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"Increase The Heat Transfer Rate of Double Pipe Heat Exchanger With Quadratic Turbulator (Baffle) Attached Twisted Tape Insert"

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Abstract-*Enhancing heat transfer surface are used in many engineering applications such as heat exchanger, air conditioning, chemical reactor and refrigeration systems, hence many techniques have been investigated on enhancement of heat transfer. One of the most important techniques used are passive heat transfer technique or Augmentation Technique such as Twisted Tape. So many researchers tried to increase the effective surface area Contact with fluid to increases the heat transfer rate in the heat exchanger. In this research study focus on enhancement of double pipe counter flow heat exchanger more efficient with Quadratic Turbulator (baffle) attached twisted tape insert and it has been compared to the simple twisted tape insert and plain tube. The performance ratio increased from 1.13% to 1.16% with simple twisted tape to turbulator attached with twisted tape insert.*

Key words: *Heat Transfer, Twisted tape, Performance Ratio, Double pipe heat exchanger, Turbulator*

1. Introduction

Heat exchangers are popular used in industrial and engineering applications. The design procedure of heat exchangers is quite complicated, as it needs exact analysis of heat transfer rate, efficiency and pressure drop apart from issues such as long- term performance and the economic aspect of the equipment. Whenever inserts technologies are used for the heat transfer enhancement, along with the improvement in the heat transfer rate, the pressure drop also increases, which induces the higher pumping cost. Therefore any augmentation device or methods utilized into the heat exchanger should be optimized between the benefits of heat transfer coefficient and the higher pumping cost owing to the increased frictional losses.

1.1. Active method:

This method involves some external power input for the improvement in heat transfer. Some examples of active methods include induced pulsation by cams and reciprocating plungers, the use of a magnetic field to disturb the seeded light particles in a flowing stream, mechanicals aids, surface vibration, fluid vibration, electro static fields, suction or injection and jet impingement requires an external activator/power supply to bring about the enhancement.

1.2. Passive method:

This method generally uses surface or geometrical modifications to the flow channel by incorporating inserts or additional devices. For example, inserts extra component, swirl flow devices, treated surface, rough surfaces, extended surfaces, displaced enhancement devices, coiled tubes, surface tension devices and additives for fluids.

1.3. Compound Method:

Combination of the above two methods, such as rough surface with a twisted tape swirl flow device or rough surface with fluid vibration, rough surface with twisted tape.

The need for high-performance thermal systems in many engineering applications has stimulated considerable interest in finding various methods to improve heat transfer in the system. The conventional heat exchangers are generally improved by means of various augmentation techniques with emphasis on many types of surface enhancements. Augmented surfaces can create one or more combinations of the following conditions that are favorable for the increase in heat transfer rate with an undesirable rise of friction:

(1) Interruption of boundary layer development and increasing turbulence intensity;
(2) Increase in heat transfer area; and
(3) Generating of swirling and/or secondary flows.

1.4. Need

Heat exchangers are used in different processes ranging from conversion, utilization & recovery of thermal energy in various industrial, commercial & domestic applications. These include power production, process, chemical and food industries, electronics, environmental engineering and waste heat recovery, manufacturing industries and air conditioning, refrigeration and space applications. Examples of heat exchangers that can be found in all homes are heating radiators, the coils on your refrigerator and room air conditioner and the hot water tank.

1.5. Problem Definition

The Augmentation technique is the best suited technique to increase the heat transfer rate of heat exchanger double pipe heat exchanger. To increase the efficiency of double pipe heat exchanger there are lots of work has been done. Baffles are generally used in the external wall of heat exchanging devices, in solar air heating, other heat exchangers. But, if it will mounting on the twisted tape, than it give the batter output and efficiency of the double pipe heat exchanger.

1.6. Objectives & Goal

This will give a new way to the researchers for tube type heat exchanger and it may helpful to the industries. It will helpful to increase the efficiency with the minimum cost of construction. Also, its installation and maintenance will goes to easy and material easily available in the market.

2. Literature survey

To obtaining the conclusion of the study some literature work has been carried out as following:

[1] **Prabhata K. Swamee, , et al.** Formulated optimal design of the exchanger as a geometric programming with a single degree of difficulty. For yield problem the optimum values of inner/ outer pipe diameter and utility flow rate used for a double pipe heat exchanger of a given length, when a specified flow rate of process stream is to be treated for a given inlet to outlet temperature.

They observed outlet temperature of the process stream is around 323 K which is well below the approachable temperature indicating the practicality of the solution. They found efficiency of the exchanger is around 63.6% which is reasonably high.

[2] **Shou-Shing HSIEH, et. al**. worked for single-phase forced convection in double pipe heat exchangers containing a two-dimensional helical fin roughness on the outer surface of the inner tube. From This Study, with a helical angle (α: 65°), a pitch to height ratio (p/e = 1.45), and three aspect ratios (shell side to tube side dia.) of D_o/D_i- 2.68, 3.48 and 5.1.Three corresponding ratios are taken of roughness height to hydraulic dia. (e/Ds) of 0.192, 0.13 and 0.08, respectively.

They found heat transfer performance is to be depended upon both the mass flow rate and the ratio of roughness height to hydraulic dia. (e/D_H).They observed that the Nusselt numbers of the ratios of roughness height to hydraulic dia. of 0,192 and 0.13 are found nearly 60 and 40%, respectively, higher than that of the ratio of roughness height to hydraulic dia. of 0.08 for all the flow rates investigated.

[3] **Timothy J. Rennie, et. al** performed an experimental study of double pipe helical heat exchanger with parallel and counter flow configuration. Overall heat transfer coefficients were calculated and heat transfer coefficients in the inner tube and the annulus were determined using Wilson plots.

They calculated a Nusselt numbers for the inner tube and the annulus. Heat transfer rates, however, are much higher in the counter flow configuration, due the increased log mean temperature difference.

[4] **H. A. Mohammed, et al.** studied an effect of louvered strip inserts placed in a circular double pipe heat exchanger on the thermal and flow fields utilizing with various types of nano-fluids. The continuity, momentum and energy equations are solved by means of a finite volume method (FVM). Reynolds number range of 10,000 to 50,000.

They used four different types of nano-particles, Al2O3, CuO, SiO2, and ZnO with different volume fractions in the range of 1% to 4% and different nano-particle diameters in the range of 20 nm to 50 nm, dispersed in a base fluid (water). They obtained result with forward louvered strip arrangement approximately 367% to 411% at the highest slant angle of α=30° and lowest pitch of S= 30 mm. They found that SiO2 nano fluid has the highest Nusselt number value, followed by Al2O3, ZnO, and CuO while pure water has the lowest Nusselt number.

[5] **Paisarn. Naphon, Et al.** investigated a heat transfer characteristics and the pressure drop in the horizontal double pipes with twisted tape insert. The twisted tape is made from the aluminium strip with thickness of 1 mm and the length of 2000 mm.R22 is used as the refrigerant for chilling the water.

They compared tube with twisted insert to without twisted tape. The twisted tape insert has significant effect on enhancing heat transfer rate. However, the pressure drop also increases. The heat transfer rate increases with increasing tube-side Reynolds number.

[6] **Smith Eiamsa-Ard, et al.** carried out an Experimental work on turbulent heat transfer and flow friction characteristics in a circular tube equipped with two types of twisted tapes: (1) typical twisted tapes (2) alternate clockwise and counterclockwise twisted tapes (C–CC twisted tapes).

They included the tapes with three twist ratios, y/w = 3.0, 4.0 and 5.0 and each with three twist angles, h = 30°, 60° and 90°.The maximum heat transfer enhancement indexes of the C–CC twisted tapes with h = 90° for y/w = 3.0, 4.0 and 5.0, are 1.4, 1.34 and 1.3, respectively.

[7] **Hamed Sadighi Dizaji, et al.** worked to increase the number of thermal units (NTU) and performance in a vertical shell and coiled tube heat exchanger via air bubble injection into the shell side of heat exchanger. In this Experiment Air bubbles were injected inside the heat exchanger via a special method and at new different conditions.

They observed that the amount of NTU and effectiveness can be significantly improved due to air bubbles injection. Exergy loss and effectiveness are always higher than those for heat exchanger without air bubble injection.

3.1. Summary of Literature Study:

Many Researchers were worked on heat exchanger and twisted tape inserts. But none of them have been worked on twisted tape insert with baffles attached, which is a new or different way to obtain enhancement in heat transfer of heat exchanger.
From these literature surveys we conclude that heat transfer rate increases with increase in contact area of fluid or residence time of fluid in the tube. For these experiments augmentation techniques were used.
When researchers increases the contact surface area of fluid by twisted tape with making a cut, wire mesh, drill hole, parabolic cutting and many more etc, than heat transfer rate in heat exchanger will be increases.

3. Research Methodology

Identified and select the area of research work from the available scope of work. Survey the related literatures and find out the research gap. Creating a line diagram for the experimental setup then collecting the components for it. After final fabrication of setup, experiments were taken on setup, it will be assemble after collection as per the diagram. The working fluid is taken as water for this experiment; cold water is passing from the inner pipe and hot water passing from the annulus. The flow of in the heat exchanger is counter flow.
Experiments has been taken for without any tape insert (plain tube), with simply twisted tape and twisted tape insert with quadratic turbulator (baffles). Data has been conducted by measuring instruments like manometer, thermocouples, temperature indicator, etc. and in the last analyze and computing the resultant data.

3.1. Data Reduction Equations

Heat transfer from hot water can be calculated by

$$Q_h = m_h * Cp_h * (Th_i - Th_o)$$

Heat transfer to cold water can be calculated by

$$Q_c = m_c * Cp_c * (Tc_o - Tc_i)$$

The average heat transfer rate can be calculated by

$$Q_{avg} = \frac{Q_c + Q_h}{2}$$

The overall heat transfer coefficient U, can be calculated from

$$Q_{avg} = U * Ai * \Delta T_m$$

Where, $Ai = \pi * di * l$ &

$$\Delta T_m = \frac{(Th_i - Tc_o) - (Th_o - Tc_i)}{\ln\left(\frac{(Th_i - Tc_o)}{(Th_o - Tc_i)}\right)}$$

Reynolds number $Re = \frac{\rho * V * d}{\mu} = \frac{4 * m}{\pi * d * \mu}$

Prandtl number $Pr = \frac{\mu * C_p}{k}$

Tube side heat transfer coefficient h_i can be calculated from

$$Nu_i = 0.023 * Re_c^{0.8} * Pr_c^{0.4} = \frac{h_i * d_i}{k}$$

Tube side heat transfer coefficient h_o can be calculated from

$$Nu_o = 0.023 * Re_c^{0.8} * Pr_c^{0.4} = \frac{h_o * d_h}{k}$$

The overall heat transfer coefficient U, can be calculated from (by neglecting thermal resistances of copper tube wall), can be calculated from

$$\frac{1}{U} = \frac{1}{h_i} + \frac{1}{h_o}$$

Friction factor can be written as

$$f = \frac{\Delta p}{\left(\frac{l}{d_i}\right) * \left(\frac{\rho V^2}{2}\right)}$$

The performance ratio or enhancement efficiency (ψ) is defined as the ratio of the heat transfer coefficient for the tube fitted with quadratic turbulator attached twisted tape to that for the smooth tube at a constant Reynolds number (Re) as follows :

$$\psi = \left(\frac{hc}{hs}\right)_{Re}$$

4.4. Experimental Setup

The experimental study is done in a double pipe heat exchanger having the Specifications as listed below:-
Material of outer and inner tube Copper
Inner pipe ID = 17 mm, Inner pipe OD=19 mm, Length = 1600 mm
Outer pipe ID =28 mm, Outer pipe OD =32mm, Length = 1500 mm
Pressure tapping to pressure tapping length = 1550mm
Water at room temperature was allowed to flow through the inner pipe while hot water was flow through the annulus side in the counter current direction. Fabricated double pipe heat exchanger with counter flow arrangement in figure 1

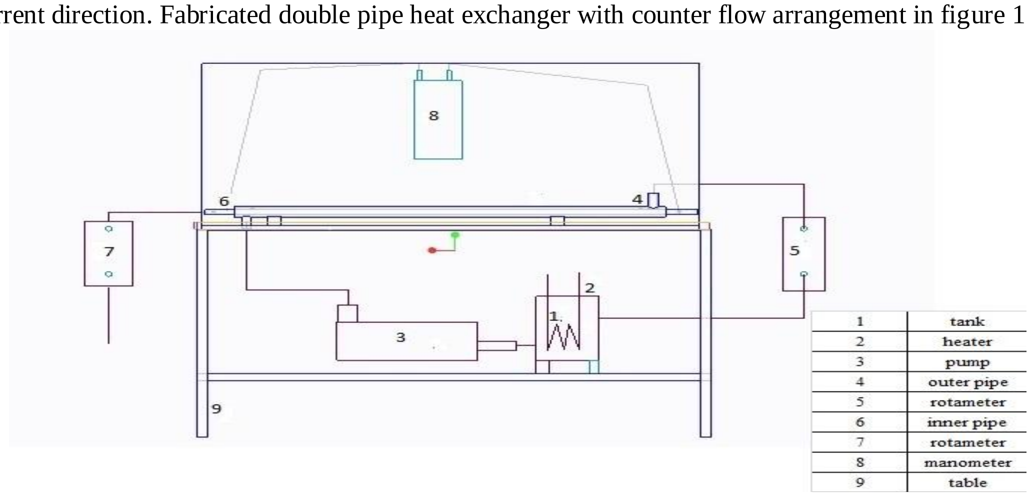

Figure 1 Experimental Setup Line Diagram

4.5. Modified Twisted Tape and Simple Twisted Tape:

Twisted tapes are the metallic strips twisted with some suitable techniques with desired shape and dimensions generally inserted in the flow. The swirling flow was introduced by using twisted tape placed inside the inner tube of the heat exchanger. The experimental results by different researchers revealed that the increase in heat transfer rate of the twisted-tape inserts is found to be strongly influenced by tape produced swirl or vortex motion. Twist ratio of 4.5 from the previous research study. Material - Stainless steel (Length: 1500 mm, Width: 16 mm, Thickness: 1.6 mm) and pitch = 72 mm, twist ratio = 4.5.

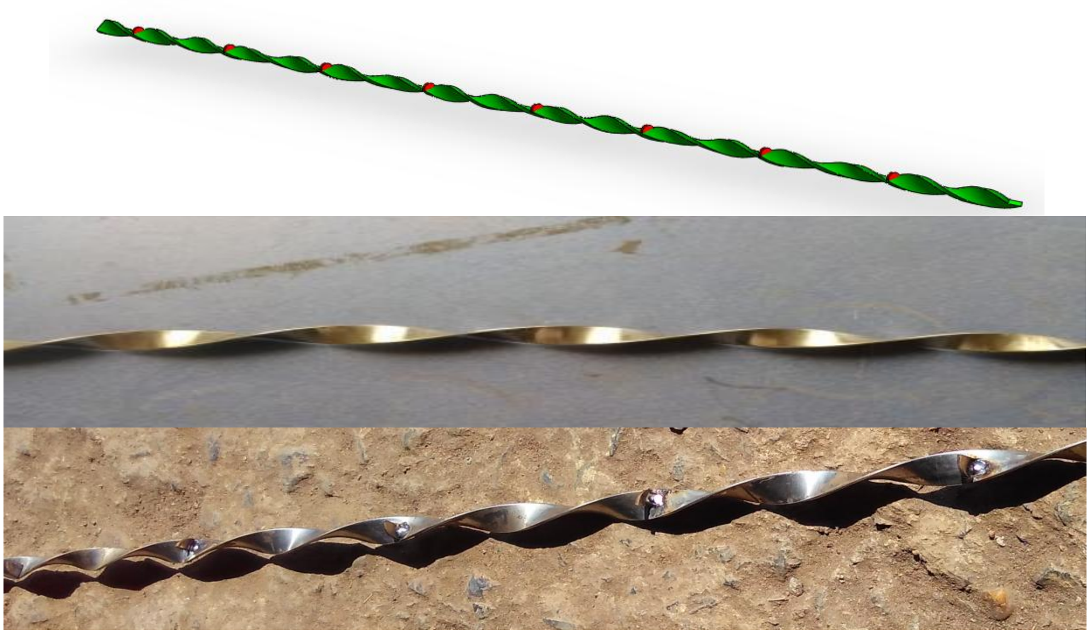

Figure 2 Twisted Tape

The swirl flow helps decrease the boundary layer thickness of the fluid flow and increase residence time of fluid in the inner tube. The enhancement efficiency and Nusselt number enhances with decreasing the twist ratio and friction factor also increases with decreasing the twist ratio. So we were used twisted tape with twist ratio of 4.5 for the purpose of increasing of heat transfer. Figure 2 shows twisted tape made of stainless steel. It is inserting in the inner pipe carefully. Modified twisted tape have same twist ratio with attached quadratic circle tabulator baffle (swirl generator) attached at the equal distance of two times the pitch.

Figure 3 Experimental setup.

It is a counter flow double pipe heat exchanger. Insulation of glass wool was provided at the outer side of outer pipe to reduce the heat loss. The tank contains fluid (water) which is heated with the help of attached heater in hot water tank. The hot fluid from the hot water tank was going to the annulus side and outlet through rotameter. Pump is provided between hot water tank and inlet of annulus to flow the hot water in the system. Outlet of hot fluid is controlled by rotameter and collected in hot water tank; recalculate it with the help of pump. Another fluid (cold water) is passing to inlet of inner pipe in counter direction through one end. Outlet of cold water was controlled by rotameter and than into drainage. Temperature of both pipes at the inlet as well as the outlet is measured with the help of thermocouple. Rotameter at outlet of both pipes is measuring the mass flow rates. Pressure of fluid in inner pipe can be measured with the help of U - tube manometer in mm of Hg. Experiments was performed with various inlet temperatures and flow rates of hot water entering the test section. In the experiments, the cold water flow rate was increased in small increments while the hot water flow rate is constant, inlet cold water and hot water temperatures were kept constant. The inlet hot and cold water temperatures were adjusted to achieve the desired level by using electric heaters controlled by on/off. Before any data were recorded, the system was allowed to approach the steady state. The flow rates of the water are controlled by adjusting the valve and measured by two calibrated with master rotameter in the Maxon Engineers. The average value of heat transfer rate is obtained by the supplied heat by hot water and the absorbed heat by cold water. Readings are being taken for following types of inserts and noted with

1. Without any insert (plain tube) 2. Simple Twisted tape inserts 3.Modified twisted tape insert.

4.6. Experimental Process

Heater is on to heat the water to 50°C to 60°C water tank of capacity. The tank is provided with a centrifugal submersible pump & a bypass valve for recirculation of hot water to the tank & to the experimental setup.

Hot water at about 50°C TO 60°C is allowed to pass through the annulus side of heat Exchanger.

Cold water is now allowed to pass through the tube side of heat exchanger in Counter current direction at a desired flow rate.

The water inlet and outlet temperatures for both hot water & cold water (T1-T4) are recorded only after temperature of both the fluids attains a constant value.

Readings will be taken with Different Types of inserts and noted in the observation table. Then collect all reading and Find out the heat transfer coefficient and uncertainty analysis from the equation.

The procedure was repeated for different cold water flow rates ranging from 0.034-0.102 Kg/sec. and hot water flow rate any one constant value was selected ranging value from 0.028-0.28Kg/sec.

Compare the theoretical and experimental results for plain tube to validate the result of experiment. Measure the effect of twisted tape insert on the heat transfer and the effect of modified twisted tape with quadratic turbulator (baffle) attached with insert and compare the results. At constant flow rate of hot side varying the cold side flow rate in which twisted tape is inserted. Find out the heat transfer co efficient and effect on friction factor.

5. Result and Discussion

5.1. Comparison between U_{theo} and U_{exp} for Plain Tube

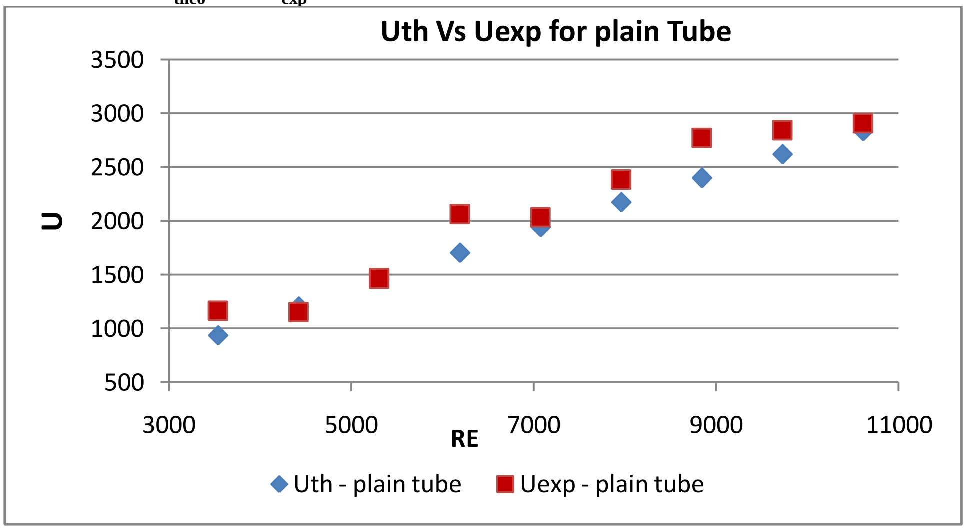

Figure 4 Graph (U_{theo} & U_{exp} Vs Re of the Plain Tube)

Figure 4 by some mathematical calculations the values of U_{theo} and U_{exp} has been obtained with respected to the Reynolds Number. Fig. 4 shows the comparative results of U theoretical and experimental for plain tube. This comparison would be taken for approve the results of heat exchanger. From these results, it has been conclude that procedure and reading data are correct and value of U_{theo} and U_{exp} are very close. So that for the further work, theoretical calculations are not required and it has been eliminated.
In this Figure 4 red line shows the values of theoretical overall heat transfer coefficient and red line shows the experimental overall heat transfer coefficient. The differences between those both values are negligible.

5.2. Nusselt Number Results

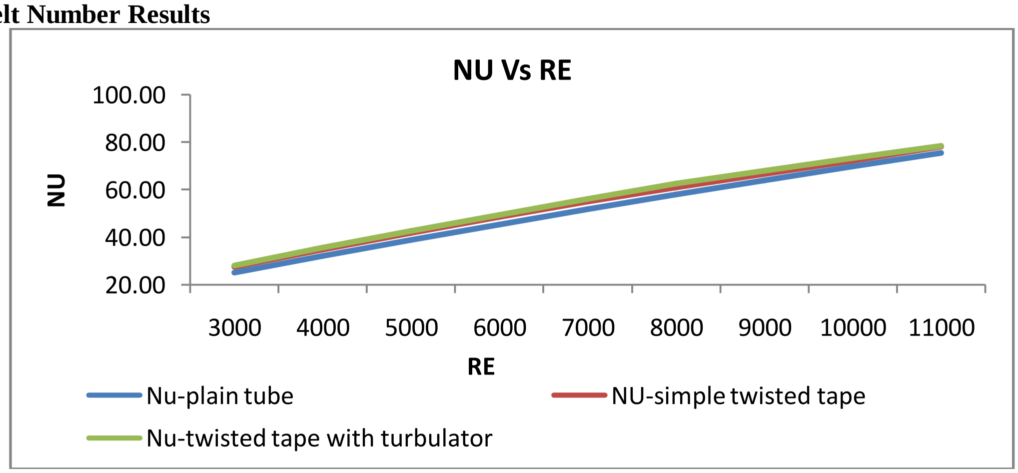

Figure 5 Graph (Nu Vs Re)

Figure 5 gives the Nu results for Plain Tube, with simple Twisted Tape Insert and with Turbulator inserts along with the corresponding performance evaluation criteria Re for each of the readings. As depicted in Figure 5, there is a Nu was drastically increased with twisted tape insert as compared to the plain tube results, and there is also increase in Nu, when Twisted tape insert with turbulator. At higher mass flow rate of working fluid from the test section gives the difference in Nu between Plain tube, with twisted tape and twisted tape use with turbulator. From Figure 5 we observe that the Nu was increased from 22 to 75 and Re was increased from 3100 to 13000. Maximum value of Nu can be predicted by the twisted tape insert with turbulator in the test section. It directly increases the heat transfer rate.

5.3. Overall Heat Transfer Coefficient Results

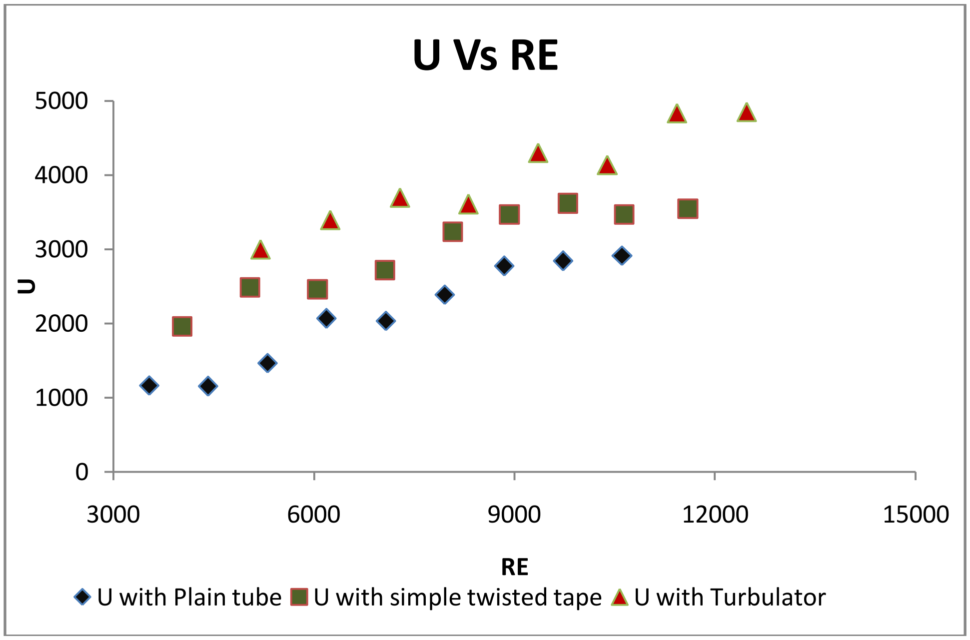

Figure 6 Graph (U Vs Re)

Figure 6 gives the U results for Plain Tube, With Twisted Tape Insert and with turbulator inserts along with the corresponding performance evaluation criteria Re for each of the readings. As depicted in Figure 6, U was increased with twisted tape insert as compared to the plain tube results, and there is increase in U, when Twisted tape insert with turbulator. At higher mass flow rate of working fluid from the test section difference in U between Plain tube, with twisted tape and twisted tape use with turbulator was increased. From Figure 6 we observe that the U was increased from 1163 to 2909 and Re was increased from 3539 to 10616. Maximum value of U can be predicted by the twisted tape insert with turbulator in the test section. It directly increases the heat transfer rate.

5.4. Friction Factor Results

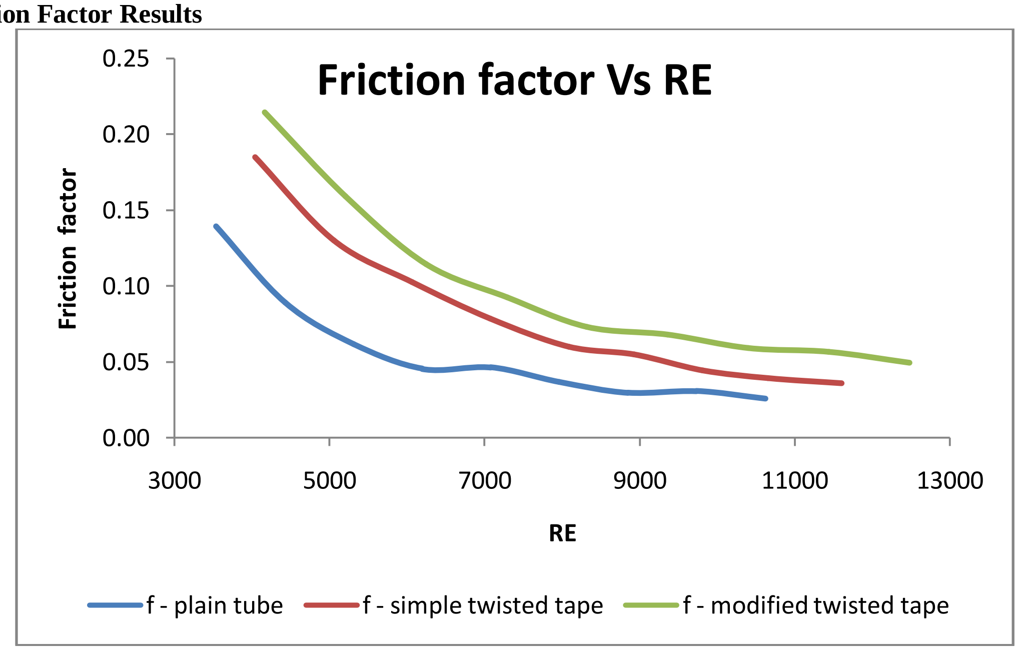

Figure 7 Graph (f vs Re)

Figure 7 gives the f results for Plain Tube, With Twisted Tape Insert and with turbulator, inserts along with the corresponding performance evaluation criteria Re for each of the readings. As depicted in Figure 7, f was increased with

twisted tape insert as compared to the plain tube results, and there is increase in f, when Twisted tape insert with Turbulator. At higher mass flow rate of working fluid from the test section difference in f between Plain tube, with twisted tape and twisted tape use with turbulator was decreased. From Figure 7 we observe that the f was decreased from 0.14 to 0.03 and Re was increased from 3500 to 11000. Minimum value of f can be predicted by the plain in the test section.
From the above results, it has been observed that, if the mass flow rate of the water in inner pipe was increased than Reynolds Number, heat transfer coefficient U and Nu has been increased and friction factor was decreased. The maximum value of the Nu, heat transfer coefficient U and friction factor has been observed in the twisted tape insert with turbulator for counter flow heat exchanger.

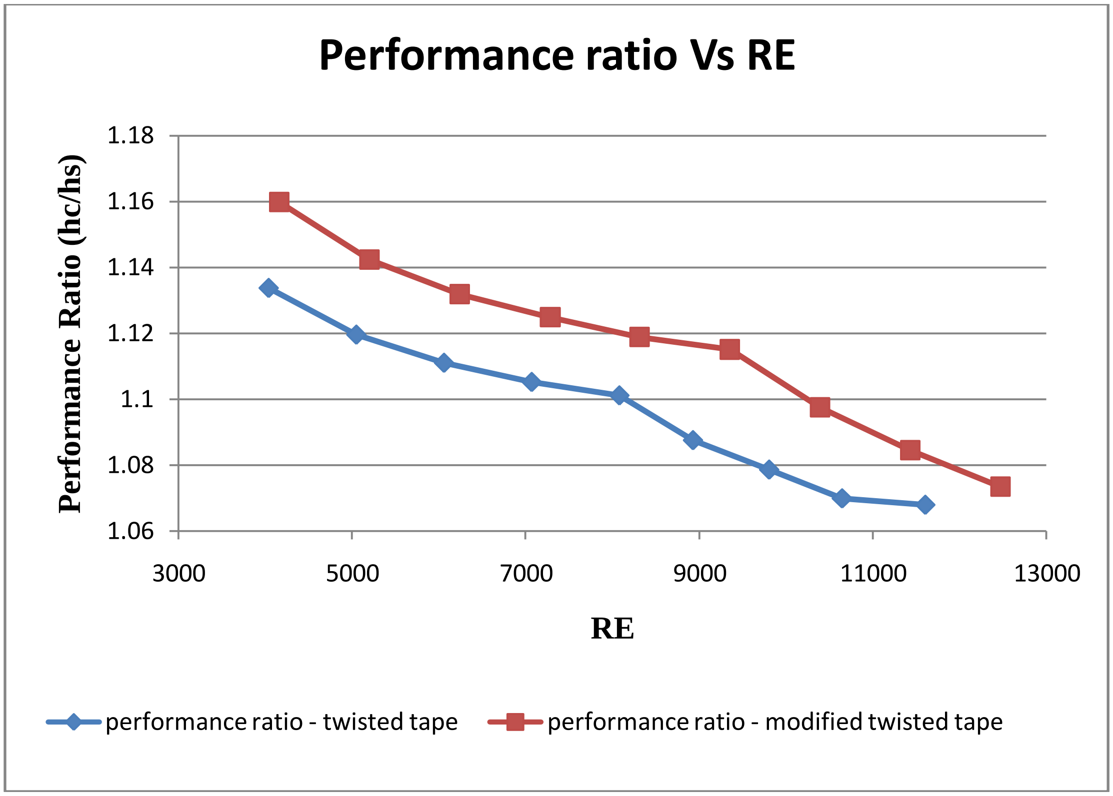

Figure 8 Performance ratios Vs Reynolds Number

The quality of enhancement concept is found from the performance ratio as shown in Figure 8. The figure shows the performance of the modified twisted tape give a high performance ratio as compared to the simple twisted tape geometry. At the 4000-4200 Reynolds number performance ratio of the modified twisted tape have 1.16 and simple twisted tape have 1.13. The performance is gradually decreases with increasing Reynolds number.

6. Conclusion

This experimental work has been done to increase the heat transfer coefficient of counter flow double pipe heat exchanger. From the above experiments, it has been observe that Nu and U was increase with respect to increase in Reynolds Number and friction factor is decreased with increasing Reynolds Number.
Maximum Nusselt Number has been observed in the experiments by twisted tape inserts with turbulator. Large difference in Nusselt Number has been observed in between plain tube and with twisted tape insert in heat exchanger. Nu for twisted tape insert with turbulator and simple twisted tape was high respectively as compared to plain tube. Also very small difference of friction factor has been observed between twisted tape and twisted tape with turbulator at higher Reynolds number.
Experimentally, Twisted Tape with Quadratic Turbulator gives higher overall heat transfer coefficient of 153 % than simple Twisted Tape and 258 % than Plain Tube at lowest Reynolds number.
Experimentally, Performance ratio is increased from 1.13 for simple twisted tape to 1.16 for twisted tape with quadratic turbulator at comparable Reynolds number.
From this experiment, it has been observed that the twisted tape insert with turbulator gives more heat transfer as compared to the plain tube and simple twisted tape insert in the counter flow double pipe heat exchanger.

References

[01] Prabhata K. Swamee, et. al. "Optimum design of double pipe heat exchanger", International Journal of Heat and Mass Transfer 51 (2008) 2260–2266.

[02] Shou-Shing HSIEH, et. al. "Heat Transfer Coefficients Of Double Pipe Heat Exchanger With Helical Type Roughened Surface", Heat Recovery Systems Vol. 7, No. 2, pp. 119-127, 1987.

[03] Timothy J. Rennie, et. al. "Experimental studies of a double-pipe helical heat exchanger", Experimental Thermal and Fluid Science 29 (2005) 919–924.

[04] H.A. Mohammed, et. al. "Heat transfer enhancement of nanofluids in a double pipe heat exchanger with louvered strip inserts", International Communications in Heat and Mass Transfer 40 (2013) 36–46.

[05] Paisarn Naphon, "Heat transfer and pressure drop in the horizontal double pipes with and without twisted tape insert", International Communications in Heat and Mass Transfer 33 (2006) 166–175.

[06] Smith Eiamsa-ard, et. al. "Performance assessment in a heat exchanger tube with alternate clockwise and counter-clockwise twisted-tape inserts", International Journal of Heat and Mass Transfer 53 (2010) 1364–1372.

[07] Hamed Sadighi Dizaji, et. al. "Experiments on air bubbles injection into a vertical shell and coiled tube heat exchanger; exergy and NTU analysis", Energy Conversion and Management 103 (2015) 973–980.

Nomenclature

A_i	Area of Inner Pipe, m^2
C_p	Specific Heat, J/kg K
D_h	Annulus Diameter, m
D_i	Diameter of Inner Pipe, m
k	Thermal Conductivity Of Fluid, W/mK
L	Effective Length, m
Nu	Nusselt Number
Pr	Prandtl Number
Q	Heat Transfer Rate, W
Re	Reynolds Number
T_c	Temperature of cold fluid, K
T_h	Temperature of Hot Fluid, K
U	overall heat transfer coefficient, W/m^2K
V	Velocity of Fluid, m/s
Δp	Pressure Drop, mm of *hg*.
ΔT	LMTD
ρ	Density Of Fluid, kg/m^3
μ	Dynamic Viscosity, kg/ms
f	Friction Factor
Ψ	Performance Ratio

