An Experimental Investigation of Performance of Different Twisted Tape Inserts on Heat Augmentation

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ABSTRACT

This paper represents the experimental work done on circular horizontal tube by using different types of inserts to enhance the heat transfer rate. Also, its effect on heat transfer coefficient, friction factor for the horizontal tube. In this experiment the flow in the pipe was turbulent flow and the inserts used are clockwise and counter clockwise twisted tape with rectangular cuts and are made of copper. The twist ratio of twisted tapes used in experimentation was 2, 2.5 and 3. The experiment shows that for the twist ratio of 2, the heat transfer rate is found to be maximum compared with twist ratio of 2.5 & 3. Also the rate of heat transfer is more than plain tube without inserts. Also it has been observed that the twist ratio does not affect the Nusselt number.

Keyword: - *Twisted tapes, Heat augmentation, Friction Factor, Turbulent flow*

1. INTRODUCTION

Heat augmentation is the process of increasing the effectiveness of heat exchangers. This can be achieved when the heat transfer power of a given device is increased or when the pressure losses generated by the device are reduced. A variety of techniques can be applied to this effect, including generating strong secondary flows or increasing boundary layer turbulence. There are three types of heat augmentation i.e. active techniques, passive techniques and compound techniques. The active techniques require input from external source. The passive techniques do not require any direct input of external power; rather they use it from the system itself which ultimately leads to an increase in fluid pressure drop. They generally use surface or geometrical modifications to the flow channel by incorporating inserts or additional devices. They promote higher heat transfer coefficients by disturbing or altering the existing flow behavior except for extended surfaces. The compound techniques has limited application and complex design. When more than two techniques are employed simultaneously to obtain enhancement in heat transfer that is greater than that produced by either of them when used individually, is termed as compound enhancement. Twisted tapes are act as turbulator which can be used to increase the rate of heat transfer. This enhancement is achieved by inducing swirl flow of the tube side fluid, resulting in higher near wall velocities and mixing of fluids thereby enhancing the heat transfer coefficient.

There are various authors who experimentally showed that, the performance of twisted tape insert in pipe is better than without inserts in pipe[1][2][3]. Also transition in flow occurs due to inserts [2]. Also it has been experimentally proved that by changing the size of twisted tapes, dimensions and geometry also shows its effects on heat transfer [3]. Also it has been shows that both friction factor and Nusselt number increases by decreasing the value of pitch of coil and duct aspect ratio [4]. They also observed both experimentally and theoretically that twisted tapes with twist ratios of 5.0 do not generate sufficient swirl intensity [4]. It also have been proved that the inserts having twist ratio more than 3 shows lower heat enhancement than inserts having twist ratio between 2 to 3[5]. Also the heat transfer enhancement index increases with decreasing Reynolds number but decreases with reducing twist ratio of inserts [5]. It has been also found that heat transfer rate for the tube with perforated twisted tape insert is higher than that twisted tape insert of same twist ratio but without perforation. The average heat transfer coefficient for the tube with perforated twisted tape inserts varies from 4.55 to 5.5 folds compared with that of the plain tube. Among the inserts tested the tube with perforation 4.6% gives the highest heat transfer rate for same Reynolds number and is around 1.8 times the value of the plain tube [6]. So, it has been found that the inserts increases the heat enhancement index but limited value of twist ratio. The inserts with varied dimensions, shape and size can also be used for both laminar and turbulent type of flow.

2. EXPERIMENTAL SET UP

The schematic diagram of the experimental set up is shown in Fig.1. Apparatus containing basic components and fluid flow system, a quarter HP centrifugal water pump, Rota-meter for measuring the water flow rate, and the heat transfer test section. The test section was made up from 1000mm of copper tube having 26mm ID and 30mm OD and thickness (t) 2mm. The Nichrome resistance wire was spirally wound uniformly on the outer surface of the test section to supply the heating power. Glass Woolies used between the tubes and heating wire for electrical insulation. The heating wire was connected to 220Volt main. Five k-type thermocouple were placed on five equally spaced points of the test section to measure the outer surface temperatures of the tube. Two thermocouples were placed at the inlet and outlet of the tube to measure inlet and outlet temperature of the water respectively. A Rota-meter of 20LPM capacity was provided to measure the water flow rate. A Manometer was used to measure the pressure drop across the tube connected to both the ends of the tube.

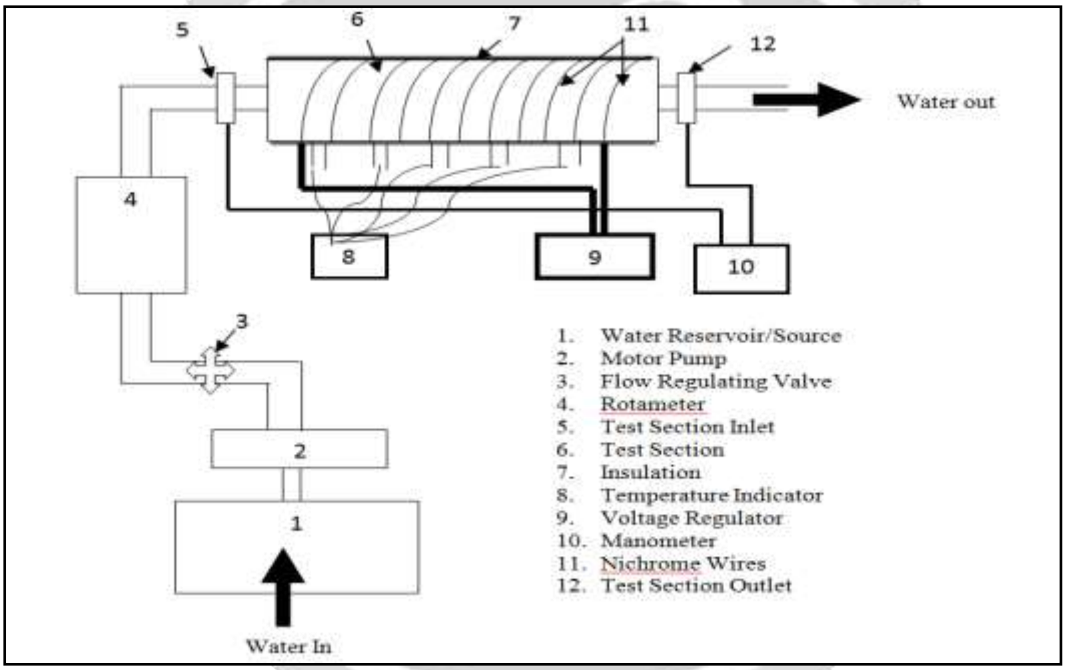

Figure -1: Schematic Experimental Set-up

2.1 Fabrication of Inserts

For the experiment the combination of alternate CW-CCW twisted tape and twisted tape with rectangular cut is used. Hence alternate CW-CCW twisted tape with rectangular cut is used. The twist ratio (y/w) where, y= pitch and w= width of the tape, is maintained as 2, 2.5 and 3. For the each tape width remains constant as 22mm and pitch is varying such as 44mm, 55mm and 66mm. The rectangular groove has been cut at the middle of each pitch having 14mm length and 8mm height.

Twisted tape is made up of copper. A rectangular sheet was purchase of thickness 1.5mm X 150mm width and 1140mm in length from the rectangular copper sheet cut longitudinal strips were being cut having width 24 X 1140mm length from the strips individual pieces for the inserts of varying twist ratio i.e. y/w= 2, 2.5 and 3. For the twist ratio 2, to achieve this twist ratio the requirement is that the w=22mm and p=44mm. So to achieve this individual roe pieces have been cut from the strip of size 23mm width X 64mm length 10mm length is given for holding surface during twisting of this strip. The rectangular cut is marked exactly the center strip at 1 longitudinal side. The marking has been made with the help of roller scale and marker.

Each of the individual pieces is first fixed into the vice then checked its straightness by with the help of die pieces can be twisted at 90^0. Twisting the rectangular slot has been cut into the pieces with the help of cutter after this the extra 20mm i.e. 10mm from each end get removed with the help of cutter to achieve the required pitches similarly the pieces inserts for various pitches says 2, 2.5, 3 are made. The table-1 gives information about dimensions of twisted tapes.

Table -1: Twisted Tape Dimensions

Sr. No.	Twist Ratio (y/w)	Total No. of Pieces	CW piece	CCW piece	Dimension Before Machining	Dimensions After Machining
1	2	23	12	11	64 X 23	44 X 22
2	2.5	19	10	9	75 X 23	55 X 22
3	3	16	8	8	86 X 23	65 X 22

2.2 Working

Before experimentation the Rota-meter and Manometer have been calibrated. The inlet cold water at 27°C from a water pump was directed through the Rota-meter and passed to the heat transfer test section. The pressure drop of the heat transfer test tube was measured with a pressure transducer. The volumetric water flow rates from the centrifugal water pump were varied by adjusting the globe valve and measured by the Rota-meter situated upstream of the test tube. The inner and outer temperatures of the water were measured at certain points with a digital panel meter unit in conjunction with the K-type thermocouples. Five thermocouples were tapped on the local wall of the plain tube and the thermocouples were placed round the plain tube to measure the circumferential temperature variation, which was found to be negligible. In each test run, it was necessary to record the data of temperature, volumetric flow rate and pressure drop of the water at steady state conditions in which the inlet water temperature was maintained at 27 °C. The Reynolds Numbers of the water were varied from 4000 to 5000. In order to quantify the uncertainties of measurements, the reduced data obtained experimentally were determined. The maximum uncertainties of non-dimensional parameters were ±7% for Nusselt number and ±8% for friction factor. The uncertainty in temperature measurement at the pipe wall was about ±2%. The experimental results were reproducible within these uncertainty ranges.

3. OBSERVATIONS

The experiment was carried under atmospheric conditions and the readings have been taken after a steady state condition has been reached. Also, the various parameters which affect the heat transfer rate, friction factor have been observed and presented the form of charts.

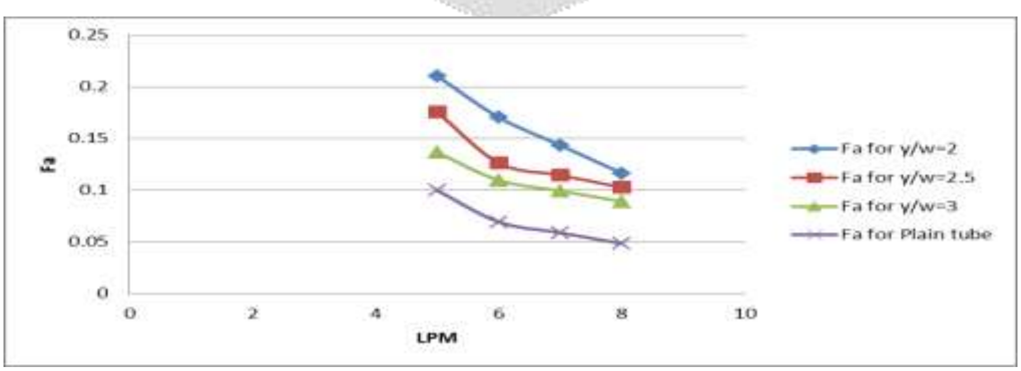

Chart -1: Variation in Friction Factor with Twist Ratio for different Flow Rate

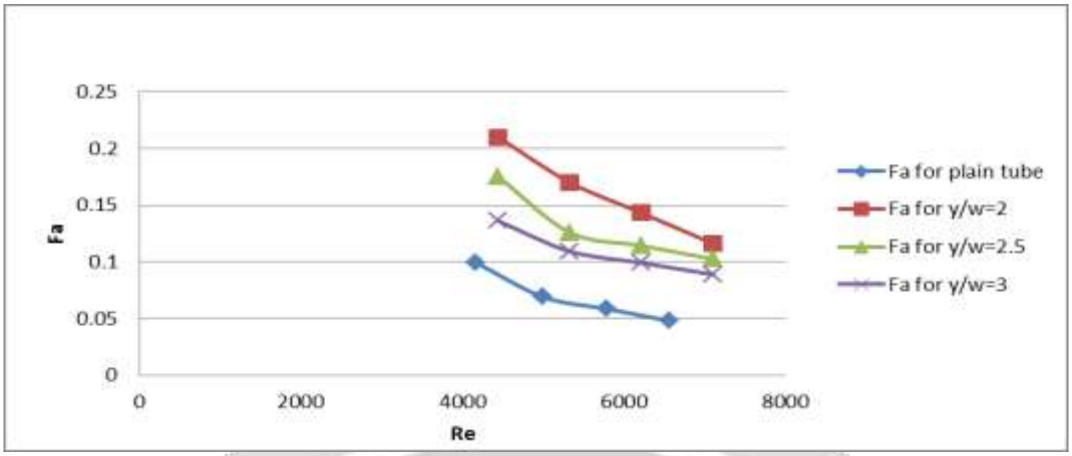

Chart -2: Variation in Friction Factor with Reynolds Number for different Twist Ratio

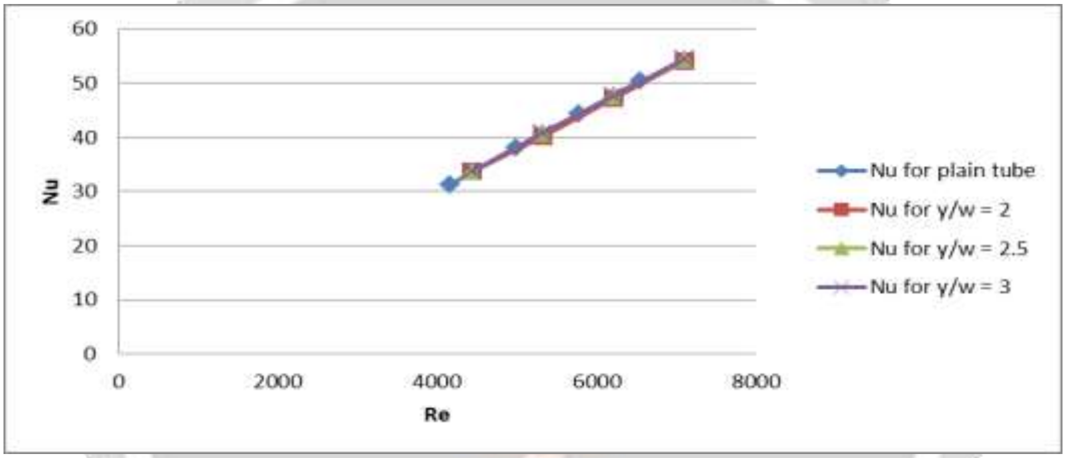

Chart -3: Variation in Nusselt Number with Reynolds Number for different Twist Ratio

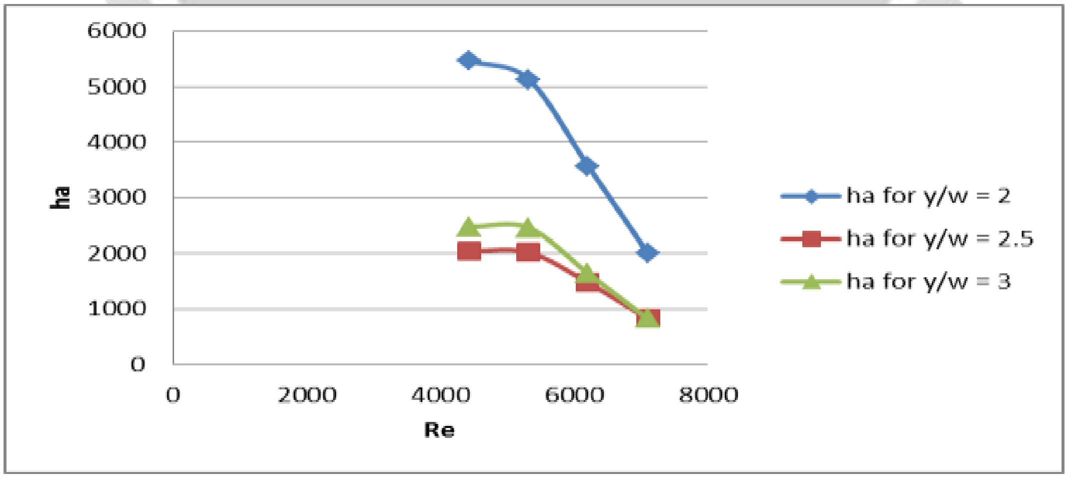

Chart -4: Variation in Heat Transfer Coefficient with Reynolds Number for different Twist Ratio

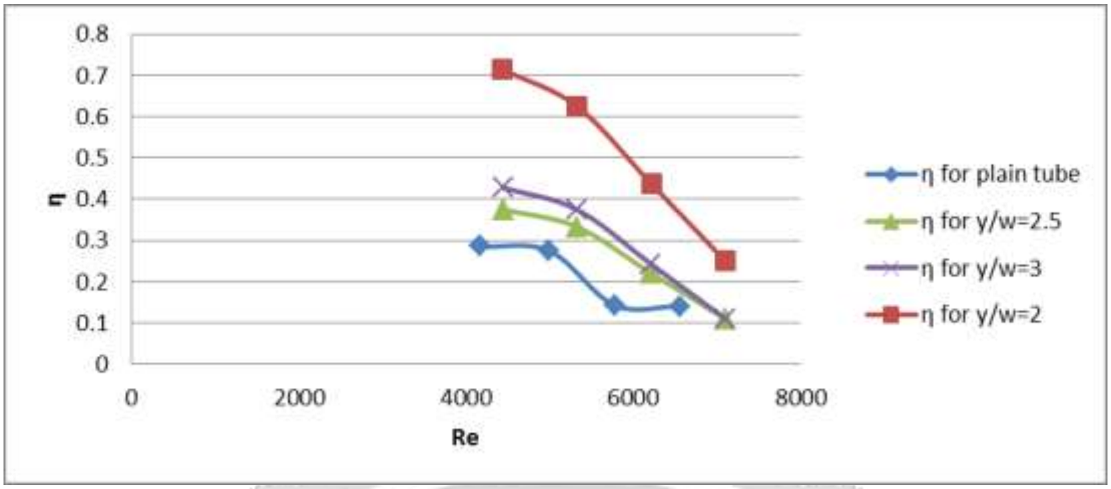

Chart -5: Variation in Effectiveness with Reynolds Number for different Twist Ratio

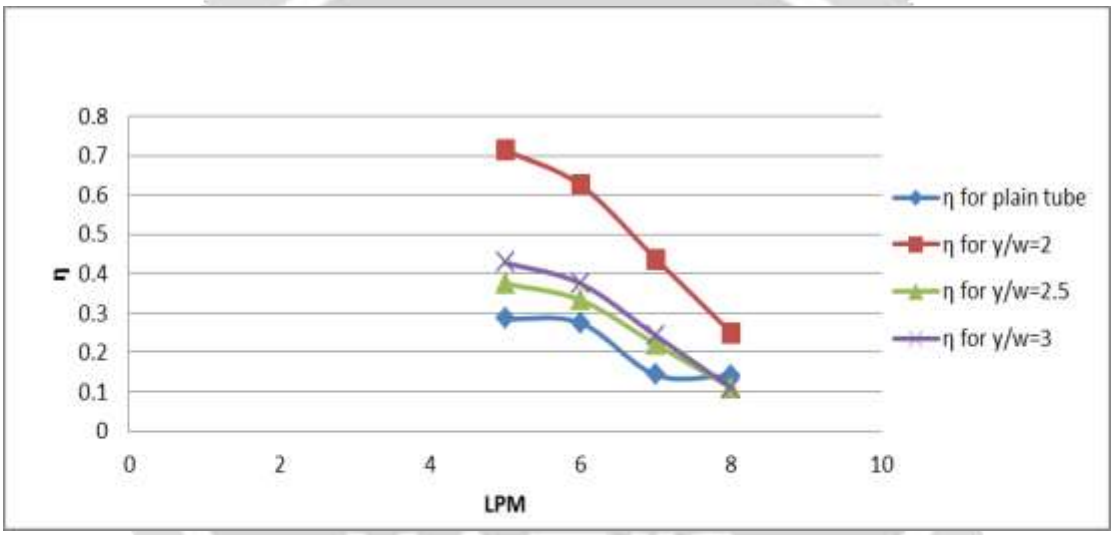

Chart -6: Variation in Effectiveness with Flow Rate for different Twist Ratio

4. DATA VALIDATION

The data validation has been carried out by comparing actual friction factor with friction factor calculated by Darcy Weishback equation. The relation between these two values shows a linear relationship with R value of 0.966.

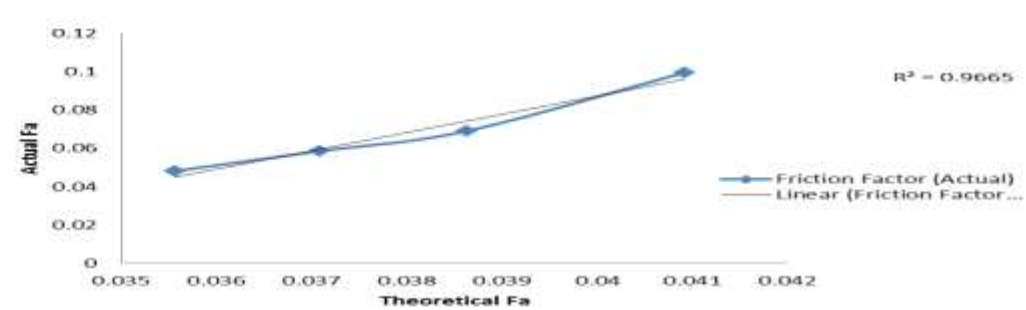

Chart -7: Data Validation for Friction Factor

5. RESULTS AND DISCUSSIONS

- From Chart-1, it is observed that friction factor [Fa] reduces as the flow rate increases. This is due to the reason that because of low velocity of fluid it remains in contact with the insert for the longer time than the plain tube. Due to higher flow rate, water i.e. working fluid smoothly passes over the tape and hence less friction factor [Fa] obtained. Also, the maximum friction factor [Fa] is found for the twist ratio y/w= 2 and as we increase the twist ratio value decreases.

- From Chart-2, it has been observed that, the increase in Reynolds No. [Re] causes decrease in friction factor [Fa]. This is because at higher flow rate, the Reynolds No. [Re] is maximum and hence it shows the reduction in friction factor [Fa] with increasing Reynolds No. [Re]. Also, the maximum friction factor [Fa] obtained for twist ratio 2 and for further increase in twist ratio [y/w] the friction factor decreases. This is due to, the reason that the increased twist ratio provide more pitch and flowing surface are which is smooth, so less friction is observed at high twist ratio y/w=3.

- From Chart-3, it has been observed that, the twist ratio has no effect on Nusselt number. Nusselt number [Nu] as it is directly proportional to Reynolds number [Re].

- From Chart-4, it has been observed that, the convective heat transfer coefficient [ha] is found maximum at twist ratio y/w=2, hence, at lower twist ratio, heat transfer is more. This is due to the reason that because of small pitches and alternate arrangement of clockwise and counter-clockwise twisted tape which forces the flow of fluid to change its swirl immediately from clockwise to counter-clockwise. The high heat transfer rate is obtained at Reynolds number [Re] 4000 to 4500 i.e. decreasing initial stage of turbulent flow and this is due to initial stage of friction.

- From Chart-5, it has been observed that, the decrease or fall in effectiveness [η] with increase or rise in Reynolds No. [Re]. This is due to that when working fluid i.e. water flows at higher velocity, it fails to absorb the heat from the surface and convection occurs is found less and goes on decreasing with increase in velocity. At lower flow rate, Effectiveness [η] is obtained at its maximum level.

- From Chart-6, it has been observed that, the effectiveness [η] is maximum at twist ratio 2. It decreases with increasing twist ratio. Since in above discussed results getting the higher convective heat transfer coefficient [ha], effectiveness also increases with decreasing twist ratio y/w=2.

6. CONCLUSION

If twisted tapes are inserted, then we get enhancement in heat transfer, also the experimental readings shows that; the heat transfer rate is more than the plain tube. In this paper, we have evaluated the effect of different twist ratio on enhancement of heat transfer. The experimental reading and observation shows that, for the twist ratio y/w=2 there is a maximum heat transfer rate, effectiveness and friction factor obtained. And further increase in twist ratio these values are less compared to the twist ratio y/w=2.

Hence we can conclude that the heat enhancement can be done by using inserts having twist ratio y/w = 2. For further increase in twist ratio will not give the proper heat transfer and also it is better than the plain tube without inserts.

7. REFERENCES

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