Experimental Observation of Heat Exchange and Pressure Drop By Using Many Inserts in a Round Tube

Mohan Gupta, Kamal Sharma

Abstract: The capability of a convectional heat exchanger (HE) in transferring heat requires improvement for conveying a considerable proportion of energy at cheaper rate and amount. For augmenting the heat transfer coefficient, different means have been employed. However, the use of inserts has become an assured method in enhancing heat transfer through endurable escalation of frictional losses. The objective of the study is the examination of a round pipe fitted along with multiple inserts with regard to its characteristics related to energy transfer and water flow; these inserts are organized in clockwise and anticlockwise attitudes.

Keywords:"Nu","Re", "F", "Twisted tape inserts".

NOMENCLATURE :

Q Heat transfer
B heat conductivity
F Friction factor
U Mean speed of water
As Surface area
ΔP Pressure drop
Nu Nusselt number
Tb Average of inlet and outlet temperature
Ts Mean surface temperature
Re Reynolds number

I. INTRODUCTION

Heat exchanger (HE) is a crucial component for power considerations and cooling cycles that provide assistance in the transference of energy by taking into consideration the variation in temperature. Energy transmission takes place from one medium to another. Each fluid passing through the heat exchanger shows variance in temperature; therefore, the walls separating each fluid also shows difference in temperature. The thermal functioning of the system depends on the capability of the energy or heat exchanger to transform the heat from high point temperature to colder temperature of water with the intention that the desired amount of heat energy is rapidly get transferred. The designers are enthusiastic to build effective and compressed energy exchangers at the lowest speculation and operating cost. There are two types of heat transfer enhancement techniques; active procedure and passive procedure. In the active procedure, outer power source is required, whereas, in the passive procedure, outer power source is not mandatory.

There are number of investigation has been performed by many researchers for increasing the energy transfer by the utilization of perverted tapes (PTps). E-ard et al**.** [1] done the trial for estimating the transference of heat and nature of friction in a circular tube that is attached to entire PTps.

The study observed, by using the inserts of PTps type in the inside conduit of a dual pipe energy HE can considerably escalate the rate of transference of heat. Nevertheless, the erosion factor of the tube concurrently increases by the use of warped tape inserts. Energy transfer and friction are amplified because of the swirling motion developing from the secondary flows of the water.

In another study, E-ard et al. [2] conducted experiment for analyzing the transference of energy and flow fluid data of the heat exchanging device that used a helical screw tape that was constructed of stainless steel. The tapes were used unaccompanied by or along with core rod inserts inside the double pipe. In the energy exchanger, there is external and internal tube with diameters 50 and 25 millimeter through which cooled and heated water flow as they are used as working fluids, and these fluids remain in shell and pipe side, respectively. The Reynolds number ranged from 2000 to 12000. The result of the experiment depicted that the transference of heat was better for the loose-fit unaccompanied by core rod than a helical screw tape along with core rod. The energy exchange rates were approximately 340% higher upon manipulating the helical screw-tape unaccompanied by core-rod insert instead of smooth tube. Though friction reduced by 50% for using a helical screw-tape with a core-rod, the heat exchange rates were 25–60% more for the tape unaccompanied by core-rod. Moreover, the efficiency became double for the helical shape screw-tape unaccompanied by core-rod.

Thianpong and their co-workers [3] for examining the compound reaction on the transference of heat and friction conducted an experiment with a biconcave tube, where a PTps was used as insertion, and water was used as test fluid. The consequences related to the average heat transfer and the pressure drops were examined using varied permutation of the twist ratio (TR) and the pitch ratio for the completely developed flow. They carried out the study using two excavated tubes with non-identical pitch proportions (PR) taken as 0.7 and 1.0 with three PTp inserts with three non-identical shape with a twist proportions of 3, 5, and 7. They also used smooth tube for the experiment, which highlighted the advantages of dimpled tube. From the results obtained inside this study, it was detect that the friction factor and convective coefficient are higher for the twisted tape inserted dimpled tube than dipped tube with no insert and a flat tube. Furthermore, upon diminishing the TR and pitch ratio values, the heat transfer coefficient and friction factor changed for both the arrangement. The Nu of the PTps inserted in the biconcave tube was 56% and 303% more than a perverted tube and a flat tube, simultaneously.

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E-ard et al. [4] in another learning explored the impact of using delta winglet tapes as place in the circular tubes. For conducting the study, a slanting delta winglet twisted tape and a straight delta-winglet twisted tape were employed. The delta-winglet twisted tapes used for the experiment had three depths of vane cut proportions 0.110, 0.210, and 0.310 and twist proportions 3.0, 4.0, and 5.0. The Reynolds number ranged from 3000 to 27000. From the obtained results, it was observed that with the reduction in twisted ratio and increase in the depth of wing cut ratio, there is increase in the heat transfer coefficient and friction factor. Furthermore, the slanting delta winglet twisted tape demonstrated increase in the heat transfer coefficient compared to that of the straight delta-winglet PTps.

E-ard et al. [5] scrutinize the ways in which the twin (2) counter and geometry with co-swirl twisted tapes affect the rate of heat transfer. Primarily, the twin counter PTps were employed as counter-swirl flow alternators, whereas the twin co-twisted tapes played the role of co-swirl flow producing inserts. The CTs and CoTs inserts with four different twist proportions (2.5, 3.0, 3.5 and 4.0) were used in conducting the experiment. The Reynolds number ranged from 3700 to 21000. Furthermore, the experiment depicted that there is enhancement of the coefficient of heat transfer and friction factor with decrease in the ratio of twist.

E-ard et al. [6] further scrutinize presentation for counter clockwise (CCW) and alternate clockwise twisted tape inserts (CCC twisted tapes) fitted with a circular tube and compared them with the performance of a classic twisted tape. The investigation was based on mainly Nine (9) types of twisted geometrical tape inserts with three different proportions for twist as 3.0, 4.0, and 5.0, along with three different angles for twist as 30, 60, and 900 were analyzed. The CCC twisted-tapes considerably increased the rate of transference of heat and friction in differentiation to the flat twisted-tapes under the same states. Moreover, the investigational data revealed that the coefficient of heat transfer for the CCC tapes increases with reduction in the TR and enhancement of the twist gradient.

Wongcharee and E-ard [7] conducted an inspection using the interspersed wings and axis twisted tapes as inserts within the round tubes. They predicted the impact of wings shape and size, wherein they considered different shapes such as triangular, rectangular, and trapezoidal for conducting the study. The twisted tapes with varied wing-chord proportions of 0.1, 0.2, and 0.3 and the fixed TR of 4.0 were employed in this experiment. They held the alternate axes at a difference of 60° in relation to the neighboring plane of tape. It was observed that the heat exchange rate and friction were more in case of tube with twisted tapes than tube absence of twisted tape. Furthermore, the substitute axis insert with trapezoidal wings demonstrated the foremost performance between other inserts considered for experimenting.

Pethkool et al. [8] conducted an experiment using non-identical helically geometries of wrinkled tubes have pitch to diameter ratio in the range of 0.18, 0.22, and 0.27. The Reynolds number span from 5500 to 60000. The coefficient of the magnification energy transfer varied between 123% and 232%.

Wongcharee and E-ard [9] in their study examined the role of different CCW and clockwise (CW) twisted geometrical tapes as inserts in the round tubes, and considered aqua as the test fluid. The Reynolds range in this study was small, i.e., between 830 to1990. There was variation in the TR of inserts, which ranged from 3 to 5. For comparison of the transference of heat level in tube with inserted tapes, they also employed smooth tubes and observed that the energy transfer coefficient and F were maximum at the TR of 3.

E-ard et al. [10] conducted a study for examining the performance related to the transference of heat and fluid flow through different non uniform twisted tapes as inserts in a circular tube and compared the results obtained with that of the smooth tube. For generating swirl flow that enhances the rate of heat exchange, a very crucial role is played by the twisted tapes; hence, the parameters associated with the different non uniform twisted tape were taken into account. The transference of heat was maximum for the tube TR of 3 with repetitive expanding–contracting type twisted tape.

Nanan et al. [11] conducted a study for examining the impact of perforated helical twisted-tape inserts in circular tubes. The variety of Reynolds number was in the range of 6000 to 20000. Maintaining the twist ratio and helical pitch ratio continuous, they considered unpredictable geometrical parameters such as the diameter ratio, perforation pitch ratio. With the decrease in perforation diameter and increase in perforation pitch, there is amplification of the factor related to thermal performance. The friction and heat transfer rate diminished with the use of helical twisted-tape inserts in comparison to the plane tube with solid insert since the fluid flow obstruction and violent intensity were reduced.

Promvonge and E-ard [12] conducted an experimental study by concurrently using PTps and cone-shaped ring swirl producers as turbulators to fulfill the objective of heat transfer through round tubes. The TR’s of twisted tapes ranged within 3.75 to 7.5. The maximum rate for the transference of heat was observed for the tube fitted with the conical-ring and twisted-tape to be 367%. Moreover, for the twisted ratio of 3.75, the enhancement of a cone-shaped ring and a PTps was around 1.96. Combining the heat transfer coefficients of the combination of a cone-shaped ring and a PTps, it was developed that cone-shaped ring and a PTp was superior to the cone-shaped ring.

Kongkaitpaiboon et al. [13] scrutinize the properties of a solid conical and penetrated conical rings placed within a concentric tube related to heat transfer and friction. The Re ranged from 4000 to 20000. For the study, the data associated with the use of smooth tube were also gathered, as it was necessary for comparing with the data obtained for conical turbulators. The analysis showed that there is increase in the heat transfer rate and F of penetrated conical rings as the pitch ratio and number of perforated holes decrease. However, the thermal performance factor reaches the highest value as the penetrated hole increases and pitch ratio decreases.

In comparison to the plain tube, the average Nusselt number for penetrated conical rings with pitch ratio of 4, 6, and 12 were 185%, 140%, and 86%, respectively.

Meng et al. [14] examined the alternating elliptical axis tube geometry for the Re varies between 500 to 50000. From the data obtained, it is observed that the performance related to heat exchange enhances as the Re has lower value. Further, the rate of heat transfer is amplified with the use of the alternating elliptical axis tube, as there is lesser increase in friction losses. Moreover, in the alternating elliptical axis tube, early transition takes place because of the variation in the alternated tube cross-section. According to the study, the transference of heat was higher owing to the production of multi longitudinal whirling mass of the fluid because of the disparities in the tube cross-section.

Faizal and Ahmed [15] examined the functioning of HE that had 20 parallel plates with indistinguishable corrugated pattern, and these plates were separated by 6mm distance. The study focused on examining the preferred geometry of corrugations that provided enhancement of the performance of HE. Moreover, it is concluded that the functioning of HE increases with decline in the warm water flow rate. With increase in fluid velocity, there is increase in the turbulence intensity of the fluid.

E-ard et al. [16] conducted a examination for examining the role of twisted tapes and round ring turbulators as inserts in round tubes for unearthing the impact of heat transfer performance and pressure drop. For the experiment, a single twisted tape was used as insert, which was encircled by a round ring. The pitch ratio and TR lies between 1 to 2 and 3 to 5, respectively, and it was observed that the experiment was successful at pitch ratio of 1 and twisted ratio of 3. With the incorporation of circular ring and tapes, the improvement in thermal performance was observed.

Thianpong et al. [17] in their study employed the penetrated twisted tapes with the parallel wing inserts fitted inside a circular tube. For heating the circular tube, the uniform heat flux condition was utilized, and the Re ranged from 5500 to 20500. The parallel wing perforated twisted tape was envisaged to restrain the F through discharge of the fluid by means of perforations in the tape. Moreover, wings were used for hindering the flow through the tube surface. From the results of the experiment, it was observed that the maximum level of thermal performance corresponds with the bottom value of the hole diameter ratio and topmost value of wing depth ratio.

E-ard et al. [18] examined the impact of non regular and regular twisted tapes. These tapes had substitute axis type inserts, which were positioned within a circular tube, wherein the Re varies between 5000 and 21500. The variation of the substitute length to the twist proportions was between 0.5 to 2 in four steps. After critically analyzing the data obtained, it was observed that the transference of heat was improved through use of the tube with the non regular substitute axis twisted tapes that have bottom value of substitute length to the TR.

For exploring the performance of HE, E-ard and Promvonge [19] used the serrated edge twisted tapes as inserts. For incessant flow of air in whirling motion, the TR of a specific value was suggested for implementation in the serrated edge twisted tapes. The Re ranged from 4000 to 20000. For successful experimentation, the results acquired from using the smooth tube with inserted normal twisted tapes were differentiated with the results obtained for using the tube having serrated edge twisted tapes. It was concluded that the performance of HE improved with reduction in the depth ratio and enhancement of the width ratio.

For better thermo-hydraulic performance, Guo et al. [20] suggested the use of the center cleared twisted tapes as inserts in the circular tube. It can be concluded through numerical examination of the standard CFD tool that there was degradation in the heat transfer and thermo-hydraulic performances owing to reduction of the edges of short width twisted tapes.

E-ard and Promvonge [21] examined that there is reduction in the heat transfer performance and pressure because of the insertion of V- shaped nozzles in circular tubes with variation in pitch proportions and concluded that the decline in potch ratio resulted in increasing the heat exchanging performance.

Chang et al. [22] conducted a study related to energy transfer and F, wherein they compared the performance of round tubes, which were attached with single, twin, and triple PTps. The study divulges that the best performance was observed for the tube fitted with the triple twisted tapes even after consuming same pumping power. Furthermore, the increase in twisted tape insert resulted in increasing the heat transfer.

Chang et al. [23] did an experiment using a tube fitted with twisted serrated tape for understanding the flow friction and energy transfer attributes. For enhancing turbulence, modification was made in the ordinarily twisted tape configuration by fixing repeated ribs over the tape surfaces. Owing to large turbulence eddy diffusions, the transference of heat is more through the serrated twisted tape than the simple tube in the absence of tape inserts. In another study, Chang et al. [24] examined the energy transfer and F related to the broken twisted tape with Re that range from 1000 to 40000. Comparing with the plain twisted tape, it was noticed that there was growth in the heat transfer coefficients; mean cooling F, and heat performance factors in the tube filled with the shattered twisted tape within the span of 1.28-2.4, 2 - 4.7 and 0.99-1.8, respectively.

Rahimi et al. [25] conducted a study for analyzing the energy transfer, F, and thermo-hydraulic performance of a circular tube. For conducting the experiment, the tube was attached with the simple, penetrates, notched, and spiked twisted tape inserts. The results obtained showed that the transference of energy was maximum for the jagged twisted tape.

Bharadwaj and Khondge [26] used a spirally grooved tube with the twisted tape insert for analyzing the heat transfer and pressure drop. Furthermore, they even observed the impact of twist attitude (CW and CCW) related to the nature of thermo-hydraulic.

E-ard and Promvonge [27] in their observation employed the jugged edge PTps as insert for exploring their role in the functioning of HE. For this study, they considered unlike serration depth and width ratio for Re ranging from 4000 – 20000. The performance of HE could be enhanced through decrease in depth ration and increase in width ratio. Moreover, in these twisted tapes, the constant flow of whirl air was attained at a fixed value of the TR.

E-ard et al. [28] conducted a study by using the center wings and repeatedly axes PTps as inserts in the round tubes. The predicted structure and size of these wings were triangular, rectangular, and trapezoidal. The obtained results demonstrated that related to the tube in the absence of twisted tape, the tube with twisted tapes showed increment in the energy transfer rate and frictional losses. The alternate axis inserts with trapezoidal wings showed better performance than other inserts.

E-ard et al. [29] conducted a experiment using a tube accompanied by peripherally-cut twisted tape insert to examine the nature of heat transfer and friction. The insert considered had different tape depth ratio and tape width ratio, and the Re ranging between 1000 and 20000. For the obtained results, it was found that the peripherally-cut twisted tapes showed considerably higher heat transfer rate and F. This increase resulted from higher violent intensity of water close to the pipe separator owing to the peripherally-cut twisted tape.

Murugesan et al. [30] done an experiment for analyzing the rate of energy transfer upon using a twin pipe HE. The study showed that through the use of square cut twisted tape, the heat transfer rate considerably increased. Furthermore, the performance improved owing to additional disturbance because of the square cut geometry. In another study, Murugesan et al. [31] used the V-cut twisted tape insert for measuring heat transfer and fluid flow and observed that the Nusselt number and F rises with drop in TR and width ratio , but there was rise in the depth ratio.

Wongcharee and E-ard [32] examined the impact of perverted tapes with repeated triangle and axes, trapezoid shape and rectangle shape wings on the transference of heat. It was observed that in comparison to the typical and normal twisted tapes with axes alternating and wings resulted in the increase of heat transfer mainly because of enhanced collision of fluid, which was induced by wings close the pipe separator.

II. EXPERIMENTAL EXPLORATION

For investigation the energy conveyer and friction parameters of round shape pipe equipped with number of inserts, provides a novel conversation for the current investigation. The novel data has been collected for pipe external diameter, water temperature (inside and outside), along with flow rate for water and pressure variation.

Experimental set up

The experimental set up shown in Figure 1 consists of the following parts:

Test tube – made of copper
Tube internal diameter – 25 millimeter
Tube thickness – 1.6 millimeter
Tube length – 1000 millimeter
Working fluid – Water
Inserts used – A plain PTp insert, a set of double (2) PTp insert in CW and CCW configuration and a combination of four(4) twisted tape insert in CW and CCW configuration along with the complete length of pipe.

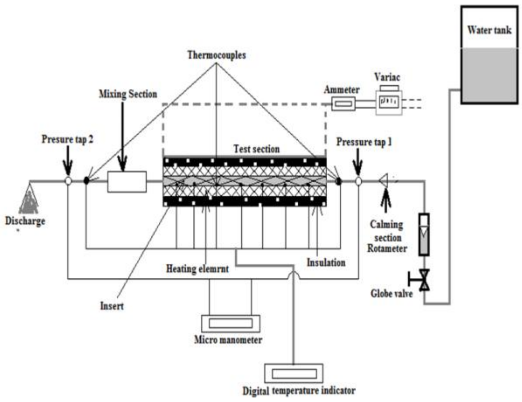

Figure-1 Set up of Experiment

2.1 Investigational methodology

During the experiment, a precisely designed insert has been fitted to the experimental part of set up with the use of an assembled glove valve along with a rotameter. A desired flow rate of the fluid has been set and directed from the constant head tank. At the same time, a heater is fixed to supply a heat flux on a regular basis to the outer part of the pipe. Once the heat flux and flow rate of water is being fixed than the measurement of tube surface temperature with inside and outside temperature of fluid has been done. As the process begin the readings of all the concern temperatures shows higher values, which may be due to instability of the water fluid. After a time span of 30 min, an individualistic temperature is recorded on each particular locations, this is attributed to system reaching out at its uniform (steady state) situation. As the system, reaches to this position the temperature at eight different positions are recorded. Simultaneously pressure head has been measured with the help of a micrometer. The data for energy transfer along with friction for a complete flow range is measured iteratively by changing the flow rate. The same process has been repeated for different types of twisted tapes to verify the diversity of the system with different types of variable parameters.

2.3 Inserts Configurations

In this experiments, the twist tapes having dissimilar width and twist pitch were put in the round experimental pipe for storing the readings related to energy transfer and friction. The deviant tapes are made by crumple the aluminum strips of 1000 millimeter length and 6, 12 and 24 millimeter width. The inserts are placed in five distinct arrangements, namely (ST), twin (CoTs), twin (CTs), (4CoTs), and (4CTs) with twist proportions of 2.4, 3 and 3.4. Figure 2 (a) to (e) shows the configurations of many types of dissimilar tape inserts used in this experiments.

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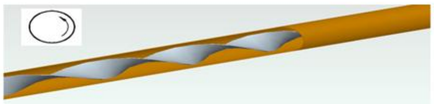
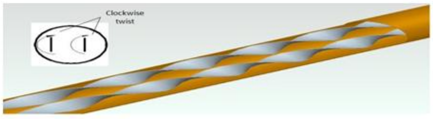
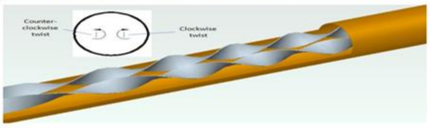
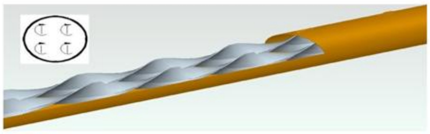


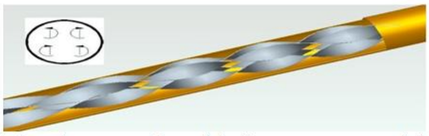


(b) circular test tube with twin co-swirl twisted tape



(c) circular test tube with twin counter-swirl twisted tape


(d) circular test tube with four co-swirl twisted tape


(e)circular test tube with four counter-swirl twisted tape

Data reduction

In this experimental investigation, water is used as a working fluid with a uniform regular heat flux environment in the entire test tube. An assumption with regards to adiabatic situation has been taken that may further defied as the energy transfer through convection from inside the hot tube to the water is considered to be equal to the energy consumed by the fluid which has been explained through equation (a) as follows:

$$Q_{water} = Q_{convection} \qquad \text{(a)}$$

The transfer of energy under convection from outer of the can be written as,

$$Q_{convection} = hA_s\left(T_s - T_b\right) \qquad \text{(b)}$$

and the heat consumed by water can be explained through equation (c), as follows:

$$Q_{water} = mC_p\left(T_{out} - T_{in}\right) \qquad \text{(c)}$$

A_s = outside area of pipe,

T_s and T_b are outside temperature of the tube and mean of the inside and outside fluid temperatures respectively.

$$A_s = \pi DL \qquad \text{(d)}$$

Where D and L are = inside dia. And length of experimental pipe respectively.

Mean of heat transfer coefficient (h)

$$h = \frac{mC_p(T_{out} - T_{in})}{A_s(T_s - T_b)}$$

The Reynold's no. (R_e) can be calculated as,

$$Re = \frac{VD}{\nu} \qquad \text{(e)}$$

the F can be measured as given below:

$$f = \frac{2D \times \Delta P}{L\rho V^2} \qquad \text{(f)}$$

The mean velocity of water (V) is measured by

$$V = \frac{m}{\rho \times A} \qquad \text{(g)}$$

The bulks mean temperature of the water-

$$T_b = \left(T_{in} + T_{out}\right)/2 \qquad \text{(h)}$$

Factor is found to be 3.95%, 3.94%, and 3.82% respectively.

III. AUTHENTICATION OF TRIAL SETUP

The readings of Nu and F for the plain tube can be differentiated with the results obtained from quality correlation & the data stored for energy transfer and fall in pressure was recorded with different types of inserts and also without inserts. The quality readings for Q and F with the through the plain test tube is find from correlations developed by Dittus Boelter correlation, which has been described as follows.

$$N_u = 0.023Re^{0.8}Pr^{0.4} \qquad \text{(i)}$$

Blasius correlation

$$f = 0.316Re^{0.25} \qquad \text{(j)}$$

Nu and F are obtained to be 2.5 % and 5.5 %, continuously.

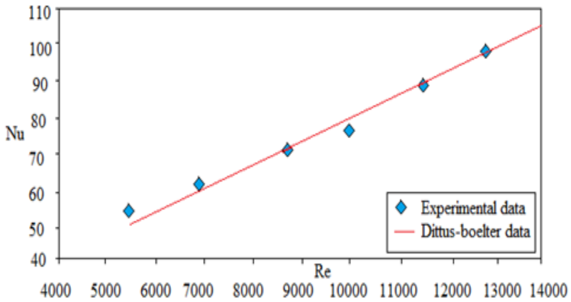


Fig. 3.1.Validation of Nusselt number data for smooth tube with the Dittus boelter data

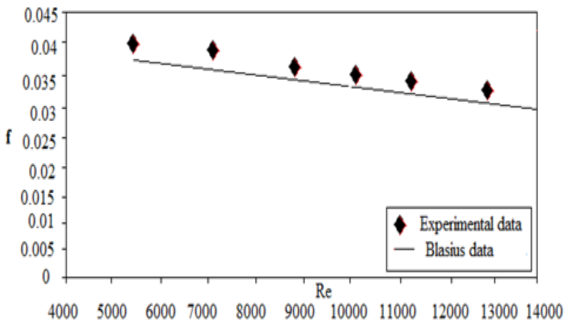


Fig. 3.2. Validation of friction factor (f) data for smooth tube with the Blasius data.

IV. RESULTS AND DISCUSSION

The data has been obtained by conducting various experiments by using dimensionless parameters for energy transfer (Q) and friction (F) through a pipe for single and a number of perverted inserts tape. Nu and F were obtained for the complete span of parameters for the variation in Re from 4000 to 13500.

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The effect of different PTps and configurationally obtained parameters on 'F' and 'h' is studied. The escalatement ratio (Nu/Nus) for the Nusselt number has also been discussed in detail. An energy transfer escalatement has been obtained by using a number of PTps. An observation has been made for the frictional losses raised because of tube insertion along with PTps by taking into consideration the escalatement ratio (f/fs) for an entire range of R_e. The discussion done in the present work provides a deep learning about the effects of PTps on the heat transfer and fluid flow.

4.1 Correlations developed between Nusselt number and friction factor

For many configurations of inserts the Nu and F correlation are considered as below-

(a) Plain twisted tape (ST):

$$N_u = 0.62Re^{0.58}N^{-0.29} \qquad \text{(k)}$$

$$f = 12.28Re^{-0.46}N^{-0.64} \qquad \text{(l)}$$

(b) Twin twisted tapes (CW):

$$N_u = 0.99Re^{0.55}N^{-0.34} \qquad \text{(m)}$$

$$f = 26.08Re^{-0.55}N^{-0.36} \qquad \text{(n)}$$

(c) Twin twisted tapes (CCW):

$$N_u = 1.1Re^{0.56}N^{-0.33} \qquad \text{(o)}$$

$$f = 33.29Re^{-0.52}N^{-0.61} \qquad \text{(p)}$$

V. CONCLUSIONS

Conclusions for the literature review concerning energy transfer and friction in a round tube with one (1), dual (2) and four (4) inserts twisted tape has been demonstrated with the use of water as a fluid for the experiments conducted in different studies. We examined the differences of energy transfer and frictional losses for varied arrangement of twisted tapes. The following conclusion has been derived from this study:

- For the numerous kinds of twisted tapes, the increases in Re causes increase in the Nu and decrease of F factor. Both the Nu and F are affected by the Reynolds number owing to increase in the number of twisted tape inserts.
- With an increment in Re the ratio with regards to Nu and F found decreases for most of the cases. Nu escalatement ratio lies between 1.11-1.23, 1.31-1.49, 1.62-1.78; 1.90-2.06 and 2.28-2.40, For (ST), (CoT), (CT), (4CoT) and (4CT) alternately while the twist proportions is used as 2.2. The F enhancement proportions are obtained in the length of 2.64-3.40, 3.10-4.10, 4.24-5.30, 5.18-6.12 and 6.50-6.91 for the configuration of inserts.
- For all cases, the increase in Reynolds number causes decrease in the enhancement proportions of Nu and F.
- With decrease in the twist ratio (y) of the twisted tapes, there is increase in the Nu and F readings regardless of the variation in Reynolds number.
- The PTp inserts can cause counter-swirl motion and co-swirl motion. However, the energy transfer and friction is higher for the former than the latter.

The thermo-hydraulic performance factor reaches the highest value for the petition of four (4) CCW twisted tapes.

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