A REVIEW ON HEAT TRANSFER AGUMENTATION USING DIFFERENT TWISTED TAPE INSERT

Sarang S. Hole[1], Prof. Yogesh G. Ingulkar[2], Hanumant B. Narute[3]
Dhole Patil College of Engineering, Pune

Abstract: Heat transfer augmentation techniques refer to increase rate of heat transfer by using different method without affecting much the overall performance of the system. Mainly these Heat transfer augmentation techniques are used in heat exchangers. The applications of heat exchanger are in Thermal Power Plant, Process Industries, Refrigerators, Air Conditioning Equipment, Automobiles, and Radars for Space Vehicles etc. In last decade, several studies on the passive techniques of heat transfer enhancement have successfully done by researcher. The present paper review mainly focus on the heat transfer enhancement Using twisted tape and modification of twisted tape towards the enhancement of heat transfer

Index Terms: Heat Transfer Enhancement, Passive Methods, Tape Inserts, Nusselt Number, Reynolds Number, Friction Factor.

I. INTRODUCTION

Heat transfer augmentation techniques related to the improvement of thermo hydraulic performance of heat exchangers. Heat transfer enhancement techniques can be classified into three different types:

1.1 Active Techniques: These techniques are more complicated from the design and use point of view. This method requires some external power input to enhance heat transfer rate. It has limited application because of the requirement of external power.

1.2 Passive Techniques: These techniques do not need any external power source to enhance heat transfer rate. They generally use surface area or geometrical modifications in the flow channel by adding inserts or additional devices. They help higher heat transfer coefficients by disturbing the behavior of existing flow.

1.3 Compound Techniques: When any two or more of these techniques are employed simultaneously to obtain enhancement in heat transfer that is greater than that produced by either of them when used individually, is termed as compound enhancement1

In this paper, a review of heat transfer enhancement using twisted tape and its modification is done. These papers promote the performance criteria of different twisted tape inserts.

Abbreviation

F	Friction Factor
Nu	Nusselt number
Re	Reynold Number
Y	Twist Ratio
α	Twist angle
Pr	Prandtl ratio
g	Thermal performance factor
WR	Width Ratio
DR	Depth Ratio
TT	Twisted Tape
VTT	V Cut Twisted tape
STT	Serrated twisted tape
CCT	Center cleared twisted tape
D/I coil	Decreasing/increasing coil pitch ratio arrangement
S	Spacing between two twisted tapes
TA	Twisted tape with alternative axis
CTs/CoTs	Twin-counter/co-twisted tapes
ETT	Edgefold-Twisted Tape
O/S DWT	Oblique/ Straight – Delta winglet Twisted tape
WTA	Centre wing and alternate axis Twisted tape

II. TERMINOLOGY USED IN TWISTED TAPE

2.1 Thermo Hydraulic Performance : For a particular Reynolds number, the thermo hydraulic performance is said to be good if minimum enhancement in friction factor results increases heat transfer coefficient significantly. Thermo hydraulic performance is generally used to compare the performance of different inserts under a particular fluid flow condition.

2.2 Overall Enhancement Ratio: The overall enhancement ratio is defined as the ratio of heat transfer enhancement ratio to the friction factor ratio.

2.3 Nusselt Number: The Nusselt number is a measure of the convective heat transfer occurring at the surface and is defined as hd/k, where d-diameter of the tube, h-convective heat transfer coefficient and k-thermal conductivity.

2.4 Prandtl Number: The Prandtl number is defined as the ratio of the molecular diffusivity of momentum to the molecular diffusivity of heat.

2.5 Pitch: The Pitch is defined as the distance between two adjacent points that are on the same plane and measured parallel to the axis of Twisted Tape.

2.6 Twist Ratio: The twist ratio is defined as the ratio of pitch length to inside diameter of the tube

III. LITERATURE SURVEY

Plain Twisted Tape

A. Klaczak [1] studied experimentally the heat transfer for laminar flow of water in an air cooled vertical copper pipe with twisted tape inserts of different pitch value. The tests were conducted for laminar flow within $1.62 \leq y \leq 5.29$ and $110 \leq Re \leq 1500$. Result shows that the heats transfer have positive relationship with the pitch value of twisted tape.

V. Hejazi, M.A. Akhavan-Behabadi and A. Afshari [2] studied the heat transfer coefficients and pressure drop during condensation of HFC-134a in a horizontal tube fitted with twisted tape. The refrigerant flows in an inner copper and the cooling water flows in annulus. And predict smooth tube and swirl flow pressure drop developed an empirical correlation.

S. Eiamsa-ard, P. Nivesrangsan, S. Chokphoemphun and P. Promvonge [3] experimentally find the heat transfer rate and thermo hydraulic efficiency of the combined devices of twisted tape and wire coil by arranging in two different forms: (1) D-coil and (2) DI-coil while the twisted tape was made with two different twist ratios.

L. Syam Sundar and K.V. Sharma [4] investigated the thermo physical properties of Al2O3 nanofluid. The experiment is carried out different volume concentrations and temperatures. From result it is concluded that, heat transfer coefficients and friction factor is higher when compared to water in a plain tube. Also develop a generalized regression equation with the experimental data for the estimation of friction factor and Nusselt number

Modified Twisted Tape

Yangjun Wang, Meiling Hou, Xianhe Deng, Li Li, Cheng Huang, Haiying Huang, Gangfeng Zhang, Changhong Chen and Weijun Huang [5] analyzed the computational fluid dynamics modeling for the optimization of regularly spaced short-length twisted tape in a circular tube. The configuration parameters are given by the ‘α’, ‘S’ and ‘y’. The result shows that the mean heat transfer and flow resistance have positive relationship with Twist angle (α).

S. Eiamsa-ard, K. Wongcharee and S. Sripattanapipat [6] mathematically studied the swirl flow in a tube induced by loose-fit twisted tape and Numerically investigated the Effects of the clearance ratio on ‘Nu’, ‘f’ and ‘g’ at two different twist ratios.

S. Eiamsa-ard, Chinaruk Thianpong , Petpices Eiamsa-ard and Pongjet Promvonge [7] made a comparative investigation of enhanced heat transfer and pressure loss by insertion of full-length dual twisted tape and regularly-spaced dual twisted tape. The result shows that all dual twisted tape with free spacing yield lower heat transfer enhancement in comparison with the full-length dual twisted tape.

Chinaruk Thianpong, Petpices Eiamsa-ard, Khwanchit Wongcharee and Smith Eiamsa-ard [8] investigated experimentally the friction and heat transfer behaviors in a dimpled tube fitted with a twisted tape, air is using as working fluid. The experiments are carried out by using two dimpled tubes with different pitch ratios. It is reveal that both heat transfer coefficient and ‘f’ in case of dimpled tube fitted with the twisted tape are higher than those in the dimple tube alone or plain tube.

Anil Yadav, [9] Experimentally investigated Influences of the half length twisted tape insertion on heat transfer and pressure drop characteristics in a U-bend double pipe heat exchanger the result found is that the heat transfer coefficient is increase by 40% with half-length twisted tape inserts when compared with plain heat exchanger.

S. Eiamsa-ard [10] experimentally investigated the effect of multiple twisted tape vortex generators (MT-VG) on the heat transfer and fluid friction characteristics in a rectangular channel. From result it is conclude that, the channel with the ‘y’ and ‘S’ provides higher heat transfer rate and pressure loss than those with the larger ‘y’ and free-spacing ratio under similar operation condition.

S. Eiamsa-ard, Chinaruk Thianpong, Petpices Eiamsa-ard and Pongjet Promvonge [11] an experimental study on the mean ’Nu’; ‘f’ and ‘g’ in a round tube with short-length TT insert. The short-length tapes mounted at the entry test section while full-length twisted tape is inserted into the tested tube at a single y = 4.0. The conclusion from experiment result is that the Presence of the tube with short-length twisted tape insert having higher heat transfer rate than tube with full-length twisted tape.

P. Promvonge and S. Eiamsa-ard [12] experimental investigated thermal characteristics in a circular tube fitted with twisted tape swirl generator and a conical-ring. From results it is conclude that the tube fitted with the twisted tape and conical-ring provides value of ‘Nu’ around 4 to 10% and heat transfer enhancement efficiency of 4 to 8% higher than that of with the conical-ring alone.

Saha, S. K, Dutta, A. and Dhal, S. K. [13] experimentally investigated the enhancement in heat transfer and pressure drop in the tube with regularly spaced twisted tape. From the result, it is concluding that ‘Pinching’ of tape rather than in connecting the tape element with rods is better proposition from thermohydraulic point of view.

Smith Eiamsa-ard, Chinaruk Thianpong and Pongjet Promvonge [14] experimentally investigated on the enhancement in heat transfer and friction factor characteristics in a double pipe heat exchanger fitted with regularly twisted tape insert. From experimental result, it is conclude that the heat transfer coefficient have positive relationship with ‘y’ and ‘S’.

HONG Mengna, DENG Xianhe, HUANG Kuo and LI Zhiwu [15] investigated experimentally the Pressure drop and heat transfer of a converging-diverging tube with evenly spaced twisted tape. Swirl was generated by evenly spaced twisted-tape elements which vary in twist ratio and rotation angle.

IV. MODIFIED GEOMETRY TWISTED TAPE

K.Wongcharee and S. Eiamsa-ard [16] experimentally investigated heat transfer enhancement, ‘g’ and ‘f’ characteristics of CuO/water nanofluid and modified twisted tape with alternative axis. The use of nanofluid with the TA provides considerably higher ‘Nu’ and ‘g’ than that of nanofluid with the plain twisted tape.

Bharadwaj, A.D. Khondge and A.W.Date [17] experimentally determined heat transfer and pressure drop

characteristics of flow of water in a 75 start spirally grooved tube with twisted tape insert are presented. It is found heat transfer enhancement in spiral tube is higher when compared to plain tube.

S.K. Saha [18] experimentally studied the heat transfer and the pressure drop characteristics of rectangular and square ducts with twisted tape insert with oblique teeth. From experiment it is conclude that, the axial corrugation in combination with twisted tape with oblique teeth gives better performance than those without oblique teeth.

S. Eiamsa-ard, C. Thianpong and P. Eiamsa-ard [19] experimentally studied the influences on 'Nu', 'f' and 'g' of Twin-counter/co-twisted tapes fitted in tube. Co-twisted tapes are used as co-swirl flow generators while The Twin-counter tape is used as counter-swirl flow generators. From results it is conclude that the Twin-counter is more efficient than the co-twisted tapes for enhancement in heat transfer.

S. Jaisankar, T.K. Radhakrishnan and K.N. Sheeba [20] experimental investigation on heat transfer rate, 'f' and 'g' of thermosyphon solar water heater system fitted with full-length twisted tape, twist fitted with rod and spacer attached at the trailing edge. from results, it is concluded that heat transfer rate in twisted tape collector is higher than the plain tube.

P. Murugesan, K. Mayilsamy, S. Suresh and P.S.S. Srinivasan [21] investigated experimentally the 'HTE', 'f' and 'g' characteristics of tube fitted with V Cut Twisted tape. The obtained results show that the mean Nu and the mean 'f' in the tube with V Cut Twisted tape (VTT) have negative relationship with 'y'.

S. Eiamsa-ard, Panida Seemawute and K. Wongcharee [22] Investigated the Effects of plain twisted tape (PTT) insert on heat transfer, 'f' and 'g' characteristics in a round tube. Nine different PTT with different 'DR' and different 'WR' were tested. From the result, it is revealed that 'Nu', 'f' and 'g' are having positive relationship with 'DR' and 'WR'.

CUI Yong-zhang and TIAN Mao-cheng [23] carried out the 3D numerical and experimental study of the heat transfer characteristics and the pressure drop of air flow in a circular tube with Edgefold-Twisted Tape(ETT) and Serrated twisted tape (STT) inserts. From the result it is conclude that the 'η' have negative relationship with 'y' and 'S'.

P. Murugesan, K. Mayilsamy, S. Suresh and P.S.S. Srinivasan, [24] experimentally studied the heat transfer and 'f' characteristics of trapezoidal –cut Twisted tape with two value of y (4.0 and 6.0). From the experiment it is conclude, that there was a significant increase in 'f' and heat transfer coefficient for tape with trapezoidal-cut.

S. Eiamsa-ard, K. Wongcharee, P. Eiamsa-ard and C. Thianpong [25] investigated Heat transfer 'f' and 'g' characteristics in a tube fitted with Delta winglet Twisted tape (DWT). Influences of the Oblique/ Straight – Delta winglet twisted tape (O-DWT and S-DWT) arrangements are also described. The obtained results show that the thermal performance factor in the tube with Oblique – Delta winglet Twisted tapes is greater than that with Straight – Delta winglet Twisted tape.

S. Eiamsa-ard, K. Wongcharee, P. Eiamsa-ard and C. Thianpong [26] experimentally studied the effects of the twisted tapes consisting of Centre wing and alternate axis Twisted tape (WT-A) in a tube. From result it is conclude that WT-A Provide higher 'Nu', 'f', 'g' than other type of tapes.

Mr. Paramveer Patil, Prof. Lalit S. Pawar, Prof. N. B. Dhamane [27] Experiments dealing with the amplification of turbulent flow heat transfer in a horizontal tube by means of cut corrugated twisted tape inserts with air as the working fluid. These experiments were conducted for plain tube with and without cut corrugated twisted tape insert at constant wall heat flux and different mass flow rates. The cut corrugated twisted tapes are of three different twist ratios as 8.33, 9.79 & 10.42. The Reynolds number used varied between 4000 to 9500. It was found that the increment of heat transfer with cut corrugated twisted tape inserts as compared to plain tube varied from 18% to 52 % for various inserts.

V. CONCLUSION

This review has considered heat transfer and pressure drop investigations of the various twisted tape placed in heat exchangers. All possible research subjects related to twisted tape have been summarized in the literature, such as pressure drop and heat transfer studies according to plain twisted tape, Modified geometry twisted tape and modified twisted tape. A twisted tape and modified twisted tape inserts mixes the flow well and therefore it performs better in laminar flow, The result also shows that twisted tape insert is more effective in laminar flow, In case of twisted tape with modified geometry, during the swirl of fluid more turbulence is created and gives higher heat transfer rate compared with plain twisted tape and modified twisted tape. The result for modified twisted tape geometry, the heat transfer rate is higher with less friction factor for both laminar and turbulent flow. These conclusions are very useful in the application of heat transfer enhancement in heat exchanger networks.

REFERENCE

[1] A. Klaczak, "Heat transfer by laminar flow in a vertical pipe with twisted-tape inserts Heat and Mass Transfer", Vol. 36 (2000), pp. 195-199, Springer-Verlag 2000.

[2] V. Hejazi, M.A. Akhavan-Behabadi and A. Afshari, "Experimental investigation of twisted tape inserts performance on condensation heat transfer enhancement and pressure drop", International Communications in Heat and Mass Transfer, Vol. 37 (2010), pp. 1376–1387.

[3] S. Eiamsa-ard, P. Nivesrangsan, S. Chokphoemphun and P. Promvonge, "Influence of combined non-uniform wire coil and twisted tape inserts on thermal performance characteristic", International Communications in Heat transfer, Vol. 37 (2010), pp. 850–856.

[4] L. Syam Sundar and K.V. Sharma, "Turbulent heat transfer and friction factor of Al2O3 Nanofluid in circular tube with twisted tape inserts",

International Journal of Heat and Mass Transfer, Vol. 53 (2010), pp. 1409–1416.

[5] Yangjun Wang, Meiling Hou, Xianhe Deng, Li Li, Cheng Huang, Haiying Huang, Gangfeng Zhang, Changhong Chen and Weijun Huang, "Configuration optimization of regularly spaced short-length twisted tape in a circular tube to enhance turbulent heat transfer using CFD modeling", Applied Thermal Engineering, Vol. 31 (2011), pp. 1141-1149.

[6] S. Eiamsa-ard, K. Wongcharee and S. Sripattanapipat, "3-D Numerical simulation of swirling flow and convective heat transfer in a circular tube induced by means of loose-fit twisted tapes", International communication in Heat and Mass Transfer Vol. 36 (2009), pp. 947-955.

[7] S. Eiamsa-ard, Chinaruk Thianpong , Petpices Eiamsa-ard and Pongjet Promvonge, "Thermal characteristics in a heat exchanger tube fitted with dual twisted tape elements in tandem", International Communications in Heat and Mass Transfer Vol. 37 (2010), PP.39–46.

[8] Chinaruk Thianpong, Petpices Eiamsa-ard, Khwanchit Wongcharee and Smith Eiamsa-ard, "Compound heat transfer enhancement of a dimpled tube with a twisted tape swirl generator", International Communications in Heat and Mass Transfer Vol. 36 (2009), pp. 698–704.

[9] Anil Yadav, "Effect of half length twisted tape turbulator on heat transfer & pressure drop characteristics inside a double pipe U-bend heat exchanger", Jordan journal of Mech. & Industrial engg., Vol. 3 No.1 (2009), pp. 17-22.

[10] S. Eiamsa-ard, "Study on thermal and fluid flow characteristics in turbulent channel flows with multiple twisted tape vortex generators", International Communications in Heat and Mass Transfer, Vol. 31 (2010), pp. 644–651.

[11] S. Eiamsa-ard, Chinaruk Thianpong, Petpices Eiamsa-ard and Pongjet Promvonge, "Convctive heat transfer in a circular tube with short-length twisted tape insert", International communication in Heat and Mass Transfer, Vol. 36 (2009), pp. 365-371.

[12] P. Promvonge and S. Eiamsa-ard, "Heat transfer behaviors in a tube with combined conical ring and twisted-tape inserts", International Communications in Heat and Mass Transfer Vol. 34 (2007), pp. 849–859.

[13] Saha, S. K, Dutta, A. and Dhal, S. K., "Friction and heat transfer characteristics of laminar swirl flow through a circular tube fitted with regularly spaced twisted-tape elements", International Journal of Heat and Mass Transfer, Vol. 44 (2001), pp. 4211-4223.

[14] Smith Eiamsa-ard, Chinaruk Thianpong and Pongjet Promvonge, "Experimental investigation of heat transfer and flow friction in a circular tube fitted with regularly spaced twisted tape elements", International Communications in Heat and Mass Transfer Vol. 33 (2006), pp. 1225–1233.

[15] HONG Mengna, DENG Xianhe, HUANG Kuo and LI Zhiwu, "Compound heat transfer enhancement of a converging-diverging tube with evenly spaced twisted-tapes", Chinese Journal of Chemical Engineering, Vol. 15 No.6 (2007), pp. 814—820.

[16] K.Wongcharee and S. Eiamsa-ard, "Enhancement of heat transfer using CuO/water nanofluid and twisted tape with alternate axis", International Communications in Heat and Mass Transfer Vol. 38 (2011), pp. 742–748.

[17] Bharadwaj, A.D. Khondge and A.W.Date, "Heat transfer & pressure drop in spirally grooved tube with twisted tape insert", J. Heat Transfer, Vol. 52 No.5 (2009), PP. 1938-1944.

[18] S. K. Saha, "Thermohydraulics of turbulent flow through rectangular and square ducts with axial corrugation roughness and twisted-tapes with and without oblique teeth", Experimental Thermal and Fluid Science Vol. 34 (2010), pp. 744–752.

[19] S. Eiamsa-ard, C. Thianpong and P. Eiamsa-ard, "Turbulent heat transfer enhancement by counter/co-swirling flow in a tube fitted with twin twisted tapes", Experimental Thermal and Fluid Science Vol. 34 (2010), pp. 53–62.

[20] S. Jaisankar, T.K. Radhakrishnan and K.N. Sheeba, "Experimental studies on heat transfer and friction factor characteristics of thermosyphon solar water heater system fitted with spacer at the trailing edge of twisted tapes", Applied Thermal Engineering Vol. 29 (2009), pp. 1224–1231

[21] P. Murugesan, 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 Vol. 38 (2011), pp. 329–334.

[22] S. Eiamsa-ard, Panida Seemawute and K. Wongcharee, "Influences of peripherally-cut twisted tape insert on heat transfer and thermal performance characteristics in laminar and turbulent tube flows", Experimental Thermal and Fluid Science, Vol. 34 (2010), pp. 711–719.

[23] CUI Yong-zhang and TIAN Mao-cheng, "Three-Dimensional Numerical Simulation of Thermal hydraulic Performance of a circular tube with Edgefold-Twisted-Tape Inserts", Journal Of Hydrodynamics, , Vol. 22 No. 5 (2010), pp. 662-670.

[24] P. Murugesan, K. Mayilsamy, S. Suresh and P.S.S. Srinivasan, "Heat Transfer And Pressure Drop Characteristics of Turbulent Flow in a Tube Fitted With Trapezoidal-Cut Twisted Tape Insert", International Journal Of Academic Research, Vol. 1. No. 1 (2009), PP. 123-128

[25] S. Eiamsa-ard, K. Wongcharee, P. Eiamsa-ard and C. Thianpong, "Heat transfer enhancement in a tube

using delta-winglet twisted tape inserts", Applied Thermal Engineering, Vol. 30 (2010), pp. 310–318.

[26] S. Eiamsa-ard, K. Wongcharee, P. Eiamsa-ard and C. Thianpong, "Thermohydraulic investigation of turbulent flow through a round tube equipped with twisted tapes consisting of centre wings and alternate-axes", Experimental Thermal and Fluid Science Vol. 34 (2010), pp. 1151–1161.

[27] Mr. Paramveer Patil, Prof. Lalit S. Pawar, Prof. N. B. Dhamane. "Analyzing Effect of Varying Pitch of Cut Corrugated Twisted Tape Insert on Augmentation of Heat Transfer". International Journal for Technological Research in Engineering. Vol. 2(2015), pp. 664-669

