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Performance Analysis of Copper Twisted Tape Inserts for Heat Transfer in A Circular Tube

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ABSTRACT
Thermal Performance of heat transfer devices can be improved by heat transfer enhancement techniques. In the present study, heat transfer from hot air to cold water by double pipe heat exchanger for plain tube and plain tube with twisted inserts is experimentally investigated at isothermal condition. The twisted tape inserts when placed in the path of the flow of the fluid, create a high degree of turbulence resulting in an increase in the heat transfer rate. By inserting twisted tape with twist ratio y=5 and y=7 in a concentric tube heat exchanger, the Nusselt number increases gradually from 920 to 6700 and it is 12-15 % higher than plain tube. This is due to the generation of secondary flow in the tube (turbulence flow). Also the heat transfer coefficient is 15 % higher than the plain tube due to increase in degree of swirl.
***Keywords**:* Circular tube, twisted tape, Heat transfer coefficients and Reynold number.

I. INTRODUCTION

In recent application twisted-tape inserts have widely been applied for enhancing the convective heat transfer in various industries, due to their effectiveness, low cost and easy setting up. Insertion of a twisted tape in a heat exchanger tube is classified as a passive enhancing technique. In general, twisted tape introduces swirl into the bulk flow which consequently disrupts a thermal boundary layer on the tube surface. Also this techniques lead to increase in heat transfer coefficient but at the cost of increase in pressure drop. So, while designing a heat exchanger using these techniques, analysis of heat transfer rate & pressure drop has to be done. Mechanisms of heat transfer enhancement by twisted tape inserts can be concluded as follows (1) the decrease of hydraulic diameter which leads to the increase in flow velocity due to portioning of the tube (2) the increase of flow path length due to helical configuration of the twisted tape (3) the increase of shear stress at wall tube and improvement of fluid mixing by secondary or swirl flow and (4) the fin contribution if the tape insert is in good thermal contact with the wall of the tube.

[1] Enhancement in heat transfer is not only achieved with plain twisted tape but it is also achieved by twisted tape with baffles (TTWB) and performance of TTWB is better as compared to plain twisted tape. With laminar flow in the tube side, and at constant tube wall temperature, Re varies from 200 to 600 with tube flow rate and shell flow constant. [2] Heat transfer, friction factor and enhancement efficiency characteristics in a horizontal circular tube fitted with conical wire coil tabulators have been investigated by using the conical coil inserts and full length wire coil inserts which are placed in test tube, through which air as working fluid is passed. Due to this wire coil inserts, the swirl flow helps to decrease the boundary layer thickness of the hot air flow and increase residence time of hot air in the inner tube. The partitioning and secondary fluid motion is generated by the wire coil inserts resulting twist mixing, improves the convection heat transfer. However, the Nusselt number augmentation tends to decrease rapidly with the rise of Reynolds number. If wire coils are compared with a smooth tube at constant pumping power, an increase in heat transfer is obtained, especially at low Reynolds number.[3] The variations of friction factor with Reynolds number for Matrix coil wire inserts was determined. The friction factor gradually reduced with rise in Reynolds number. It was observed to be maximum for insert having highest density 12 turns per pitch as compared to 8 and 10 numbers of turns. When a Matrix coil wire insert is inserted into a plain tube there is a significant improvement in Nusselt number because of secondary flow. The greater enhancement being realized at lower Reynolds numbers and for lower density for same pitch. This enhancement is mainly due to the centrifugal forces resulting from the spiral motion of the fluid. Also increases in density causes increment in Nusselt numbers as well as rise in pressure drop. [4] Twisted tape with baffles was used by maintaining the constant tube wall temperature with tube flow rate and shell flow

constant. Twisted tapes used having 2.2 twist ratios and for baffled twisted tape, baffles are positioned at equal intervals, at an angle 45^0 with normal axis of twisted tape. The heat transfer and pressure drop in case of twisted tape and twisted tape with baffles are found to increase by 110 to 120% and 130 to 140% respectively than that of plain tube. [5] Creation of holes on each segment of twisted tape changes the flow profile and generating secondary flow and approaching turbulence flow. Furthermore, the velocity of the flow increases and allowing more fluid mixing inside the tube thus provide more heat transfer across the tube. Porous twisted plate with larger numbers of holes enhance better heat transfer rate compared to plain tube and plain twisted plate.[6] The Nusselt number obtained for the tube with twisted wire brush inserts varied from 1.55 to 2.35 times in comparison to those of the plain tube. The inner convective heat transfer coefficient for twisted wire brush inserts is approximately 9-11 % higher than that for plain tube. The pressure drop for twisted wire brush inserts is 4- 5 % higher than that obtained for plain tube. The friction factor values for twisted wire brush inserts decreases which is 7-8% less than that obtained for plain tube.

Experimental Setup

Set up consist of two pipes of different diameters. The smaller diameter pipe is inserted into a pipe having greater diameter concentrically, hence called as concentric tube. The diameter of the outer pipe is 100 mm and that of inner pipe is 50 mm and the length of tube is 1.22 m. The material of outer pipe is mild steel and inner pipe is copper. There are six thermocouples are connected at same distance on the periphery of outer pipe. There are also two more thermocouples are mounted on inner pipe at inlet and outlet. The inlet and outlet temperature of the air stream and temperature of the outer pipe will be measured by RTD Sensors having a range of 0°C to 450°C. The atmospheric air from the blower is heated in a heater and then supplied to the inner pipe. The outer pipe is supplied with cold water which is pumped with the help of the submersible pump.

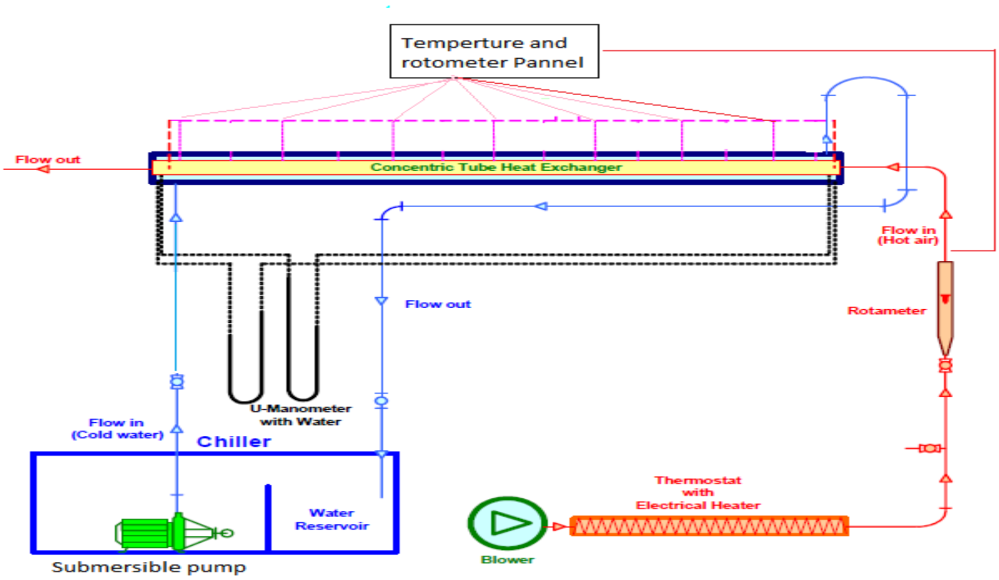

Figure no.1. Block diagram of experimental set up

II. METHODOLOGY

The tapes were twisted in two different twist ratios: y = 7 and y= 5 as shown in fig 2. Twisted tapes were made of copper. They were fabricated by twisting a straight tape, about its longitudinal axis. The twisted tape was inserted inside the inner tube from which hot air is flowing. All the pressure readings were taken under isothermal conditions. The flow rate of water was kept constant. The cooling water coming in heat exchanger is at room temperature. First the air flow rate was fixed to 30 lit/min and the steady state were allowed. Once the steady state was reached the flow rate of hot and cold fluid, temperature reading at inlet and outlet section of hot and cold fluid was taken. The flow rate of cold water was kept constant and above procedure was repeated for different flow rate of hot air viz. 60,80,105 (lit/min) one after other.

Figure no: 2. the inner tube fitted with twisted tape at different twist ratios (y = 7.0 and 5.0)

III. RESULTS AND DISCUSSION

1. Nusselt Number vs. Reynold Number

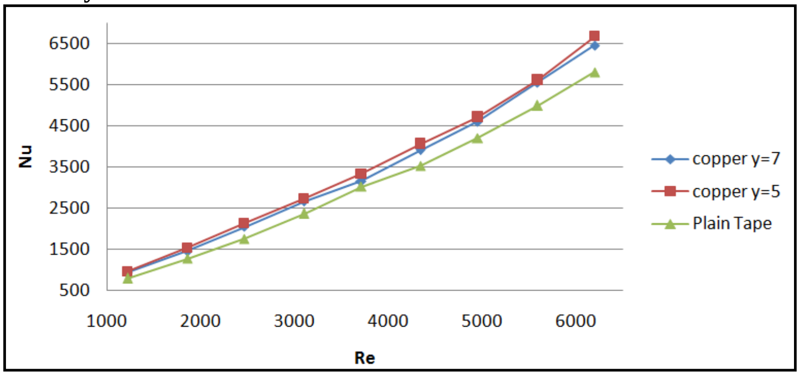

Figure no: 3 Variation of Nusselt number (Nu) with Reynolds No. (Re) for copper

Above figure 3 shows experimental result by different configuration for copper twisted tape y=5 and y=7 and it is compared with plain tube without twisted tape insert. Reynold number and Nusselt number were calculated. It is observed that for plain configuration Nusselt number increased from 500 to 6000. By inserting twisted tape y=5 and y=7 in a concentric tube heat exchanger, the Nusselt number increases gradually from 920 to 6700. It is due to the generation of secondary flow in the tube (turbulence flow). When we compared Nusselt number and Reynold number y=5 and y=7, Nusselt number increases gradually with respect to Reynold number. This happens due to generation of turbulence flow, and rate of velocity increases, this velocity increase the momentum of flow and increases heat transfer rate from above graph. It is also seen that Reynold number is directly proportional to the Nusselt number, and it is higher for twist ratio y=5 as compared to y=7 because of as numbers twist increases the twist ratio decreases.

2. Heat transfer coefficients vs. Reynold Number

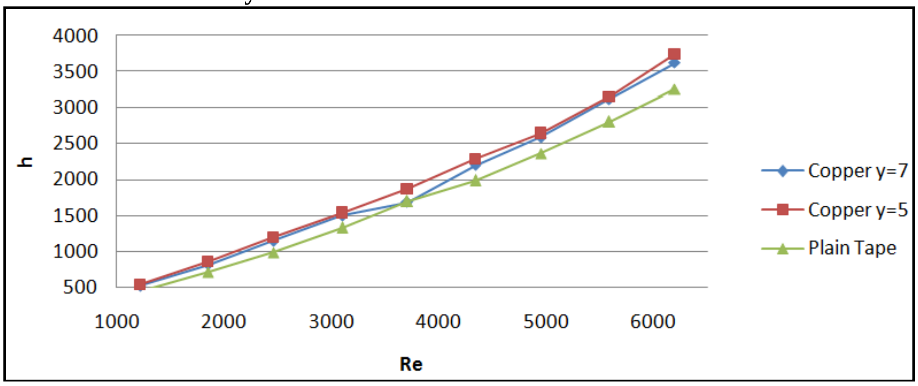

Figure no: 4 Variation of heat transfer coefficient (h) with Reynolds No. (Re) for copper tape

Figure 4 shows that variation of heat transfer coefficients and reyonld number on different twisted tape y=5 and y=7 for copper. Heat transfer coefficients increase with increases Reynold number and it is clearly seen by boundary layer phenomenon. It is observed that with increase in degree of swirl, it create more turbulence in air flow and hence heat transfer coefficients increases with decreases twist ratio. Also heat transfer coefficients not only depends on twist ratio but it is also function of velocity and viscosity of air and swirl generation.

3. Friction factor vs. Reynold Number.

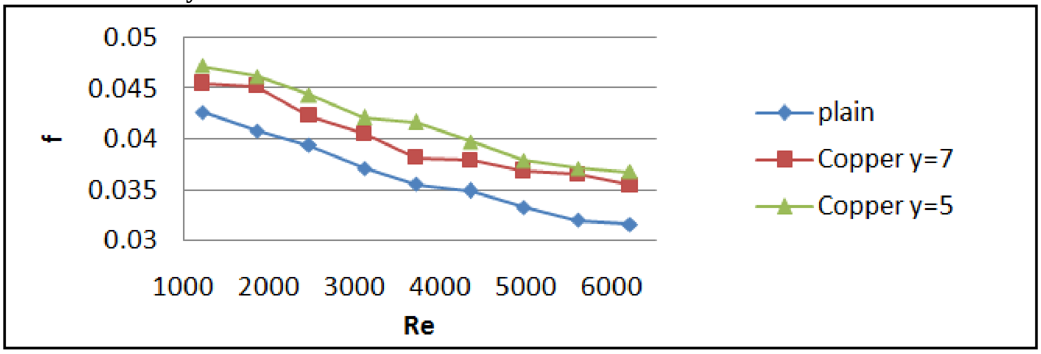

Figure no: 5 Variation of friction factor (f) with Reynolds No. (Re) for copper tape

Above figure 5 shows that the variation of friction factor and Reynold number for copper twisted tape. It is observed that with increase in Reynold number friction factors decrease. It happens due to shorter pitch length, swirl increases continuously with increasing in tangential contact between the air and twisted tape. The friction factor is inversely proportional to the velocity of air and inversely proportional to Reynold number.

IV. CONCLUSION

An experimental study was conducted to investigate the heat transfer performance and friction factor characteristics for laminar flow through a tube by means of twisted tape inserts. The mass flow rates in inner tube varied during experimentation. Air to water heat transfer study is performed and tested for counter flow configuration. Effect of inlet fluid temperature and relevant parameters on heat transfer characteristics and friction factor are considered. The study revealed that the twisted tape inserts provided significant enhancement of heat transfer with the corresponding decrease in friction factor. Due to the turbulence created and swirl flow generated the laminar flow converted in to turbulent flow. The convective heat transfer obtained from the tube with twisted tape inserts is higher than that with the plain tube without twisted tape inserts.

Based on the experimental results, the following conclusion was obtained.

1. The Nusselt number obtained for the tube with twisted tape of twist ratio y=7 is 11.8 %greater than the plain tube. Whereas for twisted tape of twist ratio y=5 is 14 % greater than the plane tube.
2. The inner convective heat transfer coefficient for twisted tape inserts is approximately 11-15% higher than that for plain tube.
3. The friction factor values for twisted tape inserts is 10-14% greater than that for plain tube.

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