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Study on Heat Transfer Augmentation of Liquid Flow Through A Pipe

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Abstract - Heat exchangers have several industrial and engineering applications. The design procedure of heat exchangers is quite complicated, as it needs exact analysis of heat transfer rate and pressure drop estimations apart from issues such as long-term performance and the economic aspect of the equipment. Whenever inserts are used for the heat transfer enhancement, along with the increase in the heat transfer rate, the pressure drop also increases. This increase in pressure drop increases the pumping cost. Therefore any augmentation device should optimize between the benefits due to the increased heat transfer coefficient and the higher cost involved because of the increased frictional losses. The present paper includes various heat transfer augmentation techniques. A literature review of heat transfer augmentation using passive techniques has been included. Experimental work on heat transfer augmentation using twisted tape and a new kind of insert called twisted angles is carried out. Inserts when placed in the path of the flow of the liquid, create a high degree of turbulence resulting in an increase in the heat transfer rate and the pressure drop. The work includes the determination of friction factor and heat transfer coefficient for various twisted tapes and twisted angles having different twist ratios. The results of twisted tapes and twisted angles having different twist ratios have been compared with the values for the smooth tube. Three twisted angles y=2.915, y=3.612, y=4.105) and three twisted tapes(y=2.149, y=3.127 & y=4.705) having different twist ratios are used in the study. For twisted angles it was observed that the heat transfer coefficient could vary from 1.16 to 2.87 times the smooth tube value but the corresponding friction factor increases by 4 to 9.6 times the smooth tube values. Similarly for twisted tapes it was observed that the heat transfer coefficient varied from 1.28 to 2.48 times and the friction factor increased by 3.19 to 9.1 times the smooth tube value. It was also observed that with an increase in Reynolds number (Re), the heat transfer coefficient increases where as the friction factor decreases.

Keywords: Reynold's Number, Heat Exchanger, Thermal Performance Factor, Heat Transfer, and Friction Factor.

I. INTRODUCTION

Heat exchangers have several industrial and engineering applications. The design procedure of heat exchangers is quite complicated, as it needs exact analysis of heat transfer rate and pressure drop estimations apart from issues such as long-term performance and the economic aspect of the equipment. The major challenge in designing a heat exchanger is to make the equipment compact and achieve a high heat transfer rate using minimum pumping power. Techniques for heat transfer augmentation are relevant to several engineering applications. In recent years, the high cost of energy and material has resulted in an increased effort aimed at producing more efficient heat exchange equipment. Furthermore, sometimes there is a need for miniaturization of a heat exchanger in specific applications, such as space application, through an augmentation of heat transfer.For example, a heat exchanger for an ocean thermal energy conversion (OTEC) plant requires a heat transfer surface area of the order of 10000 m2/MW. Therefore, an increase in the efficiency of the heat exchanger through an augmentation technique may result in a considerable saving in the material cost. Furthermore, as a heat exchanger becomes older, the resistance to heat transfer increases owing to fouling or scaling. These problems are more common for heat exchangers used in marine applications and in chemical industries. In some specific applications, such as heat exchangers dealing with fluids of low thermal conductivity (gases and oils) and desalination plants, there is a need to increase the heat transfer rate. The heat transfer rate can be improved by introducing a disturbance in the fluid flow (breaking the viscous and thermal boundary layers), but in the process pumping power may increase significantly and ultimately the pumping cost becomes high. Therefore, to achieve a desired heat transfer rate in an existing heat exchanger at an economic pumping power, several techniques have been proposed in recent years. In many literature gap shows the experimentation on perforated twisted insert like in experimental analysis of heat transfer characteristics using inserts in tubes. Heat transfer enhancement techniques refer to different methods used to increase rate of heat transfer without affecting much the overall performance of the system. Heat transfer augmentation techniques refer to different methods used to increase these techniques and broadly divided in two groups, passive and active. Active techniques involve some external power input for the enhancement of heat transfer.

Passive heat transfer augmentation method does not use any external power input. One of the ways to enhance heat transfer performance in passive method is to increase the effective surface area and residence time of the heat transfer fluid. Use of this technique causes the swirl in the bulk of the fluids and disturbs the actual boundary layer so as to increase surface area, given time and similarly heat transfer coefficient in existing system. Inserts refer to the additional arrangements made as an obstacle to fluid flow so as to augment heat transfer rate.

II. DIFFERENT TECHNIQUES OF HEAT TRANSFER ENHANCEMENT

Heat transfer enhancement, augmentation deals with the improvement of thermo hydraulic performance of heat exchangers. Different enhancements techniques have been broadly classified as passive and active techniques.

A. Active Technique

The active method involves external power input for the enhancement in heat transfer; for examples it include mechanical aids and the use of magnetic field to disturb the light seeded particles in a flowing stream, etc

B. Passive Technique

The Passive heat transfer augmentation methods does not need any external power input. In the convective heat transfer one of the ways to enhance heat transfer rate is to increase the effective surface area and residence time of the heat transfer fluids. By Using this technique causes the swirl in the bulk of the fluids and disturbs the actual boundary layers which increase effective surface area, residence time and simultaneously heat transfer coefficient increases in an existing system. Methods generally used are, extended surface, displaced enhancements devices, rough surfaces surface tension devices, Inserts requires additional arrangements to make to fluid flow which enhance and augment the heat transfer. The types of inserts are: twisted tape, wire coils, ribs, baffles, plates, helical screw insert, mesh inserts, convergent – divergent conical rings, conical rings etc. Twisted tapes are the metallic strips twisted using some of the suitable techniques as per the required shape and dimension, which are inserted in the flow to enhance the heat transfer. The twisted tape inserts are most suitable and widely used in heat exchangers to enhance the heat transfer. Twisted tape inserts increase heat transfer rates with less friction factor. The use of twisted tapes in a tube gives simple passive technique for enhancing the convective heat transfer by making swirl into the heavy flow which disrupting the boundary layer at the tube surface due to rapidly changes in the surface geometry. Which means to say that such type of tapes induce turbulence and swirl flow which induces inside the boundary layer and which gives better results of heat transfer coefficient and Nusselt number due to the changes in geometry of twisted tape inserts. Simultaneously, the pressure drop inside the tube will be increases when using twisted-tape as an insert. For this a many researchers have been done by experimentally and numerically to investigate the desired design to achieve the better thermal performance with less frictional losses. The heat transfer enhancement of twisted tapes inserts depends on the Pitch and Twist ratio.

C. Compound Enhancement

When any two or more techniques i.e. passive and active may be employed simultaneously to enhance the heat transfer of any device, which is greater than that of produced by any of those techniques separately, the term known as Compound enhancement technique.

III REVIEW WORK

Khwanchit Wangcharee[2012] in their paper, have made the Techniques to augment heat transfer. They end up with the detailed analysis of heat transfer applications. This introductory chapter on the augmentation of convective heat transfer provides background for the many applications of this “second generation heat transfer technology” cited throughout this volume. The many available augmentation techniques are described, and some representative performance data and correlations.

A. A. Rabienataj Darji [2012] also have discussed the comparison of wire coil inserts and twisted tape in their work. It was observed and noted that to disturb the central core flow the twisted tapes are the solutionbut if peripheral annular flow is to be mixed with core flow the wire coil inserts perform better. In context with heat transfer rate they have concluded that twisted tape perform better than the wire coil inserts. In process industries the fluids used have high density because of high viscosity and dirt and thus they need high pumping power. In such cases the pumping power is the important element and is drive to put constraints on selection of passive device. When pumping power is an issue pressure drop adds limitation on type of insert, as twisted tape cause more pressure drop than wire coil inserts.

C. Thianpong et. Al [2012] works in the condition of force convection by using twisted tape insert of width 16 mm thicknesses 1.2mm, length 0.5m and twist ratio 5.5, 6.5, 8.5 with circular holes of diameter 6mm and conclude that for Re no.range 2000 to 12000, the Nussult number for twisted tape insert with twist ratio 8.5,6.5 and 5.5 was found to be 23.99%, 25.64% and 29.32% respectively also the Friction factor is increased approximately by 0.20%, 0.2673 % and 0.4545 % with twist ratio 8.5, 6.5 and 5.5 respectively.

A. E. Kabeel et. al [2013] Give a Analysis of Heat Transfer in Pipe with Twisted Tape Inserts to understand the effect of change in pitch of twisted tape on the flow physics, results of Re no.800 and twist ratio 2, 3, 4 and 5 are considered and conclude the variation of twist ratio and

Re no.on heat transfer and flow characteristics using twisted tape inserts and also the heat transfer increases with decrease in twist ratio and increase in Reynolds number.

M. M. K. Bhuiya et. al [2013] found in double pipe heat Exchanger of diameter 0.015 m and length of 2.5 m with variable twisted type insert in ANSYS fluent that a trend of increase in heat transfer with the provision of insert on the heat exchanger. The heat transfer was found to increase as the Re no.was varied over the range. The result shows that effect of insert on the enhancement of heat transfer depends on both the pattern of insert and Re no.of the flow.

Heyder Maddah, Nahid ghasemi [2014] Twisted tape is widely used heat transfer enhancement technique. Present paper argues the underlying physical phenomenon of heat transfer and fluid flow through a pipe with twisted tape inserts. Effect of twist ratio for $2.0 \leq p/d \leq 5.0$ and Reynolds number for $800 \leq Re \leq 2000$ (where p/d is the pitch ratio and Re is Reynolds number) on Nusselt number and friction factor have been numerically obtained. It is noticed that decrease in twist ratio promotes radial convection while increase in Reynolds number promotes axial convection. This is evident through understanding the variation of velocities and temperature across a particular section; especially near the wall. enhancement of heat transfer. However, the friction factor of the tube with the coiled wire insert also increases.

B. Silapakijwongkul [2015] In this work, effect of the tapes twisted in clockwise and counterclockwise arrangement (C-CC arrangement) on heat transfer and friction factor characteristics in a double pipe heat exchanger was investigated experimentally. The mean heat transfer rates obtained from using C-CC twisted-tape arrangement and original twisted-tape arrangement are found to be 219% and 204%, respectively over the plain tube.

C. Thianpong[2015] This paper describes heat transfer enhancement attributed to helically twisted tapes (HTTs). Each helically twisted tape was fabricated by twisting a straight tape to form a typical twisted tape then bending the twisted tape into a helical shape. The experiments were performed using HTTs with three twist ratios (y/W) of 2, 2.5 and 3, three helical pitch ratios (p/D) of 1, 1.5 and 2 for Reynolds number between 6000 and 20,000. The conventional helical tape (CHT) was also tested for comparison. The obtained results reveal that at similar conditions (y/W and p/D.

P. Eiamsa-ard [2016] The effect of inserts on the performance of heat transfer during flow through pipes with dual twisted tape inserts. A detailed literature survey on the use of twisted tape inserts and computation thermal properties of twisted tapes is presented. CFD simulations to study the behaviour of fluid during heat transfer when flowing through pipes with dual twisted tape inserts. Results of these simulations are discussed in the paper.

Halit das, veyselozceyhan [2017] Influence of helical tapes inserted in a tube on heat transfer enhancement is studied experimentally. The maximum Nusselt number may be increased by 160% for the full-length helical tape with cantered-rod, 150% for the full length helical tape without rod and 145% for the regularly-spaced helical tape, s = 0.5, in comparison with the plain tube.

IV PROBLEM IDENTIFICATIONS

From the study of various research papers we have obtained the following problems:

1. Geometry was not suitable for higher heat transfer.
2. The main concern for the equipment design is to minimize the flow resistance while enhancing the heat transfer coefficient.
3. Performance of heat exchangers can be improved by many augmentation techniques but increase in pressure drop is always a barrier for heat transfer enhancement.

V RESEARCH OBJECTIVES

Heat transfer can also be enhanced by using coiled inserts these coiled inserts acts as a turbulence generator. The use of this generated turbulence is expected to create the tangential velocity to prolong residence time of the flow and to enhance the tangential and radial fluctuation. The objectives of this work are to:

1. Enhance the heat transfer with respect to plain tube.
2. Reduce the cost and size of heat exchanger.
3. Decrease pumping power requirement.

VI METHODOLOGY

- Make sure the components and instruments are connected properly with the experimental set up for proper operation.
- For rotameter calibration, water is collected in a bucket Weight of water collected & time of collection is noted to calculate mass flow rate of water.
- A minimum of 3 readings are taken for each flow rate & average flow rate is used for calculations.
- Twist Ratio(y) of the twisted tapes were calculated.

Twist Ratio, $y = H/d_i$

Where H = Linear distance of the tape for 180° rotation

d_i = Inner diameter of pipe

- Before starting the experimental study on friction & heat transfer in heat exchanger using inserts, standardization of the experimental setup is done by obtaining the friction factor & heat transfer results for the smooth tube & comparing them with the standard equations available.
- For friction factor determination: Pressure drop is measured for each flow rate with the help of manometer at room temperature.
- After confirmation of validity of experimental values of friction factor & heat transfer coefficient in smooth tube with standard equations, friction factor & heat transfer studies with inserts were conducted.

VII RESULT & ANALYSIS

- It was observed that for Re> 3400 i.e., in turbulent region f is nearly equal to fo. For very low Re (Re < 3400) the observed height difference in the manometer was very small, resulting in a larger deviation. The friction factor relation used was

$f = 16/Re$ (For Re<2100)

$f = 0.046 \times Re^{-0.2}$ (For Re>2100)

- Friction factor Vs Reynold No. for Tube with twisted tape insert It is observed that friction factor increases as the degree of twist in the twisted tapes increases which is indicated by a lower value of twist ratio, Hence the pressure drop increases accordingly i.e,

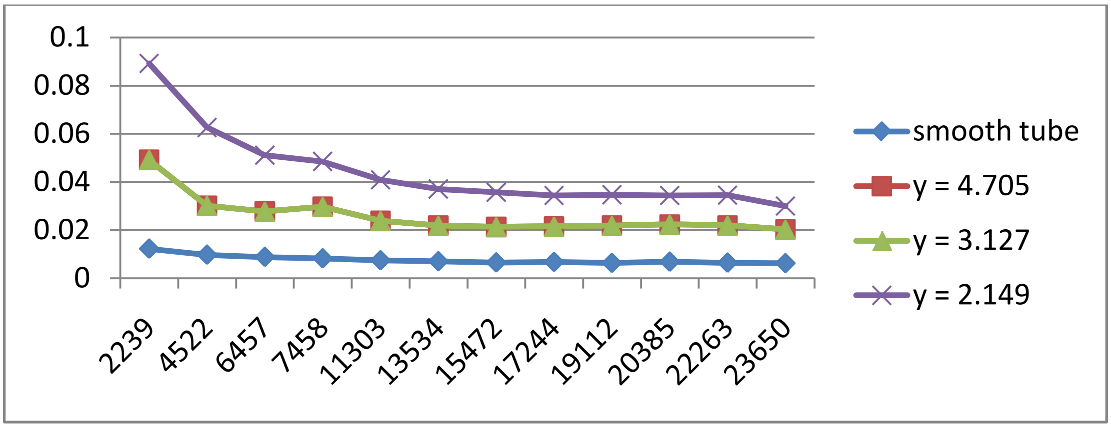

Figure 1: Friction factor Vs Re . for Tube with twisted tape insert

- Friction factor Vs Reynold No. for Tube with twisted angle tape insert It is also observed that friction factor increases as the degree of twist in the twisted angles increases which is increased accordingly.

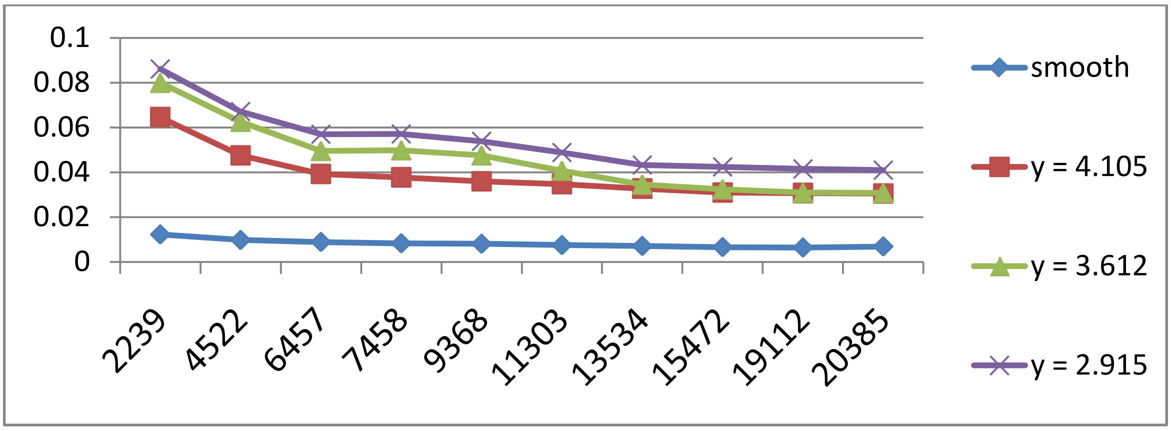

Figure 2: Friction factor Vs Re . for Tube with twisted angle tape insert

- Heat transfer coefficient Vs Reynold No. for tube with twisted tap insert .The heat transfer coefficient (film and overall) increases as the twist in the inserts increases (i.e. with decreasing twist ratio).

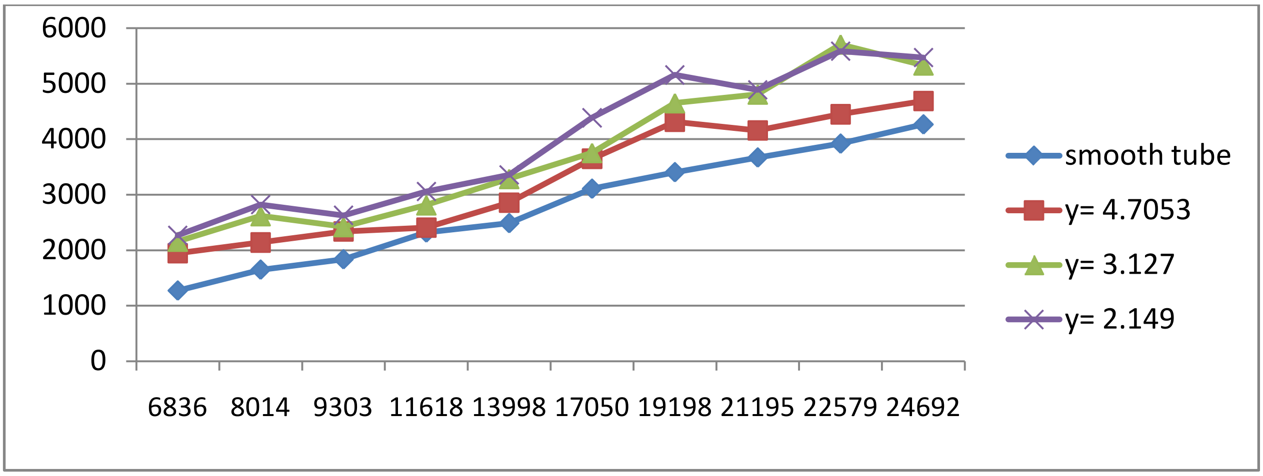

Figure 3: Heat transfer coefficient Vs Re for tube with twisted tap insert

- Heat transfer coefficient Vs Reynold No. for tube with twisted angle tape The heat transfer coefficient increases as the twist in the inserts increases (i.e. with decreasing twist ratio) as found in the case of twisted tapes.

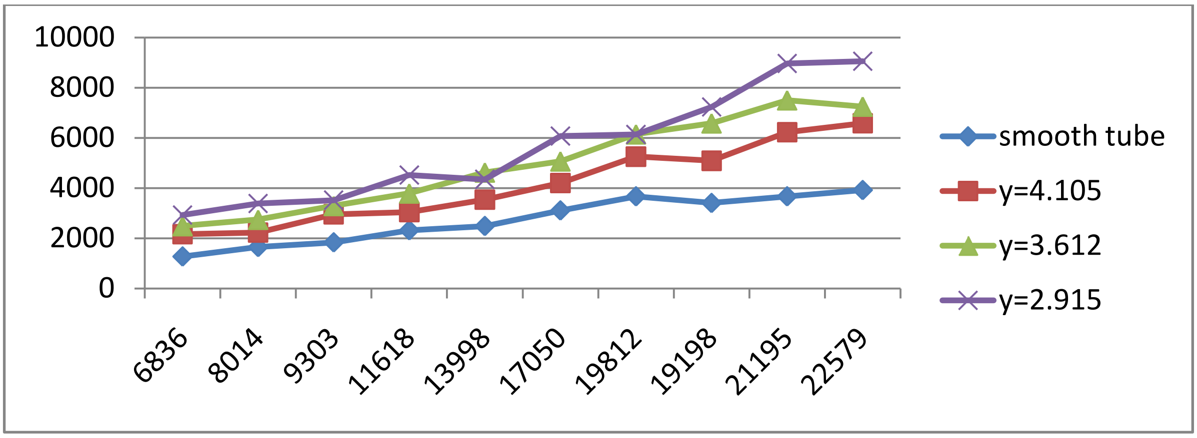

Figure 4: Heat transfer coefficient Vs Re for smooth tube and twisted angle tape

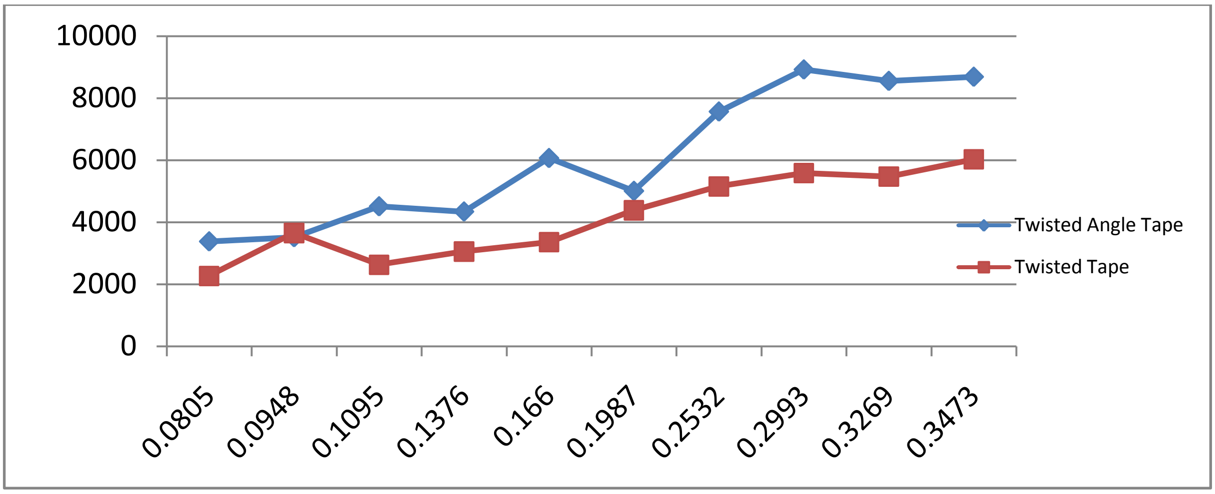

Figure 5: Comparison between twisted angle and twisted tape

VIII CONCLUSION & FUTURE SCOPE

1. The pressure drop and the heat transfer coefficient increase as the degree of twist in the tapes and angles goes on increasing.
2. For almost the same twist ratio, twisted angles show greater friction factor and heat transfer coefficient than the twisted tapes, because of higher degree of turbulence generated.
3. The range of f_a/f_o and R1 values for the twisted angle and twisted tapes are shown in the table 1 and table 2 respectively.

Table 1: For Twisted Angles

Sl.No.	Y	Range of fa/fo	Range of R1
1	4.105	4.62 to 6.59	1.11 to 1.61
2	3.612	4.80 to 8.16	1.50 to 2.05
3	2.915	6.27 to 9.56	to 2.87

For twisted angles it was observed that the heat transfer coefficients varied from 1.16 to 2.87 times the smooth tube value. But this increase is at the cost of increased frictional losses. The corresponding friction factor varied from 4 to 9.56 times the smooth tube values.

Table 2: For Twisted Tapes

Sl.No.	Y	Range of fa/fo	Range of R1
1	4.705	3.19 to 5.23	1.28 to 1.73
2	3.127	3.93 to 6.26	1.30 to 1.75
3	2.149	5.29 to 9.10	1.40 to 2.48

In the case of twisted tapes the heat transfer coefficients varied from 1.28 to 2.48 times the smooth tube value and the corresponding friction factor varied from 3.19 to 9.10 times.

We observe that with an increase in the Reynolds number (Re) the heat transfer coefficients increases for both twisted angles and twisted tapes while the friction factor decreases. In a heat exchanger, while the inserts can be used to enhance the heat transfer rate, they also bring in an increase in the pressure drop. When the pressure drop increases, the pumping power cost also increases, thereby increasing the operating cost. So depending on the requirement, one of the above mentioned inserts can be used for heat transfer augmentation. As per the performance evaluation criteria R1, the twisted angles gives better performance as compared to the twisted tape having the same twist ratio.

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