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Experimental Evaluation of Helical Coil Tube in Tube Heat Exchanger

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ABSTRACT

Heat exchangers are the essential engineering systems with wide variety of applications including many power sectors, nuclear reactors, refrigeration and air-conditioning systems, waste heat recovery systems, chemical 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. Here the fluid which surrounds a heat source receives heat, becomes less dense and rises. The working fluid that is surrounding the high temperature fluid is cooled and then moves in to replace it. After that cooler fluid gets heated and the process continues, resulting convection current. Forced convection in a heat exchanger is the flow of heat from one moving stream to another stream through the wall of the pipe. The low temperature fluid removes heat from the comparatively high temperature fluid as it flows along or across it. If it moves along the hot stream then it's called parallel flow and if they are across then its counter flow.

Keywords: HVAC, Heat Exchanger, refrigeration and air-conditioning systems.

INTRODUCTION

A heat exchanger is a piece of equipment built for efficient heat transfer from one medium to another. The media may be separated by a solid wall to prevent mixing or they may be in direct contact. They are widely used in space heating, refrigeration, air conditioning, power plants, chemical plants, petrochemical plants, petroleum refineries, natural gas processing, and sewage treatment. 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 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 maximized 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. 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. Helical coil configurations are very effective for heat exchangers and chemical reactors because of their large heat transfer area in a small space, with high heat transfer coefficients. Recently developments of heat exchangers, coil type heat exchangers are being used because the spiral coil configuration has the advantage of more heat transfer area and better flow

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PREVIOUS WORK

Chinna Ankanna (2014)[1] :-In the present days 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. This paper focus on an increase in the effectiveness of a heat exchanger and analysis of various parameters that affect the effectiveness of a heat exchanger and also deals with the performance analysis of heat exchanger by varying various parameters like number of coils, flow rate and temperature. The results of the helical tube heat exchanger are compared with the straight tube heat exchanger in both parallel and counter flow by varying parameters like temperature, flow rate of cold water and number of turns of helical coil.

Pramod S. Purandare(2012)[2] :- 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.This paper deals with the parametric analysis of the helical coiled heat exchanger with various correlations given by different researchers for specific conditions. The parametric analysis of these various correlations with specific data is presented in this paper.

Kapil Dev(2014)[3] :- 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.

Shiva Kumar(2013)[4] :- 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.

EXPERIMENTAL SET-UP:

Fig shows actual Setup diagram of helical coil heat exchanger. The set-up is a well instrumented single-phase heat exchanging system in which a hot water stream flowing inside the tube-side is cooled by a cold water stream flowing in the oute side tube. The main parts of the cycle are coiled tube heat exchanger, centrifugal pump, storage tank, and heater. The heat exchangers include a copper coiled tube and an insulated shell. The dimensions of the heat exchangers are depicted in Table. The water in storage tank is heated using an electric heater. Reaching to a prescribed temperature, pump is started to circulate the cold water in the cycle. A valve is used to control the flow rate of coolant water and hot water, respectively. The inlet and outlet temperatures of hot and cold water were recorded using thermostat by using thermocouples in the inlet and outlet tubes of each heat exchanger and sealed to prevent any leakage. Also, all the pipes and connections between the temperature measuring stations and heat exchanger were duly insulated.

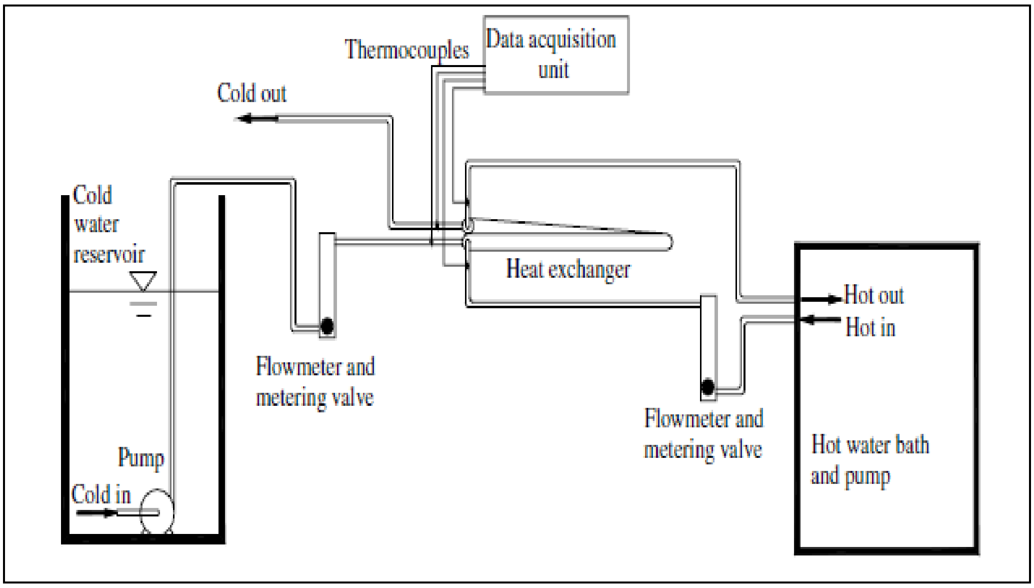

Fig.1 Schematic of Proposed Experimental Setup

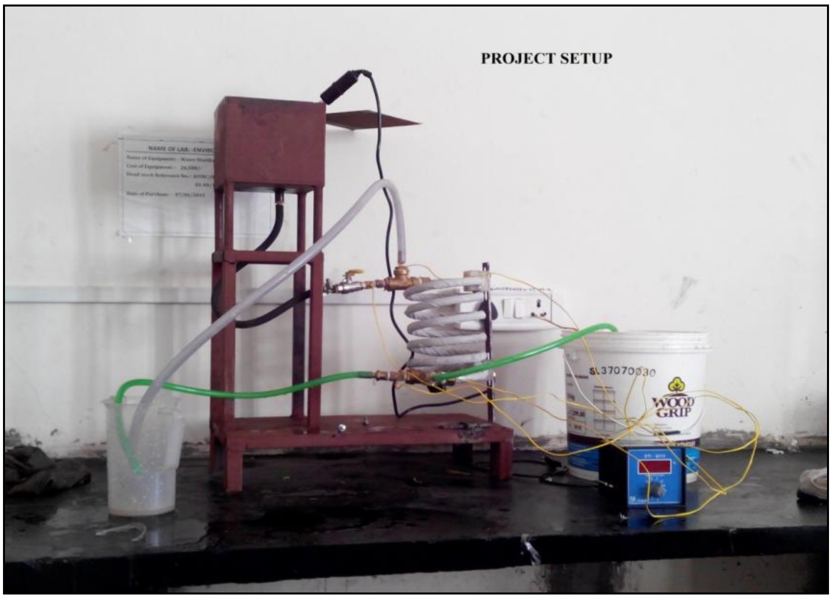

Fig 2. Actual Project Setup

RESULTS AND DISCUSSION

For Varying Mass Flow Rate:

Figure 4.1 shows the variation of drop in water outlet temperatures with the mass flow rates. It can be seen that temperature drop for helical coiled tube is higher than the straight tube. This is due to the curvature effect of the helical coil. Fluid streams in the outer layer of the pipe moves faster than the fluid streams in the inner layer. This difference in the velocity will set in a secondary flow by which heat transfer will be increased. It can be seen that for the helical coil the average temperature drop was increased by 36.56% as compared to the straight coil when the mass flow rate varied from 0.00909 kg/s to 0.011363 kg/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.

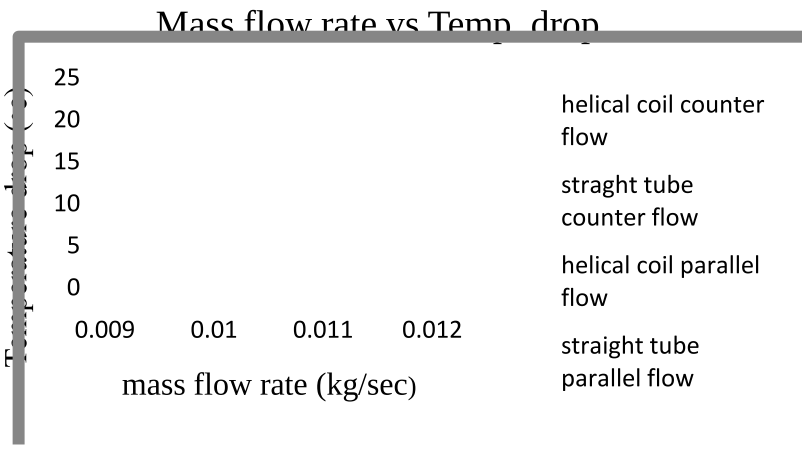

Fig.4.1 variation of temperature drop with mass flow rate

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.

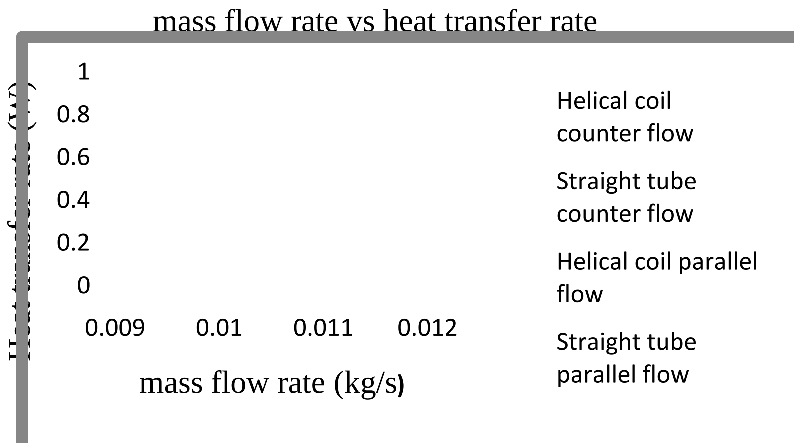

Fig.4.2 variation of heat transfer rate with mass flow rate for straight and helical tube

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

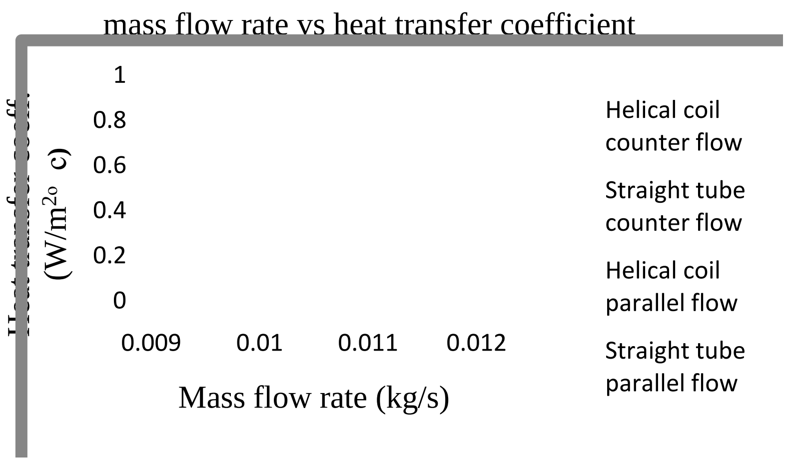

Fig.4.3 variation of heat transfer coefficient with mass flow rate for straight and helical tube

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.

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.

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