHON & SOMCHAI WONGWISES. [14] Present that heat transfer characteristics and the performance of a spiral coil heat exchanger under cooling and dehumidifying conditions are investigated. Air and water are used as working fluids.

III. SPECIFICATION OF SPIRAL TUBE HEAT EXCHANGER

following data adopted for design of spiral tube heat exchanger which is describe below,

Parameter	Tube side	Shell side
Inner temperature	70 ºC	29 ºC
Outlet temperature	56.9 ºC	31.5 ºC
Mass flow rate	0.008 Kg / s	0.072 Kg / s
Density	853.13 Kg / m^3	996.08 Kg / m^3
Specific heat	2.031 KJ / Kg K	4.18 KJ / Kg K
Dynamic viscosity	7.1×10^{-4} Ns / m^2	6.54×10^{-4} Ns / m^2

IV. RESULT AND DISCUSSION

The design of spiral tube heat exchanger has carried out and designed spiral tube heat exchanger is developed. The experiments were carried out to measure the change in temperature of hot and cold fluid. The measurements were

done by changing mass flow rate of oil and water simultaneously.
The results of the experiments are shown and discussed in the following section.

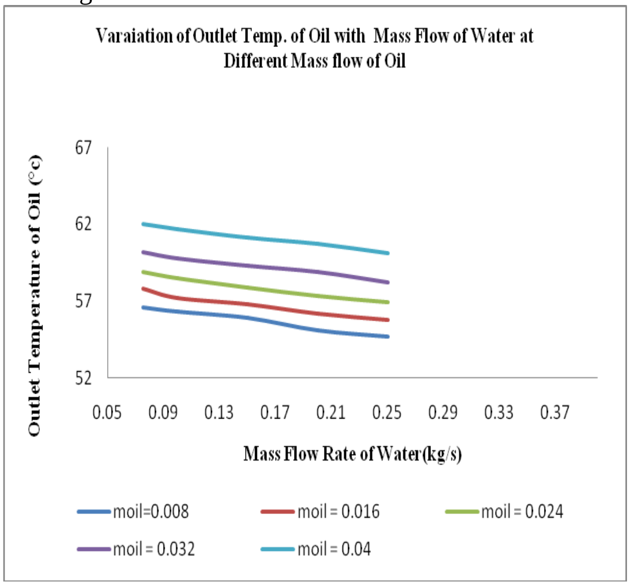

Fig. 1 Outlet Temperature of Oil (□ c) vs. Mass Flow Rate of Water (kg/s)

Figure 1 shows the effect of variation of mass flow rate of water on outlet temperature of oil for different mass flow rate of oil. It is clear from the Figure 1 that as the mass flow rate of water increases, the outlet temperature of oil decreases because increase in flow rate of water increase the heat transfer and more cooling water is available. It is observed that as the mass flow rate of oil increases at particular mass flow rate of water, the outlet temperature of oil increases. The initial rise in temperature is more and that become smaller as flow rate of oil increases.

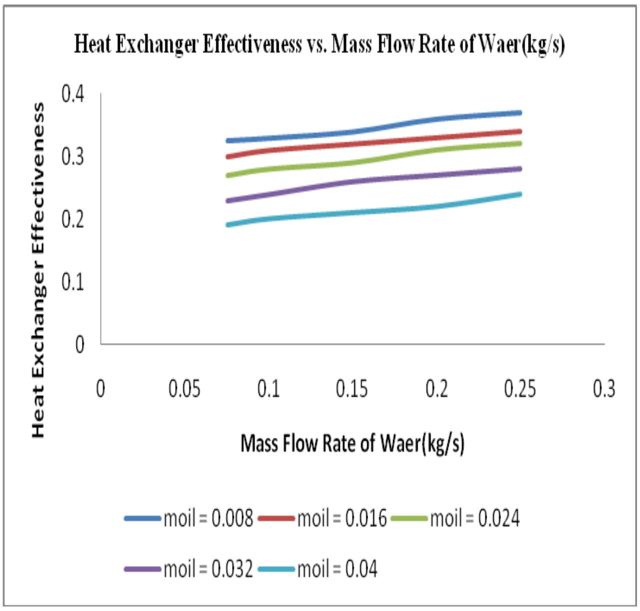

Fig. 2 Heat Exchanger Effectiveness vs. Mass Flow Rate of water (kg/s)

Fig. 2 shows the effect of the variation of mass flow rate of water to the heat exchanger effectiveness. It is obvious from the figure 2 that the mass flow rate of water increase, the heat exchanger effectiveness is decrease. The mass flow rate of water increase, the effectiveness is decrease because of the effectiveness is directly depends on the heat transfer rate.

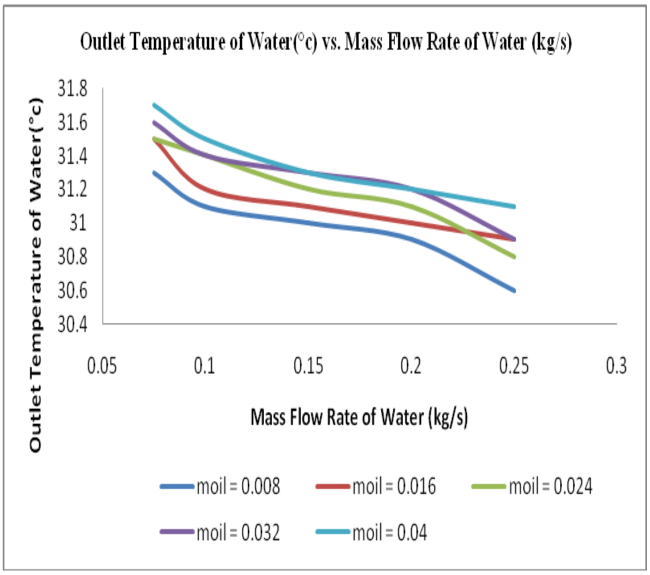

Fig. 3 Outlet Temperature of Water (□ C) Vs. Mass Flow Rate of Water (kg/s)

Fig. 3 shows that the effect of the outlet temperature of water with the mass flow rate of water, from the figure 3 shows that mass flow rate of water increase, the outlet temperature of water is also increase because when the mass flow rate of water increase than the more cooling is created and more heat transfer rate is also increase.

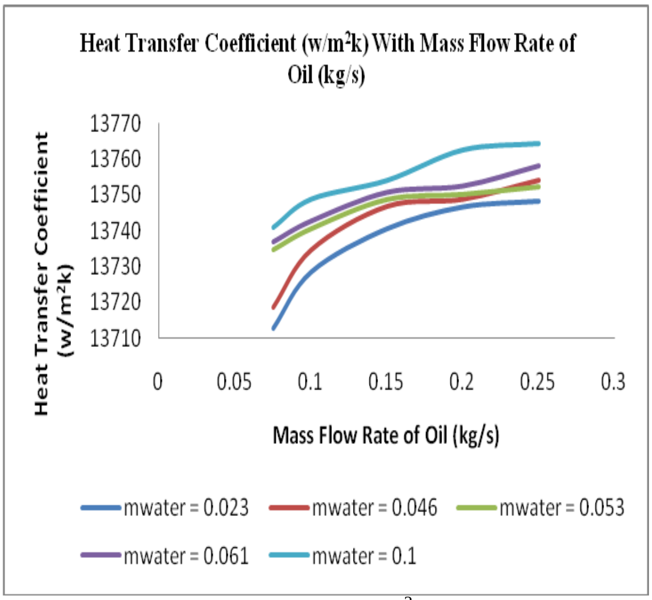

Fig. 4 Heat Transfer Coefficient (w/m^{2}k) vs. Mass Flow Rate of Oil (kg/s)

Fig. 4 shows the heat transfer coefficient with variation of mass flow rate of oil. From figure 4 that the mass flow rate of water increases with increase the heat transfer coefficient. In spiral tube heat exchanger, the spiral shape of the flow for the tube side and shell side fluids create centrifugal force and secondary circulating flow that enhances the heat transfer on both sides, therefore the mass flow rate of oil increase with increase the heat transfer rate.

V. CONCLUSION

The salient features of the present work are summarized as concluding remarks given below.

1. The design of spiral tube heat exchanger has carried out from the theoretical and empirical correlation and spiral tube heat exchanger is developed from designed data.

The designed spiral tube heat exchanger is tested experimentally.

2. The measurement of exit temperature of hot fluid (oil) and cold fluid (water) were carried out from the experimental setup developed during the course of this work. The results are consistent with published literature.
3. Exit temperature of hot fluid (oil) decreases with increase in mass flow rate of cold fluid (water).
4. Exit temperature of hot fluid (oil) increases with increase in mass f low rate of hot fluid (oil).
5. Increase in exit temperature of hot fluid is more initially, and it becomes small as mass flow rate of hot fluid (oil).
6. As the mass flow rate of cold fluid increase, effectiveness of heat exchanger decreases.
7. Exit temperature of cold fluid is decrease with increase the mass flow rate of cold fluid.

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