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Analysis of Heat Transfer in Spiral Heat Exchanger with Circumferential Fins

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Abstract – Heat exchangers are widely used in many applications such as water treatment plants, refrigeration, air conditioning, and automobiles. Radiators are one form of heat exchangers in which the fluid to be cooled is passed through a series of finned tubes and the air is flowing across the tubes, thus heat transfer occurs and the temperature of the fluid is decreasing eventually. The heat exchangers should be smaller and more energy efficient since the recent energy crises needs improved heat transfer rates. The existing radiator configuration has been modified to improve its efficiency and a compact spiral radiator has developed against a standard air cooled fin and tube radiator. In this modification, the circumferential copper fins are fitted around the spiral tubes in which water flows through these tubes and air flows across the tubes to bring heat transfer. The flow characteristics and thermal performance of this spiral radiator is analyzed and investigated.

Keywords – Spiral Heat Exchanger, ε-NTU, Circumferential Fins, Heat Transfer Rate, Nusselt Number

1. INTRODUCTION

The heat is transferred between a fluid and a solid, or between two or more fluids by using heat exchangers. The fluids in heat exchangers may be in direct contact or may be a solid wall separate them.

Space heating, chemical plants, automobiles, refrigeration, air conditioning, power stations, , petrochemical plants, sewage treatment, petroleum refineries and natural-gas processing are some of the areas where the heat exchangers are used widely. For example, the radiators found in automobiles are used to cool the engine coolant which flows through the tubes and air flows over these tubes. The heat sink is another example that is used to transfer the heat which is generated by an electronic or a mechanical device to a fluid medium.

The heat transfer rate can be maximized and the size of the heat exchanger can be reduced by developing various configurations. The movement of the flowing fluid in a spiral path is one of such configuration. The existing type of heat exchangers used in refrigeration, air conditioning and automobiles are suitably altered with spiral profile.

The spiral path of the heat exchanger is more closely matches the air flow area of the fan in a circular manner and it makes more effective utilization of air flow area. Spiral heat exchangers (SPE) have lesser space requirements and are more compact when compared with the other types of heat exchangers. In addition to this, spiral profile produces pressure drop in a lower level and it requires less pumping energy when compared with the other heat exchangers for same capacity. The spiral path has self-cleansing ability also.

2. METHODOLOGY

The experimental setup consists of a SPE which is made from copper tube and wound into spiral coils. The fins are made from copper material and wound circumferentially around the copper tube. (See Fig. 1). The heat exchanger is placed on a fixture and a blower is used to pass the air over the heat exchanger. A digital vane type anemometer is used to measure the flow of air and the temperature of air is measured by thermometer before and after passing over the SPE. An electrical heater, flow control valves and rotameter are the main components of hot water (second fluid) circuit. The electrical heater is utilized to heat the water and the rotameter & flow control valves are regulate the water flow rate. Thermometer is used to measure the inlet and outlet temperatures of the water.

determined. The temperature rise of the air across the heat exchanger was measured by thermometer. By varying the flow rate of water, the experiments were repeated.

Sl.No.	Flow Rate (LPM)	Water Inlet Temp. (^{0}C)	Water Outlet Temp. (^{0}C)	Air Inlet Temp. (^{0}C)	Air Outlet Temp. (^{0}C)	Velocity of Air (m/s)	Discharge of Air (m^3/s)

Fig. 1 Spiral heat exchanger

The water flow rate at the heat exchanger inlet was varied by flow control valves corresponding to the water level in the rotameter. The electrical heater was switched on and steady state conditions were obtained after provided sufficient time interval.
The inlet temperature of the water at the SHE is maintained constant and the outlet temperature of the same was measured. By using anemometer, the air velocity which is blowing over the SHE was

Outer diameter of the Copper Tube	=	9.2 mm
Thickness of the Copper Tube	=	0.5 mm
Outer diameter of the Copper Fins	=	22.5 mm
Total no. of fins	=	1708
Length of the Copper Tube	=	4270mm
Power of the Electric Heater	=	3000 W
Maximum flow rate of Rotameter	=	4 LPM

3. RESULTS AND DISCUSSION

The inlet temperature of the water at the SHE is maintained as 80°C and the experiments were conducted. The water flow rate was varied from 1 LPM to 3 LPM and the water outlet temperature was recorded. By tabulating these observations, results were obtained and graphs were plotted.

There is an increase in the outlet water temperature across the spiral ends. This is due to the less time available for heat transfer when the water flow rate increases

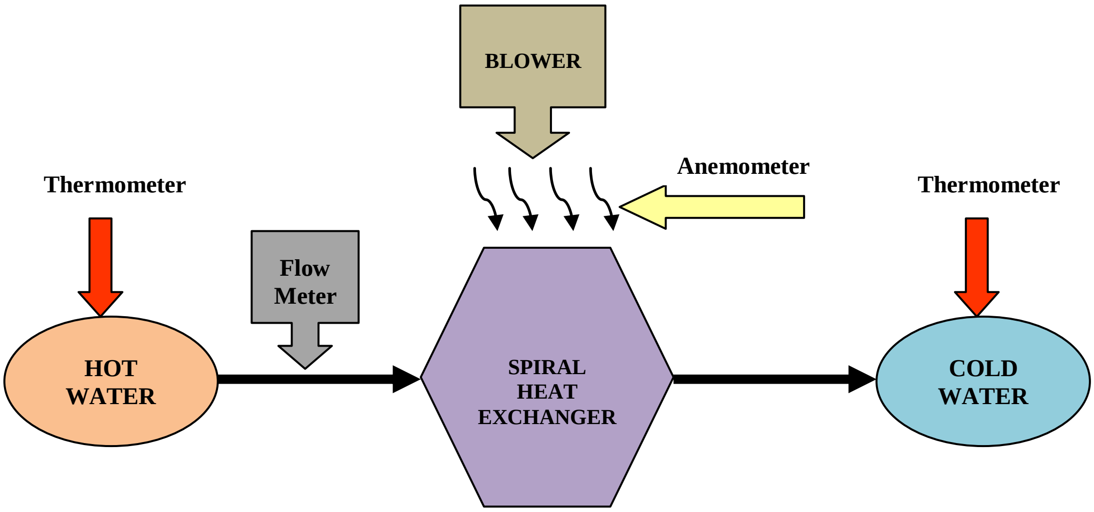

Fig. 2 Methodology

1	1	80	68	32	34	1.8	0.087
2	1.5	80	71	32	35	1.8	0.087
3	2	80	73	33	35	1.8	0.087
4	2.5	80	74	32	34	1.8	0.087
5	3	80	76	33	35	1.8	0.087

Table 1 Experimental observations

Table 2 Experimental results

Sl.No.	Flow Rate (LPM)	Reynolds Number, Re	Nusselt Number, Nu	Effectiveness, ε	Heat Transfer, Q (W)
1	1	2531	1.81	0.25	53
2	1.5	2671	1.817	0.23	965
3	2	2623	1.81	0.242	994
4	2.5	2672	1.82	0.25	1049
5	3	2607	1.81	0.21	863

It can be seen that if there is increase in Reynolds number then there is a steep rise in Nusselt number however on Reynolds number increases further, the rise in Nusselt number is found to be less profound. Figure shows that there is decrease in effectiveness when the Reynolds number increases. This is attributed to the fact that there is an increase in Reynolds number, the heat capacity of water is also increased which in turn, causes a decrease in effectiveness at increased flow rates

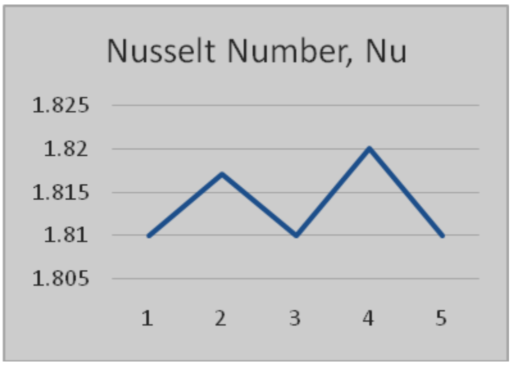

Fig. 4 Nusselt Number

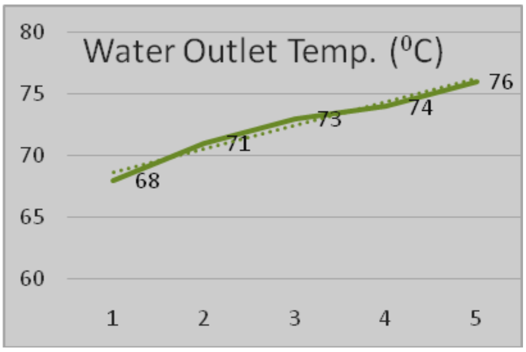

Fig. 3 Water Outlet Temperature

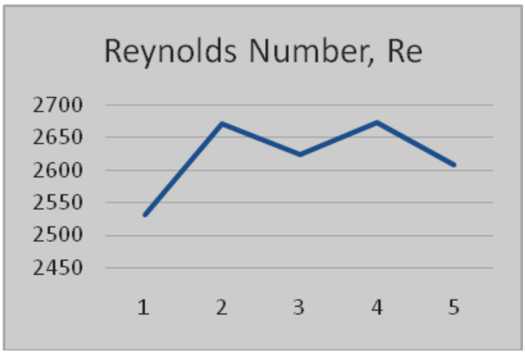

Fig. 5 Reynolds Number

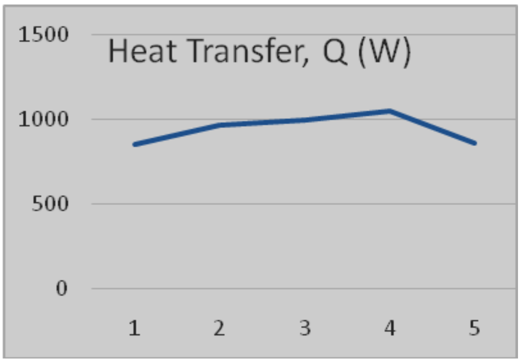

Fig. 6 Heat Transfer

Fig. 7 Effectiveness

4. CONCLUSION

The investigations were carried out experimentally on the SHE with circumferential copper fins. The heat exchanger characteristics namely rate of heat transfer, effectiveness, Nusselt number and Reynolds number were studied. The rise in flow rate of water increases the outlet temperature of water.

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