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Experimental Study of Heat transfer and friction factor in Double pipe Heat Exchanger using Twisted tape with Axial and Radial V-cut angles at constant depth of V-cu

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Abstract
We can find application of heat exchanger in our daily life such as in our homes, industries, transport vehicles, electrical and mechanical machinery etc. Heat exchangers play an important role in thermal processes in industries. Some industrial applications of heat exchanger are condensation and steam generation in power plants, thermal processing of agricultural products, processing of chemical and pharmaceutical products, liquid and air cooling of engine and turbo machinery systems, and cooling of electronics devices and electrical machines. An efficient heat exchange process in general practice can significantly increase the thermal efficiency in such applications that reduces the cost of their operation and design.
In the present work, an Experimental Study of Heat transfer and friction factor in Double pipe Heat Exchanger using axial and radial V-cut of different angles at constant depth of 4mm is carried out. A comparative study is done to evaluate the effects of twisted tape inserts for the plain tube on the heat transfer rate, Nusselt Number and friction factor through a circular pipe using water as testing fluid with a range of Reynolds number between 5600 and 10000. In the double pipe heat exchanger (DPHE), hot water is cooled in the inner tube and cold water is used as cooling fluid between the inner and outer tubes. The results shows that the heat transfer characteristics of DPHE were enhanced with twisted tape while frictional resistance also increased at the same time. The maximum increase in heat transfer rate was 35% for 45 degree axial and radial V cut angle, 27% for 30 degree axial and radial V cut angle, 26% for 15 degree axial and radial V cut angle and 18% for without V cut as compared to the plain tube without insert. The friction factor was varied from 0.13 to 0.31 for the tube fitted with axial and radial V cut twisted tape compared with no inserted twisted tape in plain tube.

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I. Introduction

Heat exchanger is a device which is used to transfer heat between two or more fluids. Heat exchangers are used in both cooling and heating processes. The fluids may be separated by a solid wall to prevent mixing or they may be in direct contact. Heat Exchangers have extensive applications in industrial Processes such as in Power Plants, food processing industries, pharmaceuticals industries etc. We can reduce the overall cost of production by implementing an efficient Heat Exchange process. Present work involves a novel configuration of twisted tape to comparatively study heat transfer and friction characteristics of circular tube with axial and radial V-cut twisted tape of 15 degree, 30 degree and 45 degree at a V-cut depth of 4 mm. Heat transfer data of proposed configuration is compared with the Plain twisted tube. A lot of techniques have been used to improve the performance of heat exchanging devices for reducing material costs and surface area and decreasing the difference for heat transfer thereby for reducing external irreversibility. Twisted tapes are very favorable for increasing heat transfer coefficient. The Nusselt number and friction factor of all dense forms of the teardrop patterned twisted tapes are higher than those of sparse counterparts. At Reynolds number 3000, the dense teardrop dimpledprotruded (D-TDP) casing achieves the greatest TPF of 1.517 among the evaluated twisted tapes by Hakanbu cak,Fuatyilmaz. (2021). Experimental Investigation of Heat Transfer Rate Using Twisted Tape with Elliptical Holes by K. R. Gawande 1 , A. V. Deshmukh* 2 in 2017. Experimental Investigation of Heat Transfer Characteristics in a Circular Tube Fitted with Triangular-Cut Twisted Tape (TCTT) Inserts by Sivakumar K1* and Rajan K2 in 2018. Experimental study on thermal performance and energy analysis in an internally grooved tube integrated with triangular cut twisted tapes consisting of alternate wings by C. Nithiyesh Kumar 1 & M. Ilangkumaran2 in 2018. Experimental Augmentation of Heat Transfer in a Shell and Tube Heat Exchanger using Twisted Tape with baffles and hiTrain Wire Matrix Inserts – A Comparative Study by Raman Bedi1 , Kiran K1 , A M Mulla2 , Manoj3 , Gurumoorthy S Hebbar1 in 2018. V- cut Twisted Tape Insert Effect on Heat Transfer Enhancement of Single Phase Turbulent Flow Heat Exchanger by Indri Yaningsih1,2,4 a), Agung Tri Wijayanta2 b), Takahiko Miyazaki3,4 c), and Shigeru Koyama3,4 d) in 2018. Thermal performance of double pipe heat exchanger with V-cut twisted Tape inserts by a) Sumitkumarsingh b)Jahar Sarkar in 2019.

PROBLEM IDENTIFICATION

However, there is no evidence in the literature of any research into the heat transfer characteristics that influence the axial and radial angle of twist of V-cut twisted tape at a constant depth in a circular tube with a conventional twisted tape configuration with V cut twisted tape. The current study uses twisted tape in a V-cut configuration to compare heat transmission and friction properties of a circular tube with axial and radial twist angles of 15 degree, 30 degree , and 45 degree at a constant depth. The proposed configuration's heat transfer data is collected and compared to a plain twisted tape. To explain the proposed arrangement, heat transfer statistics and friction characteristics are shown and discussed.

VALIDATION OF EXPERIMENTAL SET-UP

To ensure that the data produced through the trials is correct, the experimental setup is checked against conventional correlations proposed by various authors. The Gnielinski and Filonenko correlations are used to compare the values of Nusselt number and friction factor in plain tube experiments. The findings show that the experimental values are within acceptable bounds. The Nusselt number has a maximum variance of 7%, while the friction factor has a maximum departure of 7.5 percent.

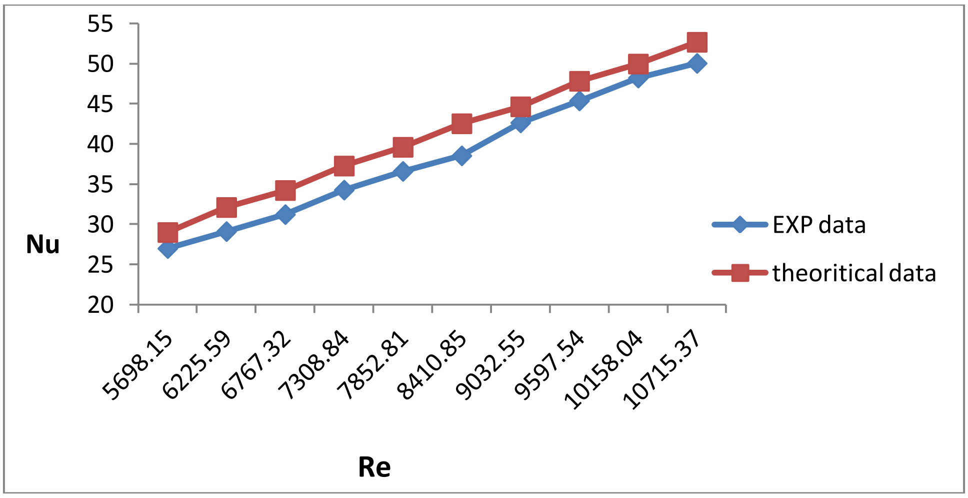

Fig 1. Comparison of the experimental Nusselt number and theoretical Nusselt number for plain tube.

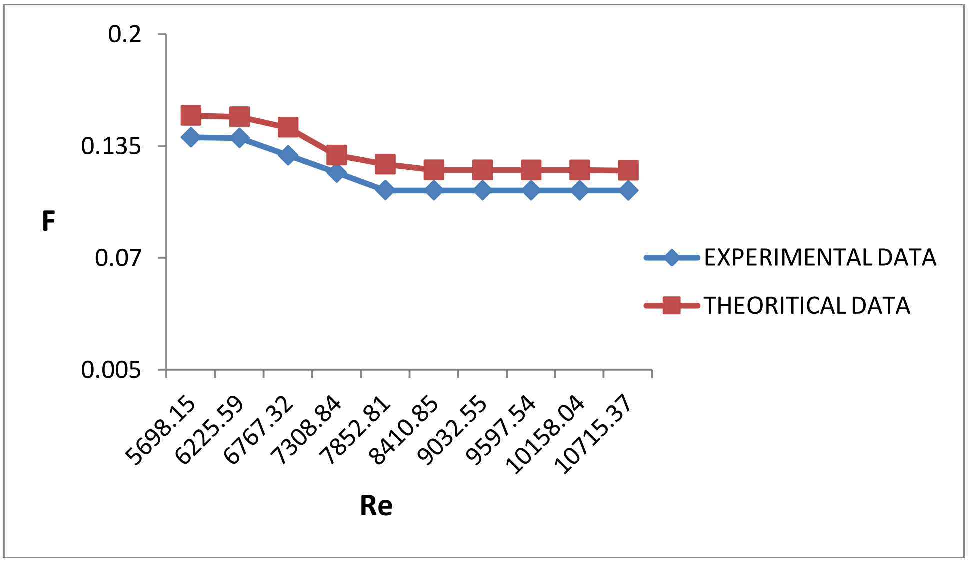

Fig 2 Comparison of the experimental friction factor and theoretical friction factor for plain tube

Experimental Setup

A Double Pipe Heat Exchanger setup is used along with twisted tape inserts. We get enough data for the experimental evaluation of heat transfer and friction characteristics of DPHE double-pipe heat exchangers for single-phase forced convective flow. Various parameters were varied over preset limits to acquire sufficient data.

The set-up consisted of the following components:

1. AC power supply
2. Heater
3. Electrical heater fired hot water boiler
4. low measuring devices
5. Plane Steel Tube
6. Externally Helical Copper Wire Wound Steel Tube
7. Twisted Inserts Outer tube [G.I]
8. Thermocouples
9. Cold water source

Hot water goes from the top-mounted hot tank to the inner tube where heat is transferred to the cold water flowing via the outer tube. The cold water entrance and outlet in the outer tube are at the top, thus the outer tube must be filled and the inner tube must be completely submerged into water. The cold water flow at the input of the outer tube is regulated and controlled by a rota-meter; this cold water extracts heat for drainage. The mass flow rate of hot water at the inner tube's entrance is governed by a rota-meter, and the hot water output is circulated to the hot water boiler for reuse. To cut down on water waste, we attached a hot water drain at the outflow to the boiler. We now employ a heater with a capacity of 9KW power in the bottom hot water boiler to give hot water ranging from 60^{o}C to 90^{o}C in order to minimise time waiting for the higher hot tank's hot water. We also have a 0.5 HP pump located at the bottom of the boiler, which pumps the hot water to the top-located hot water tank for future use. The temperature at the inlet-outlet of cold and hot water flows is measured using four thermocouples. The Experimental configuration is shown in the diagram below. Similarly, the repeated process is utilised for the copper wire wound Steel tube.

The Practical setup used for following investigation is illustrated in figure 3.

Fig 3 Experimental Setup of Heat Exchanger

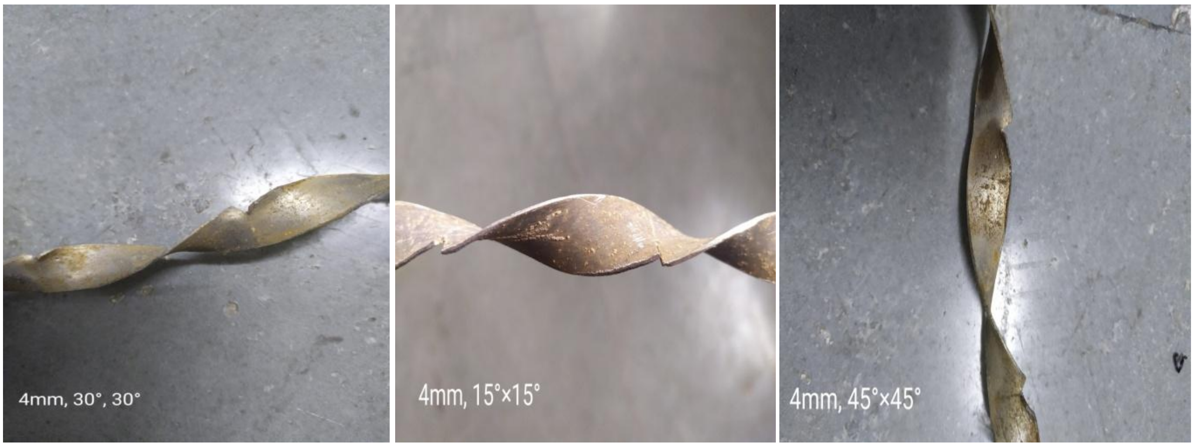

Fig 4 Axial and radial V-cut twisted tape inserts at different angles

II. RESULTS AND DISCUSSION

Present work deals about the effect of axial and radial angle of V-Cut twisted tape, ranges from 15^0 to 45^0 at a constant depth of 4mm on Nusselt number, friction factor and performance evaluation criterion of double pipe heat exchanger. It was found that the Nusselt number is maximum 50.04 at Reynolds number 10715.37 and minimum 26.98 at Reynolds number 5698.15 for plain tube with no twisted tape. The Nusselt number is 63.84 at Reynolds number 10606.28 and minimum 32.72 at Reynolds number 5616.03 for plain inserted twisted tapes insert without V-cut. The Nusselt number is 67.962 at Reynolds number 10402.83 and minimum 34.084 at Reynolds number 5581.26 for axial and radial angle of V-Cut 15^0 at a constant depth of 4mm. The Nusselt number is 71.1056 at Reynolds number 10593.10 and minimum Nusselt number 35.944 at Reynolds number 55605.25 for axial and radial V-Cut at angle 30^0 at a constant depth of 4mm. The Nusselt Number is 74.925 at Reynolds Number 10548.50 and minimum Nusselt Number 36.945 at Reynolds number 5669.82 for axial and radial V-cut angle of 45^0 at constant depth of 4mm as shown in fig 5.

This highest value of Nusselt number of plain twisted inserts is 1.27 times greater than the values for Nusselt number of plain tube and twisted tape insert with Axial and radial V-cut angle 15^0 is 1.3581 times greater than the values for Nusselt number of plain tube. The twisted tape inserts with axial and radial V-cut angle 30^0 is 1.4208 times greater than the values for Nusselt number of plain tube. The Nusselt number for a twisted tape insert with axial and radial V-cut angle 45^0 is 1.4973 times more than the Nusselt number for a plain tube.

In comparison to plain twisted tape and twisted tape with various configurations employed in the trials, the highest value of Nusselt number is achieved for axial and radial V-cut angle 45^0 at constant depth of 4mm because it generates the greatest rise in secondary flow. As a result, the formation of the boundary layer is reduced.

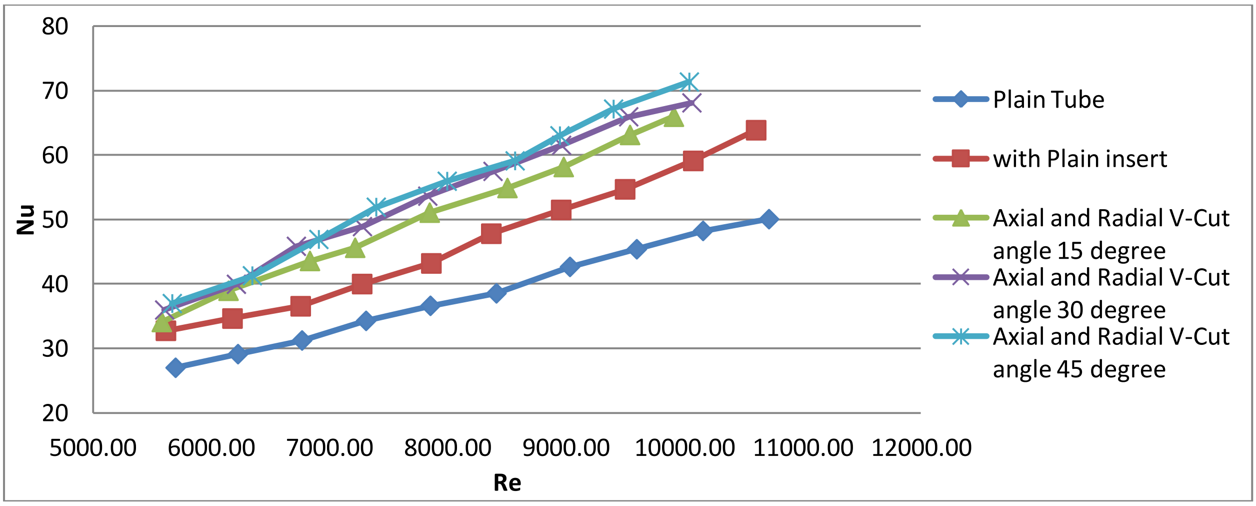

Fig 5 Variation in Nusselt number with respect to Reynolds number for different values(Plain tubes, with twisted tapes insert, twisted tapes insert at Vcut depth 4mm at different Axial and Radial angle)

At constant depth, varying the angle of axial and radial V cut from 15^0 to 45^0 increases the friction factor. It is because there is less flow area, which means there is higher contact surface resistance. As a result, simple tube is said to have the lowest friction factor. The friction factor for tube with Plain insert twisted tape is determined to be the lowest as compared to inserts with axial and radial V-cuts ranges from 15^0 to 45^0. The value of friction factor for plain tube is found to be 0.1090 for Reynolds number 10715.37 and 0.1399 for Reynolds number 5698.15, for plain twisted tape insert is found to be 0.1361 for Reynolds number 10606.28 and 0.1875 for Reynolds number 5616.035, for twisted tape insert with axial and radial V-cut angle 15^0 is found to be 0.177 for Reynolds number 10402.83 and 0.255 for Reynolds number 5581.26, for twisted tape insert with axial and radial V-cut angle 30^0 is found to be 0.1997 for Reynolds number 10593.10 and 0.295 for Reynolds number 5605.25, for twisted tape insert with axial and radial V-cut angle 45^0 is found to be 0.217 for Reynolds number 10548.50 and 0.314 for Reynolds number 5669.82.

In comparison to friction factor for plain tube, twisted tape with plain insert has a friction factor of 1.23-1.34 times, whereas twisted tape with axial and radial V-cut angle 15^0 has a friction factor of 1.62-1.82 times, 1.83-2.10 times for axial and radial V-cut angle 30^0, and 1.99-2.24 times for axial and radial V-cut angle 45^0. Figure 4.2 shows a graph demonstrating the change in friction factor as a function of Reynolds number.

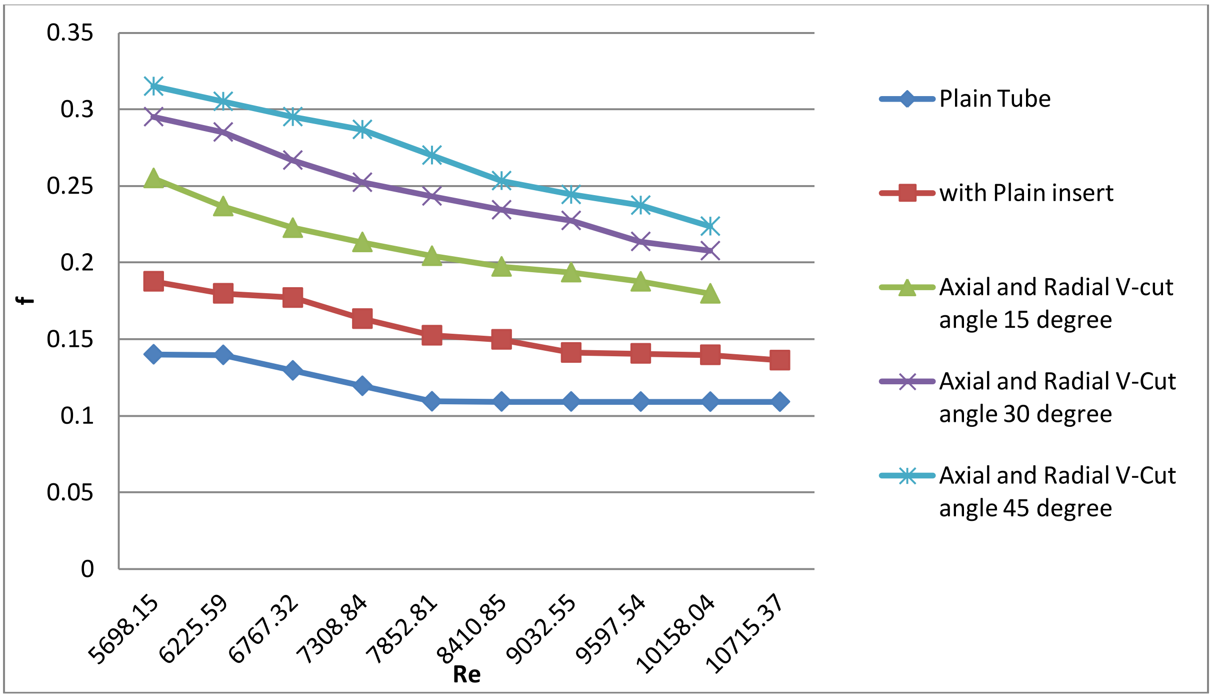

Fig 6 Variation in friction factor with respect to Reynolds number for plain tube,with twisted tapes insert, twisted tapes insert at V-cut depth 4mm at different Axial and Radial angle

The differences in performance evaluation criteria (PEC) as a function of Reynolds number in plain tubes and tubes equipped with twisted tapes with axial and radial V-cut angles of 15^0, 30^0, and 45^0 respectively is shown in Figure 7. The performance evaluation criteria for all conditions reduces as the Reynolds number increases This indicates that as the Reynolds number increases, the impact of the friction factor becomes more and more significant in contrast to the Nusselt number. The Nusselt number ratio falls as the Reynolds number rises, implying that twisted tape performs better in light turbulence. Maximum Performance Evaluation Criterion is found at axial and radial V-cut angle 45^0 with values of 1.13 for Reynolds number 5616.03 and 1.07 for Reynolds number 10606.28. Over the range of Reynolds number investigated, maximum PEC is found at axial and radial V cut angle 45^0 with a value of 1.13 at Reynolds number 5669.82 and it is 1.12 times as compared to Plain twisted tape inserts whose maximum PEC is 1.001 at Reynolds number 5616.035. On the other hand, value of performance evaluation criteria ranges from 1.037 to 1.021 for axial and radial V cut angle 15^0, from 1.019 to 1.022 for axial and radial V cut angle of 30^0. The value of PEC at axial and radial V-cut at 15^0, 30^0, 45^0 is greater than the value of PEC of plain inserted twisted tape.

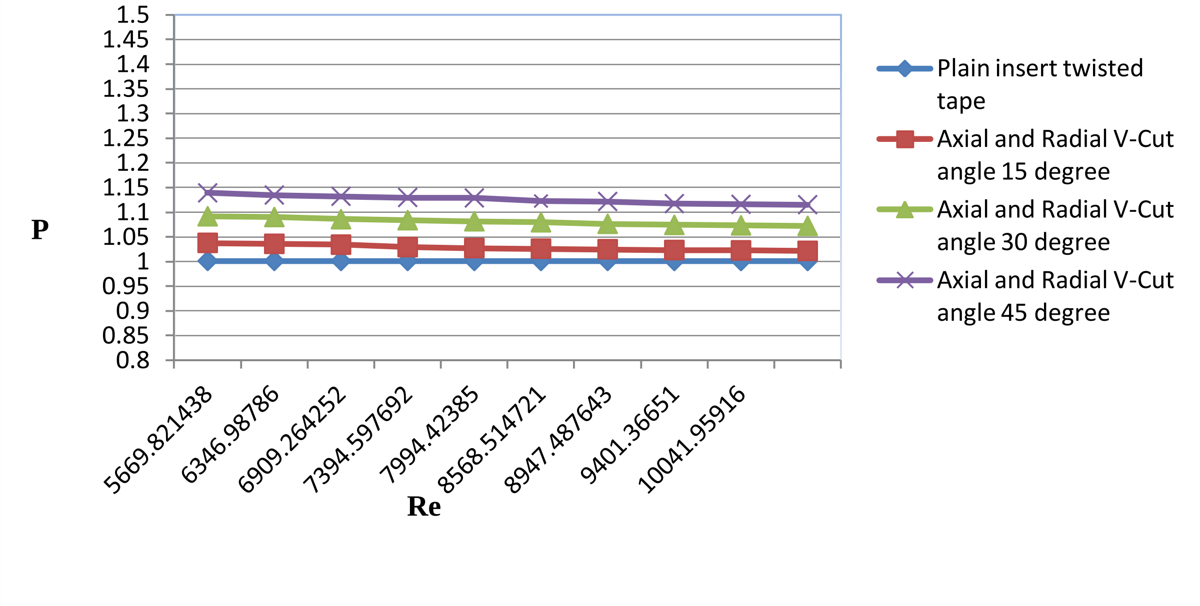

Fig 7 Variation in Performance evaluation criteria with respect to Reynolds number for twisted tapes insert with twisted tapes insert, twisted tapes insert at V-Cut depth 4mm at different Axial and Radial angle

III. CONCLUSION

Heat transfer and pressure drop were tested experimentally in a circular tube with inserted twisted tape at depth of 4mm and axial and radial V-cut angle 15^0, 30^0, and 45^0. Experiments were conducted to determine the effect of twisted tape inserts with V cuts of 4mm depths at a varying axial and radial V-cut angles on heat transfer and friction factor properties. The research focused on water as a working fluid in a turbulent flow environment. The following are some of the conclusions that can be derived from this research.

1) It is discovered that twisted tape inserts with a V-cut depth of 4mm and axial and radial V-cut angle 45^0 offers greater value of Nusselt number and friction factor than plain twisted tape inserts and plain tube over a range of Reynolds numbers investigated.

2) The highest value of Nusselt number of twisted inserts is 1.4972 times greater than the values for Nusselt number of plain tube, twisted tape insert with axial and radial V-cut angle 15^0 is 1.35 times greater than the values for Nusselt number of plain tube, twisted tape insert with axial and radial V-cut angle 30^0 is 1.42 times greater than the values for Nusselt number of plain tube, and twisted tape insert with axial and radial V-cut angle 45^0 is 1.49 times greater than the values for Nusselt number of Plain tube. The highest Nusselt number is found with a axial and radial V-cut angle of 45^0 at a constant depth of 4mm

3) This results in a reduction in the formation of boundary layer and increases the overall fluid velocity consequently; maximum value of Nusselt number is obtained for the axial and radial V-cut angle 45^0.

4) The angle of the V cut at twisted tape is found to be directly proportional to the friction factor. It rises as the angle of the axial and radial V-cut rises. It is because there is less flow area, which means there is higher contact surface resistance. In relation to the Nusselt number, the influence of twisted tape with axial and radial V-cut angle on friction factor becomes more dominant as the Reynolds number increases. As a result, the minimum friction factor for a simple tube with no twisted tape insert is presented. Furthermore a performance evaluation criterion (PEC) at angle of 45^0 at constant depth of 4mm is maximum which reflects that Nusselt number is predominant over friction factor.

5) It can be emphatically deduced from the above data that the performance evaluation criteria decreases with an increase in Reynolds number for all cases which reflects when Reynolds number increases, the impact of friction factor becomes more and more significant in comparison to Nusselt number.

6) The ratio of Nusselt number decreases with an increase in Reynolds number which means twisted tape gives better result in weak turbulence. Maximum PEC is found at axial and radial V-cut angle of 45^0 with a value ranges from 1.13 to 1.11 and it is 1.12-1.06 times for plain twisted tapes insert.

FUTURE SCOPE

This research and analysis allows various features of a Double Pipe Heat Exchanger with twisted tape inserts to be investigated, and the following research areas have been highlighted for future research:

- Experimental study of heat transfer and friction factor in double pipe heat exchanger using twisted tape inserts with V Cut at same angle but multiple V-cut depth with nanofluid.
- Experimental study of heat transfer and friction factor in double pipe heat exchanger using twisted tape inserts with V Cut with both side V-cut at constant angle with nanofluid
- Experimental study of heat transfer and friction factor in double pipe heat exchanger using twisted tape inserts with V Cut at different depth with different twist ratio.
- Experimental study of heat transfer and friction factor in double pipe heat exchanger using twisted tape inserts with V Cut of different length and at different locations.

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