

## Heat Transfers Enhancement with Different Square Jagged Twisted Tapes

Mr. A.V.Gawandare<sup>1</sup>, Prof. M.M.Dange<sup>2</sup>, Prof.D.B.Nalawade<sup>3</sup>

Department of Mechanical Engineering, GenbaSopanraoMoze College of Engineering, Pune,India

### **Abstract:**

The present experimental work are carried out with copper twisted tape inserts 3mm with 5.2,4.2 and 3.2 twists respectively. The 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 and the pressure drop. The work includes the determination of friction factor and heat transfer coefficient for various twisted wire inserts with varying twists and different materials. The Reynolds number is varied from 5000 to 16000. Correlations for Nusselt number and friction factor are developed for the twisted wire inserts from the obtained results. 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.

**Keywords:** Enhancement efficiency, heat transfer, square jagged twisted tapes, turbulent; swirling, pressure drop.

### **I. Introduction**

Heat exchangers are widely used in various industrial processes for heating and cooling applications such as air conditioning and refrigeration systems, heat recovery processes food and dairy processes, chemical process plants etc. The major challenge in designing a heat exchanger is to make the equipment compact and achieve a high heat transfer rate 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 10000 m<sup>2</sup>/MW [1]. Therefore, an increase in the efficiency of the heat exchanger through an augmentation technique may result in a considerable saving in the material cost. Furthermore, as a heat exchanger becomes older, the resistance to heat transfer increases owing to fouling or scaling. These problems are more common for heat exchangers used in marine applications and in chemical industries. In some specific applications, such as heat exchangers

dealing with fluids of low thermal conductivity (gases and oils) and desalination plants, there is a need to increase the heat transfer rate. The heat transfer rate can be improved by introducing a disturbance in the fluid flow thereby breaking the viscous and thermal boundary layer. However, in the process pumping power may increase significantly and ultimately the pumping cost becomes high. Therefore, to achieve a desired heat transfer rate in an existing heat exchanger at an economic pumping power, several techniques have been proposed in recent years and are discussed under the classification section.

### **II Heat Transfer Enhancement Using Various Square Jagged Twisted Tape Inserts**

#### **A. Present experimental work**

The experimental study on passive heat transfer augmentation using perforated twisted tape inserts for no. of twists with aluminum and copper as a material were carried on in a single phase flow heat exchanger having the specifications as listed below:-



Fig.1 Experimental set up for forced convection

**B. Experimental Set up**

Experimental set up consists of test section having tube in tube heat exchanger. Inside tube is of Copper and outside tube is of Stainless Steel. Four thermocouples are connected to the test section, two at the inlet and two at the outlet of hot and cold water respectively. Two rotameters are connected at inlet of cold and hot water to measure the flow rates. Also control valves and bypass valves are provided at inlet of both the rotameters. Two centrifugal pumps are used to circulate the cold and hot water. Two tanks are used for storing the hot water and cold water. Electric heater is attached to the hot water tank having capacity of 1500watt. To measure the pressure difference between inlet and outlet of test section of hot fluid inverted U-tube manometer is used. Different twisted tape inserts are used. The current meter is used to measure the velocity of flow through inserted tube.

**C. Experimental Set up**

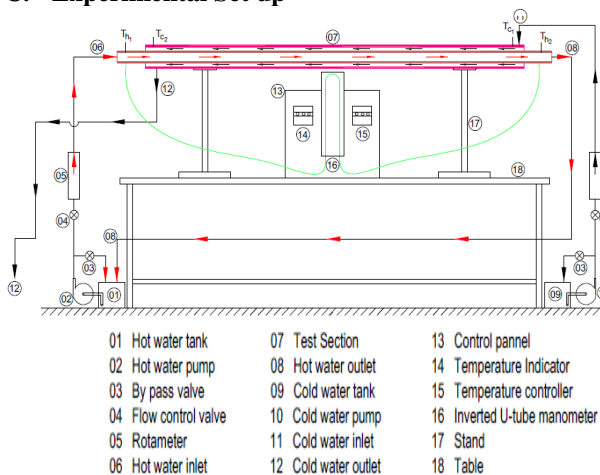


Fig .2 Schematic diagram of forced convection set up

**D. Experimental procedure :**

1. Refer to the Fig 1 and make all the cable connection carefully.
2. Switch ON the water heater wait until water temperature reaches 80
3. Switch on temperature display
4. Start cold water pump
5. Adjust flow rate of cold water at 100 LPH
6. Start hot water pump
7. Adjust flow rate of hot water at 100 LPH and keep it constant
8. The temperatures will keep on rising continuously. When steady state is reached, note all the temperatures (T1 to T4)
9. Now Adjust flow rate of hot water at 200 LPH
10. The temperatures will keep on rising continuously. When steady state is reached, note all the temperatures (T1 to T4)
11. Repeat step 9 and 10 for hot water flow rates at 300,400,500,600,700,800 and 900 LPH
12. Switch off pumps ,water heater and temperature display

**E. Specifications of inserts :**

iMaterial: Copper

- i. Width of twisted tape = 12mm
- ii. Twist ratio = 5.2, 4.2, 3.2.
- iii. Length of insert = 100cm
- iv. Thickness of inserts = 3mm



Fig.3 Copper square jagged Twisted tape (y=5.2) (Enlarged view)



Fig.4 Copper square jagged Twisted tape (y=4.2)(  
 Enlarged view)



Fig.5 Copper square jagged Twisted tape (y=3.2)(  
 Enlarged view)

### III. Methodology And Sample Calculations

#### 1) Properties of Water

a) Properties of hot water – calculated at mean bulk temperature

$$T_{bh} = \frac{T_{h1} + T_{h2}}{2}$$

#### b) Properties of cold water

$$T_{bc} = \frac{T_{c1} + T_{c2}}{2}$$

#### 2) Heat given by hot water

$$Q_h = m_h \times C_{ph} \times (T_{h1} - T_{h2})$$

#### 3) Heat given by cold water

$$Q_c = m_c \times C_{pc} \times (T_{c2} - T_{c1})$$

#### 4) Average heat transfer

$$Q_{avg} = \frac{Q_h + Q_c}{2}$$

#### 5) Overall heat transfer coefficient

$$Q_{avg} = U \times A_s \times \Delta T_m$$

##### a) Surface area of tube

$$A_s = \pi d_i L$$

##### b) Logarithmic mean temperature difference

$$\Delta T_m = \frac{(\Delta T_1 - \Delta T_2)}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)}$$

$$\Delta T_1 = T_{h1} - T_{c2}$$

$$\Delta T_2 = T_{h2} - T_{c1}$$

6) Nusselt Number of cold water flowing through the annular space.

$$Nu_o = 0.023(R_{eo})^{0.8} (P_r)^{0.3}$$

$$Re_o = \frac{\rho U_o D_h}{\mu}$$

$$D_h = D_i - d_o$$

Continuity equation –

$$m_c = \rho A_o U_o$$

7) Heat transfer coefficient of cold water flowing through the annular space.

$$Nu_o = \frac{h_o D_h}{K}$$

$$h_o = \frac{Nu_o K}{D_h}$$

8) Heat transfer coefficient of hot water flowing through the tube.

$$\frac{1}{U} = \frac{1}{h_i} + \frac{1}{h_o}$$

$$h_i = \frac{1}{\left(\frac{1}{U} - \frac{1}{h_o}\right)}$$

9) Experimental Nusselt Number of hot water flowing through the tube.

$$Nu_i = \frac{h_i d_i}{K}$$

10) Theoretical Nusselt Number of hot water flowing through the tube (DittusBoelter equation).

$$Nu_i = 0.023(R_{ei})^{0.8} (P_r)^{0.3}$$

11) Experimental Friction Factor

a)  $\Delta P = \rho g h$

b)  $\Delta P = \frac{f L \rho U_i^2}{2 d_i}$

$$f = \frac{2 g d_i h}{L U_i^2}$$

12) Theoretical Friction Factor

$$f = 0.0055 \times \left( 1 + \left( 50 + \left( \frac{10^6}{Re_i} \right)^{0.33} \right) \right)$$

13) Performance evaluation criteria

$$PEC = \eta = \frac{\frac{Nu}{Nu_p}}{\left(\frac{f}{f_p}\right)^{1/5}}$$

**IV. Results And Discussion**

**A. Validation Of The Experimental Programme**

The accuracy with which the friction factor and Nusselt number could be evaluated experimentally with the use of present experimental rig was determined by conducting preliminary experiments with plain tube without insert, and results compared with standard empirical relationships and previous research work for laminar flow. The purpose was to check the reliability of the apparatus.

**a. Heat transfer results for smooth tube**

Figure 6 shows the relation between Nusselt number v/s Reynolds number. The curve shows that Nusselt number is a function of Reynolds number. The values are in close agreement with the Dittus-Boelter equation with a maximum variation of 20 %

Fig.6 Nusselt number v/s Reynolds number for plain tube

**b. Friction factor results for smooth tube**

Figure 7 shows the relation friction factor v/s Reynolds number for turbulent flow in the tube without twisted tape insert, that is smooth tube flow conditions. This proves that the experimental test rig is validated and further experimentation can be carried out.

Friction factor obtained from the experimental investigation

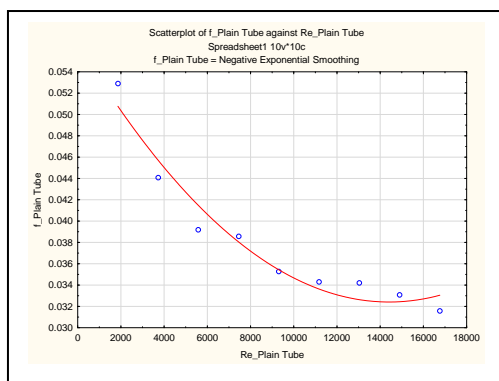


Fig. 7 Friction factor v/s Reynolds number plot for plain tube

**B. Comparison Of "Plain Tube" And "Tubes With Various Twisted Tapes**

Figure 8 shows the relation between Nusselt number and Reynolds number for plain tube and tube with various inserts, the Figure concludes that the Nusselt number is function of Reynolds number. Nusselt number increases with

increase in Reynolds number. Hence, convective heat transfer rate is more with higher Reynolds number.

Further, it can be concluded that, twisted tapes with tighter twist (with lesser twist ratio) give increased Nusselt number for a particular Reynolds number. Heat transfer rate is better with twisted tapes of lower twist ratio. Perforated tapes shown greater Nusselt number compared with plain twisted tapes.

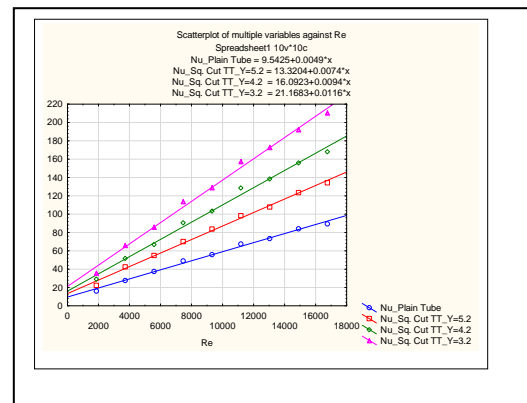


Figure 8 Nussultnumber v/s Reynolds number plot for Y=5.2,4.2,3.2

Figure 9 shows the relation between friction factor and Reynolds number for plain tube and tube with various inserts, the Figure concludes that the friction is minimum when the twisted tape is not inserted. Further, with the increase in twist, i.e. with the decrease in twist ratio, the friction factor goes on increasing for a particular Reynolds number. Perforated tapes show lesser friction factor compared with plain twisted tapes.

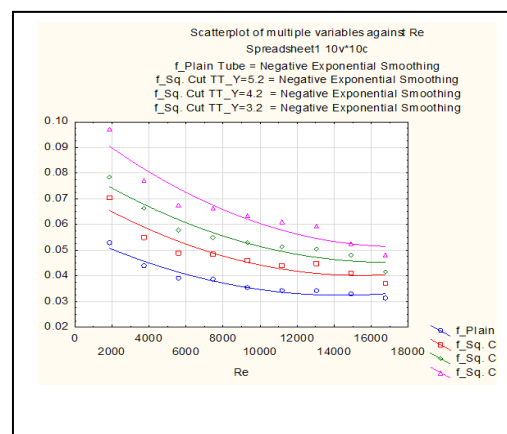


Fig. 9 Friction factor v/s Reynolds number plot for Y=5.2,4.2,3.2

The curves are very steep for lesser values of Reynolds number. This is due to the fact that, for

lower values of Reynolds number, the viscous force dominates the inertia force. For lower Reynolds number, less than 550, the curves are more leaning and the friction factor is comparatively high.

## V. Conclusions

Experimental investigation of heat transfer and friction factor characteristics of circular tube fitted with full-length square jagged twisted tape inserts of different twist ratio has been presented. Calculations and curve fitting is done and correlations are obtained. The results showed that there was an appreciable enhancement in heat transfer and that the heat transfer is more with lesser twist ratio.

- Maximum increase in Nu for plain twisted tape with  $y = 5.2$  was found to be 44 %
- Maximum increase in Nu for plain twisted tape with  $y = 4.2$  was found to be 82 %
- Maximum increase in Nu for plain twisted tape with  $y = 3.2$  was found to be 154%
- Friction factor is increased by 12 % with  $y=5.2$  in Square jagged twisted tape.
- Friction factor is increased by 27 % with  $y=5.2$  in Square jagged twisted tape
- Friction factor is increased by 51 % with  $y=5.2$  in Square jagged twisted tape
- It is concluded that heat transfer increase by 154% while friction factor increases by 51% so with less pumping power more heat transfer can be achieved

## References

- [1] Hsieh and Huang , “Experimental studies for heat transfer and pressure drop of laminar flow in horizontal tubes with/without longitudinal inserts” ,2000.
- [2] Sarma, “Heat transfer coefficients with twisted tape inserts”, 2003.
- [3] Hsieh ,“Experimental studies on heat transfer and flow characteristics for turbulent flow of air in a horizontal circular tube with strip type insert”, 2003.
- [4] PairsonNaphon ,“Effect of coil-wire insert on heat transfer enhancement and pressure drop of the horizontal concentric tube”, International Communications in Heat and Mass Transfer 33 (2006) 753–763,2006.
- [5] Smith Eiamsa-ard , PongjetPromvonge,“ Heat transfer characteristics in a tube fitted with helical screw-tape with/without core-rod inserts”, International Communications in Heat and Mass Transfer 34 (2007) 176–185.
- [6] SibelGunes, VeyselOzceyhan , OrhanBuyukalaca,“The experimental investigation of heat transfer and pressure drop in a tube with coiled wire inserts placed separately from the tube wall”, Applied Thermal Engineering 30(2010).
- [7] Dasmahapatra J. K, and Raja Rao M, “Laminar Flow heat transfer to generalized power law fluids inside circular tubes fitted with regularly spaced twisted tape elements for uniform wall temperature condition”, Fundamentals of Heat Transfer in Non-Newtonian Fluids, ASME, New York, pp. 51–58.
- [8] Al-Fahed S, and Chakroun W, 1996,“Effect of tube -tape clearance on heat transfer for fully developed turbulent flow in a horizontal isothermal tube”, Int. J. Heat Fluid Flow, Vol. 17, No. 2, pp. 173-178.
- [9] Manglik R.M and Bergles A.E, 1992,“Heat transfer enhancement and pressure drop in viscous liquid flows in isothermal tubes with twisted-tape inserts”, Heat and Mass Transfer, Vol. 27, No. 4, pp. 249-257
- [10] Manglik R.M and Bergles A.E, “Application of twisted tape inserts in tubular heat exchangers” ,Heat and Mass Transfer, Vol. 27, No. 4, pp. 249-257.
- [11] Chang S.W, Yang T.L, Liou J.S, 2007. “Heat transfer and pressure drop in tube with broken twisted tape insert”, Experimental Thermal and Fluid Science, Vol. 32, No. 2, pp. 489–501.
- [12] Saha S.K and Mallick D. N., September 2005. “Heat transfer and pressure drop characteristics of laminar flow in rectangular and square plain ducts and ducts with twisted-tape inserts”, Transactions of the ASME, Vol. 127.
- [13] Sivashanmugam, P. and Suresh, S. “Experimental studies on heat transfer and friction factor characteristics of turbulent flow through a circular tube fitted with regularly spaced helical screw tape inserts”, Advances in Energy Research, 2006, 468-473
- [14] SibelGunes, VeyselOzceyhan, OrhanBuyukalaca, “Heat transfer enhancement in a tube with equilateral triangle cross sectioned coiled wire inserts”, Experimental Thermal and Fluid Science 34 (2010) 684–691.
- [15] Rahimi .M, Shabanian S.R., Alsairafi A.A., 2009. “Experimental and CFD studies on

- heat transfer and friction factor characteristics of a tube equipped with modified twisted tape inserts”, *Chemical Engineering and Processing*, Vol. 48, pp. 762–770
- [16] Chang S.W, Yang T.L, Liou J.S, 2007. “Heat transfer and pressure drop in tube with broken twisted tape insert”, *Experimental Thermal and Fluid Science*, Vol. 32, No. 2, pp. 489–501.
- [17] Chang S.W., Jan Y.J, Liou J.S., 2007. “Turbulent heat transfer and pressure drop in tube fitted with serrated twisted tape”, *International Journal of Thermal Sciences*, Vol. 46, No. 5, pp. 506–518.