

# Experimental Investigation of Heat Transfer Performance of Groove Twisted Tape Inserts



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## ABSTRACT

The need to increase the thermal performance of heat transfer equipment, thereby effecting energy, material, and cost savings as has led to the development and use of many heat transfer enhancement techniques. These methods are referred to as augmentation or intensification techniques. The augmentation techniques categorised by two types such as active techniques & passive technique. In present study we used passive techniques such as grooved twisted tapes which having varying twisted ratios and wave width. This study deals with the analysis of heat transfer augmentation for air flowing through circular tube as test tube. In this experimental work we used forced convection set-up to find the values of heat transfer performance with twisted tapes of aluminium and copper material with various twisted ratios.

**Keywords:** fluid flow, twisted tape, heat transfer, grooved twisted tape etc.

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## I. INTRODUCTION

In the recent years, due to limited availability of energy resources and ever increasing cost of the same, the use of different techniques to augment the heat transfer has been one of the active research areas. The enhanced surfaces in the heat exchangers are often suggested to augment the heat transfer and different active and passive techniques are recommended for this purpose. One of the passive techniques to enhance the heat transfer is the application of insertion devices such as twisted tapes. The use of these devices is one of the most common techniques to enhance the heat transfer because of the easy installation and relatively low cost of these devices. On the other hand, the inserts increase the pressure drop across the heat exchangers as well. Which is undesirable, as the higher pressure drop leads to more power consumption for the circulation of working fluid. The evaporator is an integral part of any refrigeration and air-conditioning system and development of high performance heat exchanger with the least pressure drop is often one of the primary design objects. In the present work, heat transfer

enhancement for fluid flowing through a test tube with twisted tape inserts is to be analyzed using forced convection experimental set-up. In present study, we deals with smooth tube, aluminium and copper twisted tape inserts with available twisted ratios such as 8.33, 9.79, 9.375, 10.42 wave width such as 13 mm, 16 mm, 24 mm.

## II. LITERATURE SURVEY

### A. Classification of Augmentation Techniques

The various enhancement techniques [1,2] can be classified broadly as **passive** and **active** techniques. Passive techniques do not require direct input of external power, unlike active techniques. They generally use surface or geometrical modifications to the flow channel, or incorporate an insert, material, or additional device. Except for extended surfaces, which increase the effective heat transfer surface area, these passive schemes promote higher heat transfer coefficients by disturbing or altering the existing flow behaviour. This,

however, is accompanied by an increase in the pressure drop. In the case of active techniques, the addition of external power essentially facilitates the desired flow modification and improvement in the rate of heat transfer. The use of two or more techniques (passive and/or active) in conjunction constitutes *compound augmentation techniques*. The effectiveness of any of these methods is strongly dependent on the mode of heat transfer (single-phase free or forced convection, pool boiling, forced convection boiling or condensation, and convective mass transfer), and type and process application of the heat exchanger.

### B. Performance Evaluation Criteria

Besides the relative thermal-hydraulic performance improvements brought about by the enhancement devices, there are many factors [2] that should be considered to evaluate the performance of particular heat transfer equipment. They include economic (engineering development, capital, installation, operating, maintenance, and other such costs), manufacturability (machining, forming, bonding, and other production processes), reliability (material compatibility, integrity, and long-term performance), and safety, among others. The assessment of these factors, as well as the enhanced convection performance, is usually application driven. In most practical applications of enhancement techniques, the following performance objectives, along with a set of operating constraints and conditions, are usually considered for optimizing the use of a heat exchanger. **Eiamsa-ard et al.** [3] carried out an experimental investigation on heat transfer and friction factor characteristics in a double-pipe heat exchanger fitted with regularly spaced twisted tape insert. Two types of tube inserts consisting of a full-length typical twisted tape at different twisted ratios and a twisted tape with various free space ratios were used in their experiments. Their results showed that the heat transfer coefficient increased by decreasing the twist ratio. However, they illustrated that decreasing the free space ratio can increase both the heat transfer coefficient and friction factor. The operational performances of these inserts were compared experimentally and theoretically with that obtained from the classic twisted tape insert. **S. Eiamsa-ard et al.** [5] reported the details of the turbulence modeling to help in understanding of the behaviors of the incompressible swirl flows for tube fitted with the loose-fit twisted tapes in comparison with those for a tube equipped with tight-fit twisted tapes. In this work, the standard  $k-\epsilon$  turbulence model, the Renormalized Group (RNG)  $k-\epsilon$  turbulence model, the standard  $k-\omega$  turbulence model, and the Shear Stress Transport (SST)  $k-\omega$  turbulence model, were performed to study the phenomena of flow field (velocity vector and streamline), temperature field, pressure field and turbulent intensity (TKE) in a tube with twisted tape inserts. Similar works were carried out with different inserts. Heat transfer enhancement in a channel due to the presence of a triangular prism was obtained using numerical simulation [6]. The order of enhancement was about 15%. However, as expected, the augmentation was associated with enhanced skin friction. **Zhang et al.**[7] investigated the heat transfer characteristics of a helically baffled heat exchanger combined with a finned tube experimentally and theoretically.

### IV. AIM & OBJECTIVE

The current literature shows the lack of study in the area of twisted tape insert. Hence results were varying continuously according to different parameters. In this paper the experimental result is compared with and without the groove twisted tape inserts and solve systematically. The aim of the study was to determination of friction factor and Nusselt number for smooth tube and for aluminium & copper groove twisted tape inserts with varying twist ratios and wave-widths.

Hence the objectives of this experiment are as following:

1. Determination of friction factor and Nusselt number for smooth tube and for various groove twisted tape inserts with varying pitches and wave-widths.
2. To observe the effect of varying twists and wave-widths, another set of graphs are plotted for copper inserts and smooth tube.
3. Comparing results of groove twisted tape with plane tape.
4. To plot the comparison graph of aluminium & copper insert.
5. To find better grooved twisted tape than plane tape.

### III. PRESENT EXPERIMENTATION

The experimental study on passive heat transfer augmentation using groove twisted tape inserts for varying twist ratio and wave-width with copper as a material were carried on in a single phase flow heat exchanger having the specifications as listed below:-

#### A. Specifications of set up:

- 1 Inner diameter of pipe = ( $d_o$ ) = 0.026 m.
- 2 Outer diameter of pipe = ( $d_i$ ) = 0.03 m.
- 3 Length of test section =  $L = 0.7$ m.
- 4 Voltmeter = 0-200 V; ammeter 0-2 amp.

Nichrome wire (resistivity =  $1.5 \times 10^{-6} \Omega m$ ) heater wound around test pipe.



Fig.1 Experimental set up for forced convection

#### B. Specifications of inserts:

- Width of tape,  $W = 24$ mm (Constant)
- Thickness of inserts,  $t = 1$ mm (Constant)

- Twist ratios, TR = 8.33, 8.83, 9.375, 9.79 & 10.42
- Length of insert, L = 700 mm (Constant)
- Wave-width, WW = 13, 16 & 24 mm
- length = 10mm

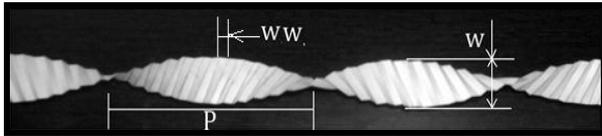


Fig.2.Groove Twisted tape inserts

The apparatus consist of a blower unit fitted with the test pipe. The test section is surrounded by nichrome heater. Six thermocouples are embedded on test section and two thermocouples are placed in the air stream at the entrance and exit of test section to measure air temperatures. Test pipe is connected to the delivery side of the blower along with the orifice to measure flow of air through the pipe. T1 measures inlet air temp & is indicated by Digital Voltmeter (DV) on the front panel. The thermocouple no 8 is used for measuring outlet air temperature. The thermocouples T2 to T7 are used

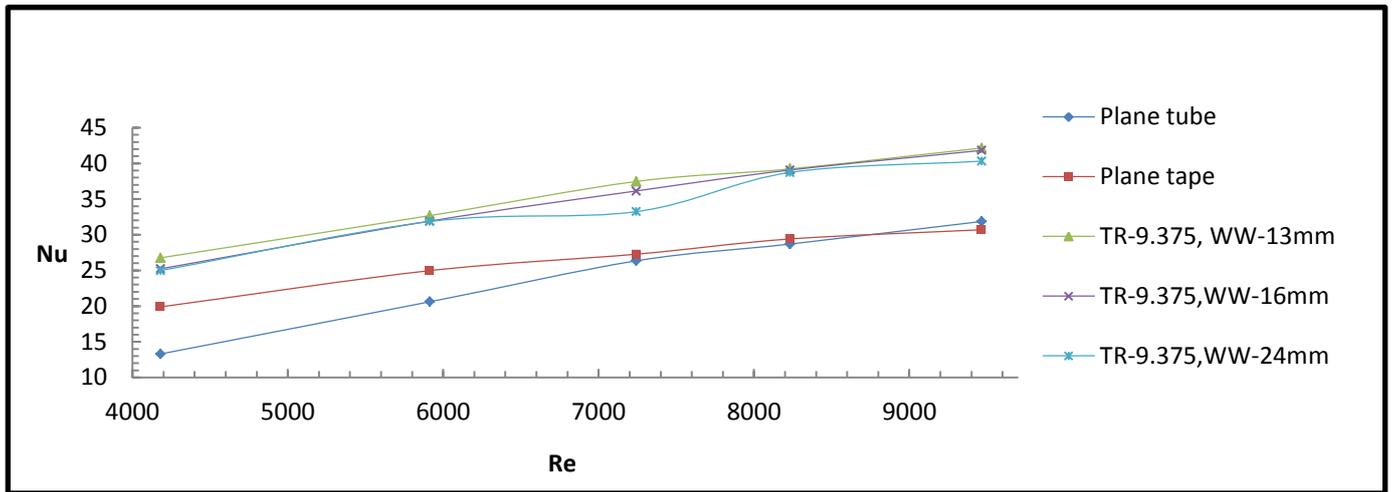
to measure surface temperature of test section. The power control unit uses an isolating transformer for stepping down mains voltage to 130 volts AC & get controlled DC output in the range 0-150 volts using uni junction transistor(UJT), pulse transformer & Silicon Controlled Rectifier (SCR) circuit & capacitive filter. The heater power is necessarily DC. The voltage signals (V) for measurement is obtained by means of a potential divider & current signal (I) is obtained by measuring the voltage drop across a small resistance. This current is measured by means of an ammeter on the front panel & for voltage measurement test points are provided below the ammeter. The output can be controlled by means of potentiometer. The ground is internally connected.

Table.1 Observation table without insert

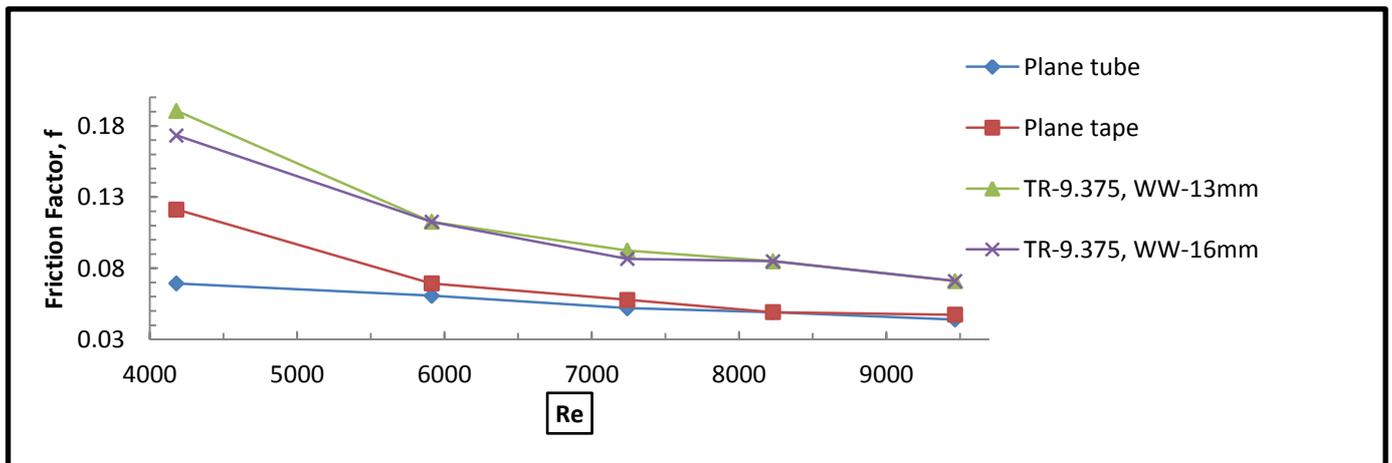
Sr No.	Temperatures °C								Manometer Difference	Inclined Manometer Reading
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	T <sub>6</sub>	T <sub>7</sub>	T <sub>8</sub>		
1	32.7	42.6	48.9	52.6	56.8	57.6	54.3	40.3	41	3.25

**Table 2.** Observation table with copper insert

Sr No.	Temperatures °C								Manometer Difference $h_w$	Inclined Manometer Reading $h_f$
	T <sub>1</sub>	T <sub>2</sub>	T <sub>3</sub>	T <sub>4</sub>	T <sub>5</sub>	T <sub>6</sub>	T <sub>7</sub>	T <sub>8</sub>		
1	31.9	40.8	45.8	48.1	50.7	50.9	49.2	40.7	41	5



**Fig. 2** Comparison of Nu for same pitch & varying wave width Al inserts



**Fig. 3** Friction factor comparison for same pitch & different wave-width Al inserts

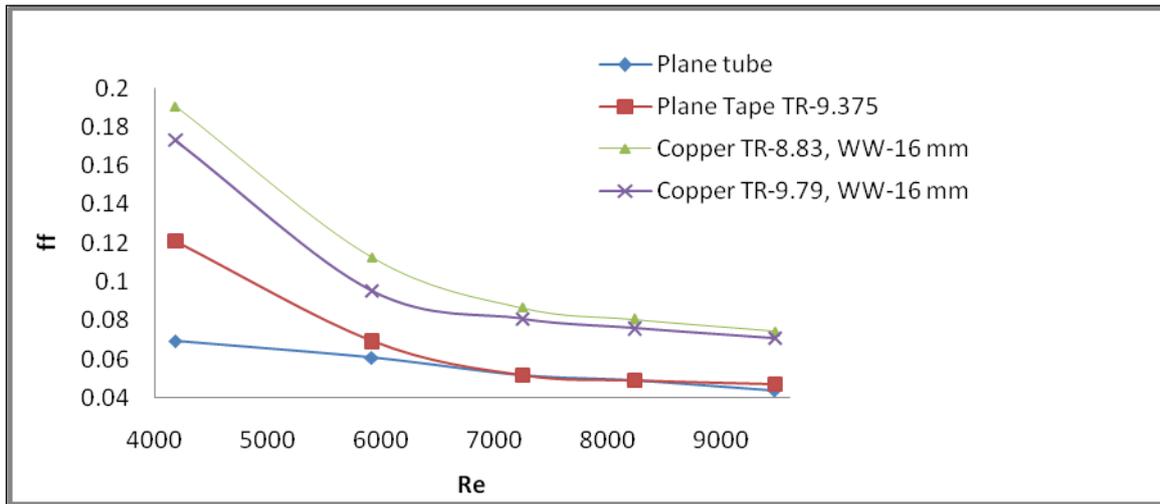


Fig.4. Friction factor comparison for Cu inserts.

V. CALCULATIONS AND GRAPHS

A. Parameters of heat transfer from circular tube without insert

As per the observation table 1 experimentation was carried out and temperature and manometer difference values obtained. This manometer difference indicates change in mass flow rate operated by the valve next to the test section, this increase in manometric head indicates increase in mass flow rate and this causes increase in Reynolds number. As Reynolds number increases the friction factor has to reduce. As per calculations the values of parameters are obtained as follows.

$$Q_a = 0.003813 \text{ m}^3/\text{s}, \text{ Re} = 10963.77, f_{th} = 0.0306417, \text{ Nu}_{th} = 35.16, f_{exp} = 0.0327, \text{ Nu} = \frac{hD}{k\text{Nu}_{exp}} = 36.34$$

B. Sample observation and result table of copper insert with TR-8.83, WW-16 mm

As shown in observation table no. 2 and graphs, Reynolds number increases then friction has to reduce, then at lower Reynolds number the friction factor is high however as the Reynolds number increases the friction factor drops as compared to the initial value. The Nusselt number increases with the increase in Reynolds number which indicates that heat transfer enhancement takes place at higher Reynolds number.

The observation table 3 gives the value of friction factor, Nusselt number after inserting copper insert with twisting ratio 8.33 and wave width 16 mm

Values given below as per calculation,

$$Q_a = 0.003292 \text{ m}^3/\text{s}, V = 6.2003 \text{ m/s}, \text{ Re} = 9466, f_{exp} = 0.06764, \text{ Nu} = \frac{hD}{k}, \text{ Nu}_{exp} = 51.12$$

The result table of grooved twisted tapes with heat transfer performance characteristics are as given below:

Table 3. Showing mass flow rate, friction factor and Nusselt number of copper insert with TR-8.83, WW-16 mm

Re	m (kg/s)	f	Nu
9466.089	0.003737	0.074405046	52.23847
8231.131	0.003249	0.080514551	48.7037
7242.43	0.002859	0.086664968	45.88915
5913.419	0.002334	0.112664459	41.59408
4181.419	0.001651	0.19066293	34.02182

VI. RESULT & DISCUSSION

A).The parameters mentioned in the above objectives are achieved by carrying out the experimentation and then making the comparisons of them for varying twist ratios and wave widths in the graphs drawn below. The Nusselt number, friction factor are the important parameters which decides the success of any experimentation work as both parameters are opposite to each other. The Nusselt number shows the percentage increase in heat transfer enhancement when inserts are placed inside a test pipe due to increase in heat transfer coefficient by comparing it, without inserts. Contradictory to it is when inserts are placed inside the test pipe the friction gets produced inside the test pipe due to which there is drop in pressure hence the desired increase in heat transfer coefficient is offset by pressure drop. Hence, the inserts should be designed in such a way that their pumping cost should get offset by heat enhancement. From figure 1-4 observed that, when

inserts are placed it is been observed that friction factor for Copper increases by only upto 2 times than smooth tube for TR-9.79 & WW-16mm. Copper inserts shows better result in terms of friction factor than smooth tube, hence insert with Copper is preferred.

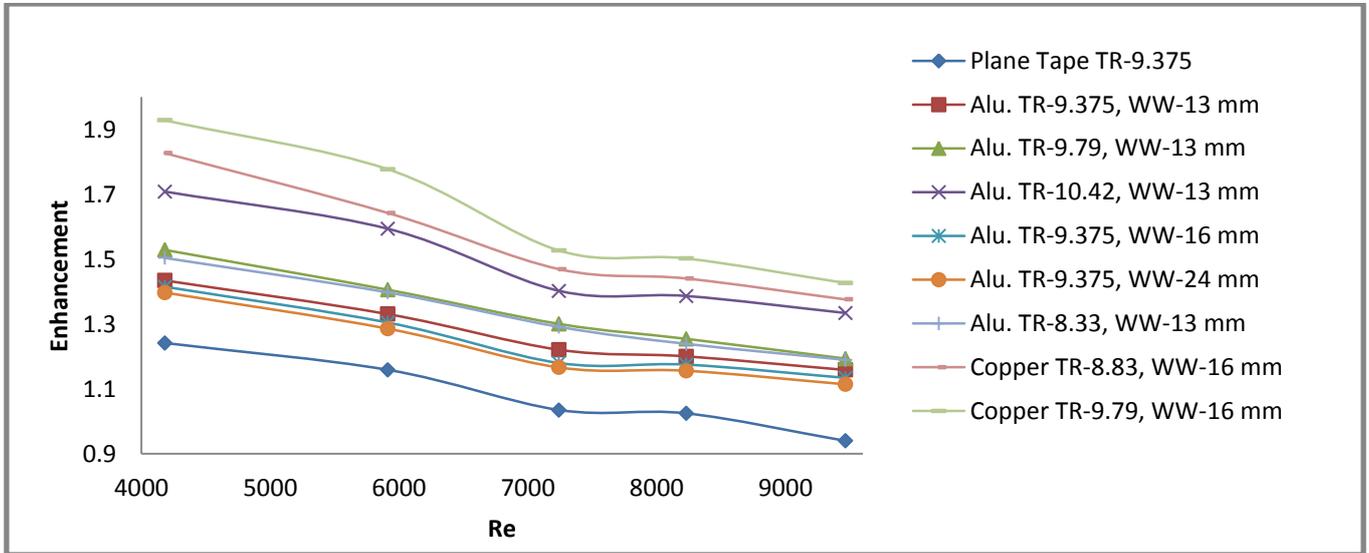
**B). Comparison of heat transfer enhancement ( $\eta$ ) among without insert, with copper and aluminium**

The Performance Evaluation criteria is most deciding parameter in terms of heat transfer enhancement and

friction factor to select which type of insert has optimum value in the above said parameters.

$$\eta = \frac{(Nu_i/Nu)}{(f_i/f)^{0.333}}$$

These PEC are plotted and certain results can be concluded from the below graph.



**Figure no.5. Enhancement for all inserts**

Through above graph it is also observed for each insert that, with rise in Reynolds number the enhancement goes on decreasing. It is also conclude The copper groove twisted tape insert with TR-9.79 & WW-16 mm gives highest rise in enhancement upto 55% as compared to plane twisted tape configuration. Hence, it can be concluded that groove twisted tapes can perform better than plane twisted tape design for same Reynolds number.

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