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# REVIEW PAPER ON HEAT TRANSFER ENHANCEMENT IN HEAT EXCHANGER TUBES BY DIFFERENT PASSIVE METHODS

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**Abstact:**

Heat Transfer Enhancement plays important role in heat exchangers of modern process plant equipments. Passive techniques for heat exchangers enhancements are more applicable as there are wide variety of attachments available for heat transfer enhancement. Higher heat transfer co-efficient can be obtained by using different techniquies of heat transfer enhancement, it reduces the required heat transfer area for same amount of heat transfer rate, At the same time these methods leads to higher pressure drop. Some methods of heat transfer enhancement are discussed here.

**Raj M. Manglik et al. [1]**

By generating helical swirling motion inside a tube with a twisted-tape insert, forced convective heat transfer was significantly enhanced. Heat transfer coefficient and friction factor correlations for both laminar and turbulent regimes were presented, and the damping effect of swirl on the transition region was highlighted. In flow boiling with net vapour generation, tape-twist-induced helical swirl pushes liquid droplets from the core to the wall to enhance heat transfer and delay dry out. In sub-cooled boiling, the radial pressure gradient due to the swirl promotes vapour removal from the heated surface to retard vapour blanketing and accommodate higher heat fluxes.

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It was concluded that twisted-tape inserts are a very effective passive enhancement technique for promoting high heat transfer rates in tubes for both single-phase and two-phase flows. In single-phase flow, the primary convection mechanism is the generation of helical swirl or secondary fluid motion that is induced by the helical curvature of the tape insert. This promotes cross-stream mixing and sharper wall gradients, which are further aided by the increased flow velocity due to the tube partitioning and blockage along with an effectively longer helical flow length. The scaling of these phenomena for both laminar and turbulent flow regimes has been delineated along with an evaluation of the transition region, where thedamping effects of tape-generated swirl were highlighted. The nature of swirl, its dimensionless representation, and concomitant development of generalized predictive correlations for heat transfer coefficients and friction factors are discussed wend evaluated.

In sub-cooled boiling, twisted tapes have been shown to be especially effective in elevating the CHF for single-tube water flows and, based on a multi-parameter analysis of experimental data, several correlations are available. Sub-cooled boiling pressure drop serves a critical role in not just the design of the cooling systems, but also in defining a hydrodynamic CHF for multiple, parallel channels that is lower than the single-tube value.

**S. Eiamsa-ard et al. [2]**

Helically twisted tapes were fabricated by twisting a straight tape to form a typical twisted tape then bending the twisted tape into a helical shape. The experiments were performed using HTTs with three twist ratios(y/W) of 2, 2.5 and 3, three helical pitch ratios (p/D) of 1, 1.5 and 2 for Reynolds number between 6000 and20,000. The conventional helical tape (CHT) was also tested for comparison. The obtained results reveal that at similar conditions (y/W and p/D), HTTs give lower Nusselt number and friction but higher thermal performance factor than CHTs. Heat transfer rate and friction factor increase as the tape twist ratio and helical pitch ratio decrease, while the thermal performance shows opposite trend. The highest thermal performance factor of 1.29 was achieved by utilizing the tape with the largest twist ratio (y/W = 3) and helical pitch ratio (p/D = 2) at Reynolds number of 6000.

**Chou Xie Tan et al. [3]**

The study was aimed to empirically investigate the heat transfer enhancement in a tube fitted with a square-cut circular ring insert in the transitional and the fully turbulent flow regimes. By performing an in-depth analysis on the experimental data, the role of insert was quantified by deriving a new non-dimensional group. This new non-dimensional group was proposed to characterize the effect of inserts on the heat transfer enhancement.

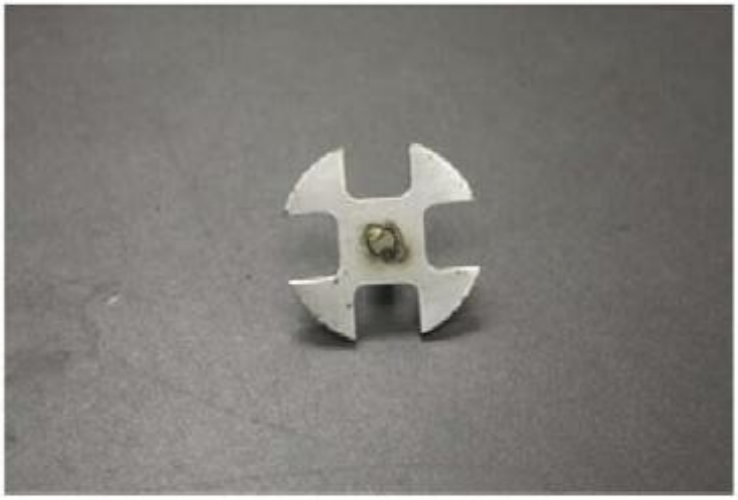

**Fig.2.2 Cross section of a square cut circular ring[13]**

It was concluded that the incorporation of the insert in the flow passage enhances the heat transfer rate, the characteristics of the flow in the transitional and the fully turbulent flow regimes induced by the effect of insert are distinct. The heat transfer augmentation was typically characterized by two pertinent parameters, namely the attendant pressure drop, $\Delta p$, and the accompanying temperature rise from the inlet and the outlet, $\Delta T$. Based on the experimentation of cases with and without insert in the flow passage, besides evaluating the increase in the Nusselt number in the transitional and turbulent flow regimes, a non-dimensional group denoted as transfer number was proposed for evaluating and comparing the importance of the pressure drop and the temperature rise. Significant heat transfer augmentation was observed at low Reynolds number and the heat transfer augmentation decreases with Reynolds number, indicating that the role of the insert becomes less significant when Reynolds number is increased. The physical significance of the transfer number provides a measure of the change of enthalpy relative to the change of flow energy in the flow direction. The transfer number can be used to explain the decrease of heat transfer augmentation in the turbulent flow regime relative to the transitional flow regime. By comparing the magnitude of the change of enthalpy and the change of flow energy, it was observed that the effect of the insert is mainly dominated by the change of enthalpy. Therefore, it can be deduced that the contribution of the change of flow energy and hence the pressure drop in the heat transfer augmentation is marginal albeit not negligible compared to the temperature rise which is the dominant parameter in the characterization of the heat transfer augmentation using an insert.

**Sujoy Kumar Saha et al. [4]**

The experimental friction factor and Nusselt number data for a laminar flow through a circular duct having axial corrugation and fitted with helical screw-tape inserts were presented. The thermo hydraulic performance has been evaluated.

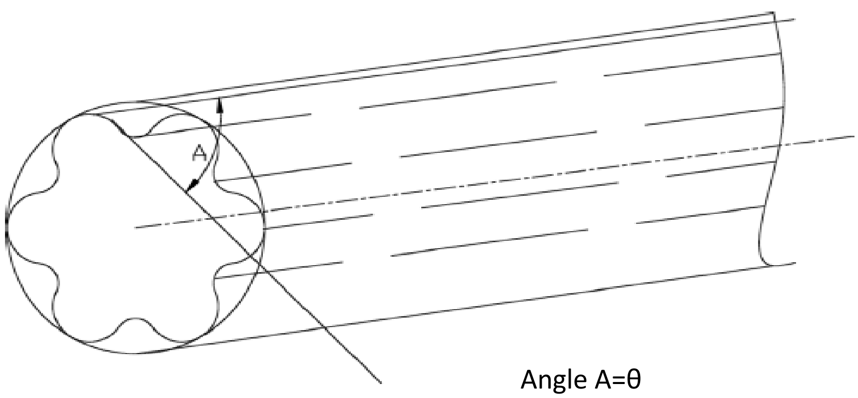


**Fig.2.3 Axial corrugated circular duct[14]**

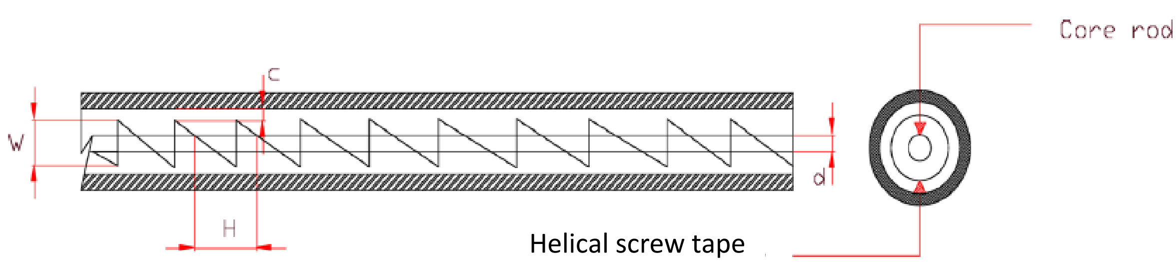


**Fig. 2.4 Helical screw tape[14]**

Both the friction factor and the Nusselt number decrease with a decrease in the value of p, i.e., initially, the screw-tape parameter; however, after p=0.31 and with a further decrease of p, no appreciable changes in the friction factor occur; however, the Nusselt number further decreases to a large extent. With the appreciable reduction in the screw-tape parameter value, the hydrodynamic boundary layer shape and thickness do not appreciably change, whereas the thermal boundary layer shape and thickness continue to change. The velocity profile does not become shallower, whereas the temperature profile becomes shallower. The friction factor increases by 10–30% with the combined use of corrugations and helical screw-tape, as compared to the separate cases of corrugations and helical screw-tape.

An approximately 25–65% increase in the Nusselt number is observed. Both the friction factor and Nusselt number behave similarly, i.e., they increase with the increase in the corrugation angle and they decrease with the increase in the corrugation pitch. The friction factor and Nusselt number are strong functions of the corrugation angle and corrugation pitch.

The major findings of this experimental investigation are that the helical screw-tape, in combination with axial corrugation, performs better than the individual enhancement technique acting alone for a laminar flow through a circular duct.

**M.A. Akhavan-Behabadi et al. [5]**

An experimental investigation was carried out to study the enhancement in heat transfer coefficient by coiled wire inserts during heating of engine oil inside a horizontal tube. The test-section was a double-pipe counter-flow heat exchanger. The engine oil flowed inside the internal copper tube, while saturated steam, used for heating the oil, flowed in the annulus. The data were acquired for the heating of engine oil while flowing in the plain tube. Later, seven coiled wires having pitches of 12–69 mm and wire diameters of 2.0 mm and 3.5 mm were put one by one in the oil-side of test-section. The effects of Reynolds number and coiled wire geometry on the heat transfer augmentation and fanning friction factor were studied. Finally, two empirical correlations have been developed for predicting the heat transfer enhancement of these coiled wire inserts. These correlations predict the experimental Nusselt number in an error band of ±20 percent.

**Haydar Eren et al. [6]**

Heat transfer characteristics of circular coil-spring turbulators were investigated by measuring the wall temperatures on the inner tube of the exchanger. Also the inlet and outlet temperatures and pressure loss of the fluid were measured. These results were parameterized by Reynolds numbers (2500< Re<12,000), outer diameters of the springs (Ds= 7.2 mm, 9.5 mm, 12 mm, and 13 mm), numbers of the springs (n= 4, 5, and 6), and the incline angles of the springs (θ=0˚, 7˚ and 10˚).

Springs were located along the inner tube of a heat exchanger. These springs behave like turbulators and hence, cause some heat transfer enhancement. The major results of the experiments were:

- Turbulators not only produce more turbulence than the smooth tube but also increase heat transfer area.
- Incline angle of the coil-springs stated along the tube has an impetus on heat transfer and pressure loss. For the smallest incline angle of the springs $\theta$ =0 deg heat transfer and friction factor have the lowest values, while for $\theta$ =10 deg the heat transfer and friction factor have the highest values.
- Second the diameter of the springs has a great effect on heat transfer and friction loss. Increasing the diameter causes significant increases in heat transfer and friction loss.
- The heat transfer and friction factor increase with increasing spring numbers, n, but the effect of n is not as powerful as the effects of diameter and incline angle.
- Heat transfer increases with increasing Re. However, the friction loss also increases.

**İrfan Kurtbaş et al. [7]**

A novel conical injector type swirl generator (CITSG) was examined in this study. Performances of heat transfer and pressure drop in a pipe with the CITSG were experimentally examined for the CITSGs' angle (α) of 30°, 45° and 60° in Reynolds number (Re) range of 10,000–35,000. Circular holes with different numbers (N) and cross-section areas (Ah) were drilled on the CITSG. In this way, total areas (At= N· Ah) of the holes on the CITSG were equaled each other. Besides, flow directors having three different angles (β=30°, 60° and 90°) to radial direction are attached to every one of the holes. This study was a typical example for decaying flow. All experiments were conducted with air accordingly; Prandtl number was approximately fixed at 0.71. The local Nusselt number ($Nu_x$), heat transfer enhancement ratio ($Nu_{er}$) and heat transfer performance ratio ($Nu_{pr}$) are calculated. It was found that the $Nu_{er}$ decreases with increase in

Reynolds number, the director angle (β), the director diameter (d), and with decrease in the CITSG angle (α).

**Nasiruddin, M.H. Kamran Siddiqui [8]**

Heat transfer enhancement in a heat exchanger tube by installing a baffle was investigated. The effect of baffle size and orientation on the heat transfer enhancement was studied in detail. Three different baffle arrangements were considered. The results showed that for the vertical baffle, an increase in the baffle height causes a substantial increase in the Nusselt number but the pressure loss was also very significant. For the inclined baffles, the results show that the Nusselt number enhancement was almost independent of the baffle inclination angle, with the maximum and average Nusselt number 120% and 70% higher than that for the case of no baffle, respectively. For a given baffle geometry, the Nusselt number enhancement was increased by more than a factor of two as the Reynolds number decreased from 20,000 to 5000.Simulations were conducted by introducing another baffle to enhance heat transfer. The results showed that the average Nusselt number for the two baffles case was 20% higher than the one baffel case and 82% higher than the no baffel case. The above results suggested that a significant heat transfer enhancement in a heat exchanger tube can be achieved by introducing a baffle inclined towards the down streamside, with the minimum pressure loss.

Conclusions:

1. Twisted tape inserts are very effective passive enhancement technique for high heat transfer rates for single phase and two phase flows.
2. For similar conditions Helically twisted tapes gives lower Nusset number and friction factor but higher thermal performance factor compared to conventional helical tapes
3. By using a square cut circular ring insert significant heat transfer augmentation was observed at lower Reynolds number and heat transfer augmentation decreases at high Reynolds number.
4. By using Helical screw tape inserts with axial corrugation 25-65% rise in Nusset number can be achieved at different flow conditions. Friction factor varies from 10-30%.
5. Coiled wire inserts of different wire diameters and different pitches play important aole in oil side heating for engine oil circuit.

6. Coil spring tabulators can be used as effective heat transfer augmentation device. The important parameters are Reynolds number, outer diameter of springs and inclined angle of spring.

7. With conical injector type swirl generator Nusselt number decreses with increase in Reynolds number, the director angle and director diameter

8. Significant heat transfer enhancement can be achieved by introducing a baffle inclined towards the down stream side with minimum pressure loss.

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