Scientific Journal of Impact Factor (SJIF): 4.72
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 5, Issue 01, January -2018

Review on Heat Transfer Enhancement Technique using Twisted Tape in Laminar and Turbulent Flow in a Circular Duct.

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Abstract- *Heat transfer enhancement technique refers to different methods used to increase rate of heat transfer without affecting much overall performance of the system. These techniques are used in heat exchangers, Some of the application of heat exchangers are in process industries, thermal power plant, air conditioning equipment, refrigerator, radar for space vehicles, automobiles etc. In the past decades several studies on passive techniques of heat transfer enhancement have been reported. This paper reviews mainly on twisted tape heat transfer enhancement and its design modification towards the heat transfer enhancement and saving pumping power.*

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

1. INTRODUCTION

Heat transfer enhancement techniques refer to the improvement of thermo hydraulic performance of heat exchanger. This can be achieved when the heat transfer power of a given device is increased or when the pressure losses generated by the device are reduced. Existing enhancement techniques can be broadly classified into three different categories.

1.1. ACTIVE TECHNIQUES

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

1.2. PASSIVE TECHNIQUES

These techniques do not require any direct inputs or outside power, rather they use it from the system itself which ultimately leads to an increase in fluid pressure drop. They generally use surface or geometrical modification to the flow channel by incorporating inserts or additional devices. They promote higher heat transfer coefficient by disturbing or altering the existing flow behavior except for extended surface.

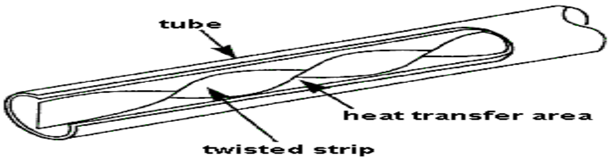
1.3. COMPOUND TECHNIQUES

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 enhancement.

ABBREVIATION

F	Friction factor
G	Thermal Performance Factor
Nu	Nusselt Number
Re	Reynolds Number
DR	Depth Ratio
WR	Width Ratio
CTT	Center cleared twisted tapes
Ŋ	Thermal Hydraulic Efficiency
Y	Twist Ratio
TT	Twisted Tapes
PTT	Plain Twisted Tapes
TA	Twisted Tape with Alternate axis
THE	Heat Exchanger
PTA	Peripheral cut alternate axis twisted tapes

TWISTED TAPE



The twisted tape are the strip of metallic with desired shape and dimension, can be inserted in the pipe in the flow direction, the twisted tape cause of flow to spiral along the tube length the tape is inserted generally do not have good thermal contact with tube wall, so the tape does not act as a fin, The corrugation channel are used in this paper and twisted tape have been investigated for circular tube this may increased the heat transfer rate and also give increase in pressure drop.

TERMINOLOGY USED IN TWISTED TAPE

1.1. *THERMO HYDRAULIC PERFORMANCE*

For a particular Reynolds number, the thermo hydraulic performance of an insert is said to be good if the heat transfer coefficient increases significantly with a minimum increase in friction factor Thermo hydraulic performance estimation is generally used to compare the performance of different inserts under a particular fluid flow condition.

1.2. *OVERALL ENHANCEMENT RATIO*

The overall enhancement ratio is defined as the ratio of the heat transfer enhancement ratio to the friction factor ratio.

1.3. *REYNOLDS NUMBER*

The Reynolds number is the ratio of inertial forces to viscous force within a fluid which is subjected to relative internal movement due to different fluid velocities, in what is known as a boundary layer in the case of a bounding surface such as the interior of a pipe.

1.4. *NUSSELT NUMBER*

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

1.5. *PRANDTL NUMBER*

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

PITCH

The Pitch is defined as the distance between two points that are on the same plane, measured parallel to the axis of a twisted tape.

1.6. *TWIST RATIO*

The twist ratio is defined as the ratio of pitch length to inside diameter of the tube.

1.7. PRESSURE DROP

Pressure drop is defined as the difference in total pressure between two points of a fluid carrying network. Pressure drop occurs when frictional forces, caused by the resistance to flow, act on a fluid as it flows through the tube.

2. REVIEW ON TWISTED TAPE

This paper mainly focuses on review of works done on twisted tapes in
a) Laminar Flow
b) Turbulent Flow
By using different types of twisted tape arrangements, such as Plain Twisted Tape (PTT),
Modified Twisted Tape (MTT), Modified Geometry Twisted Tape (MGTT).

2.1. PLAIN TWISTED TAPE

a) Behabadi [1] experimental investigated the heat transfer coefficients and pressure drop during condensation of HFC-134a in a horizontal tube fitted with twisted tapes. The refrigerant flows in the inner copper and the cooling water flows in annulus. Also empirical correlations were developed to predict smooth tube and swirl flow pressure drop.

b) Syam Sundar and sharma [2] investigated the thermo physical properties like thermal conductivity and viscosity of Al_2O_3 nanofluid is determined through experiments at different volume concentrations and temperatures. From the result it is observed that, heat transfer coefficients and friction factor is higher when compared to water in a plain tube. Also a generalized regression equation is developed with the experimental data for the estimation of friction factor and Nusselt number.

c) Promvonge [3] experimentally investigated the heat transfer rate, friction factor and thermo hydraulic efficiency of the combined devices of twisted tapes and wire coil. The experiment is carried out by arranging in two different forms: (1) Decreasing coil and (2) Decreasing / Increasing coil while the twisted tape was prepared with two different twist ratios.

2.2. MODIFIED TWISTED TAPE

a) Yadav [4] experimentally investigated on the half length twisted tape insertion on heat transfer & pressure drop characteristics in a U-bend double pipe heat exchanger. The experimental results revealed that the increase in heat transfer rate of the twisted tape inserts is found to be strongly influenced by tape-induced swirl.

b) Eiamsa-ard . [5] an experimental study on the mean Nusselt number, friction factor and thermal performance factor in a round tube with short-length twisted tape insert. The full-length twisted tape is inserted into the tested tube at a single point were pitch ratio (y) = 4.0. While the short-length tapes mounted at the entry test section. The experimental result indicates that the presence of the tube with short-length twisted tape insert yields higher heat transfer rate.

c) Saha [6] experimentally investigated the heat transfer enhancement and pressure drop characteristics in the tube with regularly spaced twisted tape element. From the result, it is observed that pinching of tape rather than in connecting the tape element with rods is betwisted tapeser proposition from thermo hydraulic point of view.

d) Mengna [7] investigated experimentally the Pressure drop and compound heat transfer characteristics of a converging-diverging tube with evenly spaced twisted tape (Converging Diverging tube). Swirl was generated by evenly spaced twisted-tape elements which vary in twist ratio and rotation angle.

e) Promvonge and Eiamsa-ard [8] investigated thermal characteristics in a circular tube fitwisted tapesed with conical-ring and a twisted tape swirl generator. The experimental results reveal that the tube fitwisted tapesed with the conical-ring and twisted tape provides Nusselt values of around 4 to 10% and enhancement efficiency of 4 to 8% higher than that with the conical-ring alone.

2.3. MODIFIED GEOMETRY TWISTED TAPES

a) Wei Liu et al. [9] investigated numerically the Heat exchanger and friction factor characteristics of laminar flow in a tube with short-width and centre cleared twisted tape. It is given that centre cleared twisted tape is good technique in lamina flow and the heat transfer can be enhanced with a change in central clearance ratio.

b) Eiamsa-ard and wongcharee [10] experimentally investigated heat exchanger, friction factor and thermal performance factor characteristics of CuO/water nano fluid and modified alternate axis twisted tape. The use of nanofluid with the alternate axis twisted tape provides considerably higher nusselt number and thermal performance factor than that of nanofluid with the plain twisted tapes .

c) Murugesan et al. [11] investigated experimentally the heat exchanger, friction factor and thermal performance factor characteristics of tube fitwisted tapesed with v cut twisted tapes . The obtained results show that the mean Nusselt number and the mean friction factor in the tube with v cut twisted tapes increases with in decrease pitch ratio.

d) Radhakrishnan. et al. [12] made experimental investigation on heat exchanger, friction factor and thermal performance factor of thermosyphon solar water heater system fitwisted tapesed with full- length twist, twist fitwisted tapesed with rod and spacer fitwisted tapesed at the trailing edge. Conclusions made from the results show that heat exchanger in twisted tapes collector is higher than the plain tube.

e) Bharatdwaj [13] experimentally determined pressure drop and heat transfer characteristics of flow of water in a 75 start spirally grooved tube with twisted tape insert are presented. It is found heat exchanger in spiral tube is higher when compared to plain tube.

f) Eiamsa-ard [14] investigated the Effects of plain twisted tapes insert on heat transfer, friction factor and thermal performance factor characteristics in a round tube. Nine different plain twisted tapes with pitch ratio, different Depth Ratio and different width ratio were tested. From the result, it is revealed that nusselt number, friction factor and thermo hydraulic performance are found to be increased with depth ratio and width ratio .

g) Chang [15] experimentally examined the turbulent heat transfer in a swinging tube with a serrated twisted tapes insert under seagoing conditions. This swirl tube swings about two orthogonal axes under single and compound rolling and pitching oscillations. Synergistic effects of compound rolling and pitching oscillations with either harmonic or non-harmonic rhythms improve heat transfer performances.

h) Chang et al. [16] experimental study that comparatively examined the spiky twisted-tape insert (swirl tube) placed in a tube. The dispersed rising air bubbles in the plain tube and the centrifugal-force induced coherent spiral stream of coalesced bubbles in the swirl-tube core considerably modify the pressure-drop and heat-transfer performances from the single-phase conditions.

The summary of the above work is given in the following table based upon the classification of the tapes, type of flow, observation and remarks

Sr .No	AUTHOR NAME	TYPE OF FLOW	CONFIGURATION OF TAPES	OBSERVATION	COMMENT
1	Behabadi	Turbulent	PTT (y=6,9,12,15)	Decrease in ‘y’ increase the heat transfer rate. Pressure drop increases with reduction in ‘y’	It is observed that the TT with ‘y’ = 9 gives the best ‘g’ with minimum pressure drop.
2	Syam Sundar & sharma	Turbulent	PTT (y=0,H/D,83)	No increase in pressure drop or ‘f’ when compared to water.	The maximum ‘g’ in the result is obtained at y=5.
3	Promvonge et al.	Turbulent	PTT (y=0 to ?)	The heat transfer and ‘f’ is more efficient in TT than wire coil.	At low Re, with y=3 the
4	Yadav	Laminar	Half Length TT	On unit pressure drop basis and on unit pumping power basis, half length TT is more efficient than full-length TT.	On unit pressure drop basis, the heat transfer performance of smooth tube is maximum followed by half-length TT.

5	Eiamsa-ard .	Turbulent	Short Length TT	The value of f and heat transfer rate ranges from 1.76-1.99, 1.16- 1.27.	Short length TT is better than full length TT on basis of 'g'
6	Saha et al.	Laminar	Regularly Spaced TT	Pinching of tape rather than connecting tape element give high 'g'.	Uniform pitch performs better than gradually decreasing pitch.
7	Mengna et al.	Turbulent	TT in CD tube	At Y=4.762 and θ= 180◦ the best heat transfer and friction factor is obtained.	Converging diverging (CD) tube with TT creates swirling motion to fluid and increase the time of contact.
8	Promvonge & Eiamsa-ard	Turbulent	Conical Ring with TT	With y= 3.75 the 'η' is 1.96.	Combined device increases the thermal performance.
9	Wei liu et al.	Laminar	Clear Centered TT	CCT gives 'g' value 7-20% more than TT.	CCT gives more fluid flow and optimal 'f'.
10	Eiamsa-ard& Wongcharee	Laminar	Alternate Axis TT	'Nu' increases with increase in 'Re' and fluid concentration.	TA makes more swirl in fluid flow with increased efficiency.
11	Murugesan et al.	Turbulent	V-cut TT	Influence of 'DR' was more dominant than 'WR' for all 'Re'.	V cut TT gives higher transfer rate and friction factor than plain tube.

12	Radha Krishnan et al.	Laminar	TT with Rod and Spacer	'Nu' is 13.5% higher than PTT and 'f' is given as 14.85.	This is well effective for laminar flow only.
13	Bharatdwaj et al.	Laminar	Spirally grooved Tube With TT	Heat transfer enhancement is increased due to swirl flow.	Spirally grooved tube will be well effective only with TT inside the tube.
14	Eiamsa-ard et al.	Laminar	PTA	'Nu', 'f' and 'g' increased with increase in depth ratio.	PTA provides high 'g' with constant pumping power
15	Chang et al.	Turbulent	Searted TT	Synergic effect of rolling and pitching oscillations improve heat transfer rate.	Serrated tube cause swirl motion and oscilation to the flow and increases 'g'.
16	Chang et al	Turbulent	Spiky TT	HTE and 'g' of spiky TT is higher than that of PTT.	Counterclockwise cut in twisted tapes creates more of fluid inside the tube.

3. CONCLUSION

This review has considered heat transfer and pressure drop investigations of the various twisted tape placed in heat exchangers. Almost all possible research subjects have been summarized on the case in the literature, such as heat transfer and pressure drop studies according to plain twisted tape, modified twisted tape, and modified twisted tape geometry. A twisted tape and modified twisted tape inserts mixes the bulk flow well and therefore performs better in laminar flow, because in laminar flow the thermal resistant is not limited to a thin region. The result also shows twisted tape insert is more effective in laminar flow, and pressure drop penalty is created during turbulent flow. In case of twisted tape with modified geometry, more turbulence is created during the swirl of fluid and gives higher heat transfer rate compared to plain twisted tape and modified twisted tape. The result shows that for modified twisted tape geometry, the heat transfer rate is higher with reasonable friction factor for both laminar and turbulent flow. These conclusions are very useful for the application of heat transfer enhancement in heat exchanger networks.

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