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Experimental Investigation of a Helical Coil Heat Exchanger

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ABSTRACT :- *Helical coil heat exchangers are one of the most common equipment found in many industrial applications. Helical coil heat exchanger is one of the devices which are used for the recovery system. The helical coil heat exchangers can be made in the form of a shell and tube heat exchangers and can be used for industrial applications such as power generation, nuclear industry, process plants, heat recovery systems, refrigeration, food industry etc. In our work we had designed, fabricated and experimentally analysed a helical coil heat exchanger and a straight tube heat exchanger. From the observations and calculations, the results of the helical coil heat exchanger and straight tube heat exchanger are obtained and are compared. From our obtained results, the helical coil heat exchanger showed increase in the heat transfer rate, effectiveness and overall heat transfer coefficient over the straight tube heat exchanger on all mass flow rates and operating conditions. The centrifugal force due to the curvature of the tube results in the secondary flow development which enhances the heat transfer rate. Comparative study shows that helical coil heat exchanger is having better performance that straight tube heat exchanger.*

KEYWORDS: - *Helical coil heat exchanger, straight tube heat exchanger, effectiveness, overall heat transfer coefficient*

I. INTRODUCTION

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 purpose of constructing a heat exchanger is to get an efficient method of heat transfer from one fluid to another, by direct contact or by indirect contact. The heat transfer occurs by three principles: conduction, convection and radiation. In a heat exchanger the heat transfer through radiation is not taken into account as it is negligible in comparison to conduction and convection. Conduction takes place when the heat from the high temperature fluid flows through the surrounding solid wall. The conductive heat transfer can be maximised by selecting a minimum thickness of wall of a highly conductive material. But convection is plays the major role in the performance of a heat exchanger. Heat exchangers are the important engineering systems with wide variety of applications including power plants, nuclear reactors, refrigeration and air-conditioning systems, heat recovery systems, chemical processing and food industries. Helical coil configuration is very effective for heat exchangers and chemical reactors because they can accommodate a large heat transfer area in a small space, with high heat transfer coefficients. The flow through a curved pipe has been attracting much attention because helical coiled pipes are widely used in practice as heat exchangers and chemical reactors. The fluid flowing through curved tubes induces secondary flow in the tubes. This secondary flow in the tube has significant ability to enhance the heat transfer due to mixing of fluid. Forced convection in a heat exchanger transfers the heat from one moving stream to another stream through the wall of the pipe. The cooler fluid removes heat from the hotter fluid as it flows along or across it.

II. EXPERIMENTAL SETUP

II.1. Experimental System

The experimental test rig is properly set up for parallel flow arrangement or counter flow arrangement. Set the volume flow rate of both hot water and cold water to a suitable value using measuring jar and stop watch. Measure the inlet and exit temperatures of hot and cold water using digital thermometer. Observations are noted and results are calculated. The graphs are plotted according to the obtained results. The same procedure is used for both helical coil heat exchanger and straight tube heat exchanger. Figure 1 shows the experimental test rig.

Figure 1: Experimental Test Rig

II.2. Experimental Procedure

Schematic diagrams of the experimental apparatus of the helical coil and straight tube heat exchangers are shown in Figures 2 & 3. The valves are properly adjusted to set the volume flow rate of both hot water and cold water. The system was operated at parallel flow and counter flow arrangements. At each condition the inlet and exit temperatures of hot and cold water was measured using digital thermometer. Observations are noted and results are calculated.

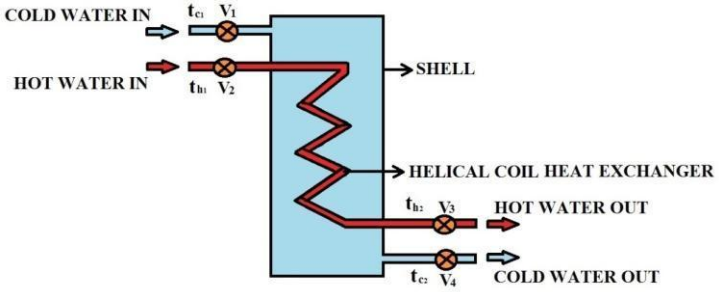

Figure 2: Schematic diagram of the helical coil heat exchanger

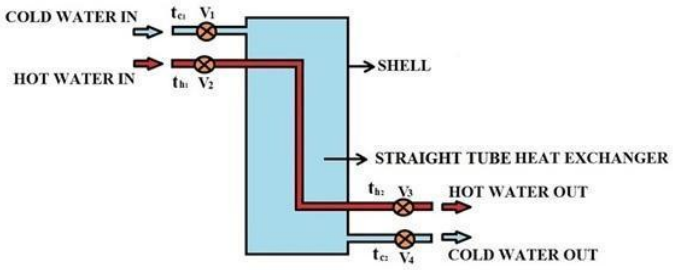

Figure 3: Schematic diagram of the straight tube heat exchanger

The experiment was done until steady state condition was attained. The performance of the helical coil heat exchanger and straight tube heat exchangers are analysed accordingly.

III. RESULTS AND DISCUSSIONS

Figure 4 gives the variation of effectiveness with inlet temperature of hot water for both helical coil and straight tube heat exchangers. It is found that the effectiveness of helical coil heat exchanger is found to be higher when compared to that of the straight tube heat exchanger for all the inlet temperatures. From this result it is found that the helical coil heat exchanger is having better effectiveness than straight tube heat exchanger.

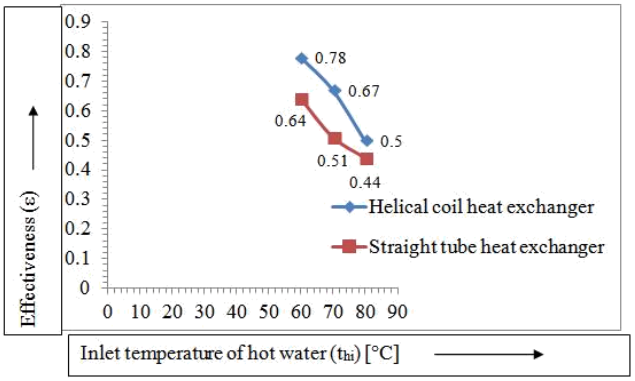

Figure 4: Variation of effectiveness with inlet temperature of hot water

Figure 5 shows the the variation of overall heat transfer coefficients with inlet temperature of hot water for both helical coil and straight tube heat exchangers. It is found that the overall heat transfer coefficients of helical coil heat exchanger are found to be higher when compared to that of the straight tube heat exchanger for all the inlet temperatures. From this result it is found that the helical coil heat exchanger is having better overall heat transfer coefficients than straight tube heat exchanger.

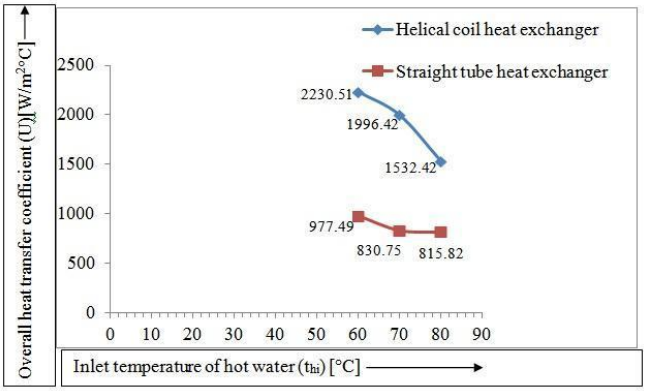

Figure 5: Variation of overall heat transfer with inlet temperature of hot water

The experimental results indicated that helical coil heat exchanger showed increase in the heat transfer rate, effectiveness and overall heat transfer coefficient over the straight tube heat exchanger on all mass flow rates and operating conditions. These results confirmed that the performance of the helical coil heat exchanger is better than straight tube heat exchanger.

Table I

Experimental observations of inlet temperature of hot water Vs effectiveness for helical coil and straight tube heat exchangers

Type of heat exchanger	Inlet temperature (°C) [t_{hi}]	Effectiveness (ε)
Helical coil heat exchanger	60	0.78
	70	0.67
	80	0.50
Straight tube heat exchanger	60	0.64
	70	0.51
	80	0.44

Table II

Experimental observations of overall heat transfer coefficients Vs inlet temperature of hot water for helical coil and straight tube heat exchangers

Type of heat exchanger	Inlet temperature (°C) [t_{hi}]	Overall heat transfer coefficients (U) [W/m²°C]
Helical coil heat exchanger	60	2230.51
	70	1996.42
	80	1532.42
Straight tube heat exchanger	60	977.49
	70	830.75
	80	815.82

IV. CONCLUSIONS

Experimental analysis for a helical coil heat exchanger was carried out and the results are compared with the straight coil under similar geometrical and operating conditions. The results of the helical coil heat exchanger are compared with the straight tube heat exchanger in parallel flow by varying parameters like temperature, flow rate of cold water and hot water. Based on the results obtained by conducting the experiments on helical (parallel flow) and straight (parallel flow) tube, the following conclusions are drawn.
The main conclusions are listed as follows:

1) The helical tube allows the fluid to be in contact for greater period of time so that there is an enhanced heat transfer compared to that of straight tube.
2) Comparative study is carried out between helical coil heat exchanger and straight tube heat exchanger. The effectiveness and overall heat transfer coefficient of heat exchanger greatly affected by the hot water mass flow rate and cold water flow rate. When cold water mass flow rate is constant and hot water mass flow rate is increased both the effectiveness as well as the overall heat transfer coefficient increases.
3) Results indicated that helical coil heat exchanger showed increase in the heat transfer rate, effectiveness and overall heat transfer coefficient over the straight tube heat exchanger on all mass flow rates and operating conditions.
4) The centrifugal force due to the curvature of the tube results in the secondary flow development which enhances the heat transfer rate.
5) Comparative study shows that helical coil heat exchanger is having better performance that straight tube heat exchanger.

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