WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Comparative Analysis of Heat Transfer Rate and Friction Factor in A Double Pipe Heat Exchanger Using Turbulator at Various Location

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ABSTRACT

The widespread utilization of heat exchangers in our daily lives and domestic settings is evident across various industries. Heat exchangers play a crucial role in applications such as condensation and steam generation in pharmaceuticals, refrigeration, internal combustion engines (IC engines), power plants, and the thermal processing of foods. Additionally, the influence of heat exchangers extends to the cooling of electrical machines and electronic devices. The overall thermal efficiency and precision of work hinge upon the design ergonomics and operational efficiency, both of which can be significantly enhanced through the use of advanced thermal heat exchangers. In essence, these versatile devices contribute significantly to optimizing processes and systems across diverse fields, ensuring improved energy management and performance.

The current experimental study investigates heat transfer and friction factors in a double-pipe heat exchanger employing twisted tapes with varying twist positions. In the configuration of a double-pipe heat exchanger, the inner tube facilitates the passage of the hot fluid, while the outer tube accommodates the flow of the cold fluid. The outer layer of the inner pipe serves as a separating barrier, preventing the mixing of the two fluids. This research aims to explore the effects of twisted tapes, specifically examining the impact of twists at different positions along the length of the tape. The findings from this experimental analysis contribute valuable insights into the heat transfer performance and friction characteristics of the heat exchanger under these specific conditions.

Also, Nusselt number and friction factor through circular pipe using water as testing fluid with a range of Reynolds number between 5500-14500. The result shows that the heat transfer characteristics of double pipe heat exchanger were enhanced with twisted tape having maximum twist while frictional resistance also increased at the same time.

When comparing the plain tube and various configurations with twisted tape used in the experiments, the highest Nusselt number value of 124 was achieved for the full-length twist at a Reynolds number of 10,000. This value is 196.42% greater than that of the plain tube. These results indicate that the full-length twist configuration provides the maximum heat transfer, as evidenced by its higher Nusselt number.

The maximum value of PEC of full-length twist is 25.47% more than the maximum value of performance evaluation criteria of second half twist at the Reynolds number 5500. The maximum value of performance evaluation criteria of full-length twist is 17.74% greater than the maximum value of PEC of first half twist at the Reynolds number 5500.

The maximum value of PEC of first half twist 15.13% more than the maximum value of PEC of second half twist at the Reynold number 8500.

NOMENCLATURE

Symbol	**Symbol name**	**Unit**
Q	Heat TRANSFERr rate	K
U	Overall heat TRANSFERr rate	W/ (m^2.K)
A	Heat TRANSFERr surface area	m2
Dt	LMTD	K
Q_{act}	Actual heat TRANSFERr rate	W
Q_{max}	Maximum heat TRANSFERr rate	W
K	Thermal conductivity	W/m.K
P	Density of the fluid	kg/m3

V	Velocity of fluid	m/s
D	Hydraulic diameter	m
μ	Dynamic viscosity	N-s/m2
P	Pitch of twisted tape	m
D	Inner diameter of inner pipe	m
α	Thermal diffusivity	m2/s
ν	Kinematic viscosity	m2/s
L	Length of Twisted tape	m
L	Tube length of the experimental section	m
Di	Diameter of inner tube	m
Tho	Outlet temperature of hot water	K
T_{hi}	Inlet temperature of hot water	K
Th	Bulk temperature of hot water	K
T_{co}	Outlet temperature of cold water	K
Tci	Inlet temperature of cold water	K
Tc	Bulk temperature of cold water	K
Uh	Mean velocity of hot water	m/s
Vh	Volume flow rate of hot water	Lit/hr
ρin	Density of hot water at inlet temperature	kg/m3
Tw	Tube wall temperature of inner tube	K
Cph	Sp. heat capacity of hot water	J/(kg·K)
N	Kinematic viscosity of hot water	m2/s
A	Surface area of inner tube	m2
Δp	Pressure drop	N/m2
Qh	Heat TRANSFERr rate released by hot water	W
Q	Mean heat TRANSFERr rate	W
Cmin	Minimum capacity of thermal energy	J/K
Vc	Volume flow rate of cold water	Lit/hr
ρh	Density of hot water at bulk temperature	kg/m3

INTRODUCTION

A heat exchanger is a device designed to efficiently transfer heat from one fluid (liquid or gas) to another fluid without the fluids coming into direct contact. This allows for the exchange of heat energy while maintaining the separation of the two fluids. Heat transfer through a heat exchanger can occur through diverse processes, including transitions from liquid to gas, liquid to liquid, and gas to gas. The versatility of heat exchange is evident through these various modes, adapting to different mediums and applications.

1.1 Principle of Heat Exchanger

The operational of heat exchangers lies in the transference of heat between two fluid sources, driven by temperature difference in accordance with the principles of the zeroth, first, and second laws of thermodynamics. While adhering to these fundamental thermodynamic laws, the design of a heat exchanger represents a substantial aspect of thermodynamics. This field intricately involves the study of heat flow.

According to the first law of thermodynamics, heat is a form of energy. This thermodynamic principle asserts the conservation of energy in all processes. According to this principle energy cannot be created nor destroyed; rather, it can undergo transfer from one medium to another.

$$\Delta \mathbf{U}_{system} = -\Delta \mathbf{S}_{surrounding}$$

The Zeroth Law of Thermodynamics conditions that when two thermodynamic systems are in thermal equilibrium with a third system, then all these systems are in thermal equilibrium with each other. This fundamental principle forms the basis for defining temperature and thermal equilibrium in thermodynamic systems.

The second law of thermodynamics conditions that heat always flow from high temperature body to low temperature body reverse of this is not possible without external support.

METHADOLOGY

3.1 Experimental setup

In this section of the study, an in-depth exploration is provided regarding the devices and components integral to the experimental setup, detailing their roles and interactions. The methodology employed in conducting the experiment is elucidated, offering insights into the specific procedures undertaken for data collection. Central to the experimental arrangement was a double pipe heat exchanger wherein water served as the primary flowing fluid. The hot water, sourced from a boiler, is directed through the inner tube, while the cold water from a water tank circulates through the annulus surrounding the inner tube. The hot water circuit is anchored by a storage tank with a capacity of 200 litres, prepared with SSR with 0.1-degree Celsius control. Within the hot water circuit, a 20-liter capacity stirrer, a 0.5HP centrifugal pump, and a rota-meter with a governing range spanning 50LPH to 500LPH are integrated. Complementing these components, an adjustable valve-equipped piping system facilitates control over fluid flow. Adequate thermal insulation, with a suitable thickness, envelops the components to minimize heat loss. Conversely, the cold water circuit comprises a 200-liter cold-water reservoir, a 0.5HP centrifugal pump, and a Rota-meter with a governing range from 50LPH to 500LPH. The piping system within this circuit incorporates appropriate valves for effective control. Detailed specifications of the double pipe heat exchanger include an inner copper tube with a 16mm inner diameter, 2mm thickness, and a length of 2500mm. The outer tube has a thickness of 3mm, an inner diameter of 30mm, and matches the inner tube's length at 2500mm. The hot water temperature within the boiler is meticulously maintained within the range of 72 to 89 degrees Celsius, while the cold water's inlet temperature is set at room temperature, fluctuating between 28 to 35 degrees Celsius. The experiment incorporates twisted tapes crafted from aluminum with a rectangular cross-section, twisted unidirectionally with a pitch of 50mm. The aluminum material boasts a thickness of 14mm, a length of 2500mm, and a width of 14mm.

Six T-type thermocouples, calibrated against thermal resistances with a measurement error of 0.1°C, are strategically affixed within the piping systems for both hot water and cold water. These thermocouples are intricately linked to a data logger for precise temperature monitoring throughout the experiment.

To evaluate frictional losses, the pressure drop of hot water coursing through the test piece is gauged using a U-tube manometer. All recorded values of temperature, pressure drop, and flow rate are diligently documented during the attainment of a steady-state condition, forming the basis for subsequent calculations.

Twisted Tapes

The twisted tape, a pivotal component altering the flow direction of the fluid, comes in various forms such as helical baffles, coiled circular wire, outer circular pipe and perforated circular ring, inner twisted square duct, and periodically varying curvature curved pipe. In this particular experiment, a 14mm width and 2.5m long Aluminium strip serve as the twisted tape. Fabricated on a LATHE, this Aluminium strip is transformed into a twisted tape shape with a constant pitch of 50 mm, achieved through a twisting movement technique spanning its entire length of 2.5m.

Figure 1 full length twisted tape

Length -2500

Twist length -2500

Pitch -50

Figure.2 first half twisted

Length of tape -2500mm

First half twist length -1250mm

Second half plane length -1250

Figure 3Second half length twist tap

Total length of tape -2500mm

Second half twist length -1250

First half plane length -1250

3.14. Double Pipe Type Heat Exchanger

The Double Pipe tube type heat exchanger, currently housed in our College HMT research lab, has been revitalized to operational status with minor maintenance efforts. The inner copper tube within the heat exchanger features a 16 mm inner diameter and extends to a length of 2.5 meters. The flow rate of hot water is meticulously measured and controlled using a rota-meter. Similarly, the cold water, directed by a second rota-meter, enters from the LH side of the outer tube and exits from the RH side. To mitigate any intermixing of hot and cold water, a Double Pipe Heat Exchanger (DPHE) configuration is adopted in the system.

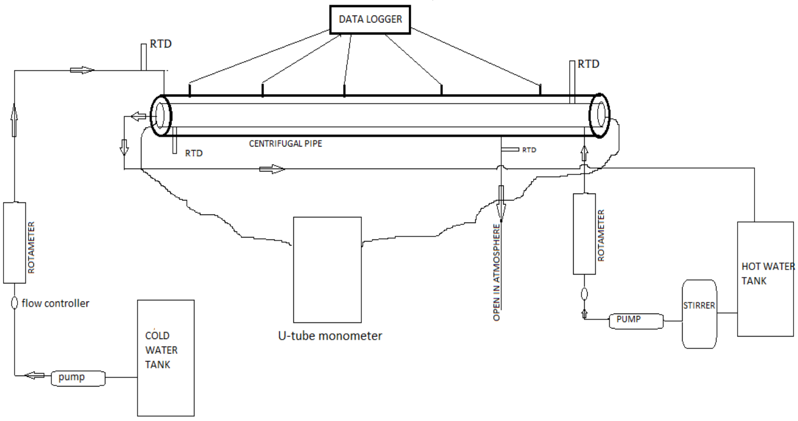

Figure 5 experimental set up

Data Reduction

Formulas are used in experiment given below

Bulk temprature hot water Th = (Thi + Tho) /2

Bulk temperature of cold water, Tc = (Tci + Tco) /2

Deviation of heat transfer rate = =(Q_h – Q_c) /Q_h x 100% (Taking the convective loss and thermal radiation values into consideration Q_h cannot be equal to QC)

Heat transfer rate absorve by cold water, $Qc = \rho c \times VcxCpc\ (Tco - Tci)$

Heat transfer rate released by hot water ,$Qh = \rho hxVh \times Cph\ (Thi - Tho)$

Friction factor $f = \Delta p / (\rho hUh^2 / 2) \times (L/D)$

Nusselt number $Nu = (hi \times D) / Kh$

Mean value of heat transfer rate $Q = (Qh + Qc) / 2 = hi \times Ax\ (Th - Tw)$

Mean velocity of hot water, $Uh = (Vhx\rho in) / (3.14D^2x\ \rho h / 4)$

Reynolds Number (For hot water), $Re = (Uh \times D) / v$

Relation used for setup validation

Gnielinski correlation

$NuDh = (f/8)(ReDh - 1000)Pr /1 + 12.7(f/8)^{1/2}\ (Pr^{2/3} - 1)$

Where;

Dh is hydraulic diameter (m) Re is the Reynolds number Pr is the Prandtl number

Nu is the Nusselt number

F is the Darcy friction factor

Result and Discussion

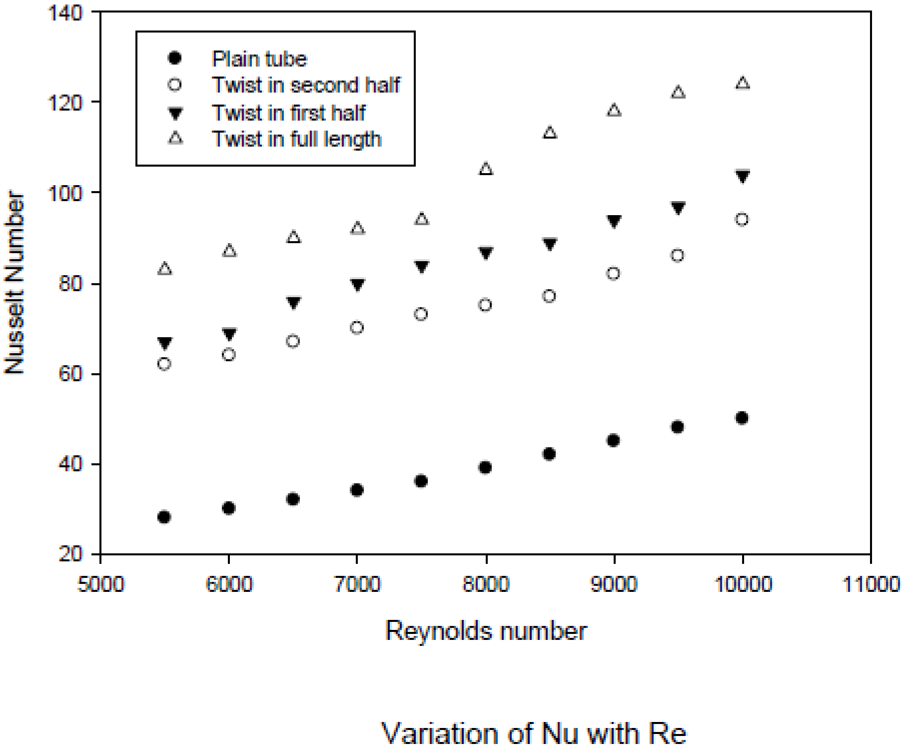

Figure 7 Data variation of Nusselt number with Reynolds number

The maximum value of the Nusselt number for the full-length twist is 196.42% higher than the Nusselt number value for the plain tube at a Reynolds number of 5500. Similarly, the maximum value of the Nusselt number for the first half twist is 139.28% greater than the Nusselt number value for the plain tube at a Reynolds number of 5500. Finally, the maximum value of the Nusselt number for the second half twist is 121.42% greater than the Nusselt number value for the plain tube at a Reynolds number of 5500.

The relationship between the Nusselt number and Reynolds number for the different configurations is illustrated in Figure 7 The graph demonstrates that as the Reynolds number increases, the Nusselt number also increases. This phenomenon can be attributed to the turbulence effect generated by the continuous flow of hot water, which enhances convective heat transfer.

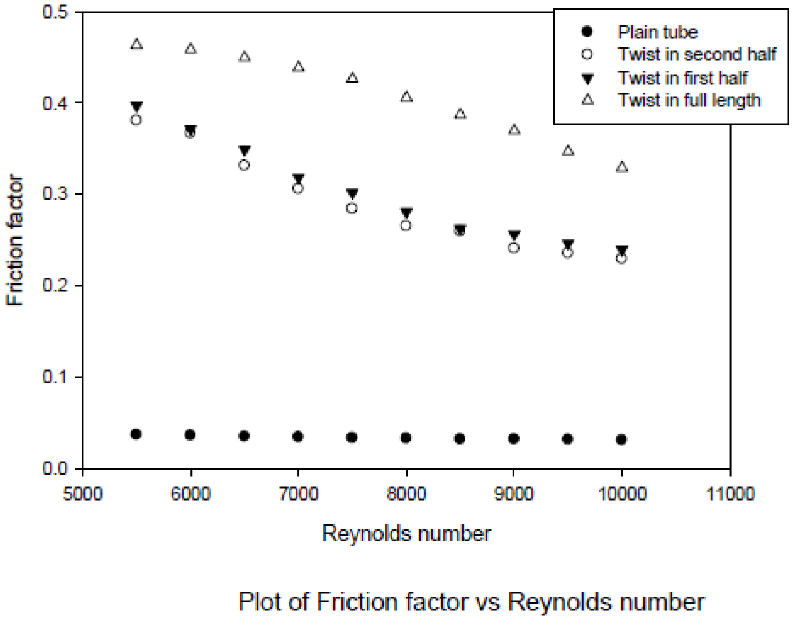

Figure 8 Variation of data of friction factor with Reynolds number

Figure 8 illustrates the relationship between the Reynolds number and the friction factor. The graph clearly demonstrates that as the Reynolds number increases, the friction factor decreases for all cases. Specifically, for the full-length twist configuration, the maximum friction factor value is 0.46 at a Reynolds number of 5500, while the plain tube exhibits the minimum friction factor value of 0.03 at a Reynolds number of 10,000.

The maximum value of the friction factor for the full-length twist is 11.52 times greater than the maximum value of the plain tube at a Reynolds number of 5500. Similarly, the maximum value of the friction factor for the first half twist is 9.73 times greater than the maximum value of the plain tube at the same Reynolds number. The maximum value of friction factor of second half twist is 9.29 times than the maximum value of friction factor of plain tube at Reynolds number 5500. The friction factor is maximum for full length twisted tape at Reynolds number 5500.

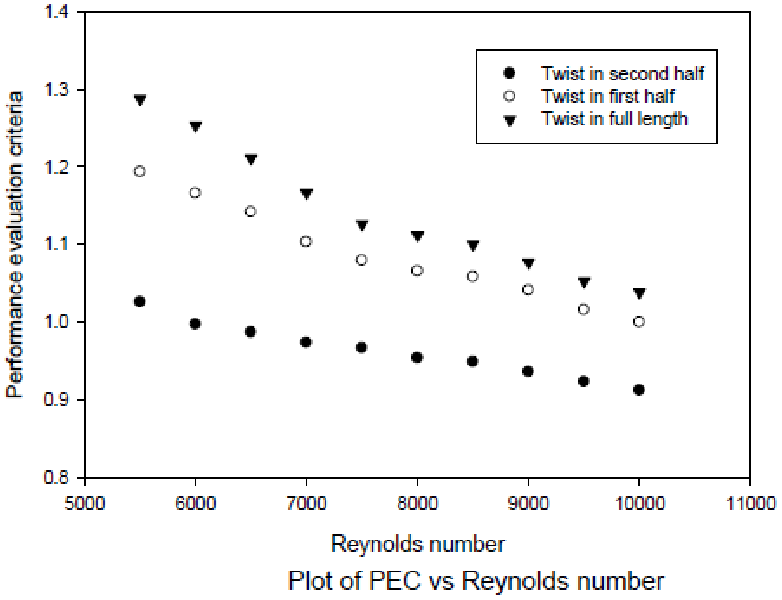

Figure 9:- Variation of PEC with Reynolds number

Figure 4.3 showcases the variation of the performance evaluation criteria (PEC) with Reynolds number for the tube configurations fitted with the first half twist, second half twist, and full-length twist. The graph unequivocally indicates a decrease in the PEC as the Reynolds number increases for all cases. This observation highlights the fact that as the Reynolds number increases, the influence of the friction factor becomes increasingly significant in comparison to the Nusselt number.

The maximum value of PEC of full-length twist is 25.47% more than the maximum value of performance evaluation criteria of second half twist at the Reynolds number 5500. The maximum value of performance evaluation criteria of full-length twist is 17.74% greater than the maximum value of PEC of first half twist at the Reynolds number 5500.

The maximum value of PEC of first half twist 15.13% more than the maximum value of PEC of second half twist at the Reynold number 8500.

5.2 Future Scope

The study and calculations conducted in this research project indicate the potential to explore various aspects of double pipe heat exchangers using twisted tape inserts and following area of research are identified for future research:-

1. Experimental study to investigate heat transfer and frictional factor in double pipe heat exchanger by using twisted tape and develop correlations for Nusselt number and friction factor.
2. Experimental study to investigate heat-transfer and frictional factor in double pipe heat exchanger by using twisted tape insert with nano fluid.

REFERENCES

(1.) Shanas Tian Pramesti ,saddenio lionize Experimental Study of Baffle Angle Effect On Heat Transfer Effectiveness Of The Shell And Tube Heat Exchanger Using Helical Baffle ISSN: 1024-1752 CODEN: JERDFO

(2.) Li et al", Numerical study on heat transfer enhancement in a tube with centrally hollow narrow twist tap under laminar flow.

10.1016/j.ijheatmasstransfer.2015.04.103

(3.) Kathait, Pawan Singh, Patil, Anil Kumar Thermo-hydraulic performance of a heat exchanger tube with discrete corrugations.

DOI: 10.1016/j.applthermaleng.2014.01.069

(4.) Shekhol-eslami, Mohammed Faleh performance using circular ring on perforated circular ring on the outer surface using DPHE (Double pipe Heat Exchanger) july 2016

(5.) Indri Yaningsih, Takahiko miyazak ,AguhgtriWijaayanta et al" , V-cut twisted tape insert effect on heat transfer enhancement of single phase turbulent flow heat exchanger. . https://doi.org/10.1063/1.5024097

(6.) Li Zhang, Hongmei Guo, Jianhua Wu, Wenjuan Du Compound heat transfer enhancement for shell side of double-pipe heat exchanger by helical fins and vortex generators 10.1007/s00231-011-0959-5

(7.) S Rozzi, R Massini, G Paciello and G. Pagliarini Heat treatment of fluid foods in a shell and tube heat exchanger: Comparison between smooth and helically corrugated wall tubes March 2007 Journal of Food Engineering 79(1):249-254 DOI:10.1016/j.jfoodeng.2006.01.050

(8.) DevendrakumarVishwakarma ,Suvanjjan Bhattacharyya et al" ,Turbulent Flow Heat Transfer through a Circular Tube with Novel Hybrid Grooved Tape Inserts. 10.3390/su13063068

(9.) Eiamsa-ard et al",Turbulent heat transfer enhancement in a heat exchanger using a corrgurated tube. https://doi.org/10.1016/j.icheatmasstransfer.2010.11.014

(10.) M. Moawed Heat transfer and friction factor inside elliptic tubes fitted with helical screw-tape inserts. Journal of Renewable and Sustainable Energy 3, 023110 (2011); https://doi.org/10.1063/1.3582940

(11.) A..VDeshmmukh , K.R Gawwande" , Experimental investigation of heat transfer using twisted tape with elliptical holes. https://researchadvances.org/index.php/IRAJTE/article/view/911/838

(12.) Wongcharee K., Eiamsa-ard S. Friction and heat transfer characteristicsof laminar swirl flow through the round tubes inserted with alternateclockwise and counter-clockwise twistedtapes. Int. Commun. Heat Mass Transf.38 (2011) 348-352.

(13.) SuriyanLaohalertdecha, somchaiwongwises, The effects of corrugation pitch on the condensation heat transfer coefficient and pressure drop of R-134a inside horizontal corrugated tube June 2010 International Journal of Heat and Mass Transfer. 53(13): 2924-2931 DOI:10.1016/j.ijheatmasstransfer.2010.01.037