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Review on Twisted Tapes Heat Transfer Augmentation

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Abstract: *This work focuses on heat transfer augmentation techniques for different types of twisted tape inserts. The present review is about twisted tape insert for heat transfer enhancement and its geometry. The twisted tape insert is a device used for increasing the heat transfer rate in heat exchanger for its easy operation and low maintaince. This review paper mainly refers previous experimental and numerical studies done using twisted tape insert for turbulent flow regime in the range of 2000 to 50000.The heat transfer in a circular tube having twisted tape has been significantly increased over plain tube. These studies are useful for the future research in the area of twisted tapes will bring more development in heat exchanger systems.*
Keywords: *Twisted tape insert, turbulent flow, Reynolds number, Nusselt number, Heat transfer*

I. Introduction

1.1 Overview of Augmentation Techniques

The process of improving the performance of a heat transfer system is referred as the Heat transferenhancement technique (augmentation technique). Nowadays, a significant number of thermal engineering researchers are seeking for new enhancing heat transfer methods between surfaces and the surrounding fluid.This technique refers to different methods used to increase rate of heat transfer without affecting much the overall performance of the system. The subject of enhanced heat transfer has developed to the stage that it was of serious interest for heat exchanger design. Large numbers of attempts have been made to reduce the size and costs of the heat exchangers.Insertion of twisted tapes in a tube provides simple passive techniques for enhancing the convective heat transfer by introducing swirl into the bulk flow and disrupting the boundary layer at the tube surface due to repeated changes in the surface shape.Passive inserts with varying geometries along with varying range of parameters are becoming major area of research leading to effective heat exchangers.We need heat transfer enhancement,to make the equipment compact, minimize the cost of energy and material, increase the efficiency of process and system, design optimum heat exchanger size, transfer the required amount of heat with high effectiveness, for given temperature difference improved heat transfer.Passive techniques are used as:

- These techniques generally use simple surface or geometrical modifications to the flow channel by incorporating inserts.
- It does not need any external power input.
- Inserts manufacturing process is simple and these techniques can be easily employed in existing heat exchanger.
- Passive insert configuration can be selected according to the heat exchanger working condition.
  It can be used in design of compact heat exchanger.
  - Twisted tapes are the metallic strips twisted with some suitable techniques at desired shape and dimension, inserted in the flow.The twisted tape inserts are popular and widely used in heat exchangers for heat transfer enhancement besides twisted tape inserts promote heat transfer rate with less friction factor penalty on pumping power. Insertion of twisted tapes in a tube provides a simple passive techniques for enhancing the convective heat transfer by introducing swirl into the bulk flow and disrupting the boundary layer at the tube surface due to repeated changes in the surface shape. This is to say such tapes induce turbulence and superimposed vortex motion which induces a thinner boundary layer and consequently results in a better heat transfer rate and higher local heat transfer due to the changes in the twisted tape shape. However, the pressure drop inside the tube will be increased by introducing the twisted tape. Hence a lot of investigators have carried out experimentally and numerically to investigate the optimal design and achieve the best thermal performance with less friction loss.

1.2 Literature Review

Wongcharee and Eiamsa-ard used alternate clockwise and counter clockwise twisted-tapes in a circular tube to decide Nu and f and thermal hydraulic characteristics. It was reported that clockwise and anticlockwise Twisted-tapes yields a maximum augmentation of Nu and f in order of 2.980 and 3.160 times the smooth tube.[1]. Saha et al. designed an experiment to simulate theenhanced heat transfer process of a tube with coaxial fins andcenter-cleared twisted tapes. This compound heat transferenhancement method had a better heat transfer performance than the method employing a tube with only coaxial fins or only twistedtapes. The larger the hollow width of the tapes, the smaller was the Nusselt number (Nu), but the flow resistance also reduced simultaneously. [2]. Bhuiya et al. experimentally studied the prediction of heat transfer in turbulent flow through a tube with perforated twisted tape inserts.The study revealed that the perforated twisted tape inserts caused an increase of heat transfer rate at the cost of increased blower power.The peripherally-cut twisted tape enhanced the heat transfer rates in terms of the Nusselt number up to 2.6 times while the maximum performance factor of 1.29was achieved in turbulent flowregime. [3]. Eiamsa-ard and Promvonge found that the use of a full-length helical tape with rod leads to higher heat transfer rate than that of full-length helical tape without rod (a typical tape) but the tape dramatically increases friction factor. On the other hand, a regularly-spaced helical tape gives lower heat transfer rate but it offers more reasonable tradeoff between the increased heat transfer and friction loss penalty. [4] .Wongcharee and Eiamsa-ard presented the effects of twisted tapes with alternate-axes andwings on heat transfer, fluid friction and thermal performance characteristics in a circular tube. It was illustrated from the results that both heat transfer rate and friction factor associated by all twisted tapes were consistently higher than those without twisted tape. Heat transfer and pressure drop characteristics were analyzed experimentally in a tube heat exchanger fitted with dual twisted tape elements in tandem [5]. Changzhong Man, Jinyu Yao*, Chong Wang has investigated experimental research on heat transfer and friction factor characteristics in a tube with a new kind of twisted tape insert using different length (2400,1800,1200,600 mm). This Experiment revealed that Nusselt number of twisted tape insert increases as compare to the plain tube. [6]. A.Hasanpour , M. Farhadi , K.Sedighi has experimentally studied double pipe heat exchanger using different twist ratios and various categories and depth ratios. Reynold number is changes from 5000 to 15000 of turbulent regime.[7].

Sombattamna , YingyongKaewkohkiat , SompolSkullong, PongjetPromvonge has experimentally worked on heat transfer enhancement in a round tube used double twisted tape air as working medium and Reynolds number from 5300 to 24000. They obtained that heat transfer and Nusseltnumber increases.[8]ChaitanyaVashistha, Anil Kumar Patil , Manoj Kumar heat transfer and fluid flow characteristics of a circular tube fitted with multiple inserts. Using different twist ratio and varied reynolds number in the range of 4000 to 14000. They obtained maximum enhancement in friction in a twisted tape than that for smooth tube. [9]. Piriyarungrod et al. investigated tapered twisted tapes insert at different taper angles (θ) ranging from 0°–0.9° and different y/W values from 3.5 to 4.5. It was reported that the Nu and f increased by decreasing taper angle and y/W. The maximum thermal performance factor of 1.05 was found for the tape with taper angle (θ) of 0.9° and twist ratio (y/W) of 3.5 at Re of 6000.[10] Siva Rama Krishna et al. performed experiments to study heat transfer characteristics of tube fitted full length twisted tape and spaced twisted tape inserts. It is also observed that heat transfer coefficient increases with increasing Reynolds number.[11] Yadav studied experimentally by insertion of half length twisted tape in a U-bend double pipe heat exchanger on heat transfer and pressure drop characteristics for a laminar flow. Comparative study of performance is obtained from heat exchanger with inserted twisted tape and plain heat exchanger i.e. without twisted tape. In a heat exchanger with twisted tape the heat transfer rate is greatly influence by tape induced swirl or vortex motion. On the basis of equal mass flow rate it was found that heat transfer performance of half length twisted tape is better and upto 40% more than plain heat exchanger.[12]

Table 1: Twisted tapes|

S.N.	Author	Fluid	Configuration	Type of investigation	Observation
1	M.K.Abdolbaqi W.H.Azami , Rizalman[22]	Turbulent $7200<Re<32400$	twin twisted tape twist ratios(5,10,15)	Experimental	Effect of twin counter and co twisted tapes on heat transfer rate, friction factor and thermal enhancement index
2	Halit Bas, VeyselOzceyhan[31]	Air Re 5132-24989	twisted tape inserts with teflon tape	Experimental	Using twisted tape separately from the tube wall instead of attached type can also supply enhancement on heat transfer
3	Manosh Pal, VeyselOzceyhan[39]	Re was 5000 to 20000	diver type of twisted tape for alternative axis triangular cut type of twisted tape..	Experimental	Enhancement efficiency is increased
4	AdemAcir, Ismail Ara MehmerEminCanli[7]	Air	Circular ring tubulators	Experimental	1)Highest heat transfer was

			3000<Re<7500 Solar air heater different pitch ratio hole no		changed as 229 % and 121 % times compared to plain tube 2) friction factor increases by 5.8 times compared to plain
5	M.Sheikholeslami, M. Gorji-Bandpy, D.D.Ganji[8]	Air	Typical circular ring tubular(TCR) Perforated circular ring (PCR) 6000<Re<12000, Pitch ratio(1.83,2.92, 5.83)	Experimental	1) Thermal performance decreases with increase in Re and pitch ratio 3)PCR leads to lower heat transfer enhancement than CR

Table 2: Types of twisted tapes

S.N.	AUTHOR	TYPE OF INSERT	NU	FRICTION FACTOR
	YEAR=2015			
1	Anant&etal.	Twisted tape with circular hole	23.99% to 29%	0.2% to 0.25%
	working medium=air	experimental		
	Re=2000 to 1200			
2	M.M.Bhuiya		60% to 240%	91% to 286%
	Re=6950 to 50050			
3	Kumbhar D.G.	Twisted tape	210.50%	35% to 32%
	Re=4200 to 1600	Experimental		
	YEAR=2016			
4	MMK Bhuiya	perforated counter twisted tape	80% to 290%	111% to 335%
	Re=7200 to50,000			
5	A. Hasanpour	Twisted tape	1.8	1.45 to 2
	Re=5000 to 15000	V cut,U cut		
6	Changzhongetal.	Twisted tape	1.42	2.42 to 4.95
	Re=3000 to 9000	(2017 paper)		
7	Halit Bas	Perforated counter twisted tape	1.756	
	Re=5132	(2012 paper)		

II. Experimentation

The experimentation was started with rising the temperature of the test section starting the blower which allows air as working fluid to enter the test section. The Dimmerstat maintains constant heat flux condition by supplying uniform voltage. The flow rate of the air was set by using flow control valve and the velocity was measured with the help of anemometer which helps to obtain required Reynolds number according to the experimentation. The experiment continues until the steady state is reached, where the temperature variation becomes negligible, and then readings were taken. At the steady state condition, data recorded are U tube manometer fluid height difference for measuring pressure drop across the pipe, wall temperature, inlet fluid temperature, exit fluid temperature. When the steady state is reached again, the data is recorded. This procedure is repeated for different Reynolds number. The experimental data was taken with and without using twisted tape insert.

III. Data Reduction Equations

1) In the present work, the air used as the test fluid flowed through a uniform heat-fluxed and insulated tube. The steady state heat transfer rate is assumed to be equal to the heat loss in the test section, which can be expressed as:-

$$Q_a = Q_{conv}$$

where,

$$Q_a = m * C_p * (\Delta T_{op} - \Delta T_{ip})$$

2)The heat supplied by the electrical winding in the test tube is found to be higher than the heat absorbed by the fluid for the thermal equilibrium test due to convection and radiation heat losses from the test section to the surrounding. Thus, only the heat transfer rate absorbed by the fluid is taken for the internal convective heat transfer coefficient calculation. The convection heat transfer in the test tube can be written as:-

$$Q_{conv} = h * A_s * (\Delta T_w - \Delta T_b Q_{conv} = h * A_s * (\Delta T_w - \Delta T_b)$$

in which

$$T_b = \frac{T_{op} + T_{ip}}{2}$$

and

$$T_w = \sum_{i=0}^{i=12} Ti$$

where

Tw is the local wall temperature and evaluated at the outer wall surface of the tested M.S tube. The average wall temperature, Tw is calculated from 12 points of surface temperatures lined equally between the inlet and the exit of the tested tube. The average heat transfer coefficient (h) and the mean Nusselt number (Nu) are estimated as follows:

$$h = \frac{m * C_p * (\Delta T_{op} - \Delta T_{ip})}{A_s * (T_w - T_b)}$$

The heat transfer is calculated from Nusselt number which can be obtained by:-

$$Nu = \frac{h * D}{k}$$

Reynolds number based on tube diameter is given by

$$Re = \frac{V * D}{\nu}$$

The friction factor (f) computed by pressure drop across the test-tube length (L) is written as:-

$$f = \frac{2 * \Delta P}{\left(L/_D\right) * \rho * V^2}$$

in which V is mean air velocity in the tube. All of thermo-physical properties of the air are determined at the overall bulk air temperature(Tb) in Eq. (4).To assess the practical use of the enhanced tube, the performance of the enhanced tube is evaluated relatively to the smooth tube at an identical pumping power in the form of thermal enhancement factor (h) which can be expressed as:-

$$\eta = \frac{Nu/_{Nuo}}{(f/_{f0})^{\wedge 1/3}}$$

IV. Conclusion

The heat transfer inside the tube with twisted tape insert was studied experimentally.In this paper, experimental and numerical investigation of different researchers from previous work on heat transfer enhancement of heat exchangers by using passive augmentation technique has been reviewed for wide range of Reynolds number. The heat transfer enhancement takes place with increase in Reynolds number. The heat transfer coefficient and Nusselt number characteristics of twisted tape insert were enhanced rapidly and increases the heat transfer rate within the heat exchanger by increasing turbulence in the flow.

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Conflict of interestthe authors declare that there is no conflict of interests regarding the publication of this paper

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