Analysis of Heat Transfer Enhancement in Circular Tube by Using V-Shaped Turbulators

[1]Mayur R. Patil and [2]H.S.Farkade,
[1]M.Tech student, [2]Assistant Professor,
[1]Thermal Engineering, [2]Mechanical Engineering, [1,2]Government College of Engineering, Amravati Maharastra, India

Abstract: An experimental study of heat transfer in a plane circular tube fitted with the V-Shaped turbulators is performed for plane circular tube. This Paper presents the experimental analysis of heat transfer coefficient and friction characteristics in a plane circular tube fitted with the V-Shaped turbulators. Experimentation are performed to check the effects of the V-Shaped turbulators on the rate of heat transfer, friction factor and enhancement of heat transfer coefficient, in a circular tube. We used the V-Shaped turbulators with the pitch ratio of 3, 4 and 5 and we concluded that the heat transfer enhancement. The average heat transfer rates obtained from using the V-shaped turbulators are 190%, 210% and 238% for turbulator Length of 200mm, 150 and 120 mm respectively. All of the experiments are performed on the same experimental set-up at the same inlet conditions with the Reynolds number, based on the tube diameter (Re), in a range of 5000 to 10000.

Keywords: *V-Shaped Turbulators, Heat Transfer Enhancement, Heat Transfer*

I. INTRODUCTION

Heat transfer augmentation techniques (passive, active or a combination of passive and active methods) are commonly used in areas such as process industries, heating and cooling in evaporators, thermal power plants, air-conditioning equipment, refrigerators, radiators for space vehicles, automobiles, etc. Passive techniques, where inserts are used in the flow passage to augment the heat transfer rate, are advantageous compared with active techniques, because the insert manufacturing process is simple and these techniques can be easily employed in an existing heat exchanger. In design of compact heat exchangers, passive techniques of heat transfer augmentation can play an important role if a proper passive insert configuration can be selected according to the heat exchanger working condition (both flow and heat transfer conditions). In the past decade, several studies on the passive techniques of heat transfer augmentation have been reported. Twisted tapes, wire coils, ribs, fins, dimples, etc., are the most commonly used passive heat transfer augmentation tools. In the present paper, emphasis is given to works dealing with twisted tapes and wire coils because, according to recent studies, these are known to be economic heat transfer augmentation tools.

Heat exchangers have several industrial and engineering applications. The design procedure of heat exchangers is quite complicated, as it needs exact analysis of heat transfer rate and pressure drop estimations apart from issues such as long-term performance and the economic aspect of the equipment. The major challenge in designing a heat exchanger is Heat exchangers have several industrial and engineering applications. The design procedure of heat exchangers is quite complicated, as it needs exact analysis of heat transfer rate and pressure drop estimations apart from issues such as long-term performance and the economic aspect of the equipment.

The major challenge in designing a heat exchanger is to make the equipment compact and achieve a high heat transferrate using minimum pumping power. Techniques for heat transfer augmentation are relevant to several engineering applications. In recent years, the high cost of energy and material has resulted in an increased effort aimed at producing more efficient heat exchange equipment. Furthermore, sometimes there is a need for miniaturization of a heat exchanger in specific applications, such as space application, through an augmentation of heat transfer. For example, a heat exchanger for an ocean thermal energy conversion (OTEC) plant requires a heat transfer surface area of the order of 10,000 m2/MW. Therefore, an increase in the efficiency of the heat exchanger through an augmentation technique may result in a considerable saving in the material cost.

II. EXPERIMENT SET-UP

We proposed to carry out on experimental set-up as shown in the figure1. The experiment setup we have fabricated is a experimental facility to test the different inserts in a circular tube. It is a open loop test section consisted of a air blower, and heat transfer analysis testing section. The test tube has a length of L=1.250m, with 0.052 m inner diameter (D), 0.060 m outer diameter (Do), and 4 mm thickness (t) of 4 mm. Figure 1 shows the diagrammatic representation of experimental set-up. In this the Test Circular tube was heated by 6 heaters of 200 mm length each connected in parallel with combined capacity of 1000 watts to provide a uniform heat flux boundary condition. The electrical output power was controlled by a 4 Amp dimmer stat to obtain a constant heat flux over the entire length of the test section.

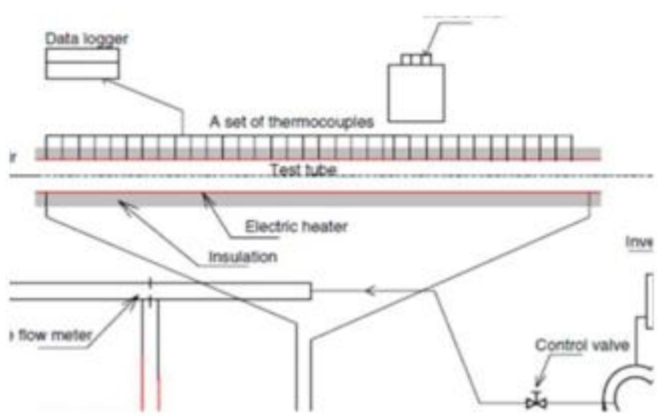


Figure 1: Experimental Setup

The outer surface of the test tube is well insulated by asbestos rope and glass wool to minimize heat loss to surroundings, and necessary precautions are taken to prevent leakages from the system. The inlet and outet temperatures of the air is measured at certain points with a multichannel temperature measurement unit in conjunction with the K type thermocouples as can be seen in Figure 1. Six thermocouples are installed on the wall of the tube and the thermocouples are placed round the tube to measure the circumferential wall temperature. The mean local wall temperature was determined by means of calculations based on the reading of thermocouples.

A. Specifications of Experimental Set-up

Following are the specifications of the various components of the used in the experimental set-up.

- Air blower 0.28 HP
- Orifice meter with inclined tube manometer is used to measure the mass flow rate of air,
- Inclined water tube manometer: range :- 0 to 50 MMW
- The test tube with length ofl=1250 mm, with 52 mm inner diameter (d), 60 mm outer diameter (do), and 4 mm thickness (t).
- Pipe heater: 6 heaters of 200 mm length each connected in parallel with combined capacity of 1000 watts.
- 8 Channel temperature recording systemunit in conjunction with 6 k-type thermocouples at equal distance on heating section wall and two for measuring inlet and outlet temperature of the air.
- Dimmer stat: 6 ampere variac.
- Control panel: Ammeter and Voltmeter

B. V-Shaped Turbulators

The V-Shaped turbulators are used to increase the turbulence inside the circular tube. The V-Shaped turbulators are made up of mild steel Circular solid rod with Diameter 40 mm, and are manufactured by the turning process on the lathe machine. Three V-shaped turbualtors with different pitch are fabricated and used.

Figure 2 represents the V-shaped Turbulators arrangement is use in this work. The V-Shaped turbulators will be made of Mild steel and details are shown in figures.

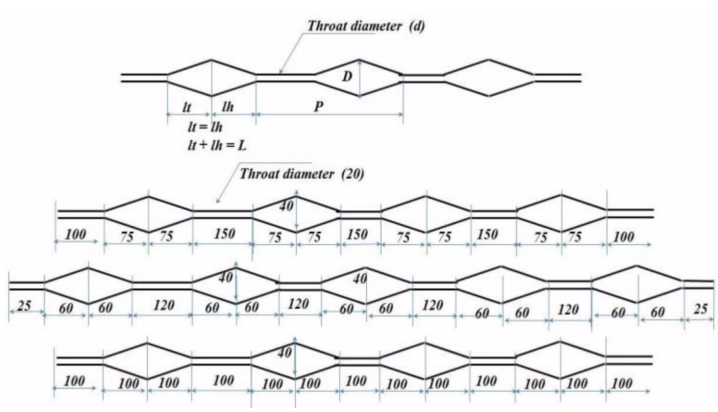


Figure 2: Details of V-shaped Turbulator

We have used three pitch ratio (PR=L/D) i.e. 3, 4 and 5. The maximum diameter D = 40 mm and throat diameter will be d = 20 mm.

III. MATHAMATICAL FORMULATION

This paperwork, the air is used as a heating fluid and is passed through a circular tube which is applied with uniformheat flux. The steady state of the heat transfer rate is assumed to be equal to the heat loss from the test section which can be expressed as:

$$Qair = Qconv \quad (1)$$

In which

$$Qair = mCpa(To-Ti) \quad (2)$$

The convection heat transfer from the test section can be written as:

$$Qconv = hA(Tw-Tb) \quad (3)$$

Whereas,

$$Tb = (To+Ti) / 2 \quad (4)$$

and

$$Tw = \Sigma\,(Tw/6)$$

Where

Two is the wall temperature of circular test section which is applied with uniform heat flux and is an average of 6 temperature recorded by thermocouples placed on the tube wall. The average heat transfer coefficient, h and the mean Nusselt number, Nu are calculated as follows:

$$h = mCpa\,(To-Ti) / A(Tw-Tb) \quad (6)$$

$$Nu = hd / k \quad (7)$$

The Reynolds number is given by

$$Re = \rho VD / \mu (8)$$

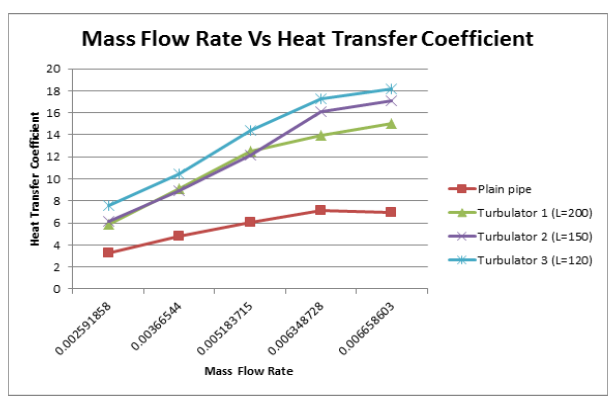
Friction factor, f can be written as

$$f = \frac{\Delta Pf}{\rho.(\frac{L}{D}).(um\,2)} (9)$$

IV. EXPERIMENTAL RESULTS

The series of experiments were carried out on the experimental test rig, the experiments were first carried out with the circular pipe without any inserts and then the same experiments were repeated by using the v-shaped turbulator fitted in the plane circular tube. All experiments were performed by providing a different mass flow rate of air by controlling the air flow by using the valve, the different opening of valves gives the different mass flow rate. Following are the results of the experiments.

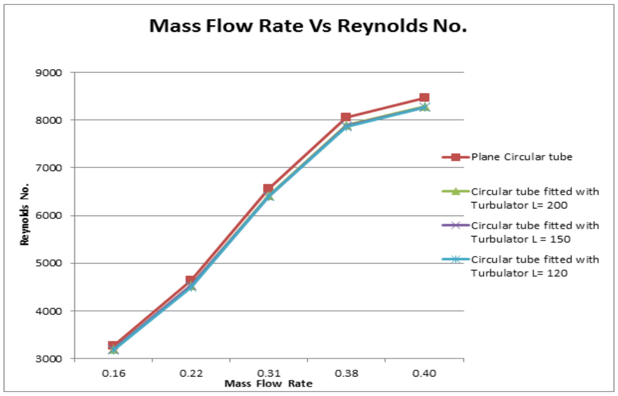
A. Heat Transfer Coefficient



The heat transfer rate increases in the v-shaped Turbulators as shown in a graph with a significant rate as compared to the plane circular tube. This increase in the heat transfer rate depends on the many factors but heat transfer coefficient is very important characteristics in the heat transfer analysis. The above figure shows that the heat transfer coefficient for the various V-Shaped turbulators with length 120 is highest and heat transfer coefficient starts reducing the length of turbulators is increases. The graph shows that the heat transfer coefficient is increased as the mass flow rate increases. This increases in the heat transfer coefficient occurred due to the turbulence caused by the v-shaped Turbulators.

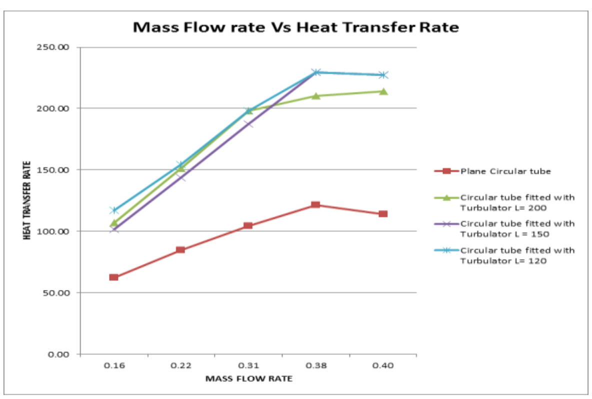
B. Reynolds No.

The graph shows that the Reynolds No. for the various V-Shaped turbulators and for plane circular tube and there is the very small difference between Reynolds no. of all cases. This increases in the Reynolds No. occurred due to the turbulence.



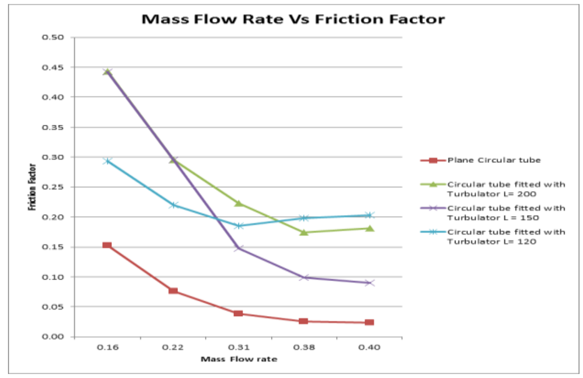
C. Heat Transfer Rate

The heat transfer rate increases by using V-shaped Turbulators as shown in graph with a remarkable rate as compared to the plane circular tube. This increase in the heat transfer is depends on the Reynolds No. and heat transfer coefficient. The below plot shows that the heat transfer rate for V-Shaped turbulators with length 120 is highest and it slightly reduces for Length 150 and 200 respectively.



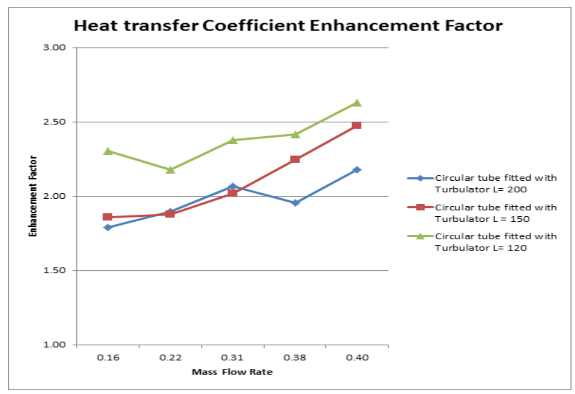
D. Friction Factor

The friction factor is most important factor for performance analysis of various heat transfer augmentation techniques. It is always observed that while using any inserts in the circular pipe it results in pressure drop because the increased fiction in pipes. This plot shows the friction factor for various V-shaped turbulators. The graph shows that the friction factor reduces as the mass flow rate increases. The friction factor for length of 120 mm is more and less for 150 mm and 200 mm length respectively.



E. Heat Transfer Coefficient Enhancement Factor

This plot shows heat transfer enhancement by using various V-shaped turbulators. The heat transfer coefficient enhance factor is increases by using V-shaped Turbulators as shown in graph with a remarkable rate as compared to the plane circular tube. This increase in the heat transfer is depends on the Reynolds No. and heat transfer coefficient. The average heat transfer rates obtained from using the V-turbulators are 190%, 210% and 238% for turbulator with the turbulator element length 200mm, 150mm and 120mm respectively over the plain tube.



CONCLUSION

Experimental investigations have been carried out to study the effects of the V-Shaped turbulators on heat transfer, friction and enhancement efficiency, in a circular tube. We used the v-turbulators with the element length 200mm, 150mm and 120mm we found the heat transfer argumentation. The results are:

- The heat transfer in the circular tube could be promoted by fitting with V Turbulators while it brings about the energy loss of the fluid flow.
- The mean heat transfer rates obtained from using the V-turbulators are 190%, 210% and 238% for turbulator with the turbulator element length 200mm, 150mm and 120mm respectively over the plain tube.
- The results shows that the heat transfer coefficient for the v-turbulator is more as compare to the plane circular tube. The results shows that the heat transfer rate is increases as the Reynolds no. increases. This increases in the heat transfer rate occurred due to the turbulence.
- The friction factor reduces with as the Reynolds no increases and this friction factor is slightly higher in v-turbulator when compared to the plane circular tube.

References

[1] Date, A. W., and U. N. Gaitonde. "Development of correlations for predicting characteristics of laminar flow in a tube fitted with regularly spaced twisted-tape elements." Experimental Thermal and Fluid Science 3.4 (1990): 373-382.

[2] Saha, S. K., A. Dutta, and S. K. Dhal. "Friction and heat transfer characteristics of laminar swirl flow through a circular tube fitted with regularly spaced twisted-tape elements." International Journal of Heat and Mass Transfer 44.22 (2001): 4211-4223.

[3] Patro, J. K., & Malviya, A. (2012). Experimental Studies on Heat Transfer Augmentation Using TMT Rods with and without Baffles as Inserts for Tube Side Flow of Liquids (Doctoral dissertation).

[4] Manglik, R. M., & Bergles, A. E. (1993). Heat transfer and pressure drop correlations for twisted-tape inserts in isothermal tubes: part I--laminar flows.Transactions-American Society Of Mechanical Engineers Journal Of Heat Transfer, 115, 881-881.

[5] Lokanath, M.S., and Misal, R.D., 2002. An experimental study on the performance of plate heat exchanger and an augmented shell and tube heat exchanger for different types of fluids for marine applications. In Proceedings of the 5th ISHMT-ASME Heat and Mass Transfer Conference (pp. 863-868). Tata McGraw-Hill.

[6] Shah, Ramesh K., and Teodor Skiepko. "Entropy generation extrema and their relationship with heat exchanger effectiveness—number of transfer unit behavior for complex flow arrangements." Journal of heat transfer 126.6 (2004): 994-1002.

[7] Hong, S. W., and A. E. Bergles. "Augmentation of laminar flow heat transfer in tubes by means of twisted-tape inserts." Journal of Heat Transfer 98.2 (1976): 251-256.

[8] Promvonge, Pongjet. "Thermal augmentation in circular tube with twisted tape and wire coil turbulators." Energy Conversion and Management 49.11 (2008): 2949-2955.