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# Experimental Study on Heat Transfer Enhancement in a Circular Tube Fitted with 'U'-Cut and 'V'-Cut Twisted Tape Insert

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**Abstract**—
*Experimental investigation of heat transfer and Reynolds number characteristics of circular tube fitted with Classic type Twisted Tape (CTT), U-cut Twisted Tape (UTT) and V-cut Twisted Tape (VTT) with twist ratios, T.R = 6.82, 5.90, 5.00 were studied. The TT inserts when placed in the path of the flow of fluid, create a high degree of turbulence resulting in an increase in heat transfer rate and pressure drop. The work includes the determination of heat transfer coefficient and Nusselt number characteristics for various twisted tapes such as CTT, UTT and VTT with different twist ratios. The Reynolds number is varied from 5000 to 12000. The experimental results indicate that the tube with the various twisted tape inserts provides considerable improvement of the heat transfer rate over the plain tube. The results were compared and the twisted tape with U-cut profile shows better heat transfer enhancement.*
**Keywords**— Heat transfer enhancement; Pressure drop; Classic type Twisted Tape (CTT); U-cut Twisted Tape (UTT); V-cut Twisted Tape (VTT)

## I. Introduction

Heat transfer augmentation techniques are widely used in areas such as heat recovery process, air conditioning and refrigeration systems, and chemical reactors. Passive and active methods of heat transfer augmentation techniques have been discussed by S.S.JOSHI et al. [1]. The passive techniques particularly twisted tape and wire coil insert the economical heat transfer augmentation tools S.S.JOSHI et al. [1]. The heat transfer coefficient and Reynolds number characteristics in a circular tube fitted with different twisted tape inserts were experimentally investigated and correlations for Nusselt number was proposed P. Murugesan et al. [2]. The heat transfer rate, friction factor and thermal enhancement factor in the tube equipped with (UTT) significantly higher than those in the tube fitted with VTT, PTT and plain tube. The additional disturbance and secondary flow in the vicinity of the tube wall generated by the UTT compared to that induced by the PTT.

A. Rahul Kumar, P.N.S. Srinivas et al. [3], experimentally investigated the swirl flow behaviour and the laminar convective heat transfer in a circular tube with twisted tape inserts. For decreasing twist ratio, the twisted tape shows that higher heat transfer coefficient and friction factor increase, because of higher degree of turbulence created. Twisted tape gives higher heat transfer coefficient than the smooth tube.

Dr.A.G. Matani, et al. [4], experimentally studied the twisted tapes are used as swirl flow generators while wire coil along with twisted tapes used as co-swirl flow generators in a test section. The experimental results indicate that the tube with the various inserts provides considerable improvement of the heat transfer rate over the plain tube. Prof. Rahul A. Lekurwale et al. [5], experimentally investigated the effect of different twisted tapes inserts on heat transfer and pressure loss behaviours in a constant heat-fluxed tube. Twisted tapes have been used extensively as a swirl generator to enhance convection heat transfer rate. Bodius salam et al. [6], experimentally investigate the Nusselt number in tube with rectangular-cut twisted tape insert were enhanced by 2.3 to 2.9 times at the cost of increase of friction factors by 1.4 to 1.8 times compared to that of smooth tube. Semi D.Salman et al. [7], numerically investigated the enhancement of heat transfer rate induced by the classical and V-cut twisted tape inserts increases with the Reynolds number and decreases with twist ratio. The results also revealed that the V-cut twisted tape with twist ratio, T.R = 2.93 and cut depth, d = 5 cm offered higher heat transfer rate with significant increases in friction factor than other tapes.

The present work reports the experimental work on heat transfer rate and Nusselt number characteristics of circular tube fitted with CTT, UTT and VTT for twist ratios 6.82, 5.90 and 5.00 with Reynolds number between 5000 and 12000. The experimental results obtained for the circular tube fitted with UTT were also compared with those for the tube fitted with VTT, CTT and the plain tube.

***Nomenclature***

| | | |
|---|---|---|
| $Q$ | Volume flow rate of air | $m^3/s$ |
| $C_d$ | Coefficient of discharge | - |
| $d$ | Orifice diameter | m |
| $\rho_w$ | Density of water | $kg/m^3$ |
| $\rho_w$ | Density of air | $kg/m^3$ |
| $\dot{m}$ | Mass flow rate of air | kg/s |
| $Q_a$ | Heat transfer rate of air | kJ/s |
| $c_p$ | Specific heat | kJ/kg.K |
| $\Delta T$ | Temperature difference | K |
| $h_a$ | Average heat transfer coefficient | $W/m^2.K$ |
| $A$ | Test Section Area | $m^2$ |
| $T_a$ | Average Temperature of air | K |

## II. HEAT TRANSFER ENHANCEMENT WITH TWISTED TAPE

The heat transfer enhancement by using twisted tape is one of the commonly used passive heat transfer enhancement technique. Twisted tapes are the metallic strips twisted with some suitable techniques with desired shape and dimension, inserted in the flow.

Twisted tapes have been used extensively as a swirl generator to enhance convection heat transfer rate in finding the way to reduce the weight, size and cost of heat exchanger systems in several industrial applications such as chemical engineering process, heat recovery process, air conditioning and refrigeration systems, chemical reactors, power plant and nuclear reactor, etc. Tubes with twisted tape insert are also an important group of the continuous swirling flow device that generates twin swirling flow motion over the whole tube length of flow at constant heat transfer coefficient, h and friction factor, f.

The twisted tape is one of the most popular groups because of low cost, low maintenance, low pressure loss and ease of construction. Twisted tapes reduce the dominant thermal resistance of the viscous stream and reduce the required heat transfer surface area. The plain tube fitted with twisted tape provides higher heat transfer rate.

| | | |
|---|---|---|
| $T_s$ | Average Surface | K |
| V | Velocity of air | m/s |
| L | Length of the test section | W |
| Re | Reynolds Number | |
| υ | Kinematic Viscosity | |
| μ | Absolute Viscosity | |
| $Nu_{actual}$ | Actual Nusselt Number | |
| $Nu_c$ | Correlated Nusselt Number | |
| k | Thermal Conductivity | |
| Pr | Prandtl Number | |
| $D_i$ | Inner diameter of the test | |
| $D_o$ | Outer diameter of the test | |

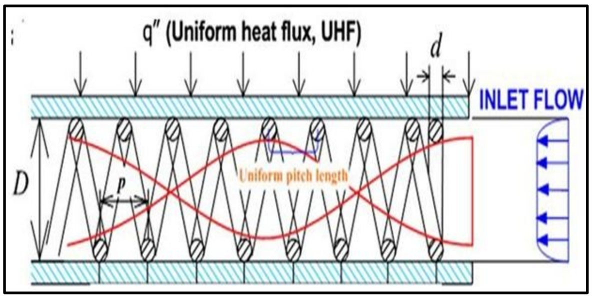



Fig 1. Test Section Fitted with Twisted Tape.

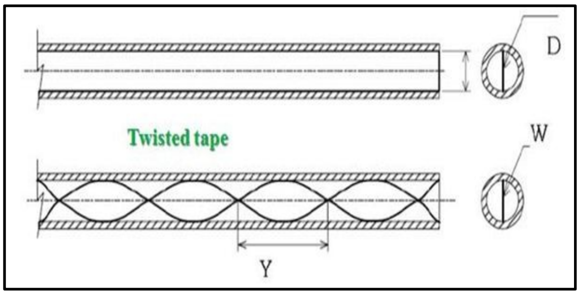
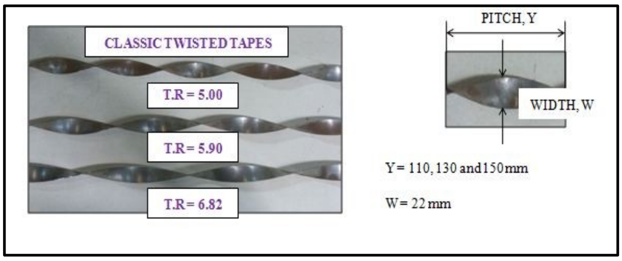



Fig 2. Twisted Tape Geometry.

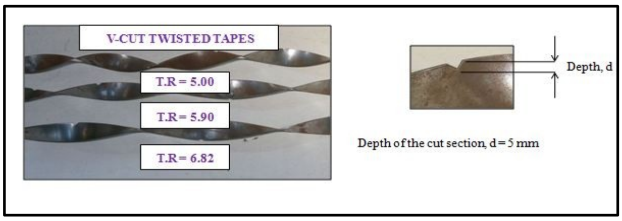
Fig 1 and 2 shows the geomerical view of twisted tape inserted into a circular tube in which air is passed with uniform heat flux conditions.

## III. Fabrication of Twisted Tapes

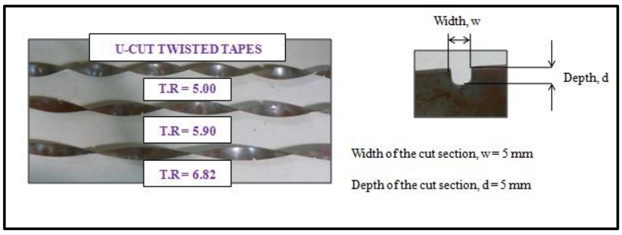
The mild steel strip of length 605 mm, width 22 mm and thickness 1 mm were taken. Holes were drilled at both ends of every tape so that the two ends could be fixed to the metallic clamps. Desired twist was obtained using a lathe machine. One end was kept fixed on the tool post of the lathe while the other end was given a slow rotatory motion by rotating the chuck side. During the whole operation the tape was kept under tension by applying a mild pressure on the tool post side to avoid its distortion. Three twisted tapes (Classic type, U-cut and V-cut) with varying twists ratios (T.R = 6.82, 5.90 and 5.00) were fabricated.




(a) Classic Twisted Tape (CTT)




(b) V-Cut Twisted Tape (VTT)




(c) U-Cut Twisted Tape (UTT)

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Fig 3. Geometries of twisted tapes with twist ratios, T.R = 6.82, 5.90 and 5.00 (a) CTT (b) VTT (c) UTT.

## IV. EXPERIMENTAL SETUP

The Schematic diagram of the experimental setup is shown in Fig 4. In this present work, 'Forced Convection Apparatus' has been used as the experimental setup. The experimental setup consisted of an inlet section, a test section, an air supply system (Electric blower) and a heating arrangement. The tube shaped inlet section; 500 mm long was made as an integral part of the test section to avoid any flow disturbances upstream of the test section and to get fully developed flow in the test section as well.

The plain tube (test section) was made of mild steel having 28 mm inside diameter, 38 mm outside diameter and 500 mm length. The Classic type, U-cut and V-cut twisted tapes were prepared of mild steel with three different twist ratios, TR = 6.82, 5.90 and 5.00. The twist ratio 'TR' was defined as the ratio of one twist (pitch, P) to the width of the twisted tape.

Nichrome wire (resistance $1.2 \times 10^{-6}$ Ω.m) was used as an electric heater to heat the test section at a constant heat flux condition. Nichrome wire was spirally wounded uniformly around the tube. The temperature of the test section for different air flow rates have been obtained from temperature indicator by adjusting desired heat input with the help of voltmeter and ammeter, at an interval of 10 minutes until the steady state is reached. The air flow rates have been measured from manometer reading. From the measured parameters, the heat transfer coefficient, Nusselt number and pressure drop have been determined.

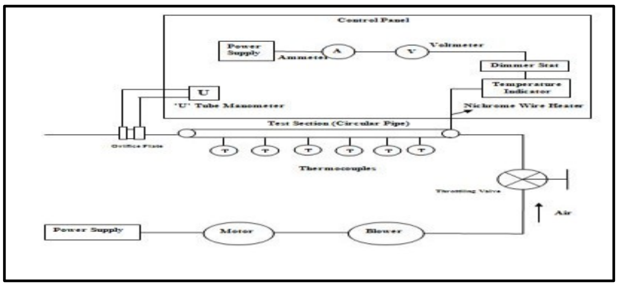


Fig 4. Schematic diagram of the experimental setup.

## V. DATA REDUCTION

I. Volume flow rate, Q

$$Q = C_d * \frac{\pi}{4} d^2 * \left(\sqrt{(2gH) * \left(\frac{\rho_w}{\rho_a}\right)}\right) * 3600$$

II. Mass flow rate, ṁ

$$\dot{m} = Q * \rho$$

III. Heat transfer rate, $Q_a$

$$Q_a = \dot{m} * c_p * \Delta T$$

IV. Average heat transfer coefficient, $h_a$

$$h_a = \frac{Q_a}{A\,(T_s - T_a)}$$

V. Velocity of air, V

$$V = \frac{Q}{\left(\frac{\pi * D_i^2}{4}\right)}$$

VI. Reynolds Number, Re

$$Re = \frac{V * D_i}{v}$$

VII. Actual Nusselt Number, $Nu_{actual}$

$$Nu_{actual} = \frac{h_a * D_i}{k}$$

VIII. Prandtl Number, Pr

$$Pr = \frac{c_p * \square}{k}$$

IX. Correlated Nusselt Number, $Nu_c$

$$Nu_c = 0.023 * ((Re) \wedge 0.8) * ((Pr) \wedge 0.4)$$

(By using Dittus-Boelter correlation)

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## VI. RESULTS AND DISCUSSION

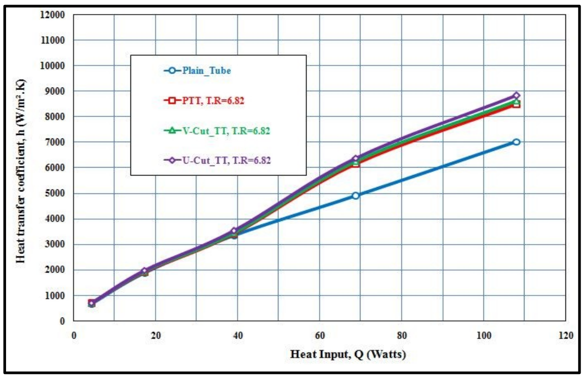


Fig 5. Heat input Vs Heat transfer coefficient comparison for various Twisted Tapes with twist ratio = 6.82.

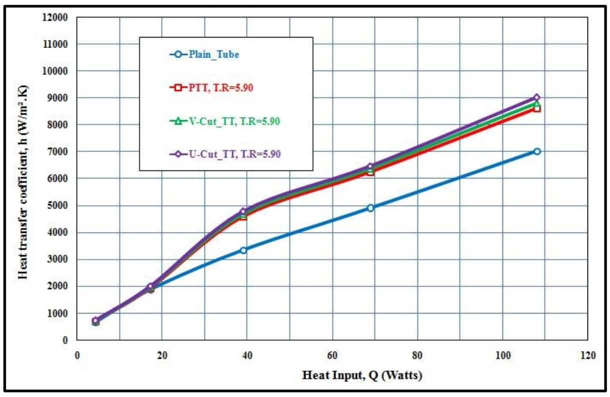


Fig 6. Heat input Vs Heat transfer coefficient comparison for various Twisted Tapes with twist ratio = 5.90.

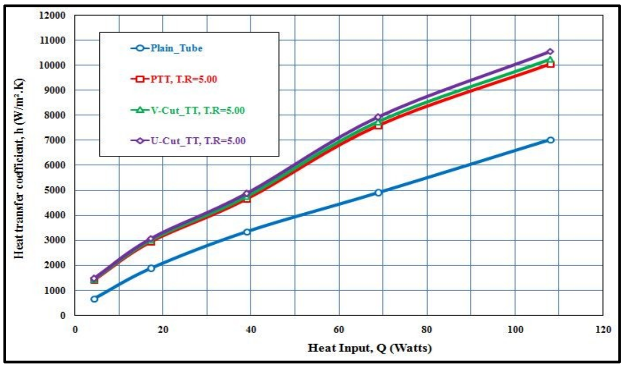


Fig 7. Heat input Vs Heat transfer coefficient comparison for various Twisted Tapes with twist ratio = 5.00.

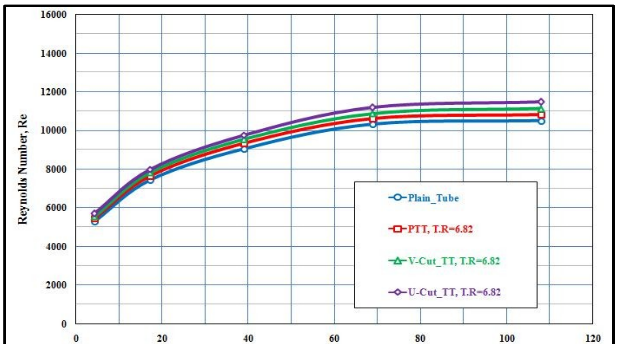


Fig 8. Heat input Vs Reynolds Number comparison for various Twisted Tapes with twist ratio = 6.82.

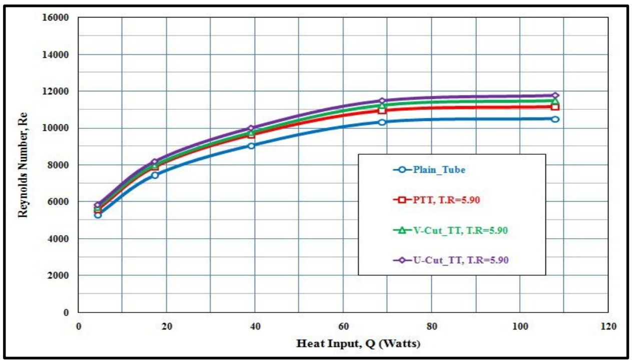


Fig 9. Heat input Vs Reynolds Number comparison for various Twisted Tapes with twist ratio = 5.90.

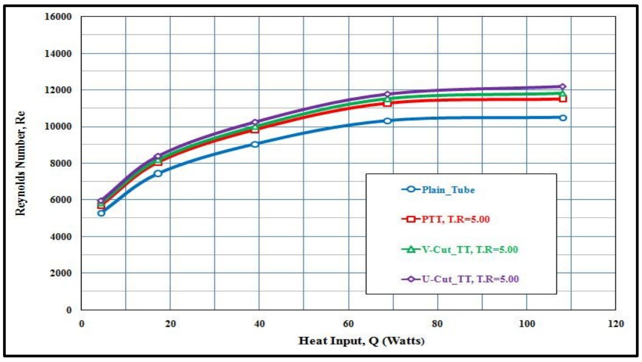


Fig 10. Heat input Vs Reynolds Number comparison for various Twisted Tapes with twist ratio = 5.00.

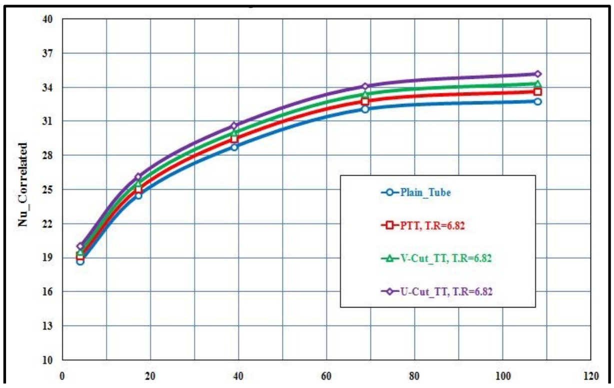


Fig 11. Heat input Vs Nusselt Number correlated comparison for various Twisted Tapes with twist ratio = 6.82.

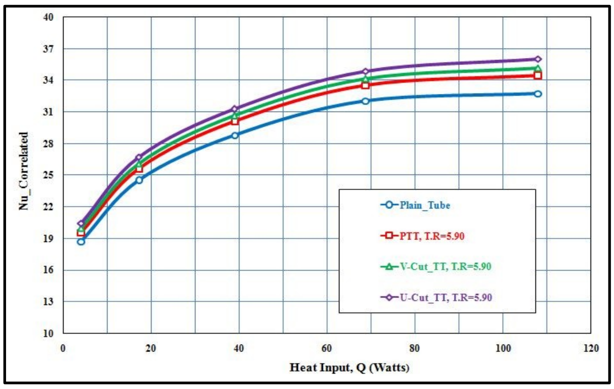


Fig 12. Heat input Vs Nusselt Number correlated comparison for various Twisted Tapes with twist ratio = 5.90.

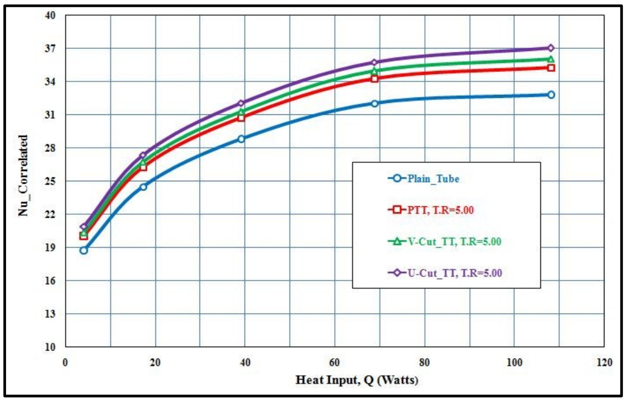


Fig 13. Heat input Vs Nusselt Number correlated comparison for various Twisted Tapes with twist ratio = 5.00.

From the Fig 5, 6, 7 it was inferred that all the three types of types of twisted tapes taken for analysis shows better heat transfer characteristics for the twist ratio = 5. Among the same twist ratio, U-cut twisted tape shows highest heat transfer coefficient when compared to other two types of TT taken for analysis. From the Fig 8, 9, 10 the better turbulence effect was observed in U-cut TT for the twist ratio = 5 due to its highest Reynolds number. From the Fig 11, 12, 13 it can be observed that Nusselt number correlation value increases linearly with Reynolds number and heat transfer coefficient. Finally from the experimental results it is inferred that with the decrease in twist ratio the heat transfer characteristics are enhanced. This increase in heat transfer may be due to swirl. The swirl may have caused the boundary layer to breakup causing increased heat transfer. Among the TT inserts U-cut profile shows best heat transfer enhancement this may be due to the fact that air flow through U-cut may have disrupted the swirl and caused turbulence in the swirl which would have broken the boundary layer leading to better heat transfer.

## VII. CONCLUSION

Studies on the heat transfer and Nusselt number characteristics in a circular tube fitted with Classic type, U-cut and V-cut twisted tape for various twist ratio has been done experimentally. The results indicate that the Nusselt number increases with decrease in the twist ratio. The results were compared and the twisted tape with U-cut profile shows better heat transfer enhancement. This increase in heat transfer may be due to turbulence created by the U-cut profile which breaks the boundary layer thereby enhancing heat transfer.

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