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"Experimental Study of Heat Transfer and Friction Factor in Double Pipe Heat Exchanger Using Combination of Helical coil Spring and Twisted Tape Insert at Different Positions"

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Abstract
In the present Experimental analysis of Heat transfer and Friction factor in Double pipe Heat Exchanger using twisted tape with first half spring, second half spring, full length spring and full length twist whose length is 2500mm and pitch length is 50mm is carried out. A comparative study is done to evaluate the effect of twisted tape inserts for plain tube on the heat transfer rate , Nusselt number and Friction factor through a circular pipe using water as testing fluid with range of Reynolds number between 5500 and 14500. The result show that the heat transfer characteristics of Double Pipe Heat Exchanger was enhanced with twisted tape where as frictional resistance also increase at the same time. The maximum value of Nusselt number for full length spring, full length twisted tape, spring in first half and spring in second half is 128.09% , 52.33% , 110.16% and 100.55% greater than the value of Nusselt number for plain tube respectively. Friction factor varies from 0.21 to 0.46 for the twisted tape. The maximum value of friction factor for full length twisted tape, full length spring, spring in first half and spring in second half is 115.22% , 1017.34% ,973.60% and 928.99% greater than the value of friction factor for plain tube respectively. The performance evaluation criteria are found to be decreasing with increase in Reynolds number. The maximum value of performance evaluation criteria for full length spring, spring in first half and spring in second half is 54.84% , 18.75% and 11.70% greater than the value of performance evaluation criteria for full length twisted tape respectively.

Keywords: *Nusselt number, heat transfer characteristics, friction factor, performance evaluation criteria, inserts twisted tape.*

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I. INTRODUCTION

We can find there is various application of heat exchanger in our daily life such as transport vehicle, industries, electrical and mechanical machinery etc. Heat exchanger plays a significant role in thermal process in industries, the industrial application of heat exchanger are steam generation and condensation in power plant, thermal processing in agricultural product, processing of pharmaceutical product, liquid and air cooling of engine and turbo machinery system and cooling of electronic devices and electrical machines. For optimum rate of heat transfer the ergonomic of designing of heat exchanger plays an important role. All the heat exchangers work on the same principle that has been derived in law of thermodynamics (Zeroth, first and second law of thermodynamics).

In this experiment we are using double pipe heat exchanger which is centrically design of holding one pipe inside other. To augment the heat transfer rate we are using combination of helical coil spring and twisted tape insert at different positions length of tape, thickness of tape, width of tape and pitch of twist is 2500mm, 0.8mm, 14mm and 50mm respectively. Tapes are (a) First half spring (b) Second half spring (c) Full length spring (d) Full length twist. A number of study have been conducted over the year that fall into several categories some analysis is done under passive method, compound method, active method, geometry change analysis and many other heat transfer method. [6] Eiamsa-ard and Saysroy performed a numerical study to find out thermo-hydraulic performance of a multichannel twisted tape inserts in laminar and turbulent flow regions. The numerical value confirm that for the laminar flow at the Reynolds number of 2000 the maximum thermal performance factor of 7.28 were acquired by using the tube with multichannel twisted tape with $N = 2$ and $y/w = 2.5$ [8] Li et al. conceded a arithmetic study on enhancement of heat transfer in a tube having centrally hollow narrow twisted tape under laminar flow condition. They reported that the tube with cross hollow twisted tape inserts have the better overall heat transfer performance for different hollow width of the tape. [9] Indri yaningsih, Mlyazak, Agungtri Wijayanta et al. performed experiment using V cut twisted tape inserts and found that at low Reynolds number gives better result and thermo-hydraulic performance tends to decrease with grow of Reynolds number. Friction factor, Nusselt number and thermal performance are falls under 3% each.

The objective of this work is to examine the heat transfer and friction characteristics in a horizontal double pipe heat exchanger using combination of helical spring and twisted tape as an insert at various location in double pipe heat exchanger. Specific aim includes:

1. Effect of position helical spring on heat transfer rate and friction factor in double pipe heat exchanger.
2. Comparing the data of Nusselt number and friction factor result with plain tube.
3. Evaluating performance evaluation criterion (PEC).

II. Proposed Methodology

The experimental setup consisted of a double pipe heat exchanger with water as the flowing fluid. Hot water coming from boiler is flowing through the inner tube whereas cold water from water tank is flowing through the annulus (around inner tube). Hot water Circuit consisted of hot water storage tank of capacity 200 liters equipped with SSR with 0.1-degree Celsius control. Stirrer of capacity 20 litres, 0.5HP centrifugal pump, a rota-meter of governing range from 50LPH to 500LHP and a piping system with adjustable valves is attached in hot water circuit and suitable thickness insulation is provided. Cold water circuit consisted of a cold-water reservoir of capacity 200 liters, 0.5 HP centrifugal pump, a rota-meter of governing range from 50LPH to 500 LPH, a piping system with suitable valves. Inner diameter of inner copper tube is 16mm and thickness is 2mm and length of 2500mm whereas thickness of outer tube is 3mm, inner diameter 30mm and length is 2500mm. The temperature of hot water inside the boiler is maintained at 72-89 degree whereas inlet temperature of cold water is at room temperature (28-35°C). Twisted tapes used in experiment is made up of aluminium of rectangular cross-section and twisted with one direction of pitch 50mm. Thickness of aluminium is 14mm, length 2500 mm and width are 14mm. 6 T-type thermocouples calibrated by thermal resistances with a measurement error of 0.1°C are attached within the piping (Hot water as well as cold water) and connected to a data logger. Pressure drop of hot water flowing in test piece is measured by U-tube manometer to consider frictional losses. Values of temperature, pressure drop and flow rate were recorded for calculation when system reached steady state condition. The twisted tapes were used for performing the experiment are (a) First half spring (b) Second half spring (c) full length spring (d) Full length twist.

Figure 1 First half spring

Figure 2 Second half spring

Figure 3 Full length spring

Figure 4 Full length twisted tape

Mathematical relations used for calculations:

- Mean velocity of hot water, $U_h = (Vh\ x\rho_{in}) / (3.14D^\wedge 2x\ \rho h / 4)$
- Reynolds Number (For hot water), $Re = (U_h\ x\ D) / v$
- Bulk temperature of hot water , $Th = (Thi + Tho)\ /2$
- Deviation of heat transfer rate , $=(Qh - Qc)\ /Qh\ x\ 100\%$ (Taking the convective loss and thermal radiation values into consideration Q_h cannot be equal to Q_C)
- Bulk temperature of cold water ,$Tc = (Tci + Tco) /2$
- Heat transfer rate absorve by cold water , $Qc = \rho c\ x\ Vcx\ Cpc\ (Tco - Tci)$
- Heat transfer rate released by hot water , $Qh = \rho_h x V_h\ x\ C_{ph}\ (T_{hi} - T_{ho})$
- Friction factor $f = \Delta p / (\rho h U_h^\wedge 2 / 2)\ x\ (L/D)$
- Filonenko Correlation $F = (1.82 \log Re-1.64)^{-2}$

Figure 5 Experimental Setup of Double Pipe Heat Exchanger (DPHE)

Sl. No.	Parameter(s)	Value (mm) / material	Value (m)
1	Outside diameter of inner tube	20	0.02
2.	Inside diameter of inner tube	16	0.016
3.	Outer diameter of outer tube	33	0.033
4.	Length of plain tube	2500	2.5
5.	Inner diameter of outer tube	36	0.036
6.	Hot water pipe material	Copper	Cu
7.	Cold water pipe Material	Galvanized Iron	Fe
8.	Heat transfer area	251.2 mm^2	0.2512 m^2

Table 1 Specification of DPHE

Validation of Experimental Setup

Experimental set-up is validated against standard correlations suggested by the researchers in order to justify the heat transfer data obtained through the experimentation. Result reveals that the experimental values are within the justify range. Total deviation is found 11.46% for Nusselt number and 9.16% for friction factor. The graph is plotted as below

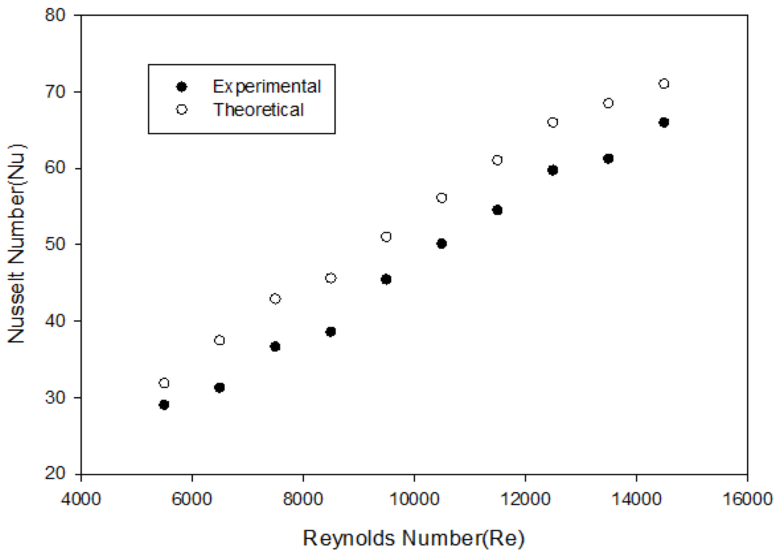


Figure 6 Comparison between experimental Nusselt number and theoretical Nusselt number with Reynolds number of plain tube.

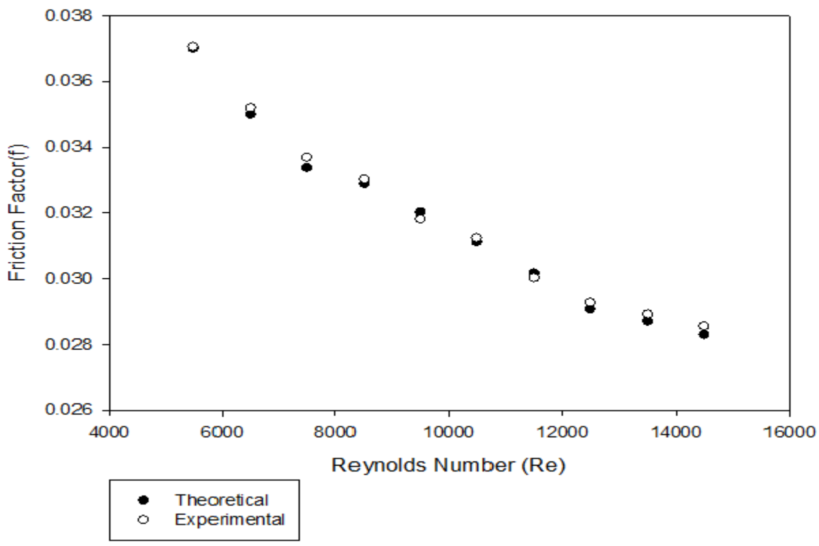
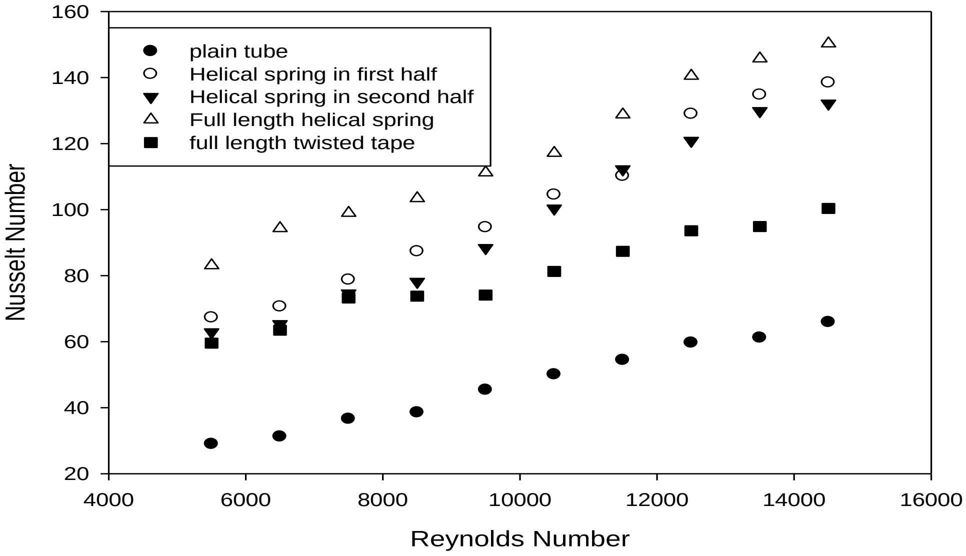


Figure 7 Comparison between experimental friction factor and theoretical friction factor with Reynolds number of plain tube.

III. RESULT AND DISCUSSION

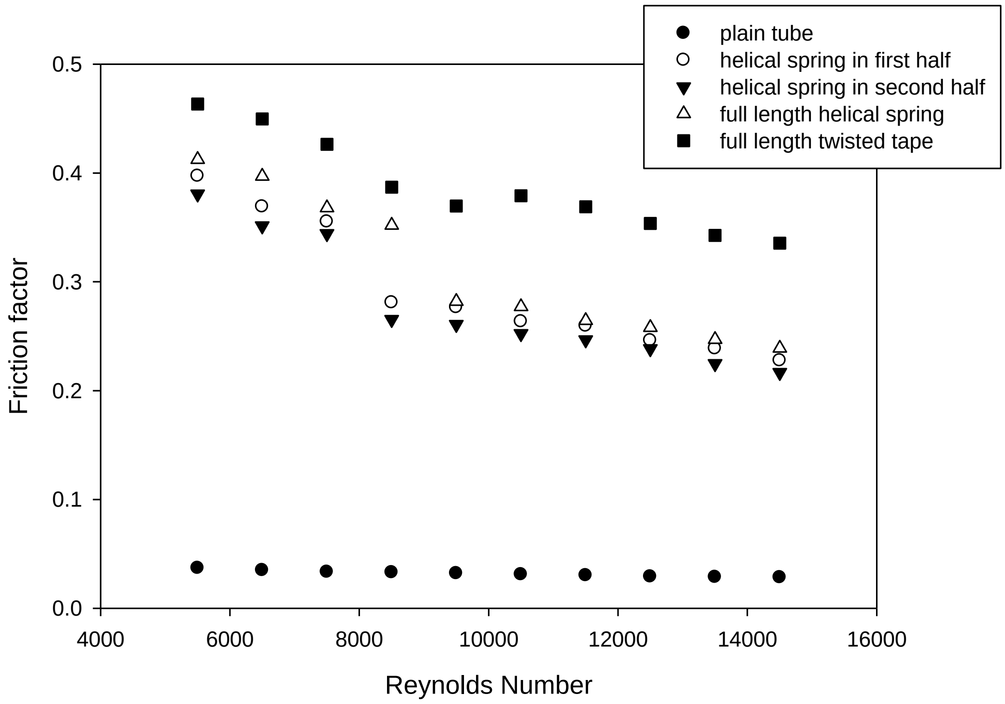
Present work deals with the effect of full length twisted tape, full length spring, first half spring and second half spring on Nusselt number , friction factor and performance evolution criterion of double pipe heat exchanger. In comparison to plain twisted tape and twisted tape with various configuration employed in the trial the highest value of Nusselt number achieved for full length spring is 150.27 at Reynolds number 14500 , which is 128.09% greater than the plain tube. It show that due to higher value of Nusselt number the heat transfer is maximum in full length spring. The variation of Nusselt number with Reynolds number for different combination is shown in figure 8, it show that increment of Reynolds number , Nusselt number also increase it is because of turbulence effect in continuously flowing hot water and therefore convective heat transfer rate increase.



Variation of Nusselt Number with Reynolds Number

Figure 8 Data variation of Nusselt number with Reynolds number

Variation of friction factor with Reynolds number is shown below in figure 9 it show when friction factor decrease Reynolds number increase in all cases. The maximum value of friction factor of full length twisted tape is 12.52 times , the maximum value of friction factor of full length spring is 11.17 times , the maximum value of friction factor of first half spring is 10.73 times , the maximum value of friction factor of second half spring is 10.28 times than the maximum value of friction factor of plain tube at Reynolds number 5500 respectively.



Variation of friction factor with Reynolds Number

Figure 10 Data variation of friction factor with Reynolds number

The variation of performance evaluations criteria (PEC) with Reynolds number in the tube fitted with first half spring, second half spring, full length spring and full length twisted tape respectively is presented in figure 11. It can be emphatically deduced from the figure that performance evaluation criteria decrease with an increase in Reynolds number for all cases which reflect when Reynolds number increase , the impact of friction factor become more and more significant in comparison to Nusselt number. The ratio of Nusselt number decrease with an increase in Reynolds number which mean twisted tape gives better result in weak turbulence.

The maximum value of PEC of full length spring is 1.54 times than the maximum value of performance evaluation criteria of full length twisted tape at Reynolds number 6500. The maximum value of PEC of first half spring is 18.75% greater than the maximum value of PEC of full length twisted tape at the Reynolds number 6500. The maximum value of PEC of second half spring is 11.70% greater than the maximum value of PEC of full length twist at the Reynolds number 6500

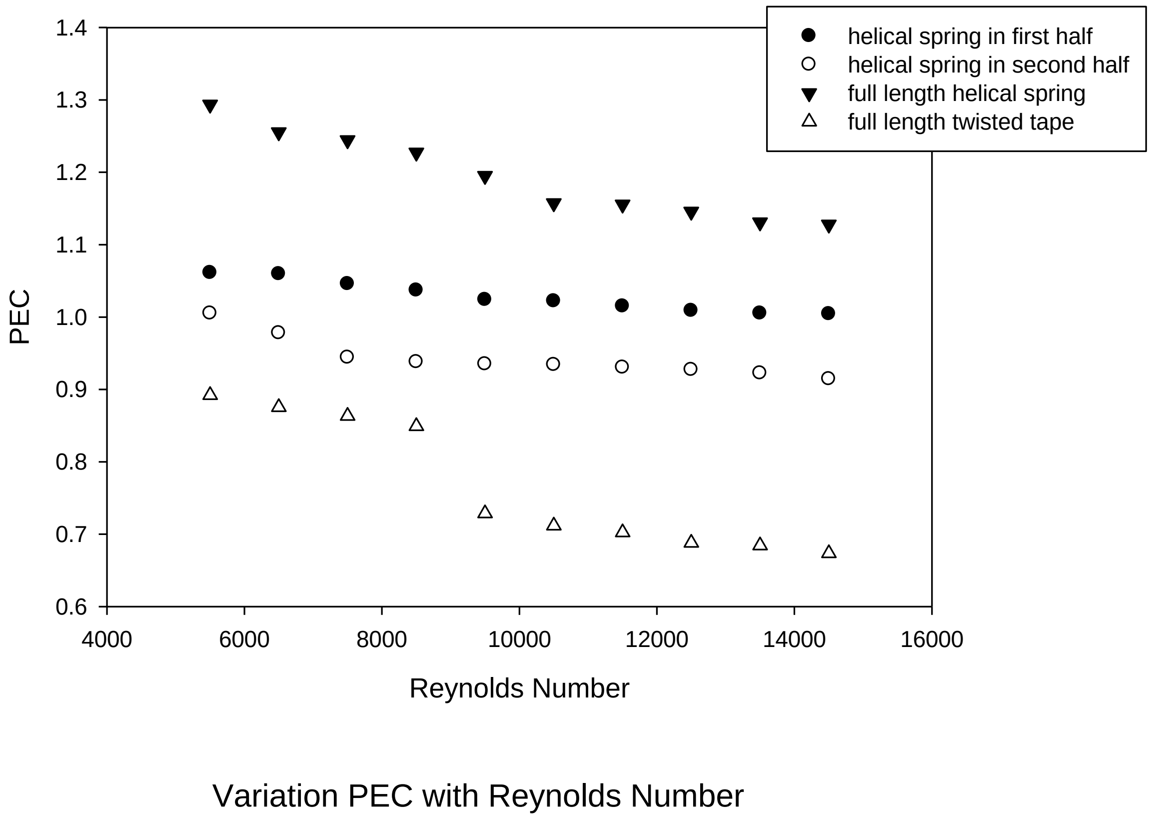


Figure 11 Variation of PEC with Reynolds number

IV. CONCLUSION

The experiment has been performed on heat transfer and friction factor characteristics in a double pipe heat exchanger with and without twisted tape and helical spring. After the experiment the effect of twisted tape and helical spring inserts on heat transfer enhancement and friction factor was studied. There are some conclusion that have been drawn from the experiment and they are –

- Nusselt number increase with increase in Reynolds number for every cases, it means Nusselt number is directly related with turbulence whereas friction factor decrease with increase in Reynolds number for every cases, it means friction factor dominates more in laminar flow than the turbulent flow.
- The maximum value of Nusselt number for full length spring , full length twisted tape, spring in first half and spring in second half is 128.09% , 52.33% , 110.16% , and 100.55% greater than the value of Nusselt number for plain tube respectively.
- It was found that for given range of Reynolds number spring insert is more effective than the twisted tape as spring produce more swirl flow than the twisted tape.
- Spring place in first half produce more swirling effect than the spring placed in second half.
- The maximum value of friction factor for full length twisted tape , full length spring, spring in first half, spring in second half is 115.22% , 1017.34% , 973.60% and 928.99% greater than the value of friction factor for plain tube respectively.

- The maximum value of performance evaluation criteria for full length spring , spring in first half , spring in second half is 54.84% , 18.78% and 11.70% greater than the value of performance evaluation criteria for full length twisted tape respectively.
- It was found that the performance evaluation criteria reduce with an increase in Reynolds number for the entire configuration which means that at higher Reynolds number friction factor become more and more significant in comparison to Nusselt number.

Future scope

This study and calculation reflect the possibility to examine many different aspects in double pipe heat exchanger with twisted tape insert and following area of research are identified for future research:-

1. Experimental study of heat transfer and frictional factor in double pipe heat exchanger by using concentric spring.
2. Experimental study of heat transfer and frictional factor in double pipe heat exchanger by using conical spring.
3. Experimental study of heat transfer and frictional factor in double pipe heat exchanger by using insert with nano fluid.

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