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HEAT TRANSFER AUGMENTATION IN A CIRCULAR TUBE USING TWISTED TAPE INSERT: A REVIEW

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ABSTRACT
Heat transfer augmentation techniques refer to different methods used to increase rate of heat transfer. These techniques broadly are of three types viz. passive, active and compound techniques. The present paper is a review of one of the passive augmentation techniques used in a circular tube which is twisted tape**.** In the present paper emphasis is given to works dealing with twisted tape inserts because according to the recent studies, these are known to be economic tool in the field of heat transfer enhancement. Passive techniques, where inserts are used in the flow passage to increase the heat transfer rate, are advantageous compared with active techniques, because the insert manufacturing process is simple and cheap and these techniques can be easily employed in an existing heat exchanger. The thermohydraulic performance of above inserts depends on the various factors such as flow conditions, geometry of pipe and insert configurations.

KEYWORDS: Heat transfer augmentation technique, Passive methods, Twisted Tape insert

INTRODUCTION
Generally, heat transfer augmentation methods are classified in three broad categories:
(a) Active method: This method involves some external power input for the enhancement of heat transfer; some examples of active methods include induced pulsation by cams and reciprocating plungers, the use of a magnetic field to disturb the seeded light particles in a flowing stream, etc.
(b) Passive method: These methods generally use surface or geometrical modifications to the flow channel by incorporating inserts or additional devices. For example, use of inserts, use of rough surfaces etc.
(c) Compound method: Combination of above two methods

Passive heat transfer augmentation methods:
Passive heat transfer augmentation methods as stated earlier does not need any external power input. In the convective heat transfer one of the ways to enhance heat transfer rate is to increase the effective surface area and residence time of the heat transfer fluids. The passive methods are based on the same principle. Use of this technique causes the swirl in the bulk of the fluids and disturbs the actual boundary layer so as to increase effective surface area, residence time and consequently heat transfer coefficient in existing system.
Following Methods are used generally used,
1. Inserts
2. Extended surface
3. Surface Modifications
4. Use of Additives.

Inserts:
Inserts refer to the additional arrangements made as an obstacle to fluid flow so as to augment heat transfer as explained earlier. Different types of inserts are
1. Twisted tape and wire coils
2. Ribs, Baffles, plates
The present paper Contributes for review of tape inserts.
Twisted tape
Twisted tapes are the metallic strips twisted with some suitable techniques with desired shape and dimension, inserted in the flow. Following are the main categories of twisted tape which are analyzed.

i. Full length twisted tape: These tapes have length equal to length of test section.
ii. Varying length twisted tape: These are distinguished from first category with regards that they are not having the length equal to length of test section, but half length, ¾ th length, ¼ th length of section etc.
iii. Regularly spaced twisted tapes: These are short length tapes of different pitches spaced by connecting together.
iv. Tape with attached baffles: Baffles are attached to the twisted tape at some intervals so as to achieve more augmentation.
v. Slotted tapes and tapes with holes: Slots and holes of suitable dimensions made in the twisted tape so as to create more turbulence.
vi. Tapes with different surface modifications: Some insulating material is provided to tapes so that fin effect can be avoided. In some cases dimpled surfaced material used for tape fabrication.

Common attributes of tape:
i. Width: Small width tapes are preferred to minimize pressure drop.
ii. Thickness: Thickness of the tape plays important role in its fabrication and also has contribution in fin effect
iii. Pitch: It is the distance between two consecutive twists measured axially.
iv Twist ratio: It is the ratio of pitch of tape to tape width. So, if width of the tape considered as a constant (as found generally) twist ratio depends on pitch only. Under this condition if pitch is more it means less number of turns.
v. Fin effect: If the tape material is conductive then during the flow some heat will be absorbed by the tape material itself till its saturation. This is simply the loss of available heat energy.

Review of work carried out:

In the recent years, considerable emphasis has been placed on the development of various augmented heat transfer surfaces and devices. This can be seen from the exponential increase in world technical literature published in heat transfer augmentation devices, growing patents and hundreds of manufacturers offering products ranging from enhanced tubes to entire thermal systems incorporating enhancement technology. Energy and materials saving considerations, space considerations as well as economic incentives have led to the increased efforts aimed at producing more efficient heat exchanger equipment through the augmentation of heat transfer. Among many techniques investigated for augmentation of heat transfer rates inside circular tubes, a wide range of inserts have been utilized, particularly when turbulent flow is considered. The inserts studied included twisted tape inserts, coil wire inserts, brush inserts, mesh inserts, strip inserts, etc.

Dewan et al. [1] has reviewed progress with passive augmentation techniques in the recent past & 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. In the present paper emphasis is given to works with dealing with twisted tapes & wire coils because according to recent studies these are known to be economic heat transfer augmentation tools. Kumar et al. [2] has mainly focused on the twisted tape heat transfer enhancement & it's design modification towards the enhancement of heat transfer & saving pumping power. Rahman et al. [3] studied experimental investigation of heat transfer enhancement through inner grooved copper tubes in a heat exchanger. A series of test were conducted to determine the condensation & evaporation performance of the inner grooved copper tubes namely B3-42 & B16-46 where R-22 was used as refrigerant. The straight & horizontal test section of the apparatus with a length of 3.67m was heated or cooled by water circulated in surrounding annulus. For both condensation & evaporation tests, the heat transfer coefficient & pressure drop are found to increase as the mass flux increases.

Shrivastava et al. [4] has been studied the enhancement in heat transfer for the forced convection condensation of R-22 saturated vapour inside a tube in presence of twisted tape inserts. The test condenser is constituted by four test sections conducted in series. Three twisted tape inserts with the twist ratio 15,9 & 6 were put, one by one, in the test condenser. The insert with twist ratio y of 6 gave the best performance & enhanced average heat transfer coefficient by 25 percent as compared to the plain flow. Sapali et al. [5] experimentally investigated two phase heat transfer coefficients & pressure drops of R-404A in a smooth & micro fin tube. The present experiment is performed for different condensing temperatures. The experimental results from both smooth & micro-fin tubes show that the average heat transfer coefficient & pressure drop increases with mass flux but decreases with increasing condensing temperature. The average heat transfer coefficient is 30-210% higher for micro-fin tube than that of smooth tube, with moderate increase in pressure drop ranging from 10-55%. New correlations based on the data gathered during the experimentation for predicting condensation heat transfer coefficients are proposed for wide range of practical applications.

Sarada et al. [6] has done experimental investigation of the augmentation of turbulent flow heat transfer in a horizontal tube by means of varying width twisted tape inserts with air as the working fluid. In order to reduce excessive pressure drops associated with full width twisted tape inserts, with less corresponding reduction in heat transfer coefficient, reduced width twisted tapes are used. Experiments were carried out for plain tube with/without twisted tape insert at constant wall heat flux & different mass flow rates. Both heat transfer coefficient & pressure drop are calculated & the results are compared with those of plain tube. Shrirao et al. [7] focused on experimental investigation of heat transfer & friction factor characteristics of horizontal circular pipe using internal threads with air as the working fluid. The experimental data obtained were compared with those obtained from plain horizontal pipe. The effects of internal threads of varying depth on heat transfer & friction factor were presented. Based on the same pumping power consumption, the pipe with internal threads possesses the highest performance factors for the turbulent flow.

Murugesan et al. [8] carried out a study of the heat transfer and pressure drop characteristics of turbulent flow in a tube fitted with a full length twisted tape coupled with trapezoidal-cut. The results show that for the twist ratio of 6.0, the mean Nusselt number and fanning friction factor for the trapezoidal-cut twisted tape are 1.37 and 1.97 times over the plain tube, respectively. When the twist ratio reduces to 4.4, the corresponding Nusselt number and fanning friction factor will increased to 1.72 and 2.85 times. These indicate that trapezoidal-cut induces significant enhancement of heat transfer coefficient and friction factor, in addition the impact will be heavier for a lower twist ratio. Kapatkar et. al. [9] investigated heat transfer and friction factor of a plain tube fitted with full length twisted tape inserts for laminar flow. They found that, for the flow in plain tubes, full length twisted tapes yield improvement in average Nusselt number, for Reynolds number range of 200 to 2000.For Aluminum tapes, the maximum improvement in Nusselt number range from 50% to 100%; for Stainless steel tapes, maximum improvement in Nusselt number range from 40% to 94% and for insulated tapes, maximum improvement in Nusselt number range from 40% to 67%. The isothermal friction factor for the flow with the twisted tape inserts are 340% to 750 % higher as compared with those of smooth tube flow, in the given range of twist ratios.

CONCLUSION

A twisted tape insert 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, if no pressure drop penalty is considered. Twisted tape in turbulent flow is effective up to a certain Reynolds number range. It is also concluded that twisted tape insert is not effective in turbulent flow, because it blocks the flow and therefore pressure drop increases. Hence the thermohydraulic performance of a twisted tape is not good in turbulent flow. These conclusions are very useful for the application of heat transfer enhancement in heat exchanger networks.

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