Experimental Study on Heat Transfer Enhancement in A Circular Tube Using Twisted Tape Insert

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Abstract- *A method which is used to improve the overall performance of the system with increasing the rate of heat transfer is known as Heat transfer enhancement techniques. These techniques are used in heat exchangers. These techniques broadly are of three type's namely active, passive and compound technique. In this work, passive enhancement techniques were studied. Passive heat transfer enhancement methods as stated does not need any external power input. Enhancement of heat transfer is achieved by inserting enhancing element like Twisted Tape (TT), ribs, baffles, wire coils, plates and rough surfaces. In this experimental study, heat transfer enhancement using twisted tape is studied. The twisted tape with classic type, U-CUT and V-cut profiles with different twist ratios are studied for its heat transfer coefficient. The results were compared and the twisted tape with U-cut profile shows the better heat transfer enhancement.*

Keywords- heat exchanger, enhancement, twisted tape inserts, three different twisted ratios of twisted tape inserts, heat transfer coefficient.

I. INTRODUCTION

This Using passive techniques in order to enhance heat transfer characteristics in heat exchanger has been an interesting topic for scientists and researchers during recent decades. Numerical and experimental studies have been conducted in order to improve heat transferred by these techniques. The demand for reduction of the cost and dimensions of heat exchanger has motivated the searchers to investigate different ways of heat transfer enhancement. Passive heat transfer enhancement techniques are mostly preferred due to their simplicity and applicability in many applications. Furthermore, in passive techniques, there is no need for any external power input except to move the fluid.

The devices in this category include surface coating, rough surfaces, extended surfaces, turbulent/swirl flow devices, convoluted (twisted) tube, and tube inserts. Various kinds of inserts have been employed in the heat exchangers such as helical/twisted tapes [1, 2], coiled wires [3–5], ribs/fins/baffles [6–8], and winglets [9, 10]. Enhanced tubes with different inserts are used extensively in the refrigeration, air-conditioning, and commercial heat pump industries as well as in the chemical, petroleum, and numerous other industries. Using inserts in tubular heat exchangers not only reduced the heat exchanger size but also provided thermal, mechanical, and economic advantages in heat exchangers. The quantities of the two fluids resident in heat exchangers, as an important safety consideration, have been greatly decreased by compact enhanced designs. The devices in this category include surface coating, rough surfaces, extended surfaces, turbulent/swirl flow devices, convoluted (twisted) tube, and tube inserts. Various kinds of inserts have been employed in the heat exchangers such as helical/twisted tapes, coiled wires, ribs/fins/baffles, and winglets. Enhanced tubes with different inserts are used extensively in the refrigeration.

The heat transfer coefficient improvement capability besides a minimum loss in friction factor defines the thermo hydraulic performance of an insert. Tube inserts have been utilized for heat transfer enhancement and fouling mitigation in different industrial fields such as petroleum refineries and chemical plants for several years. In this paper, the literature reviews are classified into louvered strip insert twisted tape, swirl flow devices insert, wire coil insert, conical ring insert, winglet-type vortex generators, and brush and pin elements inserts

Improving heat exchanger performance brings beneficial effects for industrial and engineering applications including compactness, the economy in manufacturing and operating costs as well as energy conservation. This strongly motivates research in heat transfer enhancement [1]. Turbulence flow generator is one of the techniques for increasing the composite velocity, making the eruption of the thermal boundary layer, enhancing the tangential and radial turbulent fluctuation, and therefore causes the increase in the heat transfer inside a heat exchanger tube [2-10]. Helical screw tapes (HST) have been used to introduce a swirl or turbulent near the tube wall which results in more efficient fluid mixing between near wall and core regions. The tapes were extensively modified for heat transfer enhancement such

as regularly-spaced helical tape [11-13], helical screw-tape with/without core-rod [14, 15].
The open literature showed that modified HSTs gave a broad range of heat transfer results depending on their geometries and operating conditions. Sivashanmugam and

Suresh [12] reported that regularly-spaced HSTs offered better results for heat transfer enhancement than conventional HSTs since they caused significantly lower friction factor with an only moderate decrease of Nusselt number as compared to those given by the conventional HSTs for both low and high

Reynolds number regions. Numerical results by Zhang et al. [15] revealed that HST with four different widths (w = 7.5 mm, 12 mm, 15 mm and 20 mm) gave overall heat transfer coefficients around 212% to 351% higher than that in plain tubes, accompanied by 33% to 1020% friction factor increase. The thermal performance value of the HST inserts of different width varied between 1.58 and 2.35. Sivashanmugam and Nagarajan [16] and Jaisankar et al. [18] proved that the heat transfer coefficients and thermal performance factors given by right-left HST inserts were higher than those given by conventional HST. This led to poorer overall result notified by the lower thermal performance factor. In addition, a width ratio increased, both heat transfer coefficient and pressure drop were considerably increased. However, due to the poorer trade-off between the increases of heat transfer coefficient and pressure drop, lower thermal performance factor was consistently obtained at the conditions possessing higher heat transfer coefficient.

Although HSTs have been extensively modified, coupling rib turbulators with conventional HST has not been reported, so far. In common, ribs are adapted to form artificial rough-ness, which provide heat transfer enhancement by generating vortices [23]. Therefore, the coupling ribs with HST is likely to give the combined effect of common swirl and vortex in the flow which should give rise to the stronger turbulent intensity and thus better fluid mixing as compared to those given by HST or ribs alone. This motivates the study on heat transfer enhancement associated with the helical screw tape coupled with rib tabulators (HST-R). In the present study, ribs were mounted on helical tapes at different rib-pitch ratios (p/D) of = 1.0, 2.0, and 3.0 and rib-height ratio (e/W) was varied between 0.5 and 1.5. Air was used as the testing fluid under uniform wall heat flux condition.

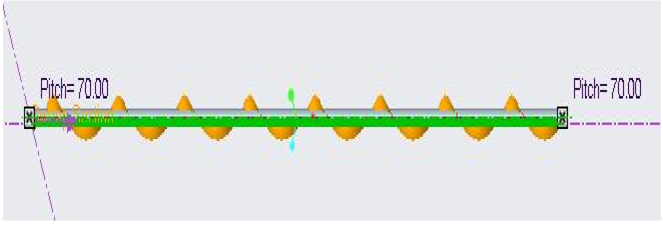

Fig 1. Helical Twisted Type

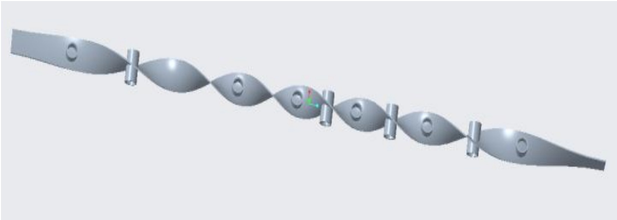

Fig 2. Twisted tape with ribs

Table 1. Specifications of Fabricated Material

specification	Helical tape	Twisted tape with rib
length	500mm	500mm
Width	20mm	20mm
Diameter	8mm (rod)	5mm (rib)
Helical height	6mm	-
Rib height	-	20mm
Twist ratio	6.82,5.90,5.00	6.82,5.90,5.00

II. EXPERIMENTAL SETUP

The experiment set up and the various measuring devices are used in the analysis is shown in the figure 3. The apparatus has a set of units which all together work as a setup and its main components are the ammeter, voltmeter, manometer and a blower unit fitted with the test pipe. The test pipe is heated by the help of a nichrome heater where test section is surrounded by the heater. Six thermocouples are embedded in the test section and two thermocouples are placed in the inlet and out of the test section. T2, T3, T4, T5 are placed between the inlet and outlet of the test pipe along with the blower. Source of the heater is given in units power and it's measured by ammeter and voltmeter. It's also noted only a part of the total heat supplied is utilized in heating the air. an indicator is used to measure the heat is known as a thermocouple and it helps in measuring the six temperature which is embedded in the test section. The flow of air in a pip is measured with the help of u-tube manometer and an orifice meter which is fitted in the board along with the pipe. To change the air flow rate in the test section a valve is placed in the outlet of the pipe. Meanwhile to change the pressure drop in the test section a valve is placed in the inlet of the pipe. Then to minimize the heat loss in the test section, the outer surface is well insulated, thus leakage is avoided in surroundings.

Fig 3. Forced convection apparatus

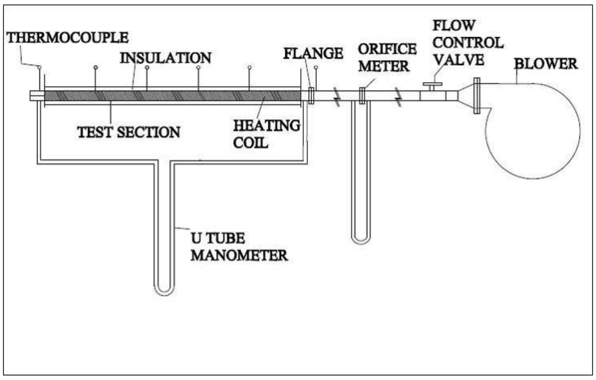

Fig 4. Line diagram of Apparatus

Procedure

Table 1: specification of forced convection apparatus

Pipe outer diameter, D_o	38mm
Pipe inner diameter, D_i	28mm
Length of the test section, L	500mm
Blower	0.28 hp motor
Orifice diameter, d	14mm
Temperature indicator	0-300° c
Ammeter	0-2 A
Voltmeter	0-100/200 V
Dimmer stat	2A/260V
Heater Nichrome wire heater wound on the test pipe	400W

First of all, the blower was started then flow control valve was operated to get a required deflection on manometer which was connected to orifice meter to get desired value of Reynolds number. Then constant heat was supplied to the test section by giving current supply to the heating coil wound around the test section. The electrical output is controlled by adjusting the dimmer stat. The readings of the thermocouples were observed every 5 minutes until the steady state condition was achieved. After achieving the steady state inlet temperature, outlet temperature and surface temperature were recorded. The experiment was performed for different Reynolds number (5000-25000). Initially, the experiment was carried out for the plain tube. Then the experiment was carried out for a different twisted tape of twist ratio 6.82,5.90,5.00 insert alternately for the same flow conditions. The width of twisted tapes used is 20mm. Each insert was taken and inserted into test section axially through one end. It is taken care that the strip doesn't scratch the inner side of the test section and get deformed. The fluid properties were calculated as the average between the inlet and outlet bulk temperature**.**

III. DATA REDUCTION

1.The rate at which air is getting heated

$$q_a = mc_p\,\Delta t$$

$$m = Q \times \rho_a$$

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

2. average heat transfer coefficient

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

3. area

$$A = \pi D_i L$$

4. Reynolds number

$$R_e = \frac{V \times D_i}{\vartheta}$$

5. Velocity

$$V = \frac{Q}{\frac{\pi}{4} \times D_i^{\,2}}$$

$$T_s = \frac{T2 + T3 + T4 + T5}{4}$$

$$T_a = \frac{T1 + T6}{2}$$

$$\Delta T = T6 - T1$$

6. Actually nusselt number

$$Nu_a = \frac{h_a \times D_i}{K}$$

7. Corrected nusselt number

$$Nu_c = 0.023 \times R_e^{\,0.8} \times P_r^{\,0.4}$$

8. Prantl number

$$P_r = \frac{C_p \times \mu}{K}$$

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IV. RESULTS AND DISCUSSION

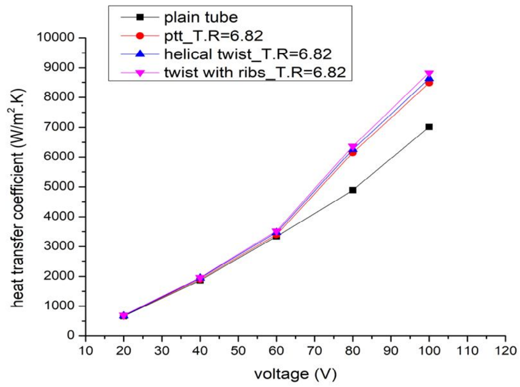

Fig 5. The plot between Voltage (V) and Heat transfer Co-efficient for twisted ratio 6.82

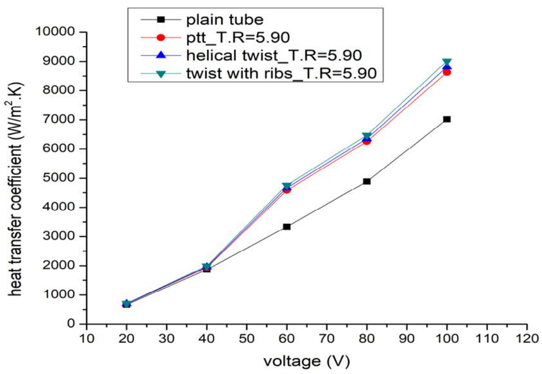

Fig 6. Plot between Voltage (V) and Heat transfer Co-efficient for twisted ratio 5.90

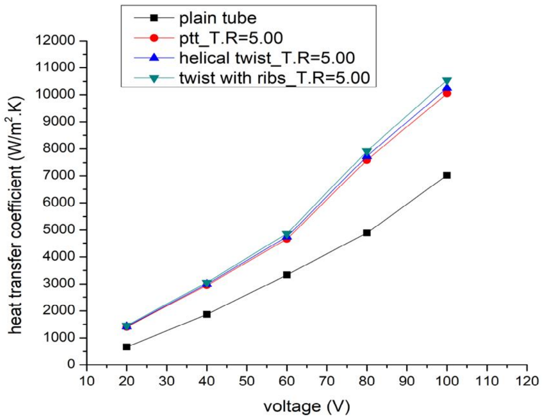

Fig 7. Plot between Voltage (V) and Heat transfer Co-efficient for twisted ratio 5.00

From the Fig 5,6,7, its observed that the twisted tape with ribs shows the better and highest heat transfer coefficient for the twist ratio = 5.90. among the various types of twisted tapes, classic type twisted tape shows lowest heat transfer coefficient. But its also inferred that heat transfer coefficient increases for all twisted tapes with twist ratio =5.90, when compared to plain tube

Discussion

From the fig 5,6,7 it was inferred that all three 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 tapes shows highest heat transfer coefficient when compared to other two types of TT taken for analysis. From the fig, the better turbulence effect was observed in U-cut TT for the twist ratio= 5 due to its highest Reynold‘s number. From the fig, 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 turbulence created by the U-cut profile which breaks the boundary layer thereby enhancing heat transfer.

V. CONCLUSION

The value of heat transfer coefficient was investigated with the flow in a circular tube fitted with twisted tape inserts with two different configurations. Experimental investigation of enhancement of heat transfer, heat transfer coefficient characteristics of a circular tube fitted on different twist ratio with twisted tape inserts has been studied. The heat transfer enhancement took place with an increase of Reynolds number. Heat transfer can be observed with plain smooth tube records were enhanced from 7% to 10% of the twisted tube heat transfer fitted in the concentric circular tube. The data obtained from the experimental value of twisted tape friction factor was decreased 2% to 6% as compared to the plain tube. The enhancements heat transfer twisted tape was achieved by due to the swirl flow action obtained with concentric tubes.

The results were compared and the twisted tape with ribs shows better heat transfer.

NOM*ENCLATURE*

f	Friction Factor
H	Heat Transfer Coefficient
Nu	Nusselt Number
Re	Reynolds Number
ΔP	Pressure drop
Q	Heat transfer rate
M	Mass flow rate of air
T_s	Surface Temperature
T_b	Bulk Temperature
C_d	Coefficient of discharge (0.64)
H_W	Head in meters of water
m	dynamic viscosity of air
K	Thermal conductivity of the air
Pr	Prandlt number
A	Surface area of
ρ_w	Density of water (1000 kg/m³)
ρ_a	Density of air(1.03 kg/m³)
C_p	Specific heat of air
q_a	Heat supplied

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