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Augmentation of Heat Transfer in a Single Phase Flow Using Simple and Modified Twisted Tape Inserts: A Review

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Abstract**: *Heat exchanger is essential devices in process industries, power plant and refineries for the exchange of heat from one fluid to another fluid. It finds wide industrial, commercial and domestic applications. Keeping in mind today's energy crisis lots of researchers are working on active and passive methods for the enhancement of heat transfer rate. Use of twisted tape insert is one of the passive methods of enhancing heat transfer rate in conventional conduits with pressure drop penalty. An exhaustive review has been presented in this paper so it will be ready reference for those who want implement twisted tape insert in the heat exchanger. The experimental investigation of plain twisted tape and modified twisted tape of various configurations with its main findings are presented in compact form. The main focused of the present study is heat transfer enhancement, friction factor and enhancement ratio for the compactness, savings in pumping power for the operation of heat exchanger.***
Keywords**: *Twisted tape, Energy crisis, Enhancement ration, Friction factor, Modified twisted tape.***

Nomenclature			
Re	Reynolds Number	P	Stream wise pitch spacing of winglet, m
Pr	Prandtl Number	WPT	Winglet perforated tapes
Nu	Nusselt Number	FF	Friction factor
HTC	Heat transfer coefficient	TEF	Thermal enhancement factor
TT	Twisted Tape	0	No twisted tape
sd	Serration depth, m	w	Perforated width
sw	Serration width, m	WR	Perforated width to tape width ratios
W	Twisted tape width	LR	Perforated length to tape width ratios
Di	Inner diameter of test section tube	d_v	Depth of V cut, m
b	winglet height, m	w_v	Width of V cut, m
B_R	winglet blockage ratio (b/Di)	DR	Depth ratio (d_v /W)
P_R	Pitch ratio (P/Di)	WR	Width ratio (w_v /W)

I. INTRODUCTION

This document is Heat exchangers are the common device used in process industries, petrochemical industries and power plants. The thermal design of heat exchanger includes the estimation of heat transfer coefficient and pressure loss for a given mass flow rate of fluid. In the present situation the use of energy is growing at higher rate due to current population growth and industrialization, therefore researcher are trying to develop heat exchanger with high heat transfer rate and minimum pressure loss for the optimum design of heat exchanger. There are two basic methods for the heat transfer enhancement, active and passive methods. Active methods requires external power source where as passive methods do not requires external power source for the heat transfer enhancement. However augmentation of heat transfer is achieved by modifications in the geometrical surfaces or insertion of elements into the heat exchanger in the passive methods. In the present paper passive methods of heat transfer augmentation by twisted tape insert is discussed which is one of the most widely adopted technique. The twisted tapes are inserted into the tube heat exchanger, it intensifies the fluid mixing. The use of twisted tape can be done with most of the fluids like water, air, different oils and chemicals. The heat exchange surfaces may be rough or smooth. The twisted tape raises the convective heat transfer coefficient both in laminar and turbulent flow and raises the overall heat transfer rate. With the use of twisted tape thought there is the augmentation of heat transfer rate but it also does penalty in terms of pressure lose so, heat there should be optimized among the augmentation of heat transfer rate and cont of pumping power.

The exhaustive reviews on the twisted tape given in this article will help researches to pick up the best suited twisted tape of a given twist ratio with minimum pressure loss and maximum heat transfer rate. Twisted tape is easy to manufacture and install even existing heat exchanger can be upgrade easily with the twisted tape inserts, Overall it is widely used passive method for the augmentation of heat transfer and facilitate the heat exchanger to be compact.

II. TERMINOLOGY USED FOR TWISTED TAPE INSERTS

Twisted tape can be generally specified by twist ratio which relates pitch and width of the twisted tape inserts. The typical twisted tape is shown in Fig.1 and main terminology related to it is described below.

A. Pitch (H): Pitch of the twisted tape is defined as the distance from one point to the corresponding next or previous point on the same plane measured parallel to the axis of a twisted tape. This is important parameter for the analysis of the twisted tape.

B. Width (W): The width of the twisted tape is define as the distance between lower and upper portion of the twisted tape measure across the axis of the twisted tape. Generally width of the twisted tape is same as internal diameter of the tube.

C. Twist Ratio (Y): It is defined as ratio of pitch to the width of the twisted tape. Y=H/Di, where Di = inside diameter of tube which is same as width of the tube.

D. Clearance: It is the distance between twisted tape and inside surface of the tube. It is also called as tube-tape clearance.

E. Enhancement ratio (η): It is defined as the ratio of heat transfer enhancement ratio to the friction factor ratio. It is used for comparing two different twisted tapes for the same pressure loss.

$$Enhancement\ Ratio = \frac{Nu_{TT}/Nu_0}{\left(FF_{TT}/FF_0\right)^{1/3}} \qquad \text{Eqn.1}$$

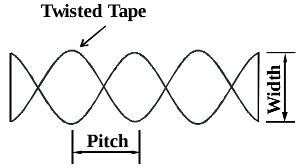


Fig.1. Terminology used for the twisted tape inserts

III.PRINCIPLE OF AUGMENTATION OF HEAT TRANSFER COEFFICIENT USING TWISTED TAPE

Manglik and Bergles [4] explain the mechanism for the heat transfer augmentation using twisted tape as per follows.

A. Twisted tape creates obstacles to the flow and results into increase in fluid velocity and loss of pressure head.

B. Fluid travels more as compare to without twisted tape as fluid has to follows twisted tape profiles.

C. Swirl flow effect generated and fluid flow velocity increases in radial and longitudinal directions.

D. Twisted tape also conducts heat from the heated wall and transfers it to the fluid and produce fin type of effect.

IV. GENERAL EXPERIMENTAL SETUP AND METHODOLOGY FOR THE INVESTIGATION ON HEAT TRANSFER RATE USING TWISTED TAPE INSERTS

Typical experimental setup used for the investigation of heat transfer augmentation using twisted tape is represented in Fig.2. The set up consists of various equipments like Pump or blower to flow liquid or gaseous fluid respectively, Flow controller device to fix the required amount of flow, test section with inlet and outlet pressure measuring devices. There is also need to measure the flow rate of the fluid. The test section is provided with twisted tape insert for which we want to investigate its performance. The test section is provided with temperature sensors at regular interval for the wall temperature measurement of the test section. Thus the measurement required are fluid flow rate, pressure at inlet and outlet of the test section, local wall temperature, Bulk fluid temperature of fluid at inlet and outlet of the test section.

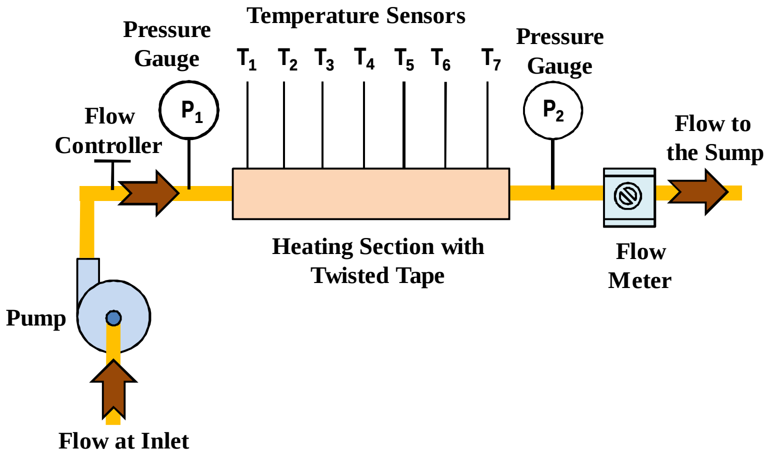


Fig.2 General setup for the enhancement of heat transfer using twisted tape insert

The experimental procedure includes flow of fluid using pump or blower depending upon gaseous or liquid fluid used to the test section through flow controller. Passage of fluid to the test section with twisted tape inserts where the fluid is heated and temperature at inlet temperature at outlet of the fluids and temperatures at various intermediate locations on the wall are measured. Then the fluid flows through the flow meter and finally discharged to the sump or it may be recalculated after cooling it into another heat exchanger if it is closed system.

V. REVIEW ON INVESTIGATIONS OF VARIOUS RESEARCHERS ON TWISTED TAPES

In the present papers reviews of key researches on plain twisted tape inserts and modified twisted tape inserts are discussed.

A. Review on Plain Twisted tape

Manglik and Bergles [4] developed correlation for friction factor and Nusselt number for the laminar flow with twisted tape insert for water and ethylene glycol as working fluid with uniform surface temperature condition. As per the Manglik and Bergles [4] the mechanism of heat transfer augmentation is “due to the tube partitioning and flow blockage, longer flow path, and secondary fluid circulation and fin effect“Flow regime map for isothermal friction factors in tube flows with twisted-tape inserts gives four region namely viscous flow, thermally developed swirl flow; swirl-turbulent transition and fully developed turbulent swirl flow based on the Reynolds number. Manglik and Bergles [5] investigated that the augmentation of heat transfer coefficient and pressure loss is strong function of twisted tape induced vortex motion for turbulent flow and uniform wall temperature. They developed correlation of friction factor for combined laminar and turbulent flow and suggest that a single expression is not sufficient to describe heat transfer in transition flow region. As per the Manglik *et al.* [6] the heat transfer enhancement increases with decrease in twist ratio.

B. Review on Serrated twisted tape

Chang *et al.* [8] worked with serrated twisted tape for heat transfer and friction factor investigation having twist ratio of 1.56, 1.88, 2.81 and ∞. The range of Re Number used was 5000–25 000. It was concluded that serrated twisted tape further enhance heat transfer as compare to the plain twisted tape. Further it was found that for a given range of Re number, thermal performance of both plain and serrated tapes increases with decreases in twist ratio. They have also developed correlation for finding out Nu number and fanning friction factor. Smith & Promvonge [9] investigated on twisted tape with serrated-edge with serration width ratio and serration depth ratio as parameter from 4000 to 20000 Reynolds numbers range. It was noted that there is augmentation of heat transfer coefficient with rise in serration depth ratio (sd/W) and heat transfer coefficient decrease with rise in serration width ratio (sw/ W).

C. Review on Staggered-winglet perforated-tapes

Sompol Skullong *et al.* [10] investigated on staggered- WPT having Re range from 4180 to 26000 for five different B_R and three P_R. It was observed that WPT generates considerable vortex and disrupt the boundary layer to create rapid mixing. It was concluded that Nu and FF rises with increasing B_R and decreasing P_R. The augmentation of heat transfer coefficient was found to be 2.4 to 4.7 times in their investigation. The correlation for the estimation of Nu, FF for the WPT and winglet TT were also developed.

D. Review on Tapered twisted tape inserts

Effect of tapered angle of twisted tape and twist ratio on heat transfer, FF and thermal performance has been reported by N. Piriyarungrod *et al.*[7] for the Re range of 6000 to 20000. It was found that FF and heat transfer increment are found to be with decreasing tapered angle and twist ratio this is because swirl intensity decrease with increase in taper angle. The thermal performance is better with increasing taper angle and decreasing twist ration. Tapered twisted tape found to be better as compared to the plain TT.

E. Review on Broken twisted tape inserts

Chang *et al.* [11] investigated on heat transfer and pressure loss for the broken twisted tape with Re in the range of 1000 to 40000 and tested Y=1, 1.5, 2, 2.5. It was investigated that use of broken twisted tape increases heat transfer and FF as twist ratio decreases and there is further increase in heat transfer coefficient as compare to plain twisted tape. Chang *et al.* [11] suggested of using broken twisted tape for the heat transfer augmentation even for the boiling heat transfer; this is because it breaks the bubble and intensifies the energy conversion into the surface energy. These inserts improves heat transfer augmentation as well as thermal performance both in laminar and turbulent flow regions.

F. Review on Wavy-tape inserts

Zhu *et al.* [12] numerically investigated on wavy twisted tape for the laminar flow for Re in the range of 200 to 2200 with width and amplitude of the waviness as varying parameters. It was observed that wavy tape generates intensified swirl vortices; this will interrupt thermal boundary layer and lead to intensified advection and augment local heat transfer coefficient. Heat transfer augmentation and pressure loss is found to be more as compare to without twisted tape and it will increases with amplitude and width of the tape.

G. Review on Double counter twisted tape inserts

Bhuiya *et al.* [14] performed work with double counter twisted tape to investigate characteristics of Nu and FF for the Re in the range from 6950 to 50,050. It was observed that Nu, FF and thermal enhancement efficiency are increased with decreased in TR. It was also noted that there is significant rise in the heat transfer coefficient for the corresponding rise of pressure loss.

H. Review on Perforated double counter twisted tape inserts

Bhuiya *et al.* [15] worked out perforated double counter twisted tape with four different porosities with Re in the range from7200 to 50,000 with uniform heat flux boundary conditions. It was reported that FF, augmentation in HTC and η were raises with decrease in porosity. Augmentation of HTC and rise in FF are significant with the use of perforated double counter twisted tape as compare to plain tape. Enhancement ratio (η) in all cases is found to be greater than one.

I. Review on Multiple twisted tapes inserts

Chaitanya *et al*. [16] investigated for HTC, FF and η for single, twin and four twisted tape insets at a time with twist ratio of 2, 3 and 3.5 for the Re in the range of 4000 to 14000. It was reported that as the number of twisted tape increases, the HTC augmentation and FF increases. The influence of Re on Nu also increases with increased number of twisted tape. Enhancement ration η decreases with increase in Re in all cases. It was also seen that HTC and FF increases with decrease in twist ratio. Counter swirl twisted tape gives better augmentation of HTC as compare to co swirl twisted tape arrangement for the similar conditions.

J. Review on Square-cut twisted tape inserts

Saysroy and Smith [13] investigated numerically the performance of square cut twisted tape inserts for Nu number and friction factor. The Re range used was 7000 to 15000, the variables are perforated width to twisted tape width ratio (WR) and perforated length to tape width ratio (LR). It was investigated that square cut twisted tape performs better compare to plain twisted tape for heat transfer augmentation. Nu and FF increases with increase in WR and decrease in LR as smaller perforations gives better flow disturbance and intensify turbulence.

K. Review on V-cut twisted tape inserts:

Murugesan *et al.* [18] worked on V-cut twisted tape insert having three TR and three different combinations of DR and WR in the Re range of 2000 to 12000.The main findings are Nu and FF with V-cut TT increases with reduction of TR, WR and increasing DR. It was also noted that V-cut twisted tape offers augmentation of HTC and η with the rise in FF compare to plain twisted tape.

L. Review on Effect of tube-twisted tape clearance on heat transfer

Sami and Walid [17] have experimentally studied the effect of tube- twisted tape clearance on heat transfer for uniform surface temperature condition in turbulent flow. Twisted tapes of five widths and three TR have been studied. It was seen that as clearance decreases the HTC increases. The main conclusion is small TR and tightly fit twisted tape gives the better augmentation of heat transfer.

VI. CONCLUSION

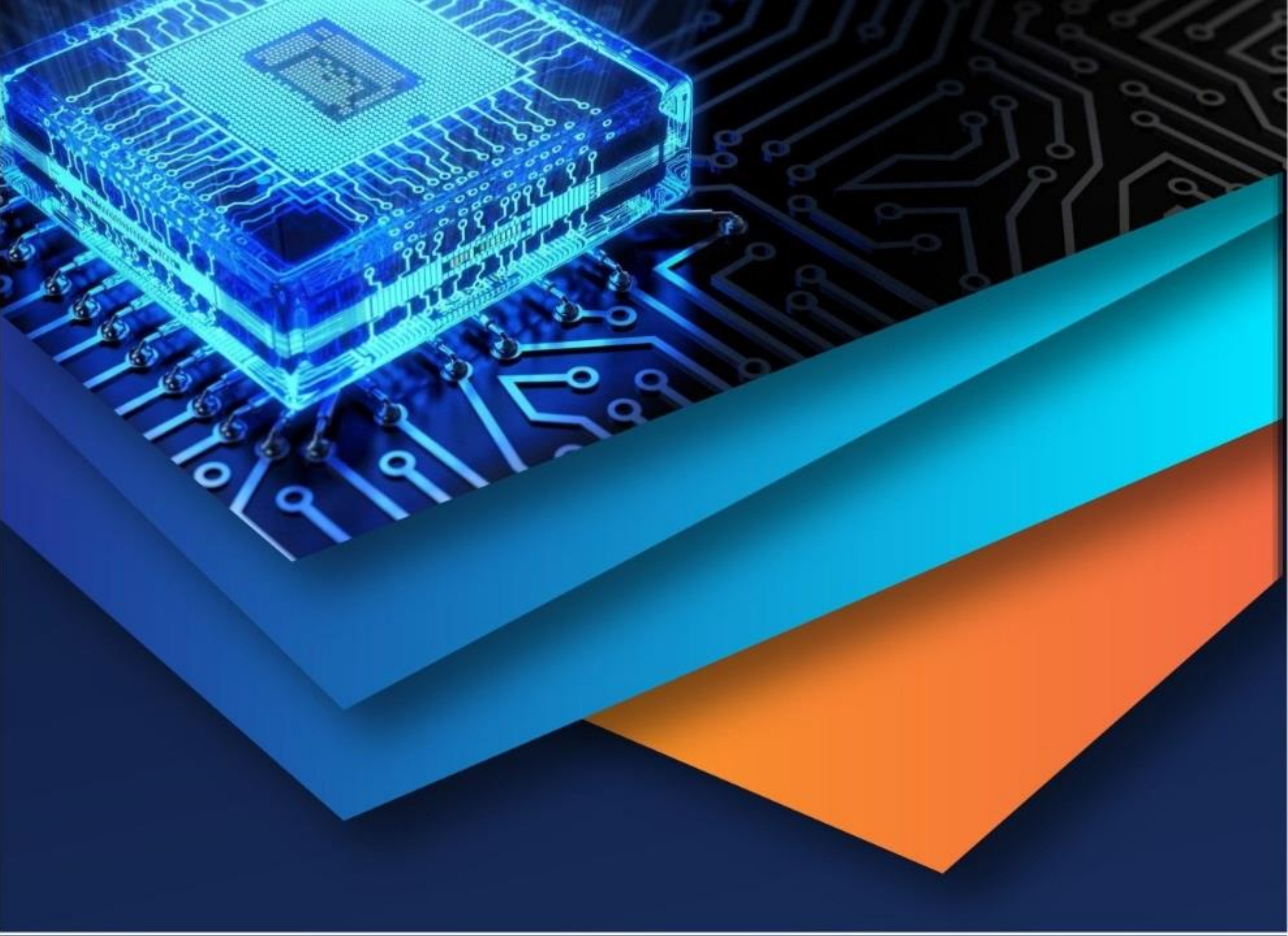
In the present review paper a comprehensive survey and evaluation on the simple and modified twisted tape inserts is carried out. The heat transfer coefficient, friction factor and enhancement ratio for a plain tube and modified twisted tape inserts with different twist ration are discussed. The key findings are

A. Lower twist ratio gives the better heat transfer augmentation for both plain and modified twisted tape inserts.
B. Lower twist ration gives higher pressure penalty for both plain and modified twisted tape inserts.
C. Enhancement ration is higher in modified twisted tape inserts as it creates more turbulence so it is recommended to use modified twisted tape as compared to plain twisted tape for compactness, pumping power saving and economy of heat exchanger.

REFERENCES

[1] Bhuiya, M. M. K., A. S. M. Sayem, M. Islam, M. S. U. Chowdhury, and M. Shahabuddin. “Performance assessment in a heat exchanger tube fitted with double counter twisted tape inserts.” International Communications in Heat and Mass Transfer 50 (2014): 25-33.
[2] Alam, Tabish, and Man-Hoe Kim. “A comprehensive review on single phase heat transfer enhancement techniques in heat exchanger applications.” Renewable and Sustainable Energy Reviews 81 (2018): 813-839.
[3] Ji, Wen-Tao, Anthony M. Jacobi, Ya-Ling He, and Wen-Quan Tao. “Summary and evaluation on the heat transfer enhancement techniques of gas laminar and turbulent pipe flow.” International Journal of Heat and Mass Transfer 111 (2017): 467-483.
[4] Manglik, Raj M., and Authur E. Bergles. “Heat transfer and pressure drop correlations for twisted-tape inserts in isothermal tubes: part I—laminar flows.” Journal of heat transfer 115, no. 4 (1993): 881-889.
[5] Manglik, Raj M., and Arthur E. Bergles. “Heat transfer and pressure drop correlations for twisted-tape inserts in isothermal tubes: part II-transition and turbulent flows.” Transactions-American society of mechanical engineers journal of heat transfer 115 (1993): 890-890.
[6] Manglik, Raj M., and Arthur E. Bergles. “Swirl flow heat transfer and pressure drop with twisted-tape inserts.” Advances in heat transfer 36 (2003): 183-266.
[7] Piriyarungrod, N., S. Eiamsa-Ard, C. Thianpong, M. Pimsarn, and K. Nanan. “Heat transfer enhancement by tapered twisted tape inserts.” Chemical Engineering and Processing: Process Intensification 96 (2015): 62-71.
[8] Chang, Shyy Woei, Yih Jena Jan, and Jin Shuen Liou. “Turbulent heat transfer and pressure drop in tube fitted with serrated twisted tape.” International Journal of Thermal Sciences 46, no. 5 (2007): 506-518.
[9] Eiamsa-Ard, Smith, and Pongjet Promvonge. “Thermal characteristics in round tube fitted with serrated twisted tape.” Applied Thermal Engineering 30, no. 13 (2010): 1673-1682.
[10] Skullong, Sompol, Pongjet Promvonge, Chinaruk Thianpong, and Monsak Pimsarn. “Heat transfer and turbulent flow friction in a round tube with staggered-winglet perforated-tapes.” International Journal of Heat and Mass Transfer 95 (2016): 230-242.
[11] Chang, Shyy Woei, Tsun Lirng Yang, and Jin Shuen Liou. "Heat transfer and pressure drop in tube with broken twisted tape insert." Experimental Thermal and Fluid Science 32, no. 2 (2007): 489-501.
[12] Zhu, Xiao Wei, Yun Han Fu, and Jing Quan Zhao. "A novel wavy-tape insert configuration for pipe heat transfer augmentation." Energy Conversion and Management 127 (2016): 140-148.
[13] Saysroy, Anucha, and Smith Eiamsa-ard. "Periodically fully-developed heat and fluid flow behaviors in a turbulent tube flow with square-cut twisted tape inserts." Applied Thermal Engineering 112 (2017): 895-910.
[14] Bhuiya, M. M. K., A. S. M. Sayem, M. Islam, M. S. U. Chowdhury, and M. Shahabuddin. "Performance assessment in a heat exchanger tube fitted with double counter twisted tape inserts." International Communications in Heat and Mass Transfer 50 (2014): 25-33.
[15] Bhuiya, M. M. K., A. K. Azad, M. S. U. Chowdhury, and M. Saha. "Heat transfer augmentation in a circular tube with perforated double counter twisted tape inserts." International Communications in Heat and Mass Transfer 74 (2016): 18-26.
[16] Vashistha, Chaitanya, Anil Kumar Patil, and Manoj Kumar. "Experimental investigation of heat transfer and pressure drop in a circular tube with multiple inserts." Applied Thermal Engineering 96 (2016): 117-129.
[17] Al-Fahed, Sami, and Walid Chakroun. "Effect of tube-tape clearance on heat transfer for fully developed turbulent flow in a horizontal isothermal tube." International journal of heat and fluid flow 17, no. 2 (1996): 173-178.
[18] Murugesan, P., K. Mayilsamy, S. Suresh, and P. S. S. Srinivasan. "Heat transfer and pressure drop characteristics in a circular tube fitted with and without V-cut twisted tape insert." International Communications in Heat and Mass Transfer 38, no. 3 (2011): 329-334.
[19] Y.A. Cengel, and A.J. Ghajar., Heat and Mass Transfer, 4th edition McGraw-Hill, 2015.

[20] Incropera, Dewitt, Bergman, Lavine, Frank P., David P., Theodore L., Adrienne S. Principles of Heat and Mass Transfer, John Wiley & Sons; 7th Edition,2013



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