Heat Transfer Enhancement in Tube by Inserting Twisted Tape with Alternate Axes

Akhilesh N. Joshi[1] Prof. S. M. Lawankar[2]
[1]M.Tech Student [2]Assistant Professor
[1,2]Department of Mechanical Engineering
[1,2]Govt. College of Engineering, Amravati, MH, India

Abstract— This project have been performed to study the influence of twisted tape with alternate axes and simple twisted tapes as turbulator and swirl flow generator. The experiments conducted using twisted tapes of the dimensions 900mm length, width 25.4 mm and thickness 2mm. The twists were made of twist ratio 2.5, 3.0 and 3.5. The Nusselt number obtained in the range of 25-97. The friction factor was found to lie in the range of 0.03-0.5. It is observed that the Nusselt number increases with increase in the Reynolds number and also increases with decrease in the twist ratio. The local convective heat transfer coefficient increases with increase in the mass flow rate and also increase by the use of simple twist and twist with alternate axes, Also as the twist ratio decreases the convective heat transfer coefficient increases.

Keywords: Heat Transfer, Twisted Tape, Heat Exchanger, Swirl Flow, Nusselt Number, Reynolds Number, Friction Factor.

I. INTRODUCTION

Heat is the form of energy that can be transferred from one system to another as a result of temperature difference. Heat transfer is commonly encountered in engineering systems and other aspects of life. The engineering heat transfer applications include equipments such as heat exchangers, boilers, condensers, radiators, heaters, furnaces, refrigerators, solar collectors etc.[1]

Heat exchangers are mostly used devices in many areas of the industries. Hence the using of high performance heat exchangers is very important for improving heat transfer rate, minimizing the size of heat transfer system and saving the overall energy use. The interests in these techniques is closely tied to energy prices and, with the present increase in energy cost, it is expected that the heat transfer enhancement field will go through a new growth phase. Although there is need to develop novel technologies, experimental work on the older ones. Hence, there have been continuous efforts to improve the efficiency of heat exchangers by various methods.

The heat transfer enhancement techniques can be classified according to the following criteria:

A. Additional devices which are incorporated into a plain round tube:

1) Insertion of twisted tape:
In the twisted tape the swirling motion persists over the entire length of the duct and the heat transfer improves due to decrease of hydraulic diameter which leads into increase in flow velocity, increase of flow path length due to helical configuration of the twisted tape, increase of the shear stress at the tube wall and improvement of fluid mixing by secondary flow.

2) Insertion of coiled wires:
The wire coil acts as a swirl flow generator and a helical flow at the periphery is produced. This rotating flow is superimposed upon the axially directed central core flow and causes centrifugal forces. In most of liquids where density decreases with temperature, centrifugal forces produce a movement of the heated flow from the boundary.

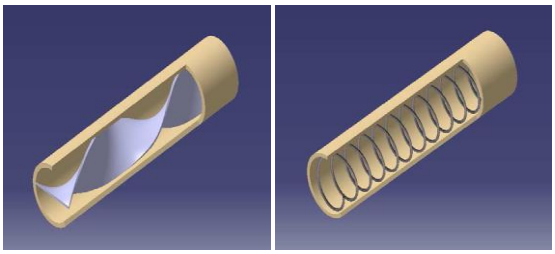


Fig.1: (a) Tube with TT (b) Tube with wire coil

B. Surface modification of a plain tube (corrugated tubes) or manufacturing of special tube geometries (internally finned tubes)

Heat transfer enhancement by augmentation of extended surfaces in duct flows has been extensively studied because of their widespread use in the engineering applications.

Heat transfer enhancement techniques have been extensively developed to improve the thermal performance of heat exchanger systems with a view to reducing the size and cost of the systems. Swirl/vortex flow is the one of the enhancement techniques widely applied to heating/cooling systems in many engineering applications.

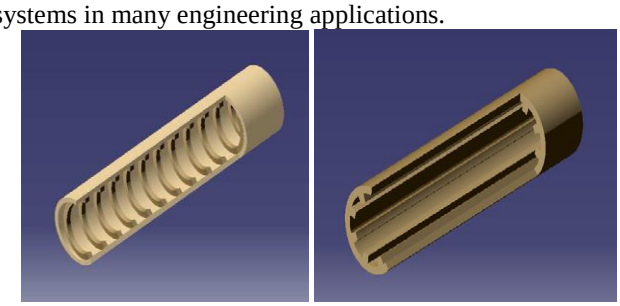


Fig. 2: (a) Microfin tube (b) Microfin tube

C. Heat transfer techniques are also classified into active and passive methods:

1) Active method:-
Active method requires an external power input such as blower or pump to flow air or water through the pipe respectively. These techniques are more complex from design point of use. It finds limited applications since it requires power supply.

2) Passive method:-
Passive method do not require any direct input of power generally rather they use surface or geometrical modification to the flow by using the inserts or additional

All rights reserved by *www.ijsrd.com*

devices such as twisted tape, wire coil, internally finned surfaces *etc*.

3) Compound method:-

The combination of above two methods for the purpose of heat transfer enhancement is called compound method.

Suvanjan Bhattacharyya, Subhankar Saha, *et. al.* [2] presented Laminar flow heat transfer enhancement in a circular tube having integral transverse rib roughness and fitted with centre-cleared twisted-tape and the experimental friction factor and Nusselt number data for laminar flow through a circular duct. Centre clearance c=0, 0.2, 0.4, 0.6, Rib pitch (P/e) =2.0437, 5.6481and rib height (e/D) =0.07692, 0.1026. Predictive friction factor and Nusselt number co-relations are also presented. They have evaluated the thermo-hydraulic performance and the major findings of their experimental investigations are that with and without centre cleared twisted tape in combination with integral axial rib. They worked within the Reynolds number range of 10-1000, got friction factor in the range of 0.017-1.2 and Nusselt no. in the range of 3-15. The friction factor and Nusselt number both decreases with increase in the value of centre clearance initially however, after c=0.4 and with further increase of c, no appreciable changes in the friction factor and Nusselt number occur.

S. Eiamsa-ard, P. Nivesrangsan, *et. al.* [3] studied Influence of combined non-uniform wire coil and twisted tape inserts on thermal performance characteristics. In this paper, heat transfer, friction factor and thermal performance behaviours in a tube equipped with the combined devices between the twisted tape (TT) and constant/periodically varying wire coil pitch ratio are experimentally investigated. The periodically varying three coil pitch ratios were arranged into two different forms: (1) D-coil (decreasing coil pitch ratio arrangement) and (2) DI-coil (decreasing/increasing coil pitch ratio arrangement) while the twisted tapes were prepared with two different twist ratios. Each device alone is also tested and the results are subjected for comparison with those from the combined devices. The experiments were conducted in a turbulent flow regime with Reynolds numbers ranging from 4600 to 20,000 using air as the test fluid.

S. Eiamsa-ard, Wongcharee, P. Eiamsa-ard Thianpong [4] conducted heat transfer enhancement in a tube using delta-winglet twisted tape inserts. The experiments are conducted using the tapes with three twist ratios (y/w = 3, 4 and 5) and three depth of wing cut ratios (d/w=0.11,0.21,0.32) over a Reynolds number range of 3000–27,000 in a uniform wall heat flux tube. The obtained results show that mean Nusselt number and mean friction factor in the tube with the delta-winglet twisted tape increase with decreasing twisted ratio and increasing depth of wing cut ratio. They got Nusselt No. in the range of 20-200. They got the friction factor in the range of 0.05-0.25. In this work delta-winglet tapes are applied as vortex generators to amplify turbulence intensities and produce secondary flows near the tube wall.

Khwanchit Wongcharee, Smith Eiamsa-ard[5] Heat transfer enhancement by using CuO/water nanofluid in corrugated tube equipped with twisted tape is presented. The investigated ranges are made on three different CuO concentrations: 0.3, 0.5 and 0.7% by volume, at three different twist ratios of twisted tape: y/w=2.7, 3.6 and 5.3 for two different arrangements of twisted direction of twisted tape relative to spiral direction of corrugated tube: parallel and counter arrangements, and within the Reynolds number from 6200 to 24000. The results achieved from the use of the nanofluid and twisted tape, are compared with those obtained from the uses of nanofluid alone and twisted tape alone.

Bodius Salam, Sumana Biswas, Shuvra Saha, *et. al.* [6] worked on Heat transfer enhancement in a tube using rectangular-cut twisted tape insert. An experimental investigation was carried for measuring tube-side heat transfer coefficient, friction factor, heat transfer enhancement efficiency of water for turbulent flow in a circular tube fitted with rectangular-cut twisted tape insert. A copper tube of 26.6 mm internal diameter and 30 mm outer diameter and 900 mm test length was used. A stainless steel rectangular cut twisted tape insert of 5.25 twist ratio was inserted and the rectangular cut 8mm depth and 14 mm width were made. A uniform heat flux condition was created by wrapping nichrome wire around test section and fibre glass over the wire. The Reynolds no. was varied in the range of 10000-19000. The Nusselt numbers obtained in the range of 100-310, friction factors in the range of 0.06-0.12.

P. Bharadwaj, A.D. Khondge, A.W. Date[7] presents Heat transfer and pressure drop in a spirally grooved tube with twisted tape insert. In this paper, experimentally determined pressure drop and heat transfer characteristics of flow of water in a 75-start spirally grooved tube with twisted tape insert are presented. Laminar to fully turbulent ranges of Reynolds numbers have been considered. The grooves are clockwise with respect to the direction of flow. Constant pumping power comparisons with smooth tube characteristics show that in spirally grooved tube with and without twisted tape, heat transfer increases considerably in laminar and moderately in turbulent range of Reynolds numbers. However, for the bare spiral tube and for spiral tube with anticlockwise twisted tape (Y = 10.15), reduction in heat transfer is noticed over a transition range of Reynolds numbers. They worked within the Reynolds number range of 500-12000, with the twist ratio of 3.4, 7.95, 10.15. They got Nusselt number in the range of 20-130 and friction factor in the range of 0.04-0.7.

Sujoy Kumar Saha, Suvanjan Bhattacharyya, *et. al.* [8] proposed Thermo-hydraulics of laminar flow of viscous oil through a circular tube having integral axial rib roughness and fitted with centre-cleared twisted-tape. The major findings of this experimental investigation are that with and without centre-cleared twisted tapes in combination with integral axial rib roughness perform significantly better than the individual enhancement technique acting alone for laminar flow through a circular duct up to a certain amount of twisted-tape centre-clearance.

Si-hong Song, Qiang Liao, Wei-dong Shen[9] Laminar heat transfer and friction characteristics of microencapsulated phase change material slurry in a circular tube with twisted tape inserts. The heat transfer of the tube wall can be negligible for small heat resistance. Twist ratio of 2, 5, 8, 10 were used They found that this slurry in the tube with twisted tape insert leads to the best performance of convective heat transfer for the bigger apparent specific heat and the intensive swirl flow. Moreover, the thermal-hydraulic performance ratios increase to a peak, then

All rights reserved by *www.ijsrd.com*

decrease gradually with increasing Re for different twist ratio. The performance ratio increases with decreasing the twist ratio only in a definite Re range, and the Re range decreases with decreasing twist ratio. Re number was found in the range of 200-2200. The Nusselt number was found in the range of 5-90. Friction factor was found in the range of 0.02-0.45.

K. Wongcharee, S. Eiamsa-ard[10] investigated Friction and heat transfer characteristics of laminar swirl flow through the round tubes inserted with alternate clockwise and counter-clockwise twisted-tapes. The thermo-hydraulic characteristics of the circular tubes equipped with alternate clockwise and counter-clockwise twisted-tapes (TA) for the Reynolds number ranging from 830 to 1990, are reported. In the experiments, the twisted tapes with three different twist ratios (l/W=3, 4 and 5) were inserted individually into the uniform wall heat flux tubes where water was utilized as the working fluid.

S. Eiamsa-ard, P. Seemawute [11] presents experimental and numerical results of the local heat transfer coefficient and flow characteristics of decaying turbulent swirl flow generated by short-length twisted tapes (STs). The STs with three different twist ratios (y/W=3, 4 and 5) were applied at the entrance of the test section. The experiments were conducted under uniform heat flux conditions for water flow rates in the range of 5200≤Re≤15,300. The results of the tube without swirl generator as well as the ones with full-length twisted tape (TTs) are also reported as the reference cases. The experimental results reveal that the tube with STs consistently yields higher local Nusselt number than that the one without swirl generator. The local Nusselt numbers decrease with increasing axial distance (x/D) due to the decaying effect. Although, STs consistently provide poorer heat transfer than TTs over the range studied, the STs with y/W=4 and 5 yield superior thermal performance factors to the TTs at the same twist ratios, for Reynolds numbers beyond 10,000 due to the prominent effect of heat transfer improvement over that of the increase of friction factor. For better understanding, the visualization of flow structure (path line and vector plot) in the tubes with STs is also presented.

II. Need of Heat Transfer Enhancement

A high cost of energy and material has resulted in an increased efforts required for producing more efficient heat exchanger equipment. The performance of conventional heat exchanger can be substantially improved by a number of enhancement techniques.

A great deal of research effort has been devoted to developing apparatus and performing experiments to define the conditions under which an enhancement technique will improve heat transfer. Heat transfer enhancement technology has been widely applied to heat exchanger applications in refrigeration, automobile, process industries *etc*. The goal of enhanced heat transfer is to encourage or accommodate high heat fluxes. This results in reduction of heat exchanger size, which generally leads to less capital cost. In addition, the heat transfer enhancement enables heat exchangers to operate at smaller velocity, but still achieve the same or even higher heat transfer coefficient. This means that a reduction of pressure drop, corresponding to less operating cost, may be achieved. All these advantages have made heat transfer enhancement technology attractive in heat exchanger applications.

III. Objectives of the Project

- To prepare simple twisted tape of twist ratio 2.5, 3, 3.5 of mild steel material.
- To prepare twisted tape with alternate axes of twist ratio 2.5, 3, 3.5 of mild steel material.
- To investigate steady state characteristics like mass flow rate.
- To find local convective heat transfer coefficient for a pipe losing heat by forced convection.
- To find average surface heat transfer coefficient for a pipe losing heat by forced convection to air flowing through it.
- To find variation of temperature with mass flow rate.
- Comparing various simple twisted tapes and twisted tape with alternate axes with bare tube.

IV. Experimental Setup and Procedure

The heat transfer enhancement apparatus consist of a blower unit which causes the flow of air through the test section. The valve is provided to control the flow of air through the test section. This change in the flow varies the Reynolds number of the flow. The air flow is measured with the help of an orifice meter which is fitted with U- tube water manometer. Thereafter there is the test section through which heat transfer enhancement is to be calculated. The test section pressure drop is measured with the help of another U-tube manometer. Six thermocouples are mounted on test section and two are suspended in air at inlet and exit in order to measure the measure temperatures at various points.

There is a control panel which consists of an ammeter, voltmeter, temperature indicator, thermocouple knob and the dimmer stat. Heat input to the test section is controlled by the dimmer stat.

Fig.3: Experimental Setup

A. Test section:

The test section consists of a test pipe of stainless steel. This stainless steel pipe is surrounded by mica sheet which is an electrical insulator. Over the mica sheet nichrome wire heater of capacity 1500W is wound evenly. The supply to the heater is controlled through the dimmerstat. The heat supplied to the heater is measured as the product of current and voltage through the dimmerstat. Over the nichrome wire mica sheet is wound again to cause electrical insulation. The glass wool is used as the thermal insulator in order to reduce the heat loss to the surrounding externally. Six thermocouples are embedded on the test section to measure

All rights reserved by *www.ijsrd.com*

the surface temperature of the test pipe and two thermocouples are suspended in the air stream at the entrance and exit of the test section to measure the temperature of the air. The thermocouple bead is insulated from the electrically heated tube wall surface by a dab of electrically non-conductive thin mica sheet in order not to be affected by electricity.

Fig. 4 Steel Pipe with Thermocouples Mount over it

B. Control panel:

The photograph of control panel is shown below, it consists of temperature indicator, voltmeter, ammeter, thermocouple knob, Dimmerstat and dimmerstat output plug. The dimmerstat is used to vary the voltage and the current will be varied accordingly to supply the power to the heater.

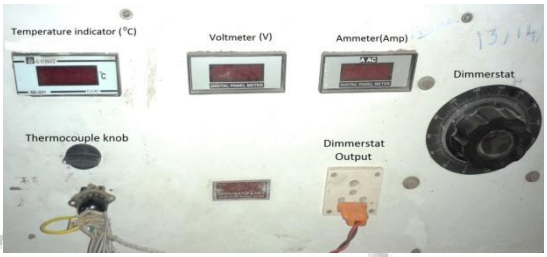


Fig. 5: Control Panel

C. Geometries of the inserts:

The simple twists and twisted tape with alternate axes of various twist ratios used in this project work are discussed in the following subsections.

D. Simple twisted tapes:

The simple tapes were twisted to some twist ratios. Twist ratio (y) is the ratio of length of one twist (l) to the width of the tape (w). The twists were made up of mild steel material. The twists were made to the twist ratio of 2.5, 3 and 3.5. The photograph below shows a twist with a twist ratio of 3.

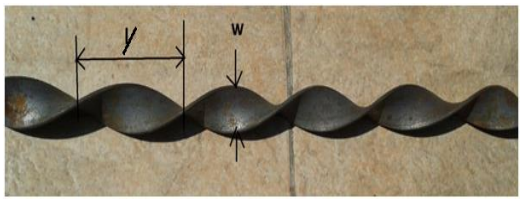


Fig. 6: Simple twisted tape

E. Twisted tape with alternate axis

The twisted tape with alternate axes were made to increase the turbulence in the direction of the flow. Twisted tape with alternate axes were made by first making the simple twisted tape. The tape of length 950 mm, width 25.4 mm and thickness 2 mm was taken. One end of the tape was fixed in the chuck and the other end is fixed in the tool post. The chuck was then rotated to get the required twist ratio of 2.5, 3 and 3.5. Then 25 mm length was cut from either side to bring the tape to the required length. The twisted tapes obtained such were then cut into pieces per twist length and then were welded maintaining the direction of twist. The ends of the twist were welded with the small strips of length 38 mm laterally to keep the tape centrally inside the pipe.

Fig. 6: Twisted tape with alternate axis.

F. Experimental Procedure

- Start the the blower and adjust the flow by means of valve to some desired difference in manometer level.
- Start the heating of test section with the help of dimmerstat and adjust desired heat input with the help of voltmeter and ammeter.
- Take the readings at an interval of 20 minutes, wait for steady state and take the reading of all thermocouples by varying the thermocouple knob.
- Note down heater input current and voltage.
- Again adjust the flow and repeat the procedure for three different manometer readings.
- Measure the pressure difference across the test section
- Take the readings for tube without insert, simple twisted tape for different twist ratio of 2.5, 3, 3.5 and then for twisted tape with alternate axis for different twist ratio of 2.5, 3, 3.5.

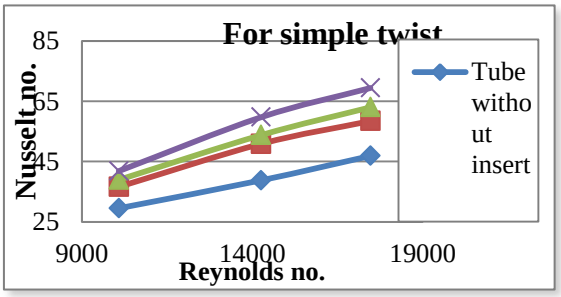
V. PERFORMANCE ANALYSIS

A. Experimental analysis

In this section, the Nusselt number, friction factor characteristics and also thermal enhancement index in a tube fitted with simple twisted tapes and twisted tape with alternate axes are presented.

B. Nusselt number

Graph below shows the variation of Nusselt number enhancement with Reynolds number for three different twist ratios (y/w = 3.5, 3.0, 2.5) of the simple twisted tapes. In general, the Nusselt number increases with the increase of Reynolds number and with decrease of twist ratio. It means that heat transfer enhancement decreases with increase of twist ratio up to y/w = 3.5 and has the least value for tube without insert.

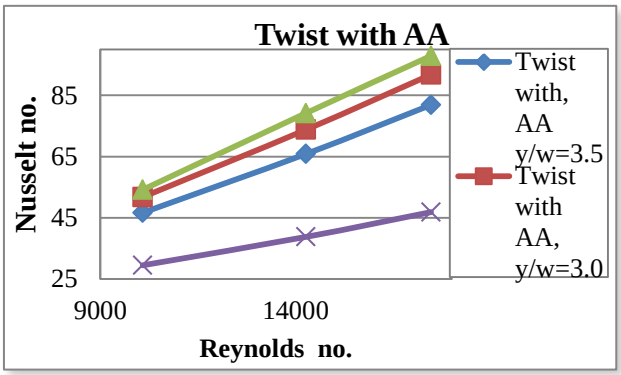


Graph.1: Variation of Nusselt no. with Reynolds no.

Experimental results of the Nusselt number (Nu) in tube of twisted tape with alternate axes (y/w = 3.5, 3.0, 2.5) presented in Graph.2. The Nusselt numbers for the plain tube acting alone are also plotted for comparison. The data show that the Nusselt number (therefore, the heat transfer coefficient) increases with increasing Reynolds number for the conventional turbulent tube flow. This is the most likely

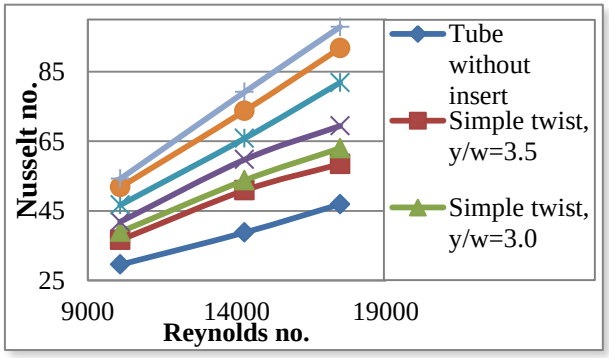
All rights reserved by *www.ijsrd.com*

caused by a stronger turbulence and better contact between fluid and heating wall. It is noted that the increasing Nusselt number in the plain tube in twisted tapes with alternate axes is caused by the generating of pressure gradient along the radial direction, and this leads to redeveloping of thermal boundary layer. The higher increase of the Nusselt number in this style of both turbulence and swirl flows is a consequence of the higher reduction of boundary layer thickness and increase of resultant velocity. Nusselt number increases with the decrease of twist ratio and the increase of Reynolds number. The highest Nusselt number is achieved for twist ratio (y/w = 2.5).



Graph.2: Reynolds number v/s Nusselt number for TT with alternate axes.

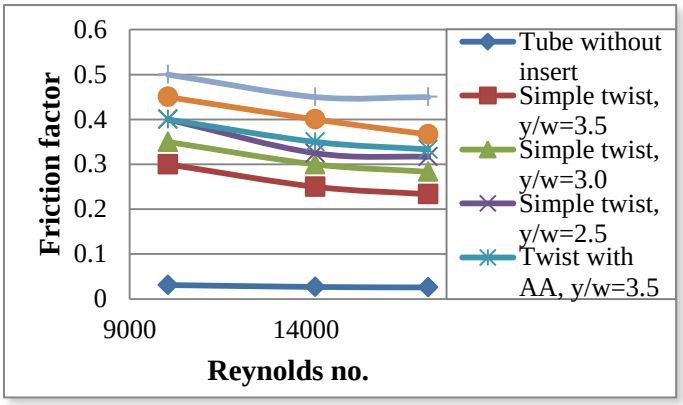
The effect of simple twisted tapes and twisted tape with alternate axes on the heat transfer rate in the form of Nusselt number is displayed in Graph 4.3 and the result is compared with that plain tube acting alone. It can be observed in the figure that the Nu increases with the rise in Re. At a similar operating condition, the twisted tape with alternate axes yields higher heat transfer rate than the simple twisted tape and plain tube acting alone. Depending on the Reynolds number and twist ratio values, the Nusselt number obtained from the inserted tube is larger than that from the plain tube alone.



Graph.3: Re v/s Nu for simple TT and TT with alternate axes.

C. Friction factor results

The combined graph of plain tube, Simple twisted tape and twisted tape with alternate axes is shown in the graph 4. From the graph it can be seen that the friction factor is the highest for the twisted tape with alternate axes for the twist ratio of 2.5. Also graph shows that overall friction factor is more for twisted tape with alternate axes as compared to simple twisted tape and plain tube.

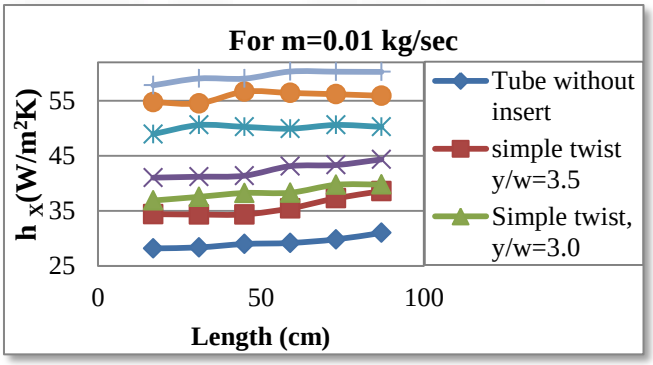


Graph.4: Re v/s Friction factor for plain tube, simple TT and TT with AA

D. Local convective heat transfer coefficient

Convective heat transfer coefficient gives the amount of heat transmitted for a unit temperature difference between the fluid and the unit area of surface in unit time. The heat transfer rate in a tube with simple twist and twisted tape with alternate axes under uniform heat flux condition for the present work is reported here in terms of convective heat transfer coefficient. The relationship between local convective heat transfer coefficient and the length of the test section is presented in the graphs below for the various mass flow rates and for the different twist ratios.

The graph below shows the variation of local convective heat transfer coefficient with respect to the length of the test section for the mass flow rate of 0.01kg/sec. From the graph it is clear that the local convective heat transfer coefficient increases with the use of twist also it increases with the decrease of twist ratio for the same value of mass flow rate.



Graph.5: local convective heat transfer coefficient along the length of the tube for m=0.01kg/sec.

VI. CONCLUSION

Heat transfer enhancement in a tube inserted with twisted tape and twisted tape with alternate axes is studied experimentally in this present study. The work has been conducted in the turbulent flow regime (Reynolds number in between 9000 to 18,000) using air as the working fluid. The findings of the work can be drawn as follows:

- The enhancement devices of the twisted tape with alternate axes show a considerable improvement of Nusselt number and friction factor relative to the

All rights reserved by *www.ijsrd.com*

simple twisted tape and smooth tube acting alone, depending on twist ratios.

- The Nusselt number is found to increase with increase in the Reynolds number and with decrease of the twist ratio. The highest Nusselt number is found to be 97 for twisted tape with alternate axes for twist ratio of 2.5 and Reynolds number of about 17460.
- Local convective heat transfer coefficient increases with the use of twisted tape and also with the decrease of twist ratio for the same value of the mass flow rate. Local convective heat transfer coefficient is found to be maximum of about $60W/m^2K$ for mass flow rate of 0.01kg/sec and for the twist ratio of 2.5 for twisted tape with alternate axes.
- Local convective heat transfer coefficient is found to increase with increase in the mass flow rate.
- The friction factor is found to increase with decrease in the Reynolds number and with decrease of twist ratio also friction factor for twisted tape with alternate axes is found to be higher as compared to that of simple twisted tape.
- The friction factor is found to be maximum 0.499 at Reynolds number value of 10080 and for twist ratio of 2.5.
- Swirl flow heat transfer is higher than non swirling flow.

REFERENCES

[1] Y. A. Cengel, "Heat Transfer- a Practical Approach", SI units 2nd Edition, Tata McGraw Hill, 2004.
[2] Suvanjan Bhattacharyya, Subhankar Saha, Sujoy Kumar Saha "Laminar flow heat transfer enhancement in a circular tube having integral transverse rib roughness and fitted with centre-cleared twisted-tape." Experimental Thermal and Fluid Science 44 (2013) pp.727–735.
[3] S. Eiamsa-ard, P. Nivesrangsan, S. Chokphoemphun, P. Promvonge, "Influence of combined non-uniform wire coil and twisted tape inserts on thermal performance characteristics." International Communications in Heat and Mass Transfer 37 (2010)pp. 850–856.
[4] S. Eiamsa-ard, Wongcharee, P. Eiamsa-ard Thianpong "Heat transfer enhancement in a tube using delta-winglet twisted tape inserts." Applied Thermal Engineering 30 (2010) pp.310–318.
[5] Khwanchit Wongcharee, Smith Eiamsa-ard, "Heat transfer enhancement by using CuO/water nanofluid in corrugated tube equipped with twisted tape." International Communications in Heat and Mass Transfer 39 (2012) pp.251–257.
[6] Bodius Salam, Sumana Biswas, Shuvra Saha, Muhammad Mostafa K Bhuiya "Heat transfer enhancement in a tube using rectangular-cut twisted tape insert." Procedia Engineering 56 (2013) pp.96 – 103.
[7] P. Bharadwaj, A.D. Khondge, A.W. Date "Heat transfer and pressure drop in a spirally grooved tube with twisted tape insert." International Journal of Heat and Mass Transfer 52 (2009) pp.1938–1944.
[8] Sujoy Kumar Saha, Suvanjan Bhattacharyya, Pranab Kumar PalP "roposed Thermohydraulics of laminar flow of viscous oil through a circular tube having integral axial rib roughness and fitted with centre-cleared twisted-tape." Experimental Thermal and Fluid Science 41 (2012) pp.121–129.
[9] Si-hong Song, Qiang Liao, Wei-dong Shen "Laminar heat transfer and friction characteristics of microencapsulated phase change material slurry in a circular tube with twisted tape inserts." Applied Thermal Engineering 50 (2013) pp.791-798.
[10] K. Wongcharee, S. Eiamsa-ard investigated "Friction and heat transfer characteristics of laminar swirl flow through the round tubes inserted with alternate clockwise and counter-clockwise twisted-tapes." International Communications in Heat and Mass Transfer 38 (2011) pp.348–352.
[11] S. Eiamsa-ard, P. Seemawute, "Decaying swirl flow in round tubes with short-length twisted tapes", International Communications in Heat and Mass Transfer, Vol. 39, (2012), pp. 649–656.

All rights reserved by *www.ijsrd.com*