Heat Transfer Augmentation Technique Using Twisted Tape Insert

Shubham Jadhav[1], Jayesh Jain[2] , Vikas Jadhav[3] , Prof .R. R. Yenare[4]

[1] Department of Mechanical Engineering, Smt. Kashibai Navale College of Engineering, Pune.
shubham.jd18@gmail.com
[2] Department of Mechanical Engineering, Smt. Kashibai Navale College of Engineering, Pune.
jjain277@gmail.com
[3]Department of Mechanical Engineering, Smt. Kashibai Navale College of Engineering, Pune.
vikasjadhav976@gmail.com
[4] Department of Mechanical Engineering, Smt. Kashibai Navale College of Engineering, Pune.
rryenare@sinhgad.edu

Abstract

Heat transfer Augmentation techniques refer to different methods used to increase rate of heat transfer without increasing size and without affecting overall performance. These techniques used in Heat Exchangers. Some of the applications of heat exchanger are in process industry, thermal power plants, air conditioning equipment's, radiator for space vehicles, automobiles etc. So, for various application heat exchangers are designed ,which needs exact analysis of heat transfer rate and pressure drop estimations. For compactness and optimize cost, augmentation techniques are used. Augmentation techniques are broadly classified in 3 types viz. Active, Passive and compound techniques. Passive techniques using different inserts are widely used nowadays because of low cost and simplicity, so here brief discussion is on heat augmentation using different inserts. Whenever inserts are used for heat argumentation, along with increase in heat transfer rate, the pressure drop (pumping loss) and friction factor also increase. So, need of optimization between benefits of increased heat transfer rate and higher cost involved due to increased pumping and frictional loss. Mainly, in this present seminar, effect on heat transfer characteristics by using twisted tapes have been studied and compare with plane tube. Also effect of different twist ratios have been seen.

Key words: Heat Exchanger, augmentation .

I. INTRODUCTION

Heat transfer augmentation techniques refer to different methods used to increase rate of heat transfer without affecting overall performance. These techniques used in heat exchangers. Heat exchangers have several industrial and engineering applications. The design procedure of heat exchangers is quite complicated, as it needs exact analysis of heat transfer rate and pressure drop estimations apart from issues such as long-term performance and the economic aspect of the equipment. The major challenge in designing a heat exchanger is to make the equipment compact and achieve a high heat transfer rate using minimum pumping power. Techniques for heat transfer augmentation are relevant to several engineering applications. In recent years, the high cost of energy and material has resulted in an increased effort aimed at producing more efficient heat exchange equipment. Furthermore, sometimes there is a need for miniaturization of a heat exchanger in specific applications, such as space application, through an augmentation of heat transfer. For example, a heat exchanger for an ocean thermal energy conversion (OTEC) plant requires a heat transfer surface area of the order of 10000 m2/MW. Therefore, an increase in the efficiency of the heat exchanger through an augmentation technique may result in a considerable saving in the material cost. Furthermore, as a heat exchanger becomes older, the resistance to heat transfer increases owing to fouling or scaling. These problems are more common for heat exchangers used in marine applications and in chemical industries. In some specific applications, such as heat exchangers dealing with fluids of low thermal conductivity (gases and oils) and desalination plants, there is a need to increase the heat transfer rate. The heat transfer rate can be improved by introducing a disturbance in the fluid flow (breaking the viscous and thermal boundary layers), but in the process pumping power may increase significantly and ultimately the pumping In recent years, the high cost of energy and material has resulted in an increased effort aimed at producing more efficient heat exchange equipment.

II. CLASSIFICATION OF AUGMENTATION TECHNIQUES:

They are broadly classified into three different categories:
1. Passive Techniques
2. Active Techniques
3. Compound Techniques.

1) Passive Techniques: These 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 behaviour except for extended surfaces. Heat transfer augmentation by these techniques can be achieved by using;

(i) Treated Surfaces: Such surfaces have a fine scale alteration to their finish or coating which may be continuous or discontinuous. They are primarily used for boiling and condensing duties.

(ii) Rough surfaces: These are the surface modifications that promote turbulence in the flow field in the wall region, primarily in single phase flows, without increase in heat transfer surface area.

(iii) Extended surfaces: They provide effective heat transfer enlargement. The newer developments have led to modified finned surfaces that also tend to improve the heat transfer coefficients by disturbing the flow field in addition to increasing the surface area.

(iv) Displaced enhancement devices: These are the inserts that are used primarily in confined forced convection, and they improve energy transport indirectly at the heat exchange surface by displacing the fluid from the heated or cooled surface of the duct with bulk fluid from the core flow.

(v) Swirl flow devices: They produce and superimpose swirl flow or secondary recirculation on the axial flow in a channel. These include helical strip or cored screw type tube inserts, twisted tapes. They can be used for single phase and two-phase flows.

(vi) Coiled tubes: These lead to relatively more compact heat exchangers. It produces secondary flows and vortices which promote higher heat transfer coefficients in single phase flows as well as in most regions of boiling.

(vii) Surface tension devices: These consist of wicking or grooved surfaces, which direct and indirect improve the flow of liquid to boiling surfaces and from condensing surfaces.

(viii) Additives for liquids: These include the addition of solid particles, soluble trace additives and gas bubbles in single phase flows and trace additives which usually depress the surface tension of the liquid for boiling systems.

(ix)Additives for gases: These include liquid droplets or solid particles, which are introduced in single-phase gas flows either as dilute phase (gas-solid suspensions) or as dense phase (fluidized beds).

2) Active Techniques: In these cases, external power is used to facilitate the desired flow modification and the concomitant improvement in the rate of heat transfer. Augmentation of heat transfer by this method can be achieved by

(i) Mechanical Aids: Such instruments stir the fluid by mechanical means or by rotating the surface. These include rotating tube heat exchangers and scrapped surface heat and mass exchangers.

(ii) Surface vibration: They have been applied in single phase flows to obtain higher heat transfer coefficients.

(iii) Fluid vibration: These are primarily used in single phase flows and are considered to be perhaps the most practical type of vibration enhancement technique.

(iv) Electrostatic fields: It can be in the form of electric or magnetic fields or a combination of the two from dc or ac sources, which can be applied in heat exchange systems involving dielectric fluids. Depending on the application, it can also produce greater bulk mixing and induce forced convection or electromagnetic pumping to enhance heat transfer.

(v) Injection: Such a technique is used in single phase flow and pertains to the method of injecting the same or a different fluid into the main bulk fluid either through a porous heat transfer interface or upstream of the heat transfer section.

(vi) Suction: It involves either vapour removal through a porous heated surface in nucleate or film boiling, or fluid withdrawal through a porous heated surface in single-phase flow.

(vii) Jet impingement: It involves the direction of heating or cooling fluid perpendicularly or obliquely to the heat transfer surface.

3) Compound Techniques: When any two or more of these 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. This technique involves complex design and hence has limited applications.

1.3 Different Inserts

Under passive techniques, different inserts are used for augmenting heat transfer. These inserts methods are widely used because of low cost, easily installation and departablility , implentatin capability on existing heat exchanger. Some of recently used inserts are tabulated below.


Figure 1 : Plane twisted tape


Figure 2 : V – cut twisted tape


Figure 3 : Serated twisted tape


Figure 4 : Perforated twisted tape


Figure 5 :Wire Coil


Figure 6 : Jagged Twisted Tape


Figure 7 : Alternative Axis Twisted Tape

1.4 Terminology Used In Twisted Tape

A) Thermo Hydraulic Performance- For a particular Reynolds number, the thermo hydraulic performance of an insert is said to be good if the heat transfer coefficient increases significantly with a minimum increase in friction factor Thermo hydraulic performance estimation is generally used to compare the performance of different inserts under a particular fluid flow condition.

B) Overall Enhancement Ratio -The overall enhancement ratio is defined as the ratio of the heat transfer enhancement ratio to the friction factor ratio.

C) Nusselt Number -The Nusselt number is a measure of the convective heat transfer occurring at the surface and is defined as hd/k, where h is the convective heat transfer coefficient, d is the diameter of the tube and k is the thermal conductivity.

D) Prandtl Number The Prandtl number is defined as the ratio of the molecular diffusivity of momentum to the molecular diffusivity of heat.

E) Pitch The Pitch is defined as the distance between two points that are on the same plane, measured parallel to the axis of a Twisted Tape.

F) Twist Ratio The twist ratio is defined as the ratio of pitch length to inside diameter of the tube.

A	Area	: [m^2]
Cp	Specific heat	: [J/kg K]
d	Tube diameter,	: [m]
d_e	U-cut depth	: mm
D_h	Hydraulic diameter	: [m]
f	Friction factor	
h	Heat transfer coefficient	: [W/m^2 K]
H	Pitch length based on 180°	: [m]
k	Thermal conductivity	: [W/m K]
L	Tube length	: [m]
m	Mass flow rate	: [kg/s]
Nu	Nusselt number	
ΔP	Pressure drop	
Pr	Prandtl number	
Q	Heat transfer rate	: [W]
Re	Reynolds number	
T_h	Hot water temperature	: °C
T_c	Cold water temperature	: °C
ΔT_{lm}	Logarithmic mean temperature difference	
U	Overall heat transfer coefficient	: [W/m^2 K
u	Velocity	: [m/s]
W	Twisted tape width	: mm
y	Twist ratio	
ρ	Density	: [kg/m^3]
M	Dynamic viscosity	: [kg/m-s]

III. METHODOLOGY

Experimental Detail

Schematic diagram of the experimental set-up is shown in figure 9. It consists of two concentric tubes in which hot water flows through the inner tube (Copper tube, di = 25 mm, L = 2000 mm) and cold water flows in counter flow through annulus (GI pipe, di = 54.5 mm). The outer tube is insulated with asbestos rope and glass wool to minimize the heat loss with the surroundings (Insulation thickness = 10 mm). Two calibrated crystal rotameters having flow ranges of 0-20 l min-1 with ±0.1 l min-1 accuracy are used to measure the cold and hot water flow rates. Seven RTD Pt 100 type temperature sensors with ±0.1ºC accuracy are used to measure the inlet and outlet temperature of the hot and cold water.

Twisted tapes are made up of aluminum strips of thickness 1.5 mm and width 23.5 mm. The twist ratio (y) is defined by ratio between one length of twist (or) pitch length (H = 50, 110, and 150 mm) to diameter. In the experimentation PTT and with twist ratios 2.0, 4.4 and 6.0 are used. Geometries of the PTT are shown in figure 10. The water is heated using 3 kW water heaters and the desired temperature is controlled by temperature controller.

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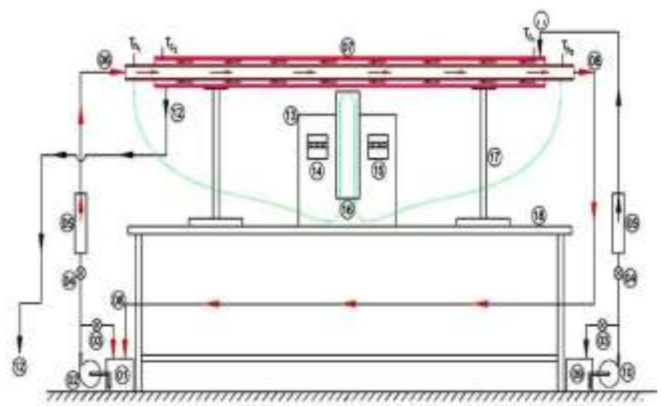
The inlet temperatures at the hot and cold water sides were kept constant at 54ºC and 30ºC, respectively. The cold water was constantly flowed at 0.166 kg s-1 whereas the hot water flow rate was adjusted from 0.033 kg s-1 to 0.12 kg s-1.

As steady state conditions were reached, the inlet and outlet temperatures of hot and cold water were recorded and pressure drop was measured using U tube manometer (manometric fluid –Carbon tetra chloride) for the case of plain tube. Thereafter, the experiment was repeated for PTT.



01	Hot Water Tank	10	Cold Water Pump
02	Hot Water Pump	11	Cold Water Inlet
03	By Pass Valve	12	Cold Water Outlet
04	Flow Control Valve	13	Control Panel
05	Rotameter	14	Temperature Indicator
06	Hot Water Inlet	15	Temperature Controller
07	Test Section	16	Control Panel
08	Hot Water Outlet	17	Temperature Indicator
09	Cold Water Tank	18	Temperature Controller

Figure 1: Experimental setup

IV. DATA REDUCTION

The data reduction of the measured results is summarized as follows:

The oveall heat transfer cofficient (U)

$$Q_{avg} = U\, A_i\, \Delta T_{lm}$$

$$\Rightarrow U = \frac{Q_{avg}}{A_i \Delta T_{lm}}$$

The annulus side heat transfer cofficient (ha) calculated from following equation,

$$\frac{h_a D_h}{k} = 0.023\ Re^{0.8}\, Pr^{0.4}$$

The tube side heat transfer cofficient (hi) calculated from following eqation

$$\frac{1}{U} = \frac{1}{h_i} + \frac{1}{h_a} \qquad (4)$$

Thus,

,Nusselt Number ,

$$Nu_i = \frac{h_i d_i}{k}$$

and Friction Factor,

$$f = \frac{\Delta p}{\left(\frac{L}{d_i}\right)\left(\frac{\rho u^2}{2}\right)}$$

V. RESULTS AND DISCUSSIONS

A. Effect of twisted tape on heat transfer

Variation of Nusselt number with Reynolds number in the tube fitted with PTT and also the plain smoth tube are presented in figure 11

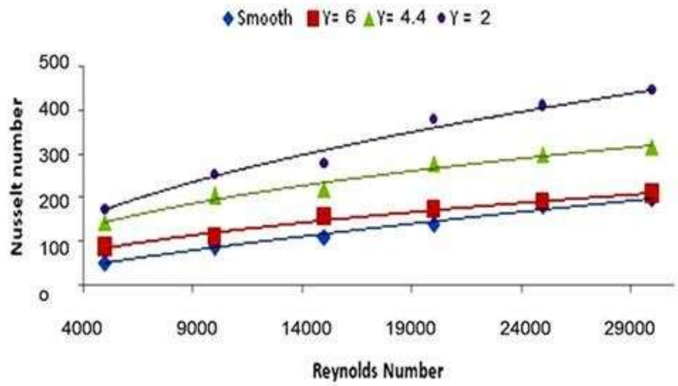


Figure-11-Graph of nusselt number v/s Reynolds number in Plane twisted tape[3]

It is observed that for all cases, Nusselt number increases with increasing Reynolds number. As expected, PTT heat transfer rates are higher than those from the plain tube fitted without twisted tape and also lower twist ratio (y =2.0) heat transfer rate is higher than those from higher ones (y = 4.4 and 6.0) due to increase in turbulent intensity and flow length across the range of Reynolds number. Mean Nusselt numbers for PTT with twist ratios, y =2.0, 4.4 & 6.0 are respectively, 1.67, 1.50 and 1.32 times better than that for the plain tube.

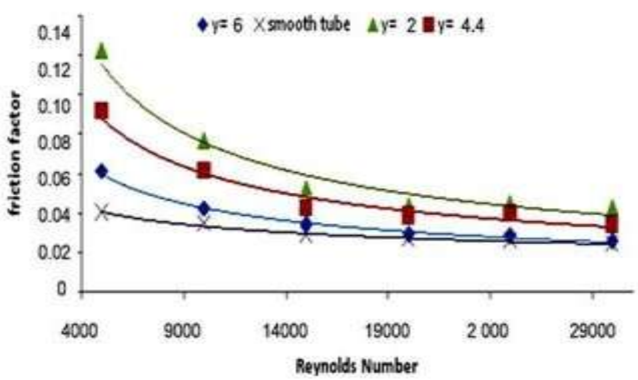


Figure-13- Graph b/w friction factor and reynolds number in Plane Twisted Tape

B. Effect of Twisted Tape on Friction Factor

Variation of friction factor with Reynolds number in the tube fitted with PTT and also the plain smoth tube are depicted in figure 13. It shows that friction factor continues to decrease with Reynolds number and friction factor for lower twist ratio (y = 2.0) is significantly more than that of higher twist ratios (y = 4.4 & 6.0) due to stronger swirl flow in the tube. Over range studied, the mean friction factor for the PTT with twist ratios, y =2.0, 4.4 and 6.0 are respectively, 3.48, 2.92 and 2.45 times higher than that for the plain tube

C. Thermal enhancement factor for PTT :

According to the literature studies [3] a comparison of heat transfer coefficients in a plain tube (p) and the tube fitted with turbulator (t) was made at the same pumping power since it is relevant to operation cost.

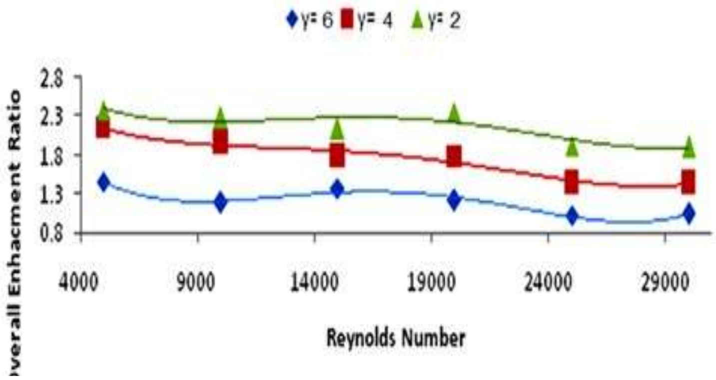


Figure-15- Graph b/w enhancement ratio and Reynolds no. in Plane Twisted Tape[3]

Thermal enhancement factor for PTT at different twist ratios y = 2.0, 4.4 and 6.0 presented in figure 15..

The thermal enhancement factor for all twisted tapes tends to decrease with increasing Reynolds number. With the use of PTTs, thermal enhancement factors were in a range between, 1.12 - 1.2, 1.03 -1.10 and 1.0 - 1.06 respectively for the twist ratios y = 2.0, 4.4 and 6.0.

CONCLUSION

In this seminar effect of twisted tape insert in HE tube on heat transfer and different characteristics have been presented.Also effect of different twist ratio in twisted tape have been seen and result can be summarized as below.

1) Mean Nusselt number and Mean friction factor in tube with twisted tape increases with decreasing twist ratio.

2) With increase in flow rate (Reynolds no.) Nusselts no. increases while friction factor decreases.

3) Over the range of Reynolds number considered average thermal enhancement factors in the tube equipped with PTT are found 1.15, 1.06, and 1.02. The thermal enhancement factors for all the cases are more than unity indicates that the effect of heat transfer enhancement due to the enhancing tool is more dominant than the effect of rising friction factor and vice versa.

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