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Review on Effect of Swirl Flow in a copper Tube Heat Exchanger

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Abstract

Heat transfer augmentation techniques (passive, active or a combination of passive and active methods) are commonly used in areas such as process industries, heating and cooling in evaporators, thermal power plants, air-conditioning equipment, refrigerators, radiators for space vehicles, automobiles, etc. Passive techniques, where inserts are used in the flow passage to augment the heat transfer rate, are advantageous compared with active techniques, because the insert manufacturing process is simple and these techniques can be easily employed in an existing heat exchanger. In design of compact heat exchangers, passive techniques of heat transfer augmentation can play an important role if a proper passive insert configuration can be selected according to the heat exchanger working condition(both flow and heat transfer conditions). In the past decade, several studies on the passive techniques of heat transfer augmentation have been reported. The present paper is a review on progress with the passive augmentation techniques in the recent past and will be useful to designers implementing passive augmentation techniques in heat exchange. Twisted tapes, wire coils, ribs, fins, dimples, etc., are the most commonly used passive heat transfer augmentation tools. In the present paper, emphasis is given to works dealing with twisted tapes and wire coils because, according to recent studies, these are known to be economic heat transfer augmentation tools. The former insert is found to be suitable in a laminar flow regime and the latter is suitable for turbulent flow. The thermo hydraulic behaviour of an insert mainly depends on the flow conditions (laminar or turbulent) apart from the insert configurations. The present review is organized in five different sections: twisted tape in laminar flow; twisted tape in turbulent flow; wire coil in laminar flow; wire coil in turbulent flow; other inserts such as ribs, fins, dimples, etc.

Keywords:- heat transfer augmentation; twisted tape; wire coil (heater)

1. Introduction:-

Heat transfer enhancement or augmentation techniques refer to the improvement of thermo hydraulic performance of heat exchangers. Heat exchangers have several industrial and engineering applications. The design procedure of heat exchangers is quite complicated, as it needs exact analysis of heat transfer rate and pressure drop estimations apart from issues such as long-term performance and the economic aspect of the equipment existing enhancement techniques can be broadly classified into three different categories:

Active Techniques:-

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

Passive Techniques:-

These techniques 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. They 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 behaviour except for extended surfaces.

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.

2. METHODOLOGY USED IN TWISTED TAPE

2.1 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.

2.2Overall Enhancement Ratio:-

The overall enhancement ratio is defined as the ratio of the 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 h is the convective heat transfer coefficient, d is the diameter of the tube and k is the thermal conductivity.

2.2 Prandtl Number:-

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

2.3 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.

2.4 Twist Ratio:-

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

3. REVIEW ON TWISTED TAPE:-

The present paper contributes for review of twisted tape inserts. The main objective of this paper is to review the work carried on plain twisted tape, modified twisted tape, and modified twisted tape geometry.

3.1 Plain Twisted Tape:-

Behabadi et al. [1] experimental investigated the heat transfer coefficients and pressure drop during condensation of HFC-134a in a horizontal tube fitted with TT. 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.

Klaczak [2] investigated experimentally the heat transfer for laminar flow of water in an air cooled vertical copper pipe with TT inserts of various pitch value. The tests were executed for laminar flow within 110 $\leq$Re $\leq$ 1500and 1.62 $\leq$ y $\leq$ 5.29. Result shows that the heat transfer increases with increase in twisted tape pitch value.

3.2 Modified Twisted Tape:-

Yadav [3] experimentally investigated on the half-length TT 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 TT inserts is found to be strongly influenced by tape-induced swirl.

Eiamsa-ard et al. [4] an experimental study on the mean 'Nu'; 'f' and 'g' in a round tube with short-length TT insert. The full-length twisted tape is inserted into the tested tube at a single 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.

Promvonge and Eiamsa-ard [5] investigated thermal characteristics in a circular tube fitted with conical-ring and a TT swirl generator. The experimental results reveal that the tube fitted with the conical-ring and TT provides 'Nu' values of around 4 to 10% and enhancement efficiency of 4 to 8% higher than that with the conical-ring alone.

Eiamsa-ard et al. [6] experimentally investigated on the 'HTE' and 'f' characteristics in a double pipe heat exchanger fitted with regularly TT insert. By comparing the result with plain tube, it is evident that the heat transfer coefficient increased with 'y'.

Saha et al. [7] experimentally investigated the HTE and pressure drop characteristics in the tube with regularly spaced TT element. From the result, it is observed that 'Pinching' of tape rather than in connecting the tape element with rods is better proposition from thermo hydraulic point of view.

3.3 Modified Geometry Twisted Tape:-

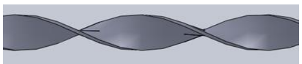
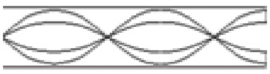
Zhang and Mao [8] carried out the 3D numerical and experimental study of the heat transfer characteristics and the pressure drop of air flow in a circular tube with ETT inserts. From the experimental study it is found that the 'η' slowly decreases as the 'y' increases.

Bharatdwaj et al. [9] 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 'HTE' in spiral tube is higher when compared to plain tube.

Murugesanet al. [10] experimentally investigated the heat transfer and 'f' characteristics of trapezoidal –cut TT with y= 4.0 and 6.0. From the experiment it is revealed, that there was a significant increase in heat transfer coefficient and 'f' for tape with trapezoidal-cut.

The summary of the above work is given in the table 1.0 based on the classification of the tape, type of flow, observation and comment.

Table 1.0 Summary of Important Investigation on Twisted Tape

Sr. No.	AUTHOR NAME`	TYPE OF FLOW	Diagram	OBSERVATION
1.	Behabadi et al.	Turbulent		Decrease in 'y' increase the heat transfer rate. Pressure drop increases with reduction in 'y'
2.	Klaczak	Turbulent		No increase in pressure drop or 'f' when compared to water.
3.	Yadav	Laminar		On unit pressure drop basis and on unit pumping power basis, half length TT is more efficient than full-length TT.
4.	Eiamsa-ard et al.	Turbulent		The 'f' from the dual TT increases up to 23% over the single twisted tape.

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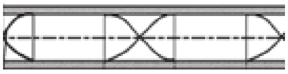
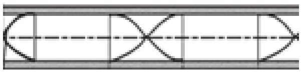
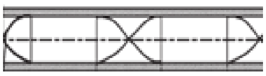
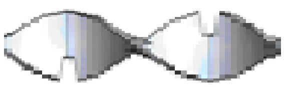
5.	Promvonge and Eiamsa-ard	Turbulent		With y= 3.75 the 'η' is 1.96.
6.	Eiamsa-ard et al.	Turbulent		Heat transfer coefficient and friction factor increases with increase in space ratio.
7.	Saha et al.	Laminar		Pinching of tape rather than connecting tape element give high 'g'.
8.	Zhang and Mao	Turbulent		The highest performance of this TT is 140% when gap width reduces to 1 mm.
9.	Bharatdwaj et al.	Laminar		Heat transfer enhancement is increased due to swirl flow.
10.	Murugesan. et al.	Turbulent		By the trapezoidal cut TT, the 'f' and 'g' increases with decrease in twist ratio.

4. 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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