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Experimental Studies on Heat Transfer Augmentation of a Heat Exchanger with Swirl Generators Inserts

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Abstract - Convective heat transfer characteristics within a heat exchanger with twisted tapes of different cuts and materials have been investigated experimentally. Effect of twisted tape of different cuts (square, circular and triangular) inside the inner tube of single unit on heat transfer and friction factor for heating of water for Reynolds number range 500-3000 was studied experimentally. The results obtained from the twisted inserts of GI, Al and Cu materials are compared and the experimental results reveal that the among the three different materials of inserts, Copper inserts performs better and too with square cuts.

Keywords: Heat Exchanger, Swirl Generators, Inserts, Nusselt Number, Reynolds Number

I. INTRODUCTION

Enhancement of heat transfer is achieved by increasing the convection coefficient or by increasing the convection surface area "h" (convection coefficient) may be increase by surface roughness to enhance turbulence. It can be achieved by insertion of a coil-spring wire or plate. The insert provides a helical roughness element in contact with the tube inner surface. Displaced inserted are used into the flow channel to improve energy transport at the heated surface indirectly. The displaced inserts mix the main flow in addition to that in the wall region. Displaced coil insert is not attached to the wall of the tube. These devices periodically mix the gross flow structure but not affecting the main flow significantly. Certain other devices as number of geometrical arrangements or tube inserts for forced flow that create rotating or secondary flow can be used. Full length twisted tape inserts or inlet vortex generator and axial coil inserts with a screw type winding are some examples of swirl flow devices.

The twisted- tape inserts as passive technique for heat transfer augmentation had been popular owing to their better thermal hydraulic performance in a single phase and condensation forced convection.

Twisted tape inserts increases the heat transfer coefficients with relatively small increase in the pressure drop. Because of the design and application convenience they have been widely used over decades to generate the swirl flow in the fluid. Size of the new heat exchanger can be reduced significantly by using twisted tapes in the new heat exchanger for a specified heat load.

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It can increase the heat duties of the existing shell and tube heat exchangers. Twisted tapes with multi tube bundles are easy to fit and remove, thus enables tube side cleaning in fouling situations. Inserts such as twisted tape, wire coils, ribs and dimples mainly obstruct the flow and separate the primary flow from the secondary flows. This causes the enhancement of the heat transfer in the tube flow. Inserts reduce the effective flow area thereby increasing the flow velocity. This also leads to increase in the pressure drop and in some cases causes' significant secondary flow. Secondary flow creates swirl and the mixing of the fluid elements and hence enhances the temperature gradient, which ultimately leads to a high heat transfer coefficient.

Twisted tape increases the heat transfer coefficient with an increase in the pressure drop. Different configurations of twisted tapes, like full-length twisted tape, short length twisted tape, full length twisted tape with varying pitch, reduced width twisted tape and regularly spaced twisted tape have been studied widely by many researchers.

In the present work, heat transfer enhancement tool i.e. twisted tape swirl generator is used, for laminar and turbulent flow for different materials. Since it is most commonly used enhancement tool. Effect of twisted tape of different cuts (rectangular, circular and triangular) inside the inner tube of single unit on heat transfer and friction factor for heating of water for Reynolds number range 500-3000 was studied experimentally. Twisted tape induced the swirl flow with in the pipe which increases the heat transfer rate and friction factor. Our main aim was to construct such a heat exchanger with compact shape with higher heat transfer rate. The results of heat transfer rate with inserts are compared with the plain tube and selection of higher heat transfer rate.

II. EXPERIMENTAL SETUP

Set up is fabricated for the analysis of the effect of fluid flow on the heat transfer rate of a tube and shell type heat exchanger for parallel and counter flow. The arrangements for the parallel and counter flow fluids within the heat exchanger are made. The inserts of various profiles/cut are inserted within the inner heated pipe. The inlet and outlet temperatures will be measured at various positions for hot and cold fluid. All thermocouples will be connected to a digital recorder to record the temperature once the steady state is achieved. The power input to the heater is controlled by a variac to control the hot fluid temperature. A digital wattmeter will used for recording the power of the heater. The comparison of performance of the heat exchanger under different conditions is made. The effect of insertion of given different profile/cuts on the pressure drop is also evaluated.

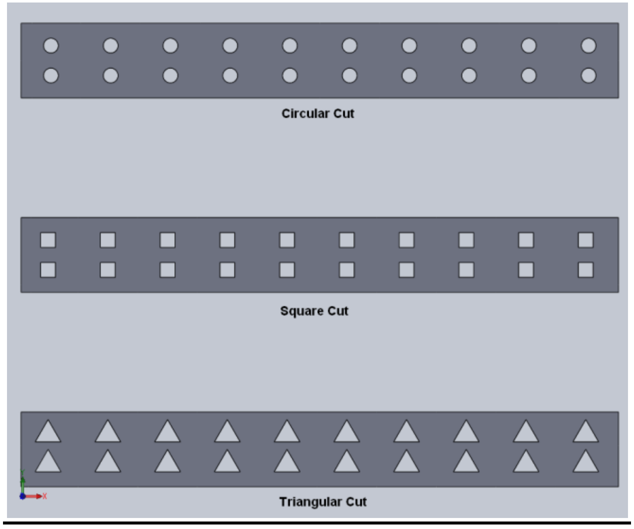

Fig.1 Different profiles/cuts on the inserts

Fig. 2 shows the schematic diagram of experimental setup. It is a double pipe heat exchanger consists of clamping section, test section, rotameters, manometer, cold water tank and constant temperature bath (500 litre capacity) for supplying hot water within built heater, pump and control system. The test section is a smooth galvanized steel tube with above mentioned dimensions. In double pipe heat exchanger hot water flows through the inner pipe and cold water flows in counter flow through annulus. The outer pipe well insulated using asbestos rope and glass wool to reduce heat loss with surrounding. Rotameter, with the flow ranges 30 to 300 .LMP accuracy used to measure the cold and hot water flow rates. Two J-type thermocouples measure the inlet and outlet temperature of cold and hot water. The pressure drop is measured by using a U-tube manometer. The experimental setup which is used to measure the temperature variation, friction factor and Nusselt number through a pipe fitted with or without twisted tape of different material within the Reynolds number range.

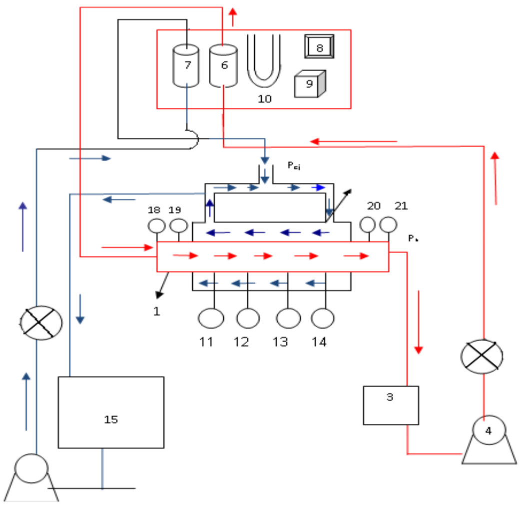

Fig.2 Schematic experimental setup

1 Inner pipe
2 Outer pipe
3 Hot water tank
4 Hot water pump
5 Hot water control valve
6 Hot water Rotameter
7 Cold water Rotameter
8 Watt meter
9 Variac
10 Manometer
11 12,13,14Temperature Sensor
15 Hot water Sump
16 Cold water Pump
17 Hot water control valve
18 21 Inlet and outlet Temperature Sensor
19 20 Inlet and outlet Pressure measurement

P_{ci} Cold water pressure at inlet
P_{co} Cold water pressure at outlet
P_{h0} Pressure of hot water at outlet
P_{hi} pressure of hot water at inlet

III. VALIDATION RESULTS

For the purpose of validating the experimental set-up and procedure, initial test runs were carried out in the experimental set-up for evaluating the friction factor variation with Reynolds number and compared the result with Paisarn Naphon [8].

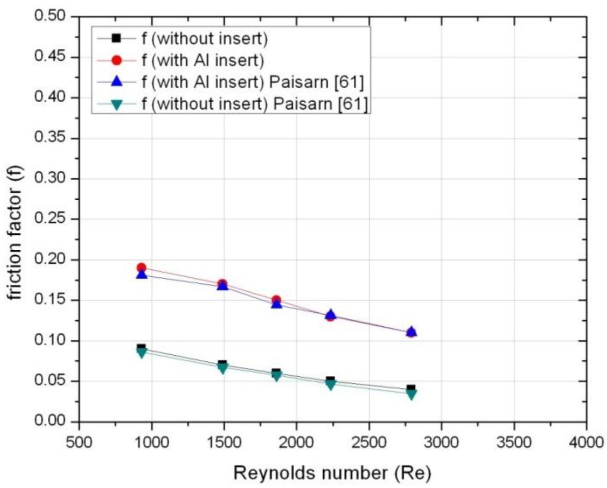

Fig.3 Validation of Experimental setup

As can be seen from the above figure 3, the present results obtained for the setup arrangement show good agreement with the results of Paisarn Naphon [8] at all Reynolds numbers, though a little deviation is observed for the comparison with the experimental results of Paisarn Naphon [8] at higher Reynolds numbers. The close agreement shown in the above figure confirms that the experimental procedure followed and the experimental data obtained for computing the Nusselt number in the present study are in accordance with the established procedure available in the literature.

IV. RESULTS AND DISCUSSION

Experiments were conducted to evaluate the thermo hydraulic performance of pipe fitted with twisted pipe and then evaluating the performance of the heat exchanger with twisted tape insert.

A. Nusselt number variation

Figure 4 shows the variation of Nusselt number with Reynolds number for plain tube and twisted tape having GI, Al and Cu inserts. The Nusselt number for twisted tape with Cu insert is higher followed by Al insert and plain tube. The twisted tape causes the flow to be spiral along the tube length and cause turbulence in the entire flow field that leads to higher heat transfer rate, the higher thermal conductivity of Cu as compare to Al and least for GI leads for higher heat transfer rate. Figure 5 shows the effect of insertion of different cuts on the Nusselt number.

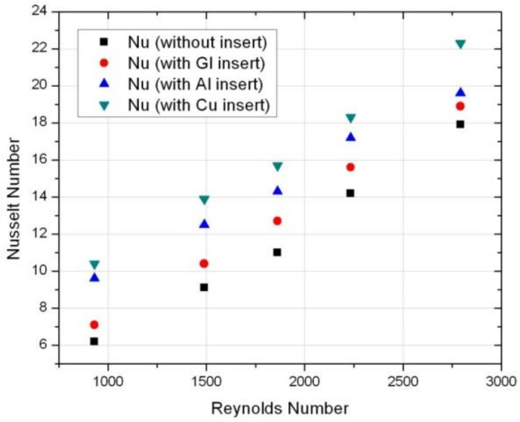

Fig.4 Nusselt number vs. Reynolds number

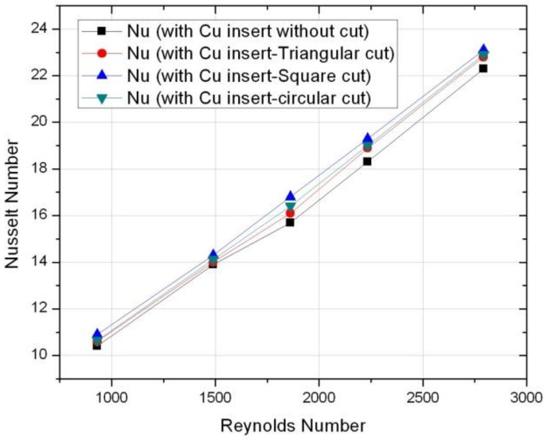

Fig. 5 Nusselt number vs. Reynolds number for different cuts

B. Friction factor results

The variation of friction factor with Reynolds number is shown in Figure 6 and 7. The variation clearly denotes the flow to be laminar and the friction factor is decreasing with increase in Reynolds number. The friction factor for twisted tape is higher than the plain tube. The measured friction factor is in good agreement with the estimated values. A gradual slope change in the friction factor with Reynolds number is attributed to the temperature dependence of fluid viscosity and the increasing contraction and expansion pressure losses at the inlet and outlet, respectively.

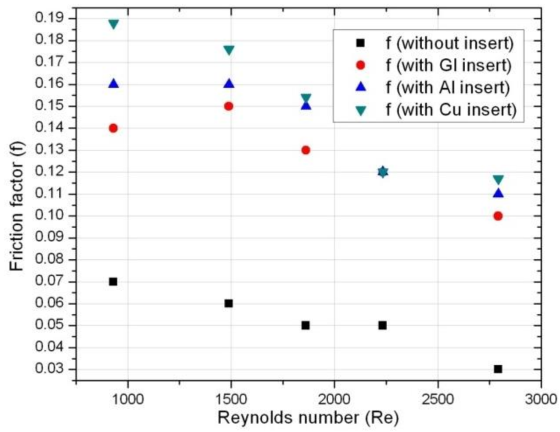

Fig.6 Friction factor vs. Reynolds number

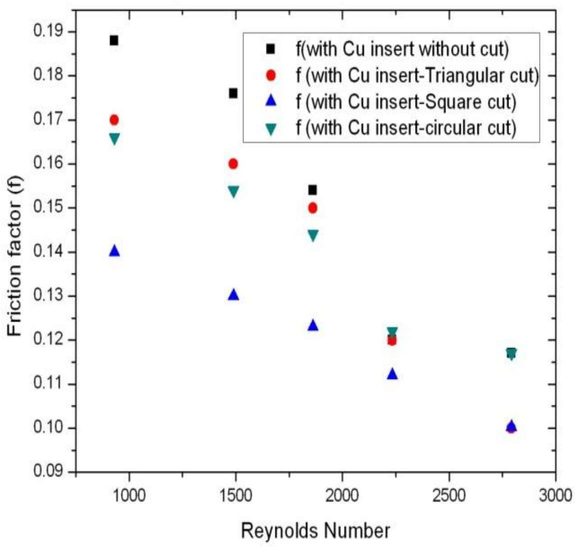

Fig. 7: Friction factor vs. Reynolds number for different cuts

V. CONCLUSION

Experimental investigations have been carried out to examine the effect of insertions of different materials (GI, Al and Cu) within the pipe. Based on the analysis of the results the following conclusions can be drawn:

- The maximum inlet and outlet minimum temperature difference is obtained in the pipe having Cu insert. This indicates that for a given constant heat input, the average Nusselt number becomes higher for pipe having Cu as insert followed by that for Al and without insert.
- There is a gradual change in the pressure drop variation with Reynolds number. This is attributed to the temperature dependence of fluid viscosity, and the increasing contraction and expansion pressure losses at the inlet and outlet of the pipe, respectively.
- It was observed that as the Reynolds number increases from 930.74 to 2792.19, the drop in hot water outlet temperature w.r.t. inlet temperature decreases due to less retention time of the fluid within the pipe.

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