Experimental Investigation of Passive Heat Transfer Enhancement Using in Plain Tape Insert

*A.P.Sivasubramaniam[1], K.Mayilsamy[2] and P.Murugesan[3]

[1]*Department of Mechanical Engineering, Paavai Engineering College, Namakkal, Tamil Nadu, India*

[2]*Department of Mechanical Engineering, PSG College of Technology, Coimbatore, Tamil Nadu, India*

[3]*Department of Mechanical Engineering, K.S.R Institute for Engineering and Technology, Namakkal, Tamil Nadu, India*

Email: [1]visuga@rediffmail.com, [2]k_mayilsamy@yahoo.com, [3]pmksrct@gmail.com

Abstract

In present days, almost all the industries that use heat exchangers use them at present with inserts required to improve the convective heat transfer rate of the system without the overall performance getting affected. Even the inserts can be conveniently set up and require less maintenance aside from the cost benefits.Given the successful role of inserts in the usage of exchangers, the present study experimentally examines the contribution of plain tape inserts that are mounted within the plain tube of a dual pipe heat exchanger (DPHE) to increase the system's heat transfer capacity.Using a simple tube under counterflow structure for variable pressure drops in hot water, an experimental system is used to conduct the test process and measurement is performed for various mass flow speeds of hot and cold water inlet temperatures at 53^{0}C and 30^{o}C respectively.From the experimental measurements the thermal enhancement factor and even the properties of heat flow and friction effect are learned from the results of the experiments.The experiments are repeated with the proposed insert profiles to compare the results with that of the plain tube. It is observed from the tests that the plain tape insert gave the highest thermal enhancement level.

Keywords: *Heat transfer enhancement, friction factor, plain tube & plain tape.*

1. Introduction

The double pipe heat exchanger may be a way of simplifying the interchange of two fluids with heat b / w by not reacting at various temperatures.Two forms of heat transfer occurs in heat exchanger such as convection & conduction. Typically convection happens in each operating fluids & conduction through walls of heat exchanger that separates the fluids. The potential to increase the coefficient of heat transfer along with reduced reduction of the friction factor determines the inserts.For various industrial areas, tube extensions are used for developments in the heat transfer of fossil fuel and for chemical plants in just a few years.The second law increases effectiveness and entropy production by raising the driving force of properties as compared by the rise in the coefficient of heat transfer.The research provides an evaluation of friction factor & heat transfer coefficient for various inserts of different thicknesses and materials (Aluminum & Copper) discussed by **AjitShinde et al., [1] [2]**.

*A.P.Sivasubramaniam1

The heat transfer, friction factor and factor improvement of a single circular tube and a circular tube with two separate types of aluminum and acrylic alloy inserts was experimentally studied by**Herlekar et al., [3] [4]**. **Naga Sarada et al., [5]**investigated the twisted tape insert thermostats ranged from 36 to 48 per cent for the full width, 33 to 39 per cent in contrast with the flat tube for the reduced width of 22 mm inserts.This change is primarily attributed to the centrifugal forces that arise from the spiral movement of the fluid that suggested by **KhudheyerMushatet et al., [6][7]**.

The heat transfer augmentation techniques apply to various methods such as Swirl-flow systems involve a variety of geometric arrangements or forced flow tube inserts that produce revolving and/or secondary flow was discussed by**Dhumal et al., [8]**. Spinning tubing, turbochargers, spinning inserts, and axial spinning core inserts are used to increase transmission without dramatically affecting the overall system output.

The tube mounted multiple twisted tapes with a superior thermal performance compared to the single tube due to its constant multi-swirling fluid flow & multi-longitudinal vortices were analyzed by **Chakole&Sali [9]**.The higher percentage of twisted band inserts also helped improve thermal efficiency as a consequence of an increased contact area, residence time, swirl speed and fluid mixing with a longitudinal vortex flow.

The thermal transfer properties of tubing equipped with split and twisted tape inserts at various twisting ratios have been investigated by **Murugesan et al.[10,11]** (one of this paper's authors).The results suggest that the twisting ratio decreases similar trends in the Nusselt number and the friction factor is higher.The heat transfer & friction factor properties that experimental results using copper-wavy twisted tape inserts with circular holes were studied by **KurhadeAnantSidhappa et al., [12]**. In the heat exchanger, the pressure loss (pumping loss) & the friction factor was examined by **ShubhamJadhav et al., [13] [14]**, where inserts used for the heat argumentation & rate of heat transfer increases.The laminar and turbulent flow regimes in the Reynolds range from 240 to 3500, and from 1400 to 16100 respectively, in which ethylene and water are used as working fluids for the experiments by **Bozzoli et al. [15].**

The experiment conducted with the twisted of metallic strip which is of width ‘w’, thickness ‘t’, having a periodical helical pitch of 1800 twist for creation of swirl and turbulent flow in the channel. At a constant twist ratio of 2.5, twisted tape inserts in five different width ratios of 0.35, 0.44, 0.53, 0.62 & 0.71;**PrashantTikhe&Andhare [16]**.The swirl flow produced by tape inserts, leading to increased intensity and tangent interaction between the flow of fluid and the wall of the tube, was investigated by**AvinashPatil et al., [17]**.The effect of heat transfer in different grooved water tubes compared with the flat tubes of a fully formed turbulent water flow was examined by **Murugesan et al., [18-21]** (one of the author of this paper).The heat transfer & friction factor characteristics of a circular tube equipped with helical screw tapes & regularly spaced helical screw tape inserts with various twisting ratios, both for laminar flow & turbulent flows, have been experimentally studied.Two separate type twisted rubbers, including the V twisted tape and the Horizontal wing twisted tape with the y = 2.0 ratios of 4.4 and 6.0, have been studied by **Qasim Mahdi & Ali Abdulridha Hussein [22]**.The increase in copper nano fluids in the single tube without twisting the coefficient of heat transfer varies with the amount of Reynold and the volume concentration of the nano particles

PravinMahakalkar&Jawre [23] [24] showed that the twisted tape tube without any circular hole has further enhanced convective heat transfer efficiency by about 40% compared to the plain tube, while the flow friction has decreased. The twisted tape with a circular hole in the middle tube has an approximate 50 per cent higher thermal efficiency than the twisted circular hole.The use of semi-circular cutting inserts creates friction and superimposed vortex movement (swirl flow) resulting in a thinner boundary layer and thus a better heat transfer coefficient with comparatively low flow resistancehas described by **PawanSawarkar et al., [25]**. The twisted semi-circular cut tape with plain twisted tape along with a plain tube to conduct for comparison under specific procedure testing condition. The twisted tape with a circular hole in the tube reveals that the twisted circular hole tape is around 50 per cent thermal output.Nusselt values were substantially greater than those of a smooth tube and the highest rating was found for 25 mm spacing with U-shaped insert. The amount and factor of Nusselt friction for the tube is in the U type. The results obtained in Nusselt Number 1.2 times better & 6.85 to 8.18 times enhanced in friction factor with respect to the plain tube, it is introduced by **Razzaq et al., [26]**.

Based on analysis of the available literature, changes were found to have a greater effect on the efficiency of the heat exchanger dual-rohr heat exchanger in inserte such as the cutting of twist tapes, mesh inserts, trapezoidal configuration, spiral wire, brush inserting. The explanation behind the high thermal enhancement factor is that those small gaps created by the inserts carry a fair level of pressure drop in the device. This thesis explains the experimental work on heat transfer & friction factor characteristics of a dual-pipe thermal exchanger with Plain Tape (PT).

2. Setup for Experimentation

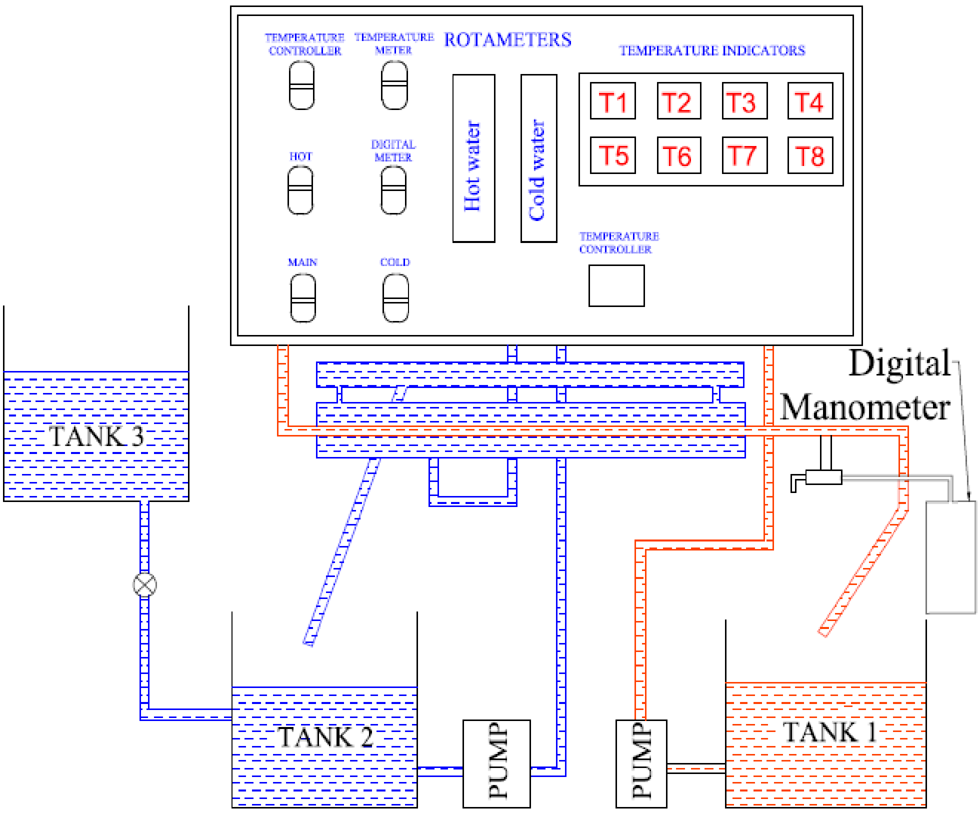

Figure 1. Schematic Diagram for Counter Flow DPHE

Figure 1 displays the schematic outline of the test system.The electric heater is initially triggered and the desired temperature is controlled with a temperature controller by regulating the heater. The hot water is turned on, the hot water pressure is set in the test section by means of a bypass valve and the hot water flows through a rotary valve to the internal test tube. During the laminar flow, hot water passes the 0 to 2 LPM Rotameter and hot water passes the 0 to 20 LPM Rotameter for turbulent flow. The cold water is pumped into an annulus through a control valve in the direction of the counter flow to heat water from a cold tank and excess cold water is returned to the tank by the valve.

The constant condition is achieved for the first run within 1 hour and for the following runs within 25 minutes.The inlet temperatures at the hot and cold water sides are kept constant at 53 ± 1℃ and 30 ± 1℃ respectively. The cold water at room temperature constantly flows at 10LPM whereas the flow rate of hot water is adjusted from 2 to 8LPMturbulent flow with 0.5LPM increments respectively. Only after the temperature is constant are the input and output temperatures of warm and cold water reported. The pressure drop calculation eliminates air bubbles from the manometer, so that when the flow stops the liquid level in both extremities is equal.After reaching steady state, pressure drop measurements are also taken by differing the flow levels of hot water under laminar and turbulent flux conditions.Figure 2 displays the plain tape (PT) geometry.

Figure 2. Geometry of PT

The temperature is maintained by the temperature sensor and the heating is handled by 3 KW water heaters.The inlet temperatures were kept steady at 53^0C and 30^0C on both sides of the hot and cold water. The flow rate of cold water continued to be 0.166 kg / s while the flow rate of hot water mass was changed between 0.033 kg / s and 0.133 kg / s and improved at 0.008 kg / s.During stable conditions, the temperature intake and exit of hot and cold water and the pressure fall were monitored using the manometric U-Tube manometer – carbon tetra-chloride–for the plain tube.The experiment for plain tapes (PT) was replicated subsequently. The table summarizes the details of the behavioural study, tape inserts and operating conditions Table 1.

Table 1. Experimental Set-Up Parameters

(a)	Inner tube inner diameter (plain tube) (d_i)	25.0mm
(b)	Outer tube inner diameter (plain tube) (d_o)	54.5mm

(c)	Test tube length	2000mm
(d)	Material of inner tube	Copper
(e)	Material of outer tube	Galvanized iron
Plain tapes		
(a)	Tape width	23.5mm
(c)	Tape thickness	3mm
(d)	Materials	Aluminium
Test conditions		
(a)	Reynolds number, (Re)	2000 to 12000
(b)	Type of flow in inner tube and annulus	Turbulent
(c)	Inlet hot water temperature	53^0C
(d)	Inlet cold water temperature	30^0C

3. Data Reduction

Data reduction equations are expressed from Eqn. 1 to Eqn.11.

Heat transfer from hot fluid,

$$Q_h = m_h C_{ph} \,(T_{h1} - T_{h2}) \qquad (1)$$

Equation for Heat received by the cold fluid,

$$Q_c = m_c C_{pc} \,(T_{c2} - T_{c1}) \qquad (2)$$

The average heat transfer rate (Q_{avg}),

$$Q_{avg} = \frac{Q_c + Q_h}{2} \qquad (3)$$

Overall heat transfer coefficient (U),

$$Q_{avg} = U * A_i * \Delta Tm \qquad (4)$$

Where,

$$A_i = \pi * d_i * l$$

$$\Delta Tm = \frac{(T_{h1} - T_{c2}) - (T_{h2} - T_{c1})}{\ln\left(\frac{T_{h1} - T_{c2}}{T_{h2} - T_{c1}}\right)}$$

Reynolds number for Annulus side

$$Re_a = \frac{u_a * D_h}{v_c} \qquad (5)$$

Nusselt number for Annulus side,

$$Nu_a = 0.023 * Re_a^{0.8} * Pr_c^{0.4} \qquad (6)$$

Heat transfer coefficient (h_a) for Annulus side

$$Nu_a = \frac{h_a * D_h}{k_c} \qquad (7)$$

Inner tube side heat transfer coefficient (h_i),

$$\frac{1}{U} = \frac{1}{h_i} + \frac{1}{h_o} \tag{8}$$

Inner tube side Nusselt number (Nu_i),

$$Nu_i = \frac{h_i * d_i}{k_h} \tag{9}$$

Inlet Reynolds number (Re_i),

$$Re_i = \frac{u_h * d_i}{v_h} \tag{10}$$

Friction factor calculated by,

$$f = \frac{\Delta P}{\left(\frac{L}{d_i}\right) X \left(\frac{\rho u^2}{2}\right)_h} \tag{11}$$

Where,

$\Delta P = (\rho_m - \rho_{tf})\ g\ \Delta h$

4. Results and Discussion

For this portion, a single-tape tube heat exchanger provides a characteristic heat exchange and friction factor and a heat enhancement factor for the tube.The experiments are performed by inserts (PT) in the range b / w 2000 and 12000 of Reynolds.

4.1 Validation of Plain Tube Experimental Results

Figure 3 shows the Nusselt number variance with Reynolds for the plain tube. The experimental data's are comparing with the plain tube forced convection correlations of Dittus–Boelter (1930) equation (12) and Gnielinski (1976) equation (13) with the discrepancy of ± 14.5 % and ± 5.0 % respectively for Nusselt number

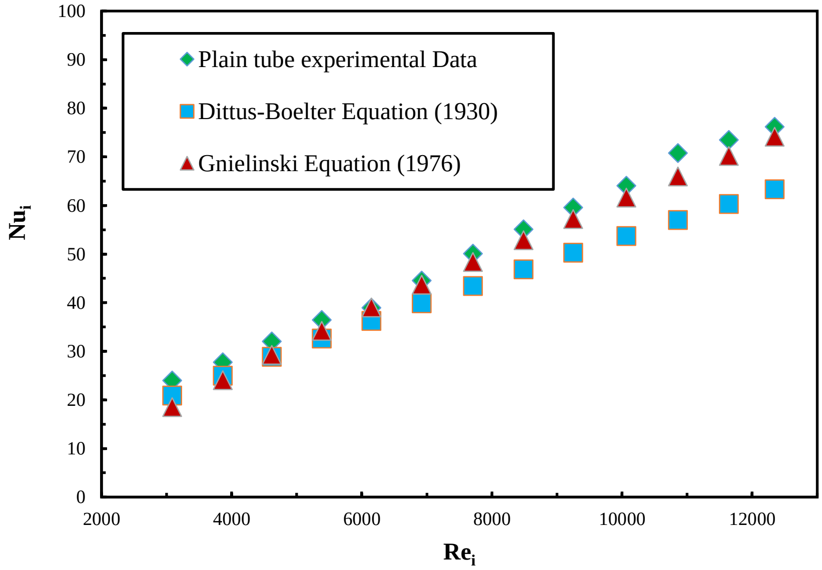

Figure 3.Data Verification of NusseltNumber for Plain Tube under Turbulent Flow

$$Nu = 0.023\ Re^{0.8}\ Pr^{0.3} \tag{12}$$

$$Nu = \frac{\left(\frac{f}{8}\right)(Re-1000)\,Pr}{1+12.7\left(\frac{f}{8}\right)^{0.5}\left(Pr^{\frac{2}{3}}-1\right)} \qquad (13)$$

Figure 4 shows the friction factor variance with Reynolds plain tube number. The experiment's results was compared to the Blasius equation (14) and the Petukhov equation (1970) (15) for ±9% and ±7,5% for the friction factor respectively.

$f = 0.0791Re^{-0.25}$ (14)

$f = (0.790 \ln Re - 1.64)^{-2}$ (15)

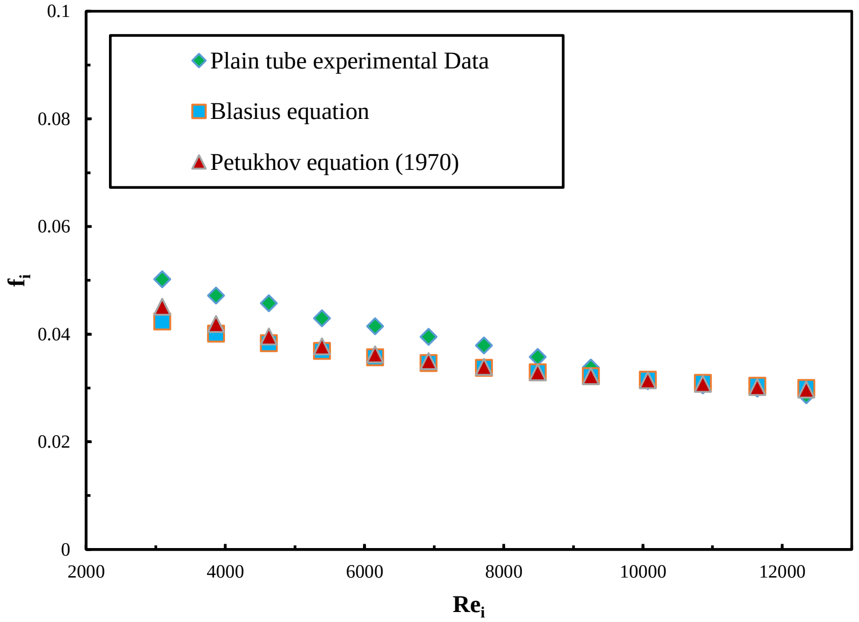

Figure 4. Data Verification of Friction Factor for Plain Tube under Turbulent Flow

In addition, the effects of the single pipe are contrasted with the Nusselt and frictional factor as follows.

$Nu = 0.00595Re^{0.95}Pr^{0.33}$ (16)

$f = 0.255Re^{-0.374}$ (17)

The equations (16) & (17) are found to represent the experimental results within ± 1 % for Nusselt number and ± 11.5 % for friction factor. These correlations (16), (17) are useful to evaluate the theoretical thermal enhancement factor associated by plain tape (PT) in the sub section 4.3.

4.2 Validation of Plain Tape (PT) Experimental Results

The test results of the Nusselt numbers and friction factor tube are checked using Sieder and Tate equations and a plain tubes correlation.The comparison of the current Nusselt number & friction factor with the plain tape.

The following correlations for Nusselt number and friction factor developed by the present experimental results for a plain tube fitted with PT (18, 19)

$Nu = 0.0067\,Re^{0.9855}Pr^{0.33}$ (18)

$f = 1.0002\,Re^{-0.2771}$ (19)

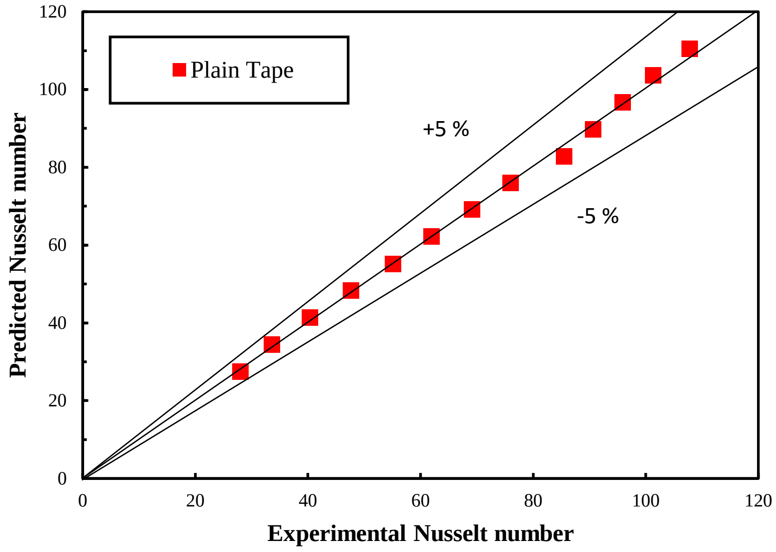

Figure 5.Predicted Verses Experimental Nusselt Number for PT under Turbulent Flow

The current findings apply to ±5% for the amount of Nusselt, and to ±20% for the friction factor. The current results are fairly reliable.

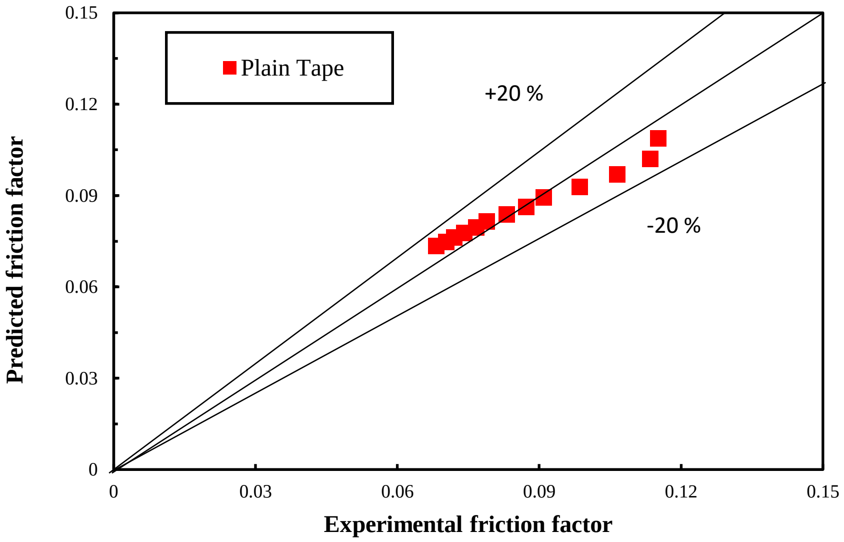

Figure 6. Predicted Verses Experimental Friction Factor for PT under Turbulent Flow

4.3 Thermal Enhancement Factor for PT

The comparison of the heat transfer coefficients (p) in the single tube and the turbulator tube (t) is compared in recent literature studies as being important to operating costs. The same power pumping was used.

The following can be done under constant pump power from the single tube to the inserted tube:

$(\bar{V}\Delta P)_p = (\bar{V}\Delta P)_t$ (20)

Where there relationship between friction factor and Reynolds number hasgiven below

$(f\ Re^3)_p = (f\ Re^3)_t$ (21)

The ratio of the convective heat transfer factor from the turbulator to the thermal increase factor for theplain tube at equal pumping capacitywhich can be expressed as

$$\eta_{(the)} = \left|\frac{h_t}{h_p}\right|_{pp} \quad (22)$$

Employing Eqn. (16), (18) and (22), the enhancement efficiency for the plain tape (23) can be written as

$$\eta_{(PT)} = \left|\frac{h_t}{h_p}\right|_{pp} = 2.0844\ Re^{-0.076} \quad (23)$$

Thermal enhancement factor for PT calculated from Eqn. (23) and PT are presented in Figure 7.

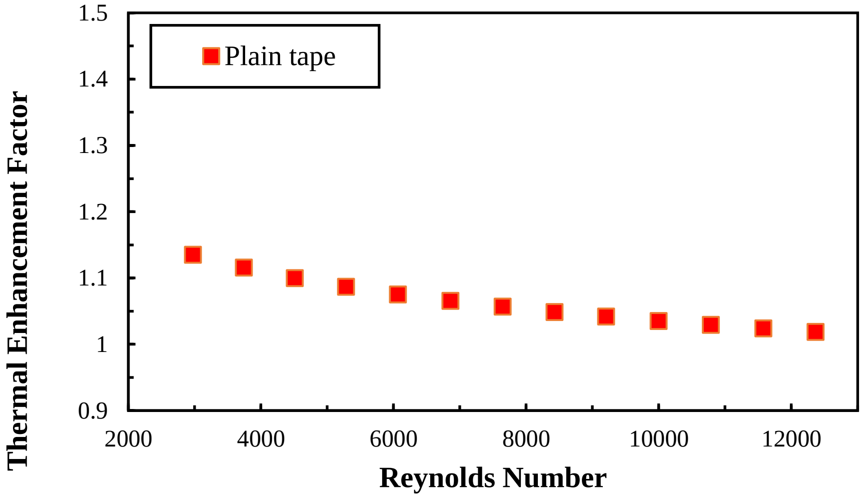

Figure 7. TEF vs. Re for PT in Experimental

5. Conclusion

The present study describes experimental study of heat transfer, friction factor and circular tube thermal enhancement in turbulent regimes (2000 <Re>12000), fitted with plain tape (PT). The conclusions can be drawn as follows.

- The Nusselt number and friction factor for the tube fitted with plain tape (PT) are noticeablybetter than that of plain tube.
- A number of factors for thermal improvements over the Reynolds number are found to be between 1.01 and 1.13 in the PT-equipped tube.The thermal enhancements factors are more than unity in all cases suggest that the impact of the improving tool on heat transfer is more predominant than that of increasing friction factor.
- Empirical equations are established, and the experimental data is reasonably equipped with the Nusselt number, friction factor & thermal enhancement factor of the PT.
- The plain tape has improved the transfer of heat; therefore PT can be replaced to reduce the heat exchanger size in the place of a plain tube.

Nomenclature

A	Area, m^2
C_p	Specific heat, J/kg K
d	Tube diameter, m
f	Friction factor
h	Heat transfer coefficient, W/m^2 K
k	Thermal conductivity, W/m K
L	Tube length, m
m	Mass flow rate, kg/s
Q	Heat transfer rate, W
Q_h	Heat transfer from hot fluid
Q_c	Heat received by cold fluid
$m_h \& m_c$	Mass flow rate of hot & cold fluid
$C_{ph} \& C_{pc}$	Specific heat of hot & cold fluid
$T_{h1} \& T_{h2}$	Hot water inlet & outlet temperature
$T_{c1} \& T_{c2}$	Cold water inlet & outlet temperature
Re	Reynolds number
Nu	Nusselt number
ΔP	Pressure drops
Pr	Prandtl number
Δh	Difference in Manometer Fluid
ρ_m	Density of Carbon Tetra Chloride

Subscripts

Avg	Average
a	Annulus
c	Cold
h	Hot
i	Inner
lm	Logarithmic mean temperature
o	Outer
1	Inlet
2	Outlet

Abbreviations

DPHE	Double Pipe Heat Exchanger
PT	Plain Tape
RTD	Resistance Thermometers
TEF	Thermal Enhancement Factor

References

[1] ***AjitShinde R, YogeshBhalerao J&NileshTotla B,***“*Thermal Performance of Serrated Plate Inserts in Circular Pipe”, International Journal of Mechanical and Production Engineering**(2017)**, pp. 154-159.*

[2] ***Paresh Joshi A &PatilV H, “****Experimental Analysis of Heat Transfer Enhancement of Wavy Twisted Tape Insert”, International Journal of Advance Research in Science and Engineering**(2015)**, pp. 295-310.*

[3] ***Herlekar M M, Nalawade D B &Kamble D A,****"Convection Heat Transfer Augmentation from Twisted Tape Insert of Non-conducting Material", Journal of Applied Science and Computations* ***(2019)****, pp. 2838-2842.*

[4] ***DhirajShinde D, Patil A M, &SagarJagtap V,****"Experimental Study of Heat Transfer Parameters using internal threaded pipe fitted with inserts of different materials", International Journal of Innovations in Engineering Research and Technology* ***(2015)****, pp. 1-7.*

[5] ***Naga Sarada S, Sita Rama Raju A V, KalyaniRadha K&Shyam Sunder L,****"Enhancement of heat transfer using varying width twisted tape inserts", International Journal of Engineering Science and Technology* ***(2010)****, pp. 107-118.*

[6] ***KhudheyerMushatet S&Baydaa Hussein A,*** *"Effect of Optimum Arrangement of Conical Turbulators with Twisted Tape on Heat Transfer Enhancement in a Heated Tube", International Journal of Mechanical & Mechatronics Engineering,* ***(2018)****, pp. 33-49.*

[7] ***Rahul Dahekar M, MoneyioushJindey, PareshSathawane&AkashAtram,****"An Experimental Investigation of Performance of Different Twisted Tape Inserts on Heat Augmentation", IJARIIE* ***(2017)****, pp. 3003-3009.*

[8] ***Dhumal A H, Kerkal A H G M&Pawale K T,****"Heat Transfer Enhancement for Tube in Tube Heat Exchanger Using Twisted Tape Inserts", International Journal of Advanced Engineering Research and Science* ***(2017)****, pp. 89-92.*

[9] ***Chakole M M&Sali N V,****"Experimental Investigation of Thermal Characteristics with Multiple Twisted Tapes Inserts in Tubular Heat Exchanger", International Journal of Advance Research in Science and Engineering* ***(2015)****, pp. 217-227.*

[10] ***Murugesan P, Mayilsamy K &SureshS,****"Heat Transfer and Friction Factor in a Tube Equipped with U-cut Twisted Tape Insert", Jordan Journal of Mechanical and Industrial Engineering****(2011)****, pp. 559-565.*

[11] ***Murugesan P, Mayilsamy K&Suresh S,****"Heat Transfer in Tubes Fitted with Trapezoidal-Cut and Plain Twisted Tape Inserts", Chemical Engineering Communications* ***(2011)****, pp. 886-904.*

[12] ***KurhadeAnantSidhappa, SonalHande S, SwarupPatil B&VivekanandMaske R,****"Heat Transfer Enhancement by using Twisted Tape Inserts with Circular Holes in Forced Convection", International Journal of Innovations in Engineering Research and Technology* ***(2016)****, pp. 1-7.*

[13] ***ShubhamJadhav, Jayesh Jain, VikasJadhav&Yenare RR,*** *"Heat Transfer Augmentation Technique Using Twisted Tape Insert", International Conference on Ideas, Impact and Innovation in Mechanical Engineering* ***(2017)****, pp. 1684-1690.*

[14] ***ChaitaleeBodake, Ghuge N C, Daund V S &Kuyate P B,****"Investigation on Heat Transfer Enhancement of Flowing Water inside a Circular Tube Having Twisted Tape Inserts using CFD", International Journal of Advance Research in Science and Engineering* ***(2018)****, pp. 531-539.*

[15] ***Bozzoli F, Cattani L, Mocerino A, Rainieri S, and Pagliarini G,****"Experimental investigation on the convective heat transfer enhancement in tubes with twisted-tape inserts", Heat Transfer Conference****(2019)****, pp. 1-9.*

[16] ***PrashantTikhe&Andhare A M,****"Heat Transfer Enhancement in Circular Tube using Twisted Tape Inserts of Different Width Ratio under Constant Wall Heat flux Condition", International Journal of Engineering Research & Technology* ***(2015)****, pp. 593-599.*

[17] ***AvinashPatil M, Patil A R&Wadekar P M,****"Experimental Investigation of Heat Transfer Enhancement in Tube in Tube Heat Exchanger with Perforated Twisted Tapes", International Advanced Research Journal in Science Engineering and Technology* ***(2017)****, pp. 243-251.*

[18] ***Murugesan P, Mayilsamy K & Suresh S,****"Turbulent Heat Transfer and Pressure Drop in Tube Fitted with Square-cut Twisted Tape", Chinese Journal of Chemical Engineering* ***(2010)****, pp. 609-617.*

[19] ***Murugesan P, Mayilsamy K& Suresh S,****"Heat Transfer and Friction Factor Studies in a Circular Tube Fitted with Twisted Tape Consisting of Wire-nails", Chinese Journal of Chemical Engineering****(2010)****, pp. 1038-1042.*

[20] ***Murugesan P, Mayilsamy K, Suresh S & Srinivasan P S S,****"Heat transfer and pressure drop characteristics in a circular tube fitted with and Without V-cut twisted tape insert", International Communications in Heat and Mass Transfer****(2010)****, pp. 329-334.*

[21] ***Murugesan P, Mayilsamy K&Suresh S,****"Heat Transfer in a Tube Fitted with Vertical and Horizontal Wing-Cut Twisted Tapes", Experimental Heat Transfer* ***(2012)****, pp. 30-47.*

[22] ***Qasim Mahdi S& Ali Abdulridha Hussein,****"Enhancement of Heat Transfer in Shell and Tube Heat Exchanger with Tabulator and Nanofluid", International Journal of Mechanical Engineering and Technology****(2016)****, pp. 125-138.*

[23] ***PravinMahakalkar V &Jawre S S,****"Heat Transfer Enhancement by Using Twisted Tape with Circular Holes and Alternate Axis", International Journal of Scientific Engineering and Research* ***(2017)****, pp. 64-67.*

[24] ***NareshDhamane, MayurJadhav&RushikeshJejurkar,****"Augmentation of Heat Transfer using Drilled Hole & Cut Twisted Tape Inserts", International Journal of Current Engineering and Technology* ***(2016)****, pp. 104-108.*

[25] ***PawanSawarkarA&PramodPachghare R,****"Experimental Analysis of Augmentation in HeatTransfer Coefficient Using Twisted Tape with Semi-Circular Cut Insert", International Journal of Science and Research* ***(2015)****, pp. 1174-1179.*

[26] ***Razzaq M A, Hossain M A M,Ahamed J U and Barman H,****"Enhancement of Heat Transfer using U Shaped Twisted Tape Inserts in Different Spacing for Turbulent Flow", Mechanical Engineering Research Journal****(2016)****, pp. 7-13.*