Experimental analysis for enhancement of heat transfer with triangular baffled twisted tape in double pipe heat exchanger

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ABSTRACT

The investigation was aimed to optimize of twisted tape by design triangular baffles on it and estimate results by the experimental setup. Research were performed on the different setup for counter flow, in which double pipe heat exchanger, twisted tape was used as orientation to calculate with the modified i.e. triangular baffled twisted tape (TBT). Experiment has been performed to study the influences of Triangular baffled twisted strip on the heat transfer and effectiveness in a circular tube channel. The experiment conducted with the twisted of metallic strip which is of width 'w', thickness 't', having a periodical helical pitch of 180^0 twist for creation of swirl and turbulent flow in the channel. The experimental results for the Reynolds number ranged from 8000 to 10500, where found nusselt number varies from 30 to 215 at different setup, using water as the test fluid are examined. In the studied, the existence of channel with (TBT) leads to augment in heat transfer rate larger than the use of smooth channel around 94.156% and effectiveness is also highest in this setup which is 0.618. In addition, the thermal augmentation of double pipe heat exchanger is also determined and it is adept tube insert which can be broadly used in heat transfer enhancement of turbulent flow.

Keywords: Double pipe heat exchanger, Triangular baffled twisted (TBT), Nusselt number, Reynolds number.

INTRODUCTION

Heat exchanger is apparatus which transfers the heat energy between two fluids that are at dissimilar temperature whereas keeping the mixing with each other. Heat exchanger is broadly used in a number of industries. Cost of energy, cost of materials and heat transfer enhancement is a issue of much interest to work on method of how to augment rate of heat transfer and increase higher thermal efficiency, but in the practice pumping power increases eventually, the pumping cost become high. Heat transfer improvement methods play a very important role for laminar flow heat transfer since the heat transfer coefficients are usually low for laminar flow in plain tubes [1,2,3,4]. The heat transfer rate can be improved by disturbance in the fluid flow, which can be achieved by with the twisted tape/turbulator place in circular tube. Placing of turbulators in the flow channel is one of the excellent Passive heat transfer enhancement techniques due to their advantages of easy production, procedure as well as low maintenance [5,6]. In general, the performance of turbulators depends on their geometries. In former investigations, turbulators with quite a lot of shapes were utilized to advance heat transfer. The inserts [7,8] studied included coil wire inserts, brush inserts, mesh inserts, strip inserts, twisted tape inserts etc. Augmentation of convective heat transfer in inside flows with tape inserts in tubes is a well-acclaimed technique engaged in industrialized practices.

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Heat transfer enrichment or improvement method refers to the enhancement of thermohydraulic performance of heat exchangers. Presented enhancement method can be generally classified into three different categories:

1. Passive Techniques
2. Active Techniques
3. Compound Techniques.

A. Passive Techniques:

These methods usually use surface or geometrical modifications to the flow guide by incorporating place or supplementary devices. They encourage high heat transfer coefficients by troubling or changing the existing flow performance which also leads to augment in the pressure drop [1]. Extended surfaces case, useful heat transfer area on the side of the extended surface is enlarged. Passive techniques [2] embrace the benefit over the active techniques as they do not involve any direct effort of external power. Heat transfer enhancement by these method can be achieved by using:

1) Treated Surfaces
2) Rough surfaces
3) Extended surfaces
4) Displaced enhancement devices
5) Swirl flow devices
6) Coiled tubes
7) Surface tension devices
8) Additives for liquids

B. Active Techniques:

These methods are more multipart from the use and design judgment as the method requires a few external power input to reason the desired flow adjustment and enhancement [6] in the rate of heat transfer. It finds limited application because of the need of external power in many practical applications. In relationship to the passive techniques, these methods have not shown a lot prospective as it is hard to provide outside power input in various cases. Various active techniques are as follows:

1) Mechanical Aids
2) Surface vibration
3) Fluid vibration
4) Electrostatic fields
5) Injection
6) Suction
7) Jet impingement

C. Compound techniques:

A compound enhancement technique is the one where over one of the beyond mentioned methods is used in arrangement with the purpose of further improving the thermo-hydraulic performance of a heat exchanger.

TWISTED TURBULATOR DETAILS:

The aluminium material was use for making the twisted tapestrip. It is suitable for low weight, high strength, better flexibility, good for corrosion resistance and thermal conductivity (237 W/m-K).

(a)Aluminium plain Strip: The twisted strip were made by aluminium straight tape with tape length (L) of 1530 mm, tape thickness (t) of 0.5 mm, and tape width (w) of 10 mm for the typical twisted tape.

Fig 1 Plain twist strip(PT)

(b)Aluminium Twisted Strip with triangular baffled:These are related tothe simple twisted stripe but with triangular baffled in strip per pitch. The base of triangular section is 1/3rd of width of the strip and the height of triangular section is equal to the radius of the copper pipe.

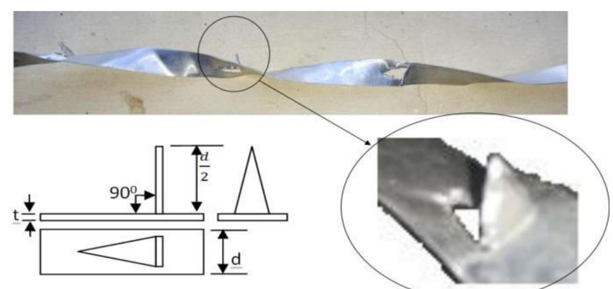

Fig 2 Triangular baffled twist strip(TBT)

The use of twisted tape for heat transfer enhancement was early reported by Kurhade Anant Sidhappa et. al [9] works in the condition of force convection by using twisted tape insert of width, thicknesses and twist ratio with circular holes and conclude that for Reynolds number range 2000 to 12000, the Nussult number & also the Friction factor is increased. Some attempts were made [10,11,14] a Analysis of Heat Transfer in Pipe with Twisted Tape Inserts to understand variation of twist ratio and Reynolds number on heat transfer and flow characteristics using twisted tape inserts and also the heat transfer increases with decrease in twist ratio and increase in Reynolds number.N.A.Uzagare et. al [12] after analyzing heat transfer augmentation using V-Jagged twisted tape

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gives The heat transfer enhancement, thermal performance and friction factor characteristics of V jagged twisted tape turbulator inserted tube will be investigated experimentally.D.S. Nakate et. al [13] Performed for heat exchanger by inserting twisted tape turbulators with baffle For same twist ratio, Baffled reduced width twisted tape with holes & Baffled reduced width twisted tape shows higher heat transfer coefficient & friction factor increase because of higher degree of turbulence created also gives higher heat transfer coefficient than the reduced width twisted tapes.Heydar Maddah et. al [15,21] work to find out effect of twisted-tape turbulators and nanofluid on heat transfer in a double pipe heat exchanger of the inner and outer diameters of the inner tube was 8 and 16 mm. The conclusion given by them is increases in the heat transfer and overall heat transfer coefficient about 12% and 20% also increases in the efficiency about 10% and 30% as With increases in the friction factor about 2% and 2.5% as compared to the base fluid.

K. Hata et. al [16,17] studied twisted tape induced swirl flow pressure drop and heat transfer in vertical circular tube by computational method. Heat flow in this type of exchanger found exponentially increased whereas twisted tape induced pressure drop. the pressure drop tends to increase with the rise in mass flow rate while the friction factor and performance factor give the opposite trends. Pawan A. Sawarkar et. al [18] presented effect of using twisted tape with semi-circular cut insert and conclude that the semi-circular cut twisted tape offered a higher heat transfer rate and friction factor. Friction factor decreases with increase of Reynolds number with increase in cut radius with aluminum twisted tape of width .

Sami D. Salman et. al [19] have investigated CFD Analysis of Heat Transfer and Friction Factor Characteristics in a Circular Tube Fitted with Quadrant-Cut Twisted Tape Inserts in which Tube Test section for plain tube with a discrepancy less than $\pm$8% for Nusselt number and $\pm$10% for friction factor, respectively. Al Amin et. al [20] observed enhancement of heat transfer Using a Rotating Twisted Tape Insert in a Copper pipe. S.D.Patil et. al [22] have analysis of twisted tape with straight winglets to improve the thermo-hydraulic performance of tube in tube heat exchanger in his setup a double pipe heat exchanger consisting of a calming section which is of a Plain copper tube. For same twist ratio, Straight delta winglets shows greater heat transfer coefficient & friction factor than the value we got form inserts Typical Twisted Tape because of increased degree of turbulence created.

DETAILS OF EXPERIMENTAL APPARATUS:

In experiment, the PT and TBT were placed into the copper concentric tube as shown in Fig. 1 & Fig. 2. The tube was good insulated to avoid heat loss. The representation of the conduct test setup is presented in Fig. 3. The Experimental setup is consists of (1) a geyser for supply hot water (2) a digital temperature indicator used for showing different terminal temperature (3) thermocouples used for measuring the temperature of fluid and the tube wall (4) simple opening and closing valves to control the supply of water. (5) Copper tube were used to convey more heat from hot water to cold water, (6) a 5mm thick PVC pipe having a inside diameter of 25mm is used for transport cold water which is the external side of the copper pipe co-axially. (7) supply pipe is attached to main supply which farther divides in two parts one is associated to geyser and other is directly supplied in the PVC pipe., (8) main switch panel, (9) A aluminium twisted strip having 1.53 m in length, 1cm in width and 0.5 mm thick sheet.

The setting of the different setups is only based on the closing and opening of the valve to get a required flow and the insert in the copper pipe. For the simple tube heat exchanger the setup is without insert, but for the twisted tape setup a strip of aluminium having a length equal to the length of copper pipe that is 1.53 m and width equal to the internal diameter of the copper pipe that is 5.1 cm is regularly twisted in axial spiral. For measuring velocity the discharge of both the hot fluid and cold fluid is measured by measuring the volume of the fluid passes through the pipe with in 60 sec. By the value of discharge and area of the particular pipe gives the velocity at that area.

Experiment is performed on the setup with the three for counter flow, in which plane concentric pipe and twisted tape heat exchanger is used as a reference to compare with the modified i.e. triangular baffled twisted tape heat exchanger.

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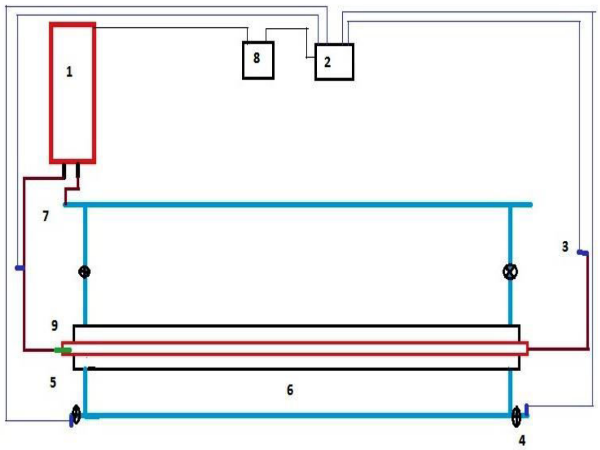

Fig 3 Schematic diagram of experimental apparatus.

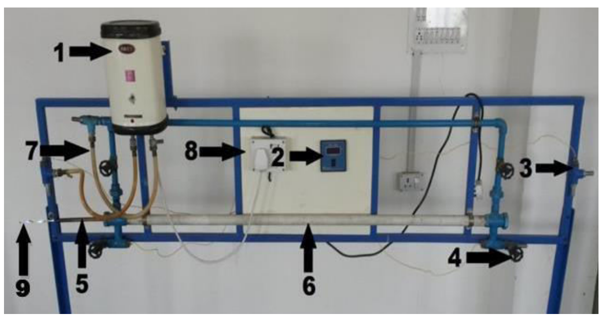

Fig 4 Actual diagram of experimental apparatus.

Table 1 Technical detail of the Parts of Experimentation.

Parameter	Value
Inner pipe (copper) inner dia. (d_i)	1cm
Inner pipe (copper) outer dia. (do)	1.1 cm
Outer Pipe (PVC) inner dia. (dpi)	2.54 cm
Outer Pipe (PVC) outer dia. (dpo)	2.74 cm
Length of copper pipe & twisted tape strip (l)	1.53 m
Width of twisted tape strip (b)	1 cm
Thickness of twisted tape (t)	0.5 mm
Inlet temp. of cold water (tci)	30°C
Inlet temp. of hot water (By Geyser) (thi)	57°C
Hot water flow rate (Q)	0.033 lit/s
Cold water flow rate (Qc)	0.066 lit/s
Heat transfer area (A_p)	0.05287 m^2
Cross sectional area of copper pipe (A_{cs})	0.7854 cm^2
Density of water @ 57°C (ρ)	986.66 Kg/m^3
Viscosity of water @ 57°C (μ)	0.000489Kg/ms
Prandtl number Pr @ 57°C	3.255
Thermal conductivity of water (k_w)	0.621 KW/mk
Thermal conductivity of Cupper (k_{cu})	401 KW/mk

DATA REDUCTION

A litter measuring vessel is filled with the flowing water at the exit condition for both hot and cold water and the time of filling the one litter is observed

1. Discharge of cold and hot water,

Q= Volume filled by fluid per unit time (1)

2. Velocity of hot water in plane co centric tube,

V= Q/ Acs (2)

3. Velocity of hot water in plane co centric tube with simple twisted tape & triangular baffled twisted tape,

$$v = \frac{G}{\rho}\left[1 + \left(\frac{\pi}{2y}\right)^2\right]^{1/2} \quad (3)$$

4.Mass flow rate,

m = ρAV = ρQ (4)

5. The heat gained by the water in term of enthalpy change can be expressed as: Hot water heat rate,

Qh = m c_p (thi - tho) (5)

6.LMTD (Logarithmic Mean Temperature Difference),

$$\theta_m = \frac{\theta 1 - \theta 2}{In\frac{\theta 1}{\theta 2}} \quad (6)$$

7. Experimental overall heat transfer coffiecient,

U = Qh / A θ_m (7)

8. The flow regime can be defined from the Reynolds number. Reynolds No. of hot water,

Re= ρVD/ μ (8)

9. Theoretical Nusselt number,

Nu_{th}= 0.023 $Re^{0.8}Pr^{0.3}$(Mc Adam Equation)

$Nu_{th}=5.172(1+(.005484Pr^{0.7}(Re/y)^{1.25}))^{0.5}$(Hong & Bergles Equation) (9)

10. The mean convective heat transfer coefficient (h) and the mean Nusselt number (Nu) are then estimated as follows: Experimental Nusselt no.,

Nu ex=hd/kw (10)

11. Experimental Convective Heat Transfer coefficient (w/m2k),

$h=1/(U^{-1}+(D^i/2K_{cu})(\ln(D_o/D_i)))$ (11)

12.Theoretical Friction factor,

f_{th1}=16/Re (For PT)

$f_{th2}=(0.790*\ln(Re)-1.64)^{-2}$(Petukhov Equation) (12)

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13.Effectiveness,

$$\mathcal{E} = C_h (t_{hi} - t_{ho}) / C_{min} (t_{hi} - t_{ci}) \quad (13)$$

RESULTS AND DISCUSSION

The conducting tests was carried out with counter flow in a concentric tube heat exchanger without, with simple twisted tape and with modified (triangular) baffled twisted tape i.e. Passive heat transfer rate enhancement methods. LMTD, Overall heat transfer coefficient, Convective heat transfer coefficient Nusselt no. and friction factors are calculated for all cases experimentally and theoretically. These parameters were plotted by following graphs are plotted to compare the performance of all the different setups.

The outcome of the arrangements by applying all the experimental setup conditions are obtained with the help of comparative table 2 and graphs between Re number and Nu number are plotted. The increase in the rate of heat transfer, increase in overall heat transfer coefficient, increase in velocity and increase in effectiveness are obtained from the calculation which are arranged in the tabular form.

Table 2 Consolidate result for all setup

COMULATIVE DATA	Setup1	Setup2	Setup3
Q_h (KW)	1.4476	1.7695	2.326
Q_c (KW)	1.5326	1.8666	2.5
LMTD (°c)	18.76	17.125	13.7936
Overall heat transfer coff. U (KW/°C m^2)	1.459	1.954	3.1895
Effectiveness of heat exchanger Ɛ	0.385	0.47	0.6185
Efficiency of heat exchanger η (%)	20.834	47.7	94.156

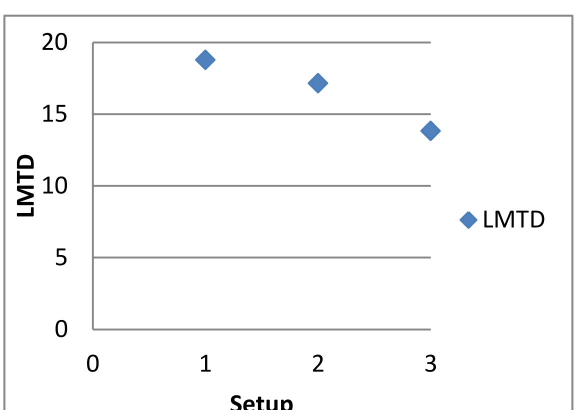

Fig. 5. Experimental LM T D vs. Different setup

The Re number in increased from 8474.43 for plan pipe to 8967.5 for pipe having twisted tape then to 10025.283 for the baffled twisted tape. This increase in Re number tends the flow to turbulence which increases the heat transfer rate.

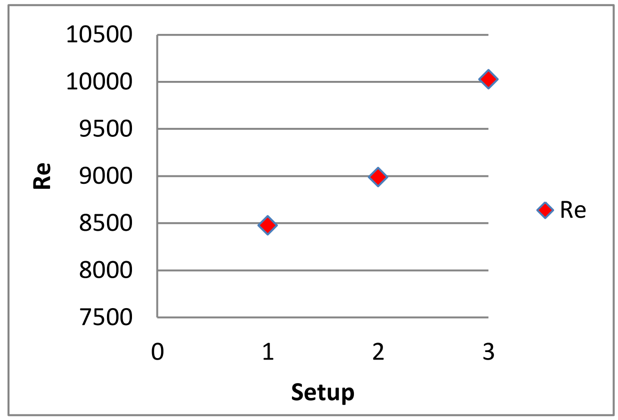

Fig. 6. Experimental Reynolds number vs. Different setup

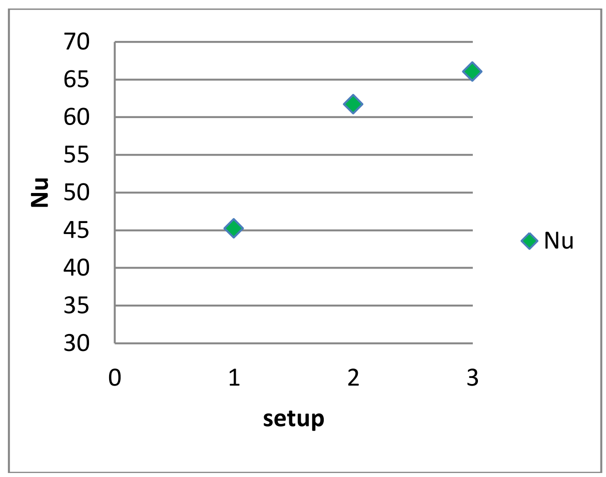

Fig. 7. Experimental Nusselt number vs. Different setup

The rate of heat transfer in the term of efficiency of the heat exchanger is the highest in the setup 6 which is a counter flow triangular baffled concentric tube heat exchanger. The efficiency of this setup with respect to the parallel flow plane tube heat exchanger is 94.156%

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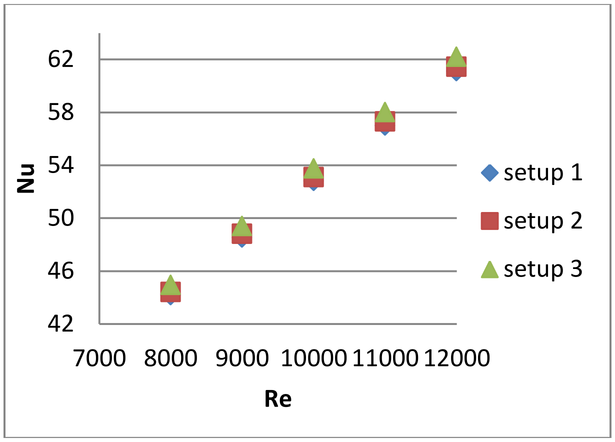

Fig. 8. Theoretical Nusselt number vs. Theoretical Reynolds number by Mc Adam Equation for Plane Tube and Hong & Bergles Equation for Twisted Tape Tube

The theoretical Nu number is increased from 35.62 to 58.75 to 212.3 for counter flow. This increase in Nu number is due to increases the convective heat transfer coefficient. i.e. cause by increases the heat transfer rate.

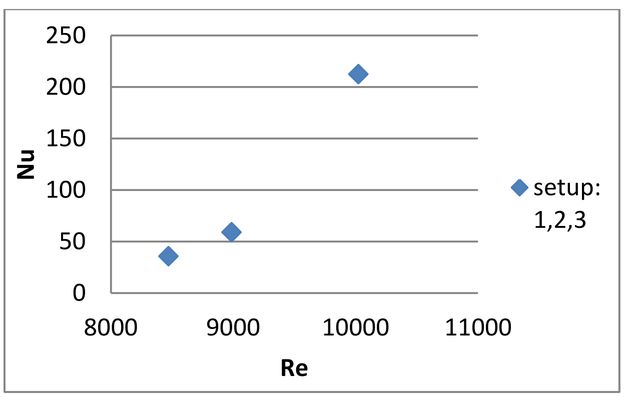

Fig. 9. Experimental Nusselt number vs Experimental Reynolds number

The value of theoretical friction factor falls from 0.03299 for plan tube to 0.03244 for tube contains simple twisted tape to 0.031457 for triangular baffled twisted tape on the basis of experimental Reynolds number by Petukhov Equation.

CONCLUSION

Numerical study of description of Nusselt number, turbulent concentration, effectiveness and performance evaluation criterion of turbulent flow in a circular channel connected with twisted tape place were conducted.

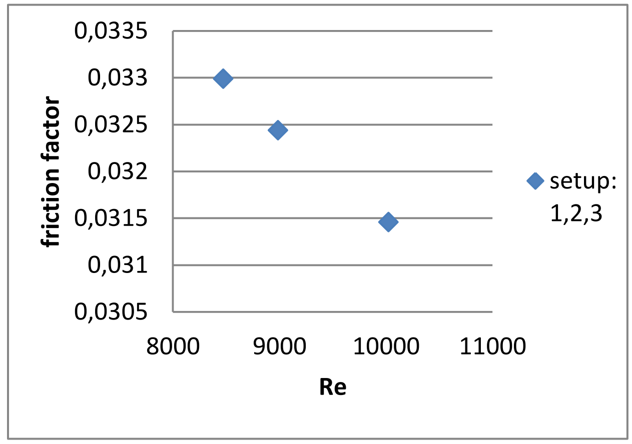

Fig. 10. Theoretical Friction Factor vs. Experimental Reynolds number by Petukhov Equation

The efficiency of heat exchanger with twisted tape placing has a high overall performance. The effectiveness of the heat exchanger is highest in the setup 3 which is counter flow triangular baffled double pipe heat exchanger, Higher value of Re number i.e. promoting the flow towards turbulence, Gives a high range of Nusselt number under a predefined domain, Increase in heat transfer efficiency with increase in overall heat transfer coefficient. Thus, it is a promising tube insert which can be extensively used in heat transfer augmentation of turbulent flow.

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