HEAT TRANSFER ENHANCEMENT BY SWIRL FLOW DEVICES

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Abstract

Heat transfer augmentation techniques refer to different methods used to increase rate of heat transfer without affecting much the overall performance of the system. 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. Twisted-tape is one of the most important members of enhancement techniques, which employed extensively in heat exchangers. Twisted tapes are the metallic strips twisted with some suitable techniques with desired shape and dimension, inserted in the flow. This paper demonstrates the various studies on twisted tapes inserts.

Key words: Heat transfer augmentation, Thermohydraulic performance, Twisted tape, Wire coil

I. INTRODUCTION

The process of improving the performance of a heat transfer system or increase in heat transfer coefficient is referred to as heat transfer augmentation or enhancement. This leads to reduce size and cost of heat exchanger. An increase in heat transfer coefficient generally leads to additional advantage of reducing temperature driving force, which increases second law efficiency and decreases entropy generation. General techniques for enhancing heat transfer can be divided in three categories. One is passive method such as twisted tapes, helical screw tape inserts, rough surfaces, extended surfaces, additives for liquid and gases. The second is active method, which requires extra external power, for example mechanical aids, surface fluid vibration, use of electrostatic fields. Passive methods are found more inexpensive as compared to other group.

Twisted tape is one of the most important members useful in laminar flow from this group. Twisted Tape Twisted tape inserts increases the heat transfer coefficients with relatively small increase in the pressure drop.

They are known to be one of the earliest swirl flow devices employed in the single phase heat transfer processes. Because of the design and application convenience they have been widely used over decades to generate the swirl flow in the fluid. Size of the new heat exchanger can be reduced significantly by using twisted tapes in the new heat exchanger for a specified heat load. Thus it provides an economic advantage over the fixed cost of the equipment. Twisted tapes can be also used for retrofitting purpose. It can increase the heat duties of the existing shell and tube heat exchangers. Twisted tapes with multitube bundles are easy to fit and remove, thus enables tube side cleaning in fouling situations. Inserts such as twisted tape, wire coils, ribs and dimples mainly obstruct the flow and separate the primary flow from the secondary flows. This causes the enhancement of the heat transfer in the tube flow. Inserts reduce the effective flow area thereby increasing the flow velocity. This also leads to increase in the pressure drop and in some cases causes' significant secondary flow. Secondary flow creates swirl and the mixing of the fluid elements and hence enhances the temperature gradient, which ultimately leads to a high heat transfer coefficient.

In general, swirl flow generators are placed in the flow passage to augment the heat transfer rate, and this reduces the hydraulic diameter of the flow passage. Heat transfer enhancement in a tube flow by inserts such as twisted tapes, screw tape is mainly due to flow blockage, partitioning of the flow and secondary flow. Flow blockage increases the pressure drop and leads to increased viscous effects because of a reduced free flow area. Blockage also increases the flow velocity and in some situations leads to a significant secondary flow. Secondary flow further provides a better thermal contact between the surface and the fluid because secondary flow creates swirl and the resulting mixing of fluid improves the temperature gradient, which ultimately leads to a high heat transfer coefficient. Fig. 1 shows a typical configuration of twisted tape which is used commonly.

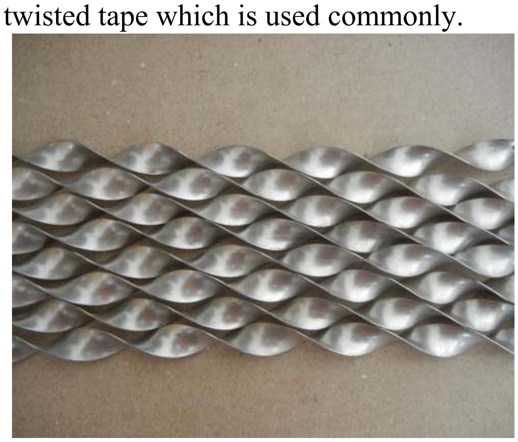

Fig. 1 : Twisted Tape

II. REVIEW OF LITERATURE

Shaha and Dutta [11] reported experimental data on twisted tape generated laminar swirl flow friction factor and Nussult number for a large Prandle number (205<Pr< 518) and observed that on the basis of constant pumping power short length twisted tape is good choice because in this case swirl generated by the twisted tape decays slowly down streams which increases the heat transfer coefficient with minimum pressure drop as compared to full length twisted tape. Fig. 2 shows the different types of twisted taps. Manglik and Bergles [12] considered twisted tape with twist ratio (3, 4.5 and 6.0) using water (3.5<Pr<6.5) and proposed correlation for Nussult number and friction factor and reported physical description and enhancement mechanism. Loknath [13] reported experimental data on water (240<Re<2300, 2.6<Pr<5.6) of laminar flow through horizontal tube under uniform heat flux condition and fitted with half-length twisted tape. He found that on the basis of unit pumping power and unit pressure drop half-length twisted tape is more efficient than full length tape. Shaha and Chakraborty [14] found that laminar flow of water (145<Re<1480, 4.5<Pr<5.5, tape ratio 1.92<y<5.0) and pressure drop characteristics in a circular tube fitted with regularly spaced, there is drastic reduction in pressure drop corresponding reduction in heat transfer. Thus it appears that on basis of constant pumping power a large number of turn may yield improved thermo hydraulic performance compared with single turn on twisted tape. Royds [15] reported that A tube inserted with twisted tape performs better than plain tube and twisted tape with tight twist ratio provides better heat transfer at a cost of increase in pressure drop for low Prandle number fluid. This is due to the small thickness of thermal boundary layer for low Pradle number fluid and tighter twist ratio disturb entire thermal boundary layer thereby increasing heat transfer with increase in pressure drop. Date [16] reported that friction and Nu for water flow in tube containing twisted tape deviate 30 percent than experiment with plain tube. Klaczak [17] found usefulness of short length twisted tape with water (1300<Re <8000) than full length twisted tape. Al-fahed et al. [18] found that there is an optimum tape width depending upon twist ratio and Re for best thermodynamic characteristics for full length tape with water. Manglik and Bergles [19] developed correlation for both lamina and turbulent flow (3.5<Pr<6.5) with tape but shows that correlation for laminar turbulent transition need to be developed with water. For more details readers can referee Waghole et al. [20].

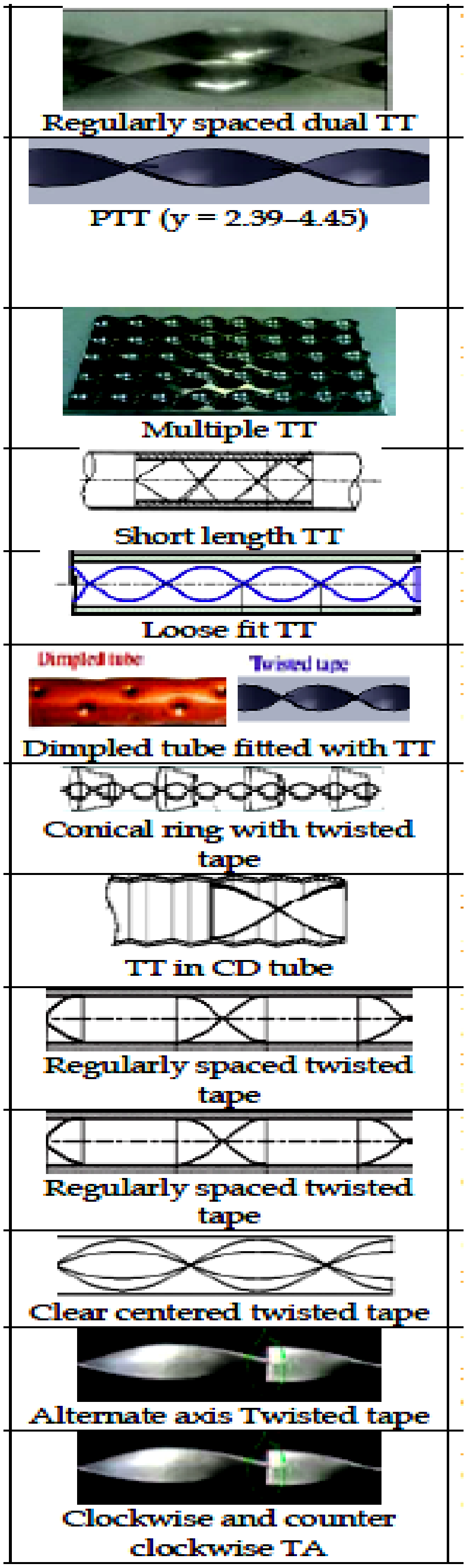

Fig. 2 : Different Types of Twisted Tap.

Several investigations have been carried out to study the effect of turbulators (turbulent promoters)with different geometries on thermal behaviors in the heat exchanger, for example twisted-tapes [21,22], wirecoils [23,24], dimpled or grooved tubes [25,26], winglet/fins [27,28], and combined turbulators. However, twisted tapes as one of passive turbulators have been applied extensively to enhance convection heat transfer in heat exchanger systems due to the need for finding the way to reduce the size and cost of those systems. For decades, the heat transfer enhancement by twisted-tape insert has been widely investigated both experimentally and numerically. Krishna et al. [29] experimentally investigated the heat transfer characteristics in a circular tube fitted with straight full twist insert with different spacer distances. Influence of the tube equipped with the short-length twisted tape on Nu, f and thermal performance characteristics for several tape-length ratioswas examined by Eiamsa-ard et al. [30]. The effect of twisted tape consisting wire-nails and plain twistedtapes with three different twist ratios fitted in a heat exchanger pipe using water as the test fluid on thermal characteristics was studied experimentally by Murugesan et al. [31]. Liao and Xin [32] reported the heat transfer behaviors in a tube with three-dimensional internal extended surfaces and twisted-tape insertswith variousworking fluids. Chiu and Jang [33] presented the experimental and numerical analyses on thermal–hydraulic characteristics of air flow inside a circular tube with 5 different tube inserts; longitudinal strip inserts both with/without holes and twisted-tape inserts with three different twist angles for inlet velocity ranging from 3 to 18 $m \cdot s^{-1}$. Eiamsa-ard and Promvonge [34] conducted an experimental study on turbulent flow and heat transfer characteristics in a tube equipped with two types of twisted tapes: (1) typical twisted tapes and (2) alternate clockwise and counterclockwise twisted-tapes. Nine different clockwise and counterclockwise twisted-tapes were tested in that work and included the tapes with three twist-ratios and three twist-angles. The experiments were performed for Reynolds number of 3000 to 27000 using water as working fluid. The twin and triple twisted tapes used to generate twin and triple swirl flows in a circular tube were reported by Chang et al. [35].

III. Conclusion

Heat exchanger as equipment to facilitate the convective heat transfer of fluid inside tubes is frequently utilized in many industrial applications, such as chemical engineering process, heat recovery, air conditioning and refrigeration systems, power plant and radiators for automobiles. In general, heat transfer enhancement in heat exchangers can be divided into two methods. One is the active method requiring extra external power sources such as fluid vibration, injection and suction of the fluid, jet impingement and electrostatic fields. The other is the passive method that requires no other power source. The devices in this category are surface coating, rough surfaces, turbulent/swirl flow devices, extended surfaces etc.

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.

A twisted tape mixes with bulk flow and arebetter for laminar flow than any other inserts. However twisted tape inserts performance also depends fluid properties such as Prandtle number .If the Prandtle number is high (Pr>30) twisted tape will not provide good thermo hydrodynamic performance compared with other inserts such as wire coil inserts.

This helical screw tape can help to promote higher heat transfer exchange rate than the use of twisted-tape because of shorter pitch length which leads to stronger swirling flow and longer residence time in the tube. Because of lower pressure drop and ease of manufacturing, the twisted-tape is, in general, more popular than the helical screw-tape having a higher heat transfer rate at the same mass flow rate. However, at low values of Reynolds number the pressure drops for using both tapes are not much different. Heat transfer of square tubes was found considerably higher than the circular tube. This is mainly because of square duct has high surface to volume ratio.

The combined use of full-length twisted-tape and transverse ribs enhances the thermohydraulic performance of the square and rectangular ducts compared to the use of only twisted-tape or only transverse ribs for laminar flow. The short-length twisted tape in square and rectangular ducts performs worse than the full-length twisted tape. However, regularly spaced twisted-tapes perform significantly better than the full-length twisted tapes.

This review paper discusses the considerable experimental work which has been done on heat transfer augmentation using twisted tape inserts. This paper reviews the investigation carried out by various researches in order to enhance the heat transfer, nusselt number, and friction factor by the use of twisted tapes inserts of different shapes, sizes and orientation.

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