Heat Transfer Augmentation using Twisted Tape Inserts Having Different Cut Sections: A Review

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Abstract— Heat transfer enhancement techniques refer to different methods used to increase rate of heat transfer without affecting much the overall performance of the system. These techniques are used in heat exchangers. The use of passive devices like twisted tapes, roughness elements, wires inserts etc. are effective methods of heat transfer augmentation. The twisted tape insert is a device used for increasing the heat transfer rate in the heat exchanger system due to its advantages of easy fabrication, operation as well as low maintenance. This review paper mainly focuses on Previous experimental and numerical studies done in the area of heat transfer augmentation using twisted tape insert with different cuts like semi-circular cut, v-cut, delta-winglet cut, rectangular cut, and the effects of these cuts on heat transfer enhancement, pressure drop, friction factor and thermal performance factor characteristics in heat exchanger tubes. These studies reveal that the future research in the area of twisted tapes will bring more development in the heat exchanger systems.

Index Terms— Cut, heat transfer enhancement, swirl flow, twisted tape.

I. INTRODUCTION

The goal of enhanced heat transfer is to encourage or accommodate high heat fluxes. The heat transfer techniques enables heat exchanger to operate at smaller velocity, but still achieve the same or even higher heat transfer coefficient. This means that a reduction of pressure drop, corresponding to less operating cost. Heat transfer augmentation techniques refer to different methods used to increase rate of heat transfer without affecting much the overall performance of the system.

Generally, heat transfer enhancement methods are classified in three broad categories:

1. Passive Techniques: The techniques which do not require any direct input of external power; rather they use it from the system itself which ultimately leads to an increase in fluid pressure drop are passive techniques. These generally use surface or geometrical modifications to the flow channel by incorporating inserts or additional devices. They promote higher heat transfer coefficients by disturbing or altering the existing flow behavior except for extended surfaces. Heat transfer enhancement by this technique can be achieved by using treated surface, extended surface, rough surface, swirl flow devices.

2. Active techniques: These techniques requires some external power input to cause the desired flow modification and improvement in the rate of heat transfer so these techniques are more complex from the use and design point of view. These finds limited application because of the need of external power in many practical applications.

3. Compound techniques: When any two or more of these techniques are used simultaneously to obtain enhancement in heat transfer which is greater than that produced by either of them when used individually, is known as compound enhancement. [1]

II. REVIEW ON DIFFERERNT CUT SECTION TWISTED TAPE INSERTS:

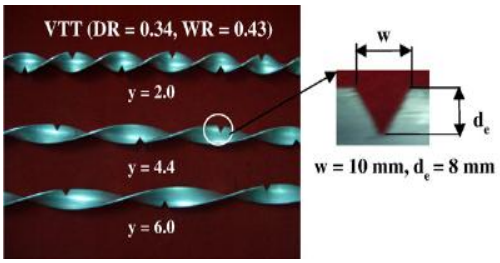
Sami D. Salman et.al numerically studied heat transfer and friction factor characteristics of a circular fitted with V-cut twisted tape insert having twist ratio (y = 2.93) at different cut depths (w = 0.5, 1, and 1.5 cm) for laminar flow. They also studied Classical twisted tape (CTT) with different twist ratios (y = 2.93, 3.91, 4.89) for comparison. They found that as Reynolds number increases and twist ration decreases, the heat transfer rate induced by the classical and V-cut twisted tape inserts increases. Also the V-cut twisted tape with twist ratio y = 2.93 and cut depth w = 0.5 cm offered higher heat transfer rate with significant increases in friction factor than other twisted tapes. When they compared the results of V cut twisted tape with experimental and simulated data of right-left helical tape inserts (RLT), observation was that V-cut twist tape offered better thermal contact between the surface and the fluid which is the main reason behind high heat transfer coefficient. Maximum heat transfer (107%) was obtained by using this configuration. [2]

Fig.1. V-cut twisted tape insert.

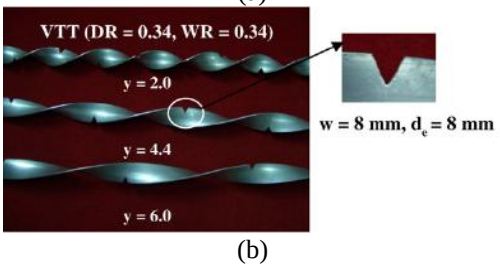
Nivedita Uzagare et.al experimentally investigated the heat transfer enhancement in a circular tube by inserting V-Jagged twisted tape having Jag Of width and depth

(We=10mm,De=8mm) And (We=10mm,De=10mm) with 100mm Pitch And Two different Materials (Copper And Aluminum) . In the experiment working medium was air with Constant Heat Flux condition and varying mass flow rate. They determined heat transfer rate, friction factor, Nusselt Number and compared it with the plain tube and plain tape. The results show that as Reynolds number increase from 6000 to 13000, the heat transfer coefficients increases for v-jagged twisted tape by 52% to 90% for copper and 50% to 75% for aluminum with respect to plain tube. Friction factor for aluminum is less (0.04) as compared to other materials so aluminum tape with (we=10mm, de=8mm) has minimum pressure drop. [3]

P Murugesan et.al have done experimental investigations using v-cut twisted tape inserts as shown in figure1 on heat transfer, friction factor and thermal performance factor characteristics in a circular tube for three twist ratios (y=2.0, 4.4 and 6.0) and three different combinations of depth and width ratios (DR=0.34 and WR=0.43, DR=0.34 and WR=0.34, DR=0.43 and WR=0.34). The average Nusselt number and friction factor for the tube with VTT of DR=0.43, WR=0.34 is respectively, 4.51% and 7.86% higher than those given by the tape with DR=0.34 and WR=0.34. Similarly, tube with VTT of DR=0.34 and WR=0.34 is 4.24% and 8.02% higher than those for DR=0.34 and WR=0.43.The obtained results show that the mean Nusselt number and the mean friction factor in the tube with v-cut twisted tape increase with decreasing twist ratios (y), width ratios (WR) and with increasing depth ratios (DR).From all the results obtained, the maximum value of Nusselt number is 1.36 to 2.46 times higher than the plain tube in the presence of VTT. [4]



(a)



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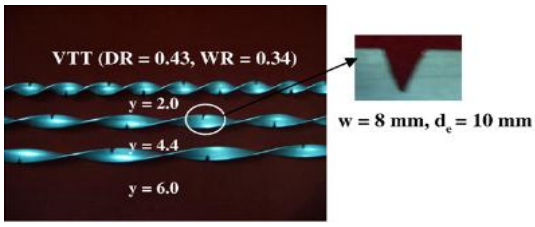

(c)

Fig.2. V- cut twisted tape inserts with a)w=10, d_e=8, b) w=8 and d_e=8 and c) w=8 and d_e=10. [4]

Salam B, et.al have done experientations for measuring tube side heat transfer coefficient, friction factor and heat transfer enhancement efficiency of water for turbulent flow in a circular tube fitted with rectangular-cut stainless steel twisted tape insert. The rectangular cut used had 8 mm depth and 14 mm width with uniform heat flux condition.They used a copper tube of 26.6 mm internal diameter and 30 mm outer diameter and 900 mm. The results show that the Nusselt number increases with the increase of Re. Experimentally calculated Nu value inreased by 2.3 to 2.9 times at the cost of increase of friction factors by 1.4 to 1.8 times compared to that of smooth tube.They found 68% enhancement of heat flux for tube with rectangular-cut twisted tape insert (qe) than that of smooth tube. As Re increases the heat transfer enhancement efficiency increase and its range was found to be in between 1.9 to 2.3. [5]

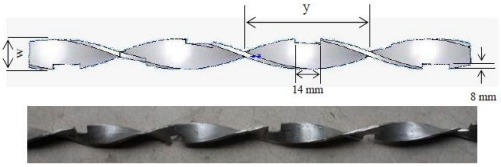

Fig.3. Rectangle cut twisted tape inserts. [5]

Sushama Garad et al. done numerical analysis of square notched twisted tape insert in a tube by varying pitch with air as a working fluid. The results for simple twisted tape insert, square notched with double slot twisted tape insert at different twist ratio (4, 5, and 6) determined. Reynolds number varied from 35000-45000.Both pressure drop, heat transfer coefficient, Nusselt number are calculated and compared with plane tube. They found that heat transfer enhancement of square notched twisted tape double slot is about and 19.57%, 44.31%, & 75.79% using square notched twisted tape insert for 150mm, 125mm and 100 mm pitch as compared with plane tube.

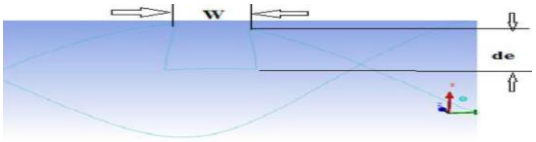

Fig.4. Geometry of square notched twisted tape slot. [6]

Fig.5. Geometry of square notched single slot twisted tape [6]

P.V. Durga Prasad et.al experimentally analyzed the effect of trapezoidal-cut twisted tape insert in a double pipe U-tube heat exchanger using Al2O3 water based Nano fluid on the heat transfer coefficients and the corresponding friction factors. Nano fluid particle volume concentration of 0.01% and 0.03% , flow rates ranging from 0.0333 kg/s to 0.2667 kg/s, twist ratios ranging between 5 and 20 and Reynolds number in the range 3000<Re<30000 used for experimentation. The experimental observations show that the Nusselt number of entire pipe for 0.03% concentrations of Nano fluid with trapezoidal-cut twisted tape inserts of H/D = 5 is increased by 34.24% and friction factor increased by 1.29 times as compared to water as working fluid . They conclude that Convective heat transfer, friction factor as well as thermal performance factor with the application of Nano fluid and trapezoidal-cut inserts are higher than those with the individual techniques. Also with an increase in volume concentration of the nanoparticle, heat transfer coefficient and friction increases. [7]

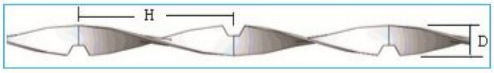

Fig.6. Schematic representation of trapezoidal-cut twisted tape [7]

H. Barman et.al experimentally studied turbulent flow heat transfer in a tube having different spacing of a U shaped twisted tape inserts with water as working fluid. The test section consisted of a circular copper tube of 26.6 mm inner diameter, 900 mm length with five K-type thermocouples. They measured Bulk temperature and pressure drops. The aluminum inserts were 800 mm in length, 25 mm width, 1.5 mm thickness and twisted ratio of 5. They calculated Heat flux, friction factor and Nusselt number to analyse heat transfer performance of circular tube fitted with and without inserts in turbulent regimes (4000<Re<20000). They found that Heat transfer rate for inserts 25 mm, 40 mm and 80 mm in spacings in U-shape increased by 4, 3, 2 and Nusselt number risen by 1.2, 1.18, 1.06 times respectively compared to smooth tube. Heat transfer performance for inserts were found 1.57~1.67, 1.32~1.40, 1.17~1.27 times better than smooth tube. [8]

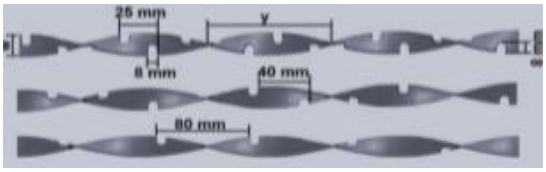

Fig.7. U-cut twisted tape inserts [8]

M. A. Razzaq et.al experimentally measure tube side heat transfer coefficient, pressure drop, friction co-efficient and percentage of increase in these parameters by using U-cut twisted tape inserts into the tube for water as working fluid. The test section includes a circular tube made up of copper having 26.6 mm inside diameter, 30 mm outside diameter and 900 mm effective length. A stainless steel U-cut twisted tape insert with 5.29 twist ratio and 0.4 mm in thickness was inserted into the smooth tube. The U-cut had 8 mm depth and width. Experimental results show that the heat flux was in the range of 18.33-28 kW/m2 for smooth tube and 32.07-47.24.00 kW/m2 for tube with insert for Reynolds number in the range of 10153-19217. Nusselt number with U-cut twisted tape insert was increased by 2.76 to 3.24 times with compared to smooth tube and friction factor with U-cut twisted tape insert was also increased by 1.6 times with compared to plain tube. Also Coefficient of convective heat transfer increased by 2.77 to 3.04 times for U-cut twisted tape insert compared to plain tube. They observed that U-cut twisted tape was responsible for extra disturbances between the wall surface of the tube and with the secondary flow. [9]

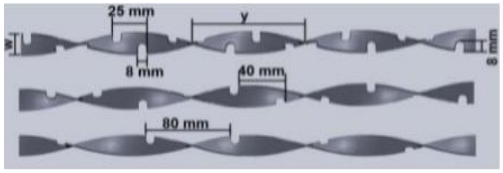

Fig.8. U-cut twisted tape inserts [9]

A Pawan et.al has done experimental investigations to find out the effect of semi-circular cut twisted tape inserts (STT) with twist ratios 3.5 and 5.3. on heat transfer and friction factor characteristics in a circular tube. For this experimentation the twisted tape with two different twist ratios for Reynolds number (Re) ranges between 4000 to 9000 under uniform heat flux conditions were used. They found that, heat transfer rate increases with decrease in twist ratio (y) and increase in cut radius (R). When Re is maximum friction factor decreases for STT 3.5 with cut radius of 10mm compared to STT 3.5 with cut radius of 5mm. They have concluded that the tube with STT has more friction factor as compared to smooth tube, but for increase in cut radius, it reduces simultaneously. From all the results obtained, the maximum value of Nusselt number is found with STT 3.5 with cut radius of (R) 10mm. [10]

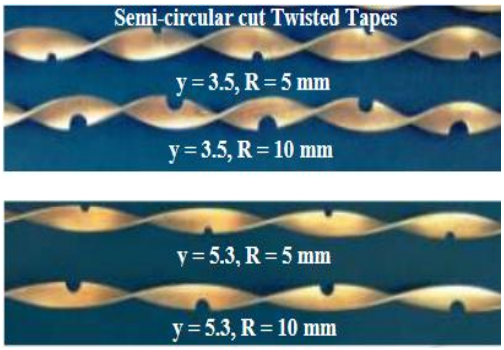

Fig.9. Semi-circular cut twisted tapes. [10]

Pratik P. Ganorkar et.al experimentally investigate the effect of Elliptical-cut twisted tape insert on heat transfer, friction factor and thermal performance factor characteristic in a circular tube with twist ratio (y= 8.0)

and five different combinations of major and minor axis ratios (Z=5, Z=4, Z=3.3, Z=3, Z=2.5). The variation in Re was in the range of 5000-22000. The experimental results show that heat transfer rate, friction factor and thermal performance factor are higher for Elliptical-cut twisted tape as compared to the plain twisted tape. Also the influence of the increasing minor axis found to be more dominant than that of the decreasing major axis for all the Reynolds number. The effect of heat transfer enhancement due to the Elliptical-cut twisted tape insert is more dominant than the effect of the rising friction factor. [11]

Fig.10. Semi-circular cut twisted tapes. [11]

All the above experimental investigations conclude that as Reynolds number increases, Nusselt number increases and friction factor decreases. For all twisted tape inserts whatever may be the geometry and shape, Nusselt number and friction factor found to be increased as the twist ratio of the tape increases. Twisted tape generates swirling flow which causes higher turbulence and greater mixing in the tube as well as it makes the boundary layer thinner. This is the major influencing factor for heat transfer enhancement. Heat transfer rate is higher when cuts are provided on the twisted tape insert compared to the plain twisted tape insert and plain tube without insert. As depth of cut increases the heat transfer increases at the cost of comparable increase in pressure drop and friction in a circular tube.

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