

Influence of Geometry of Twisted Tape Insert on Heat Transfer Augmentation

S. Sam Godwin Sathyaraj, M. Sivasubramanian, K.D Jaganathan.



Abstract: Heat exchangers are commonly used devices in several industrial applications owing to their high performance in transferring the heat from the hot nature to cold nature. Heat exchangers are necessary for saving energy, there are lots of methods implied to increase the thermal performance of heat transfer device by changing the surface of the flow area of the fluids. In most of the methods there is an insertion in the flow passage like twisted tape or blocks to make a disturb in the flow. Mainly these twisted tapes have a vital role in the heat transfer characters. In this present paper the various techniques used in increasing the heat transfer with the insertion of twisted tape and its geometrical influences on the performance of heat transfer were studied and reported.

Keywords : Heat transfer augmentation, Twisted Tape inserts, Swirl flow, Reynolds number heat transfer enhancement, Twist ratio.

I. INTRODUCTION

Heat transfer enhancement is used varied by the uses of the heat exchangers in the various industrial applications. These heat exchangers are classified into two methods based the technique used in the exchangers. Basically these methods are considered by the characteristic of the exchangers and the flow path augmentation has been seen by various types of the tapes. These tapes are varied in types rectangular cut, square cut, with or without oblique teeth and the flow path in the heat exchangers are varied by rough surface and swirl flow. In here these methods are useful for the cost effective methods in the low range of cost will give the maximum efficiency in the heat transfer coefficient. These will generate flow in the swirl manner will get a high friction as it will flow through the maximum surface area. Instead these methods the heat transfer is maximized by the external source like mechanical aids and surface flow vibrations and electrostatic field uses.

Tubular heats exchangers are used in the chemical process industries because of its low coefficient of heat

transfer, the flow over the tube have a laminar flow which had a high flow rate of hot fluid. This present study reviews the role of the geometrical changes in the insertion of the twisted tape on intensification of heat transfer. The geometrical changes include the aspect ratio of the twisted tape, perforations, external cuts and modifications in its surface.

II. LITERATURE REVIEW

Double pipe heat exchangers with concentric nature has a twisted tape insert with various twist ratio has been discussed by Watcharin et al [1] It is reported that Nusselt number had increased about 188% and 159% respectively .The medium used for heat transfer is Hot air. As the hot air will be in swirling flow, there will be a high friction force of 3.37 and 2.94 times when compared with plain tube, and $y = 5.0$ and 7.0 respectively. Further it is also found that friction will be smaller for $y = 5.0$ and higher for $y = 7.0$. Rectangular and square duct inserted has a twisted tape insert with axial corrugations investigated experimentally by Sujoy Kumar [2] .here the twisted tape has two forms that is tape with and without oblique teeth. The medium used for heat transfer is Hot air, the ranges of the Reynolds number will be 10,000 to 100,000. there is a 50% better performance in the twisted tube without Tilted teeth when compared with twisted tube with tilted teeth of axial corrugation. Heat transfer in copper pipe with stainless steel twisted tape has the ratio of 5:3 is investigated in an experiment done by Bodius et al. The Reynolds number range varied from 9500 to 20000, the smooth tube has heat flux variation from 9 to 18kw/m² and 15 to 31 kw/m² for tube having the twisted tape insert [3]. There is an increase of Nusselt number for the tube having the insertion of twisted tape was about 2.9 to 4 times than that of the smooth tube. The heat flux had increased averagely as 70% for tube with twisted tape insert than the smooth tube. The investigation of heat transfer with the ratio ranges from 2 to 4 with the intervals of 0.5 and the clearance ratio ($C/D = 0.0178$ and 0.0357) with 5132 to 24989 is the range of the Reynolds number is experimented by Halit Bas and Veysel Ozceyhen. It is also tested with zero clearance ratios for comparison [4]. They have also stated that the clearance ratio decreases when the Nusselt number increases. Increases in the twist ratio will also plays vital role in the increase of Reynolds number. They have found that at 1.756 with the clearance ratio of 0.0178 the highest heat transfer rate is obtained. Center wings and alternate axis in twisted tape investigated for the thermo hydraulic properties by Eiamsa-ard et al. This experiment was conducted with three types of twisted tape, tape with wings alone, tape with alternate axis, typical twisted tape with the twist ratio of 3.0 [5].

Manuscript published on 30 December 2019.

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The Reynolds numbers conducted ranges between 5200 to 22000. Twisted wings were formed at the middle line of the tape with three varied angles namely 43, 53, and 74. In further it is also found that twisted tape with middle axis and another axis gave the highest performance in the Nusselt number and friction factor and thermal performance with 17.7%, 30.6% and 7.8 % compared with twisted tape with center wings, 20.8%, 53% and 4.9 higher than twisted tape with another axis, 62%, 123% and 24% higher than the twisted tube

The experimental of visualization of flow characteristic produced by twisted tape having another axis and classic twisted tape was conducted by Panida Seemawute and Smith Eiamsa-ard [6]. It is carried out with technique of dye injection, the outcome of the twist ratio for heat transfer and fluid friction are also resolute from this visualization method. The twisted tape with another axis performed better than the typical twisted tape. The experimental investigation of twisted tape with rectangular cut with tube side coefficient of heat transfer was conducted by Bodius Salam et al [7]. They used water as flow median with a Reynolds number ranging from 10000 – 19000 and 14 to 22 kw/m^2 is the variation of heat flux for even tube and 23 – 40 kw/m^2 for the tube with insert. Nusselt number acquired from twisted tape insert with rectangular cut 2.3 to 2.9 times higher the rate of friction factors from 1.4 to 1.8 times when compares with even tubes. They had found that the coefficient of heat transfer of 1.9 to 2.3 will raised by the raise in Reynolds number.

Flow and Heat transfer has been numerically investigated by Computational Fluid Dynamics Arsha et al [8]. They used circular tubes with twisted tape inserted having the twisted ratio of 3 and 4 considerably along with plain tube for comparison. They conducted the analysis by three Reynolds numbers 8500, 11000 and 14000. Simulations are conducted in the basic Computational Fluid Dynamics tool, ANSYS FLUENT. The changes in the Nusselt number, Heat Transfer and Friction Factor has been reported. The compared variation in the Nusselt number for experimental and Analytical basis are 58-70% and 65-75% respectively, for the twist ratio 3.0 and 36-42% and 36-48% for the twist ratio 4.

The experiment of round pipe with central spiral corrugation unevenness, having the twisted tube with tilted teeth is investigated by Pranab Kumar Pal and Sujoy Kumar Saha. The viscous oil is the medium used here with laminar flow. The angle ranges from 0° to 90° [9]. The friction factor will have raise in a certain value and Nusselt number respectively. The twist ratio for the tape is 2.5 and 5 with the helix angle will be from 30° to 60° with the intervals of 15° and the height will be of 0.05263, 0.07895 and 0.1053. From these given terms, the heat transfer is increased by 21-85% for constant pumping and there is reduction of 64-80% in pump power. A four-sided duct with winglet vortex generator and the combined twisted tape has experimental study for heat transfer by Pongjet Promvonge et al. The air is the flow median in this experiment with the 4000 to 30000 is the ranges for the Reynolds number [10]. The twisted ratio in the tape is 4 and 5 for the three winglet to the duct, the height ratios ranges from 0.1 to 0.5 with time intervals of 0.5 and the winglet pitch of the tape width ratio are 2, 2.5, 4 and 5. Form these values the experiment is conducted. From this experimental setup, they have founded that there is a 17%

higher performance in heat transfer at the vortex flow than to the plain twist tube insert.

Perforated helical twisted tape is been investigated for heat transfer by Nanan et al [11]. They conducted with various span ratios of 0.2 to 0.6 with an intervals of 0.2 and various perforation pith ratio (s/w) of 1 to 2 with an intervals of 0.5, 2 and 3 were the respective pitch ratio and twist ratio. The Reynolds number ranges from 6000 to 20000. This investigation will be carried out in normal tube and helical twisted tape inserted tube for comparison. Heat transfer, friction loss and thermal performance characters increases because of the span ratio decreases and pitch ratio raises. They had concluded the maximum performance factor as 1.28 by perforated helical twist tube.

Twisted tape inserted in the square duct and the circular pipes were the flow of ethylene glycol will be laminar is experimentally conducted by S.V. Patil and P.V Vijay Babu [12]. The varied twist ratios are $\gamma = 2.66, 3.55, 4.01$ and 5.10. The Reynolds Number ranges from 50 to 1000. And the flow through four-sided duct and circular tubes with twisted tube are also considered for the comparison of the thermal and friction factors. They concluded that the Nusselt numbers are 5.44 to 7.49 and 2.46 to 4.87 times greater for the plain four-sided duct and for the constant twist ratio is 2.66 and the mean Nusselt number is 2.10 times greater for the given circular tube.

The thermo hydraulic performance of several types of helical twisted tapes had investigated by Smith Eiamsa-ard et al in the method experimentation [13]. The heat transfer augmentation by three types of helical twisted tape with the tape width ratio of 0.1 to 0.2 with intervals of 0.05 for calculating the friction factor, thermal performance and heat transfer. Here the ranges of the Reynolds number from 6000 to 20,000. There is a raise in the Nusselt number of double helical twisted tube and triple helical twisted tube of 15.6% to 17.6% and 19.5% to 23.4% respectively. The friction factor is also increased by 83% to 206% and 143% to 335%. And there is an increase of 3.9% to 20.3% and 8.3% to 26.2% in thermal performance. When related with single helical twisted tubes. The multi shaped duct with twisted tape insert is been investigated for the heat transfer and friction factor by Rupesh J. Yadav et al. They compared the non-circular duct with the circular duct. They used different twisted ratios ($Y = 3.5, 4.5, 5.5$ and 6.5). 400 to 2500 were the ranges of Reynolds number. Finally they had concluded the plain duct with insertion of twisted tape has a raise in Friction Factor and Nusselt number [14].

Tapered twisted tapes with alternate angles has been investigated for heat transfer by the method of experimentation Piriayarungrod et al [15]. The varying twist ratios for the are 3.5 and 4.0 and 4.5. 6000 to 20,000 was the range of the Reynolds Number. They had resolved that the 1.05 is the maximum thermal performance factor is given by tube with twisted tape with angle of 0.9° and twist ratio, 3.5 at Reynolds number 6000. Single double and triple twisted tapes inserted in the tube were the heat transfer is numerically investigated by Zhu and Chen with a single phase convective method [16].

They used wall surface improvement equations and second order discrete FVM method to calculate the flow characteristic for air and heat transfer. They compared the results with classical empirical equation. And concluded that the resistance has increased by 6.0–8.7 with the insertion of single twisted tape, by 9.4 – 14.4 with double twisted tape insert and higher value of 13.5 – 21.2 with the triple twisted tape in the tube.

The heat transfer has been analyzed in the tube with twisted tape insert in an experiment conducted by Ramakumar et al [17] In the Computational Fluid Analysis the taper increases along the flow direction. They have a fixed twist ratio of 3. The twist tape angle will vary from 0.3 to 0.7 with the interval of 0.1. Three Reynolds numbers get fixed for the CFD analysis 8545, 11393 and 13333. They calculated the heat transfer pressure drop as Nusselt number and the overall performance ratio was increased by 17%. The overall enhancement ratio is estimated with the taper angle as 0.5. heat transfer was investigated in a plain circular tube inserted with double twisted tape with v shaped ribs at an angle of 30° in an experiment conducted by Sombat Tamna et al [18]. They have used air as a testing fluid with the Reynolds number ranging from 5300 to 24000. They have the fixed twist ratio as 4 and the four v shaped ribs called as block ratios are 0.07, 0.09, 0.14 and 0.19. They concluded that the heat transfer and pressure loss were higher in the largest blockage ratio with v ribbed twisted tapes. The Nusselt number varies from 1.56 – 2.3 while the friction force will range from 2.06 – 4.94 times for the ordinary tube.

The tube is numerically investigated for the heat transfer fitted with twisted tape swirl generators in an experiment conducted by Suvanjan Bhattacharyya et al. [19] They had the configuration parameters entrance angle pitch in the range of 180°, 160° and 140°, 100 to 20,000 was the varying range of the Reynolds number . They had concluded with the result of the larger entrance angle and the smallest twist ratio has increased efficiently because of high turbulence intensity. The heat transfer is investigated in a tube with multiple four-sided perforated twisted tapes with geometrical parameters like width ratio and twist ratio in an experiment conducted by Amar Raj Singh Suri et al. [20]. Here the ratio width varies from 0.083 to 0.333 and twist ratio also varies from 2.0 to 3.5 and the Reynolds number varies from 5000 to 27,000. They had compared the perforated square twist tape with plain twist plate. They had concluded that the Nusselt number is maximum when the ratio of width is 0.250 and the ratio of twist is 2.5, the friction force is maximum when the ratio of width is 0.250 and ratio of twist is 2.0 and the maximum thermo hydraulic performance occurred at the ratio of width is 0.250 and ratio of twist is 2.5.

Gawande and A.V Deshmukh had experimented the coefficient of heat transfer in the tube side and circular tube for the friction factor with the twisted tape having rectangular cut with the twist ratio of 5.25[21]. They have compared this with twisted tape with and without elliptical hole. They used air as a median, 10,000 to 19,000 was the variation of the Reynolds number. The increase of Nusselt number is at a rate of 28 to 30 % for the tape without elliptical cut and changes from 47 to 60% for the tape with elliptical hole in it. They had concluded that the twisted tape with the vent is seen 2 to 4% efficient than the ordinary tape. The summary of the review is reported in table 1.

TABLE 1 SUMMERY OF THE OBSERVATIONS OF THE STUDY

Reference	Authors	Type of Fluid/Reynolds Number	Configuration of Twisted Tape	Investigation	Observations
[1]	Watcharin et al	Hot Air 2000< Re<12000	Insertion of twisted tape in Concentric double pipe	Investigation of Twisted tape in concentric double pipe	Friction force 3.37 times higher than the plain tube for $y=5.0$ and 2.97 times for $y = 7.0$.
[2]	Sujoy kumar	Hot Air 10,000< Re<12000	Twisted tape with oblique teeth	Investigation of twisted tape with oblique teeth in Non-Circular Tube	The performance is 50% higher
[3]	Bodius et al	Water 9500<Re<20,000	Stainless steel Twisted Tape	Investigation stainless twisted tape in circular pipe	An average of 70% enhancement is seen in the heat flux than the smooth tube.
[4]	Halit bas and Veyssel Ozceyhen	Air 5132<Re<24,989	Twisted tape inserted in the Separation of Tube Wall	Investigation of Heat transfer with the twisted tape insert	The heat transfer rate is higher as 1.756 for $\phi/D = 0.0178$.
[5]	Eiamsa-ard et al	Water 5200<Re<22,000	Twisted tape with centre wings and alternate axis	Investigation of heat transfer of twisted tape	A higher Nusselt number, friction factor, and thermal performance of 62%, 123% and 24% has been recorded respectively.
[6]	Panida seamawute and smith eiamsa ard	Water 10<Re<10,000	Twisted tape with alternate axis	Investigation of Flow and heat transfer of twisted tape with alternate axis	Higher Nusselt number of 70% and friction factor of 110% for $y/W=3$ in the twisted tape with alternate axis is denoted.
[7]	Bodius salam et al	Water 10,000 <Re<19,000	Twisted tape with rectangular cut	Investigation of heat transfer with the rectangular cut twisted tape	Difference in Nusselt number 2.3 to 2.9 and Friction factor is 1.4 to 1.8.
[8]	Arsha et al	Air 8500, 11000, 14000	Twisted tape	Investigation of heat transfer in twisted tape with CFD	A comparison done on the results of the experimental and analytical work for that the friction factor 58-70% and Nusselt number 65-75% for TR 3.0
[9]	Pranab kumar pal and sujoy kumar saha	Viscous Oil 1<Re<1000	Twisted tape with oblique teeth	Investigation of circular duct with integral spiral corrugation	For the corrugation helix angle heat transfer has increased by 21-85%.
[10]	pongiet promvongee et al	Air 4000<Re<30,000	Twisted tape with V-Winglets on two and four walls	Investigation of swirl vortex	Recorded a 17% higher performance of heat transfer with vortex flow.
[11]	k. Nanan et al	Water 6000<Re<20,000	Perforated Helical Twisted Tape	Investigation of heat transfer with perforated helical twisted tape	The maximum performance factor is observed as 1.28 in perforated helical twisted tape.
[12]	S.v. patil and P.v vijay babu	Ethylene glycol 50<Re<1000	Twisted tape	Investigation of heat transfer in square duct inserted with twisted tape	Observed a 2.10 times greater Nusselt number for the square duct insertion.
[13]	Smith eiamsa-ard et al	Air 6000<Re<20,000	Helical Twisted Tape	Investigation of thermohydraulic performance with double and triple helical twisted tape	Nu of DHTT and THHT increases from 15.6% to 17.6% and 19.5% to 23.4%, the fr increases by 83% to 206% and 143% to 335%. And there is an increase in thermal performance by 3.9% to 20.3% and 8.3% to 26.2% Compared when compared with SHTT.

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[14]	Rupesh J. Yadav et al	Air $400 < Re < 2500$	Twisted tape with different Twist Ratio	Investigation of friction factor and heat transfer in non-circular tubes	The Nusselt Number has increased from 7 to 11 and the friction factor increased from 0.65 to 0.8 for the Re 2500.
[15]	N. Piriyaarungrod et al	Water $6000 < Re < 20,000$	Tapered Twisted Tape	Investigation of heat transfer with Tapered twisted tape insert	Recorded a maximum thermal performance factor of 1.05 for the taper angle of 0.9° and the Tr is 3.0.
[16]	J.D Zhu and H. Chen	Water $Re = 20,000$	Double spiral and triple spiral Twisted tape	Investigation of numerical study o enhanced heat transfer	Observed an increase in the Resistance from 6.0 – 8.7 for single TTI and 9.4 – 14.4 for double TTI and 13.5 – 21.2 with the triple TTI
[17]	B.V.N Ramakumar et al	Water $Re = 8545, 11393$ and 13333	Tapered Twisted Tapes	Investigation of numerical analysis with tapered twisted tape	Recorded an increase in the overall performance as 17% in the taper angle 0.5° .
[18]	Sombat Tamna et al	Air $5300 < Re < 24,000$	V- Ribbed Twisted Tapes	Investigation Of heat transfer in tubular heat exchanger with v ribbed twisted tapes	Observed an increase in the Nusselt Number from 1.56 – 2.3 times and the Friction Factor from 2.06 – 4.94.
[19]	Suvanjan Bhattacharyya et al	Air $100 < Re < 20,000$	Twisted tape turbulator	Investigation of heat transfer with twisted tape turbulator at difference entrance angle	Recorded that the largest entrance angle and the smallest twisted ratio will increase with the high turbulence intensity.
[20]	Amar Raj Singh Suri et al	Water $5000 < Re < 27000$	Multiple square perforated twisted tape	Investigation of heat transfer in the multiple square perforated twisted tape	Observed the maximum thermo hydraulic performance at a width ratio of 0.25 and the twist ratio 2.5.
[21]	K.R. Gawande and A.V. Deshmukh	Air $10,000 < Re < 19000$	Twisted tape with and without elliptical hole	Investigation of tube-side heat transfer rate with elliptical hole	Observed that the Nusselt number has increased from 28-30% without the elliptical hole and from 47-60% with hole.

III. CONCLUSION

This review reports that the heat transfer through the heat exchangers raised by changing the characteristics in the flow passage of the fluids by introducing inserts. Based on the surface contact of the fluids with the inserts the heat transfer noticeably increased. This review depicts influence of the geometry of the twisted tapes making swirl passages and tapes with different dimensions shows a higher heat transfer coefficient. It increased with twisted tape with different dimensions like having rectangular cut, oblique teeth, helical twisted tape; V- ribbed twisted tapes and elliptical hole on the twisted tapes. Many of the researches reported the change in twist ratio leads to get accurate twist ratio at which the maximum heat transfer rate acquired. Still there exists a scope for the further research in this influence of twisted tapes considering in transverse direction of flow instead of axial flow situations.

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