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Effect of Twisted Tape Inserts On Heat Transfer in A Concentric Tube Heat Exchanger

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Abstract - **Work presents the effects of twisted tape inserts of different materials and different twist ratio on the performance of concentric double pipe heat exchanger by using air and water as working medium. 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. The twisted tapes of copper and aluminium are used for experiment with two different configuration of each twisted tape, one having twist ratio (y/D) =5 and other having (y/D) =7. The results shows that the heat transfer rate of heat exchanger with the twisted-tape inserts is found to be strongly influenced by tape-induced swirl or vortex motion. It is found experimentally the heat transfer coefficient and nusselt number in a heat exchanger with copper twisted tape is higher by 9% and 9.5% than that of aluminum twisted tape. Nusselt number depends on rate of heat transfer and thermal conductivity for different material of twisted tape. The values of Nusselt number for copper material is higher than for aluminium because of higher thermal conductivity of copper and it is also denser as compared to aluminum and keeps heat maximum.**

Keywords: **Concentric tube, Heat transfer, twisted tape with copper and aluminium and Friction factor.**

Introduction

It has been commonly known that the performance of heat exchangers, for single-phase flow can be improved by many augmentation techniques. In general, heat transfer enhancement technique can be divided into two groups, namely active and passive techniques. The active technique requires extra external power source. The other is passive technique, which requires no direct employment of the external power. Among various techniques, insertion of twisted tapes swirl generator is one of the most promising techniques, which has been widely adopted for heat transfer augmentation. A lot of passive techniques are applied to increase thermal performance of heat transfer devices such as treated surfaces, rough surfaces, swirling flow devices, coiled tubes, and surface tension devices Helical coil wire swirl tabulator is one of the commonly used passive types for heat transfer augmentation due to their advantages of steady performance, simple configurations and ease of installation. The use of twisted tapes inserts for better performance of heat exchanger is strongly influenced by the types of material used for twisted tape [1]. By inserting aluminium twisted tape with twist ratio y=5 and y=7 in a concentric tube heat exchanger, the Nusselt number increases gradually from 860 to 6200 and it is 7 to 9 % higher than plain tube. This is due to the generation of secondary flow in the tube (turbulence flow). Also the heat transfer coefficient is 9 % higher than the plain tube due to increase in degree of swirl. This is because of thermal conductivity of aluminium is superior to other material. [2] The twisted tape placed inside the inner test tube of the heat exchanger with different twist ratios, y = 5.0 and 7.0. It is found that the increase in heat transfer rate of the twisted-tape inserts is found to be strongly influenced by tape-induced swirl or vortex motion. The maximum Nusselt numbers by using the enhancement devices with y = 5.0 and 7.0 are 188% and 159%, respectively, higher than that for the plain tube. The enhancement efficiency and Nusselt number increases with decreasing the twist ratio and friction factor also increases with decreasing the twist ratio. The partitioning and blockage of the tube flow cross-section by the tape, resulting in higher flow velocities. [3] The swirl flow behavior and the laminar convective heat transfer in a circular tube can be increased by drilling the holes at both ends of tape so that the two ends could be fixed to the metallic clamps. Three tapes with varying twist ratios were fabricated (y_w=5.25, y_w =4.39, y_w =3.69).It was observed that heat transfer coefficients and friction factor increases with decreasing twist ratio. [4] Insertion of twisted tape insert with oil and water as working medium with two different twist ratio of 3.5 and 7, the twisted tape of lower twist ratio (y = 3.5) gives higher heat transfer coefficient (by 1.39 times) than higher twist ratio (y = 7). When only heat transfer capacity of heat exchanger is criteria regardless of pressure drop or pumping power the twisted tape is more superior as compared with smooth tube (1.6 to 1.8 times).[5] The performance of tube heat exchanger can be improved by using special configuration of wire mesh twisted tape with different twist ratio for laminar flow. Heat transfer coefficient and friction factor increases with the decrease in twist ratio compared with plane tube. Twisted wire mesh for twist ratio 7.0 and 5.0 augment the heat transfer rate 2.09 and 1.69 times compared with the plane tube. The performance ratio for twisted wire mesh is greater than one therefore enhancement is competent in the point of energy saving. The twisted wire mesh proves to be a better insert than conventional twisted tape. [6] The copper square jagged twisted tape twisted tape, when placed in the path of the flow of the fluid, creates a high degree of turbulence resulting in an increase in the heat transfer rate and the pressure drop. The results of varying twists in square jagged tape with different pitches have been compared with the values for the smooth tube. The 3mm thick with 3.2 twists copper insert shows increase in Nusselt number values by 76% however there is increase in friction factor by only 19.5% as compared to the smooth tube values. [7] 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.[8] 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 friction factor values for twisted wire brush inserts decreases which are 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.

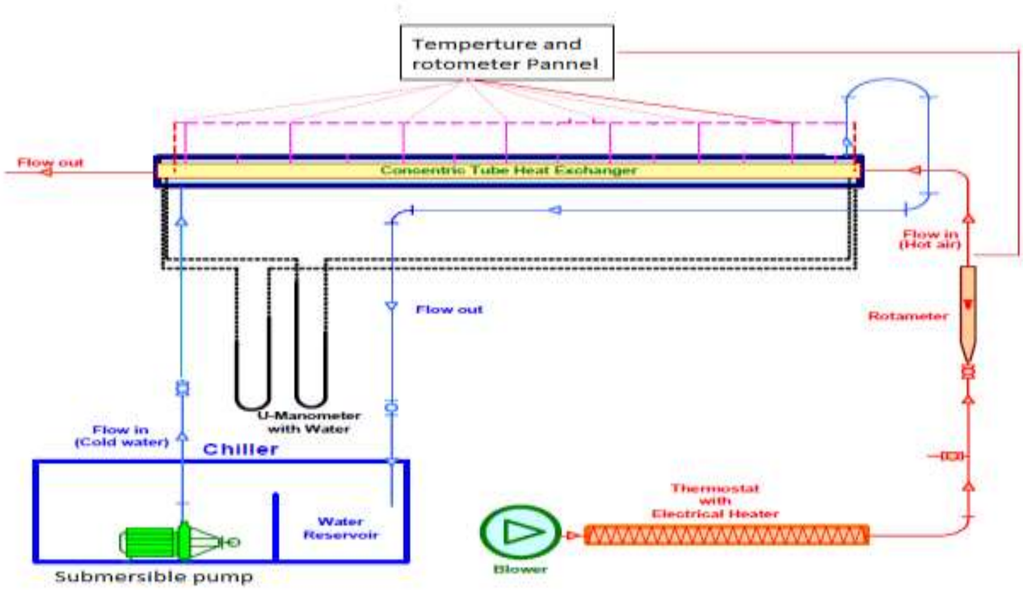

Figure 1. Block diagram of experimental set up

Methodology

The tapes were twisted in two different twist ratios: y = 5 and y= 7 as shown in fig. 2 Twisted tapes were made of copper and aluminium, fabricated by twisting a straight tape, about its longitudinal axis. The twisted tape was inserted inside the inner tube through which hot air is flowing. All the pressure readings were taken under isothermal conditions. The flow rate of water was kept constant and 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. 30,60, 80, 105 (lit/min) one after other.

Figure: 2. Copper and Aluminium twisted tape (y = 5.0 and 7.0)

Results and Discussion

1. ***Nusselt Number vs. Reynold Number***

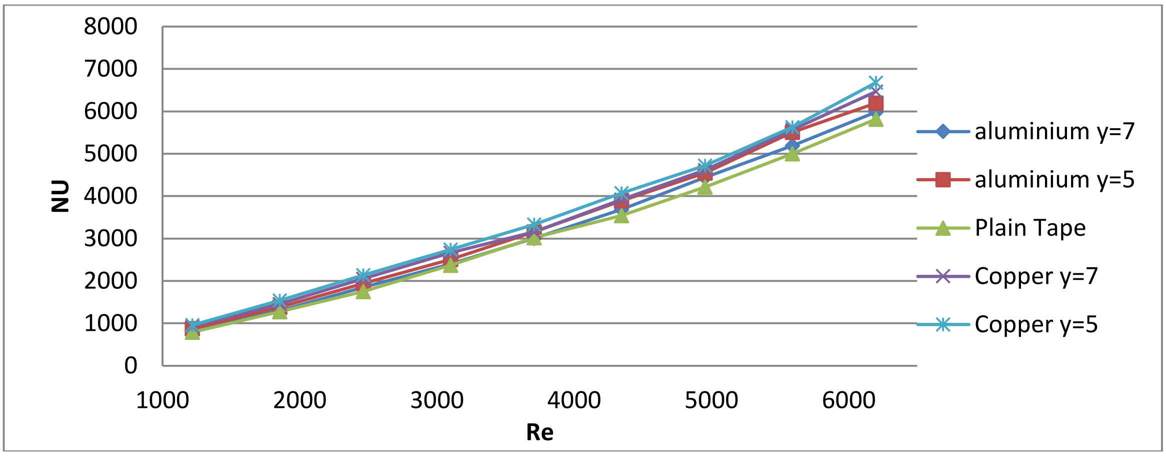

Fig.3 Variation of Nusselt number (Nu) with Reynolds No. (Re) for Aluminum tape and copper tape

From fig 3 shows that heat transfer rate were calculated from different reading at different temperature for regular interval of time. When we plot graph between Nusselt numbers Vs Reynold number, it is observed that Nusselt number increases with Reynold number. The value of Nusselt number for copper material y=5 is found to be 5650 and y=7 is found to be 5530 and also range for Reynolds number varies from 1000-6000. For aluminum material of y=5 is found to be 5500 and for y=7 it is 5200 for same Reynolds number. This happens due to disturbance in velocity profile of flow and momentum. Nusselt number depends on rate of heat transfer and thermal conductivity for different material of twisted tape. The values of Nusselt number for copper material is higher than for aluminium because of higher thermal conductivity of copper and it is also denser as compared to aluminum and keeps heat maximum.

2. ***Heat transfer coefficients vs. Reynold Number***

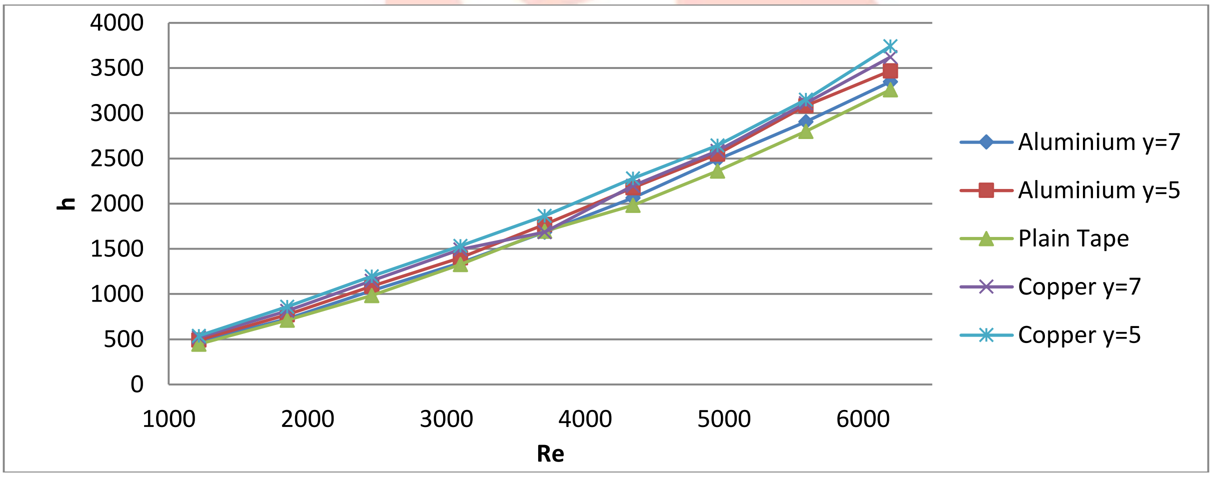

Fig.4 Variation of heat transfer coefficient (h) with Reynolds No. (Re) for Aluminum tape and copper tape

Fig 4 shows that variation of heat transfer coefficients and Reynold number. The experimental reading had been taken at different twist configurations and the graphs are plotted between heat transfer coefficients and Reynold number for copper, aluminium twisted tape and is compared with plain tube. It is observed that heat transfer rate for all the configuration increases with increases in Reynold number. The heat transfer coefficients h is maximum for copper material and it is found to be 3150 w/m^2 ^{0}c for y=5, similarly for y=7 it is observed to be 3110 w/m^2 ^{0}c, and is varies from 500 to 3200 w/m^2 ^{0}c. Reynold number range varies from 1000-6000. For the aluminium material for same configuration y=7 and y=5 heat transfer coefficients lower as compared to copper twist material, and it is found to be 3080 w/m^2 ^{0}c for y=5 and for y=7 it is 2900 w/m^2 ^{0}c respectively. This is because of thermal conductivity of copper is superior to aluminium, also aluminium radiate heat into air because of its lower density as compared to copper.

3. ***Friction factor vs. Reynold Number.***

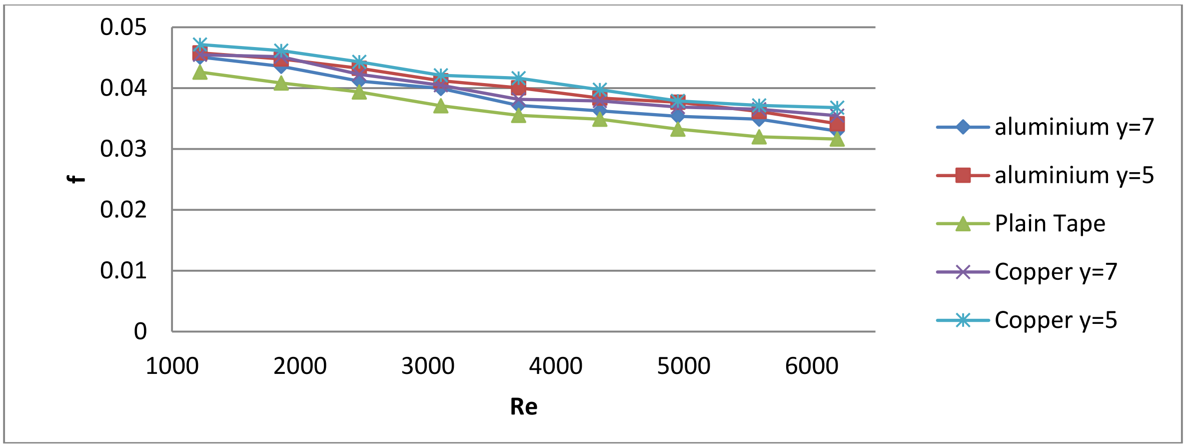

Fig.5 Variation of friction factor (f) with Reynolds No. (Re) for Aluminum tape and copper tape

From experimental calculation the values of friction factor were calculated. These values are plotted against Reynolds number as representing in fig.5. It is observed that friction factors decreases with increasing in Reynolds number. The value for configuration y=5 and y=7 for copper twist material is decreases from 0.04718 to 0.03678 and 0.04546 to 0.3547 respectively. Similarly for aluminum material the value for configuration y=5 and y=7 is decreases from 0.0458 to 0.0.3416 and 0.04511 to 0.03295. This indicates that for higher Reynolds number the friction factor is less. This is due to their exist small disturbance that can be amplified to produce turbulent condition. As Reynolds number increases force start becoming more dominant and disturbance get amplified to a point when turbulence occurs. Hence value of friction factors is less for relatively large Reynolds number.

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 of copper and aluminium. 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 were considered. The experimental result shows that the twisted tape inserts provided significant enhancement in heat transfer with the corresponding decrease in friction factor with Reynold number range from 1000 to 6000. Due to the turbulence created and swirl flow generated the laminar flow converted in to turbulent flow. Also the effect of different twisted tape materials was investigated. The convective heat transfer obtained from the tube with copper twisted tape inserts is higher than that the aluminium twisted tape inserts.

Based on the experimental results, the following conclusions were obtained.

1. The Nusselt number obtained for the tube with copper twisted tape of twist ratio y=7 is 7.0%greater than aluminium twisted tape for same twisted ratio. Whereas for copper twisted tape of twist ratio y=5 is 7.8% greater than aluminium twisted tape for same twisted ratio.

2. The heat transfer coefficients obtained for the tube with copper twisted tape of twist ratio y=7 is 6.8 % greater than aluminium twisted tape for same twisted ratio. Whereas for copper twisted tape of twist ratio y=5 is 7.9% greater than aluminium twisted tape for same twisted ratio.

3. The friction factor obtained for the tube with copper twisted tape of twist ratio y=7 is 6.5 %greater than aluminium twisted tape for same twisted ratio. Whereas for copper twisted tape of twist ratio y=5 is 7.4% greater than aluminium twisted tape for same twisted ratio.

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