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Review Article

EFFECT OF TWISTED-TAPE INSERTS ON HEAT TRANSFER IN A TUBE—A REVIEW

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The development of high-performance thermal systems has increased interest in heat transfer enhancement techniques. Heat transfer augmentation techniques refer to different method used to increase rate of heat transfer without affecting much the overall performance of the system. Heat exchangers are widely used in industry both for cooling and heating. Creation of turbulence with the help of twisted tape in the flow passage is one of the favorable passive heat transfer augmentation techniques due to their advantages of easy fabrication, operation as well as low maintenance. The purpose of this review presents the effect of twisted tape inserts on the heat transfer enhancement, pressure drop, flow friction and thermal performance factor characteristics in a heat exchanger tube.

Keywords: Heat transfer, Twisted tape inserts, Flow friction, Turbulance, Swirl flow motion

INTRODUCTION

Heat transfer enhancement or augmentation techniques refer to the improvement of thermo hydraulic performance of heat exchangers. Among many techniques (both passive and active) investigated for augmentation of heat transfer rates inside circular tubes, a wide range of inserts have been utilized, particularly when turbulent flow is considered. A lot of methods are applied to increase thermal performance of heat transfer devices such as treated surfaces, rough surfaces, swirling flow devices, coiled tubes, and surface tension devices. Furthermore, as a heat exchanger becomes older, the resistance to heat transfer increases owing to fouling or scaling. These problems are more common for heat exchangers used in marine applications and in chemical industries. In some specific applications, such as heat exchangers dealing with fluids of low thermal conductivity (gases and oils) and desalination plants, there is a

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need to increase the heat transfer rate. The heat transfer rate can be improved by introducing a disturbance in the fluid flow (breaking the viscous and thermal boundary layers), but in the process pumping power may increase significantly and ultimately the pumping cost becomes high. Therefore, to achieve a desired heat transfer rate in an existing heat exchanger at an economic pumping power, several techniques have been proposed in recent years and are discussed in the following sections.

Types of Heat Transfer Augmentation Techniques

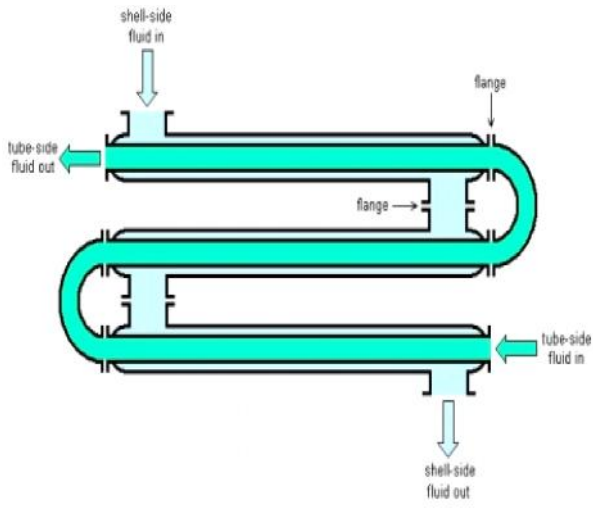
Active Techniques: These techniques are more complex from the use and design point of view as the method requires some external power input to cause the desired flow modification and improvement in the rate of heat transfer. It finds limited application because of the need of external power in many practical applications. In comparison to the passive techniques, these techniques have not shown much potential as it is difficult to provide external power input in many cases. Various active techniques are as follows:

1. Mechanical Aids
2. Surface vibration
3. Fluid vibration
4. Electrostatic fields
5. Injection
6. Suction

Passive Techniques: These techniques 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 behavior (except for extended surfaces) which also leads to increase in the pressure drop. In case of extended surfaces, effective heat transfer area on the side of the extended surface is increased. Passive techniques hold the advantage over the active techniques as they do not require any direct input of external power. 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 generally used,

1. Treated Surfaces
2. Rough surfaces
3. Extended surfaces
4. Swirl flow devices
5. Coiled tubes

Figure 1: Double Pipe Heat Exchanger



Note: Inside hot water and outside cold water.

Compound Techniques: When any two or more techniques employed simultaneously or compoundly to obtain enhancement in heat transfer is termed as compound enhancement technique. The rate of heat transfer in case of compound technique is greater than that produced by either of them when used individually. The Compound techniques are

1. Extended surfaces that are treated,
2. Rough surfaces with additives.

TERMINOLOGIES

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.

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.

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 Twisted Tape.

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

Plain Twisted Tape

The heat transfer coefficient and flow friction characteristics in a concentric double pipe heat exchanger can be studied by introducing the swirling floe with the help of twisted tape placed inside the inner test tube of the heat exchanger with different twist ratios, y = 5.0 and 7.0. It is found that the increase in heat transfer rate of the twisted-tape inserts is found to be strongly influenced by tape-induced swirl or vortex motion. Over the range investigated, the maximum Nusselt numbers for using the enhancement devices with y = 5.0 and 7.0 are 188% and 159%, respectively, higher than that for the plain tube. The enhancement efficiency and Nusselt number increases with decreasing the twist ratio and friction factor also increases with decreasing the twist ratio. The partitioning and blockage of the tube flow cross-section by the tape, resulting in higher flow velocities. Secondary fluid motion is generated by the tape twist, and the resulting twist mixing improves the convection heat transfer (Watcharin Noothong *et al.*, 2006). Similarly, In order to reduce excessive pressure drops associated with full width twisted tape inserts, with less corresponding reduction in heat transfer coefficients, reduced width twisted tapes of widths ranging from 10 mm to 22 mm, which are lower than the tube inside diameter of 27.5 mm can be used. The twisted tape with three different twist ratios (3, 4 and 5) each with five different widths (26-full width, 22, 18, 14 and 10 mm) respectively. With this varying width twisted tape the reynolds number varied from 6000 to 13500 and the enhancement of heat transfer with twisted tape inserts as compared to plain tube varied from 36 to 48% for full width (26 mm) and 33 to 39% for reduced width (22 mm) inserts (Naga Sarada *et al*., 2010).

Investigation of the swirl flow behavior and the laminar convective heat transfer in a circular tube with twisted-tape inserts for the stainless steel strip of length 125 cm, width 16 mm and thickness 1.80 mm can be used. Also by drilling the holes at both ends of every tape so that the two ends could be fixed to the metallic clamps. During the whole operation the tape was kept under tension by applying a mild pressure on the tool post side to avoid its distortion. Three tapes with varying twist ratios were fabricated (yw = 5.25, yw = 4.39, yw = 3.69). It was observed that heat transfer coefficients and friction factor increases with decreasing twist ratio (Rahul Kumar and Srinivas, 2013). The effect of different twisted ratio inserts on double pipe heat exchanger with and without twisted tape insert with oil and water as working medium had been carried out with two different twist ratio of 3.5 and 7. The twisted tape of lower twist ratio (y = 3.5) gives higher heat transfer coefficient (by 1.39 times) than higher twist ratio (y = 7). When only heat transfer capacity of heat exchanger is criteria regardless of pressure drop or pumping power the twisted tape is more superior as compared with smooth tube (1.6 to 1.8 times) (Pardhi and Prasant Baredar, 2012).

Modified Twisted Tape

The heat transfer enhancement can be achieved by using different twist geometries and with different twist ratios. The swirling flow can be introduced also using half-length twisted tape placed inside the inner test tube of the heat exchanger. Heat transfer rate of the twisted-tape inserts is found to be strongly influenced by tape-induced swirl or vortex motion. The heat transfer coefficient is found to increase by 40% with half-length twisted tape inserts when compared with plain heat exchanger. On the basis of equal mass flow rate, the heat transfer performance of half-length twisted tape is better than plain heat exchanger, and on the basis of unit pressure drop the heat transfer performance of smooth tube is better than half-length twisted tape (Anil Singh Yadav, 2009). Similarly the valve of heat transfer and friction factor of double pipe heat exchanger can be improved with help of Reduced Width Twisted Tape (RWTT), Baffled Reduced Width Twisted Tape (BRWTT1) and Baffled Reduced Width Twisted Tape with holes (BRWTT2) with three tapes of different twist ratio (yw = 3.69, yw = 4.39, yw = 5.25). Based on constant flow rate, the heat transfer coefficient were found to be 1.18-3.66, 2.61-7.07 and 3.58-8.08 times the smooth tube values for RWTT, BRWTT1 and BRWTT2 respectively. Baffled Reduced width twisted tape and Baffled Reduced width twisted tape with holes performs much better than the Reduced Width Twisted Tapes (RWTT) of the same twist ratio [6]. Experimental investigation of heat transfer and friction factor characteristic of double pipe heat exchanger fitted with twisted wire mesh for twist ratio 7.0 and 5.0 carried out for turbulent flow. Heat transfer coefficient and friction factor increases with the decrease in twist ratio compared with plane tube. Twisted wire mesh for twist ratio 7.0 and 5.0 augment the heat transfer rate 2.09 and 1.69 times compared with the plane tube. The performance ratio for twisted wire mesh is greater than one therefore enhancement is competent in the point of energy saving. It was found that the twisted wire mesh proves to be a better insert than conventional twisted tape (Veeresh Fuskele and Sarviya, 2012).

Investigation carried out to find the overall performance of suitably designed. The full length, tape with hole, tape with baffles in a concentric tube heat exchanger with twist ratio of each 6. The full length twisted tape increases heat transfer by a percentage of 8.9%. The heat transfer coefficient of twisted tape with holes and baffles were less as compared to full twisted tape (Maughal Ahmed Ali Baig *et al.*, 2013). The plain tube with/ without wavy twisted tape with wave-width of 13, 16 and 24 mm of same pitch insert at constant wall heat flux and different mass flow rates. Highest Nusselt number was obtained for tape with wave-width 13 mm. the percentage rise in Nusselt numbers for wavy twisted tapes compared to plain tube are about 32-98%, 31-89% and 26-87% for tape with wave-widths of 13, 16 and 24 mm respectively for twist ratio = 9.375. This is due to strong turbulence intensity generated by corrugations on inserts leading to rapid mixing of the flow causing heat transfer enhancement. It is observed that the reduction in wave-width causes increment in Nusselt numbers as well as rise in pressure drop (Dhamane *et al.*, 2014). The heat trsnsfer rate can be augmented with the help of rod-pin inserted at different distance of 50 mm, 100 mm, 150 mm along the length of tube. Comparing the results obtained from these two different sets of experiments, it is found that heat transfer through tube can be enhanced by using inserts inside the tube up to 9.8 times than tube without insert. It was also concluded that the heat transfer coefficients increases up to 4.1 times when x = 50 mm (distance between inserts), 4.2 times when x = 100 and 4.4 times when x = 150 mm as compared to smooth tube (Chowdhuri *et al.*, 2011).

Flow characteristics induced by twisted tape consisting of alternate-axis (TA) has been comparatively investigated to that induced by typical Twisted Tape (TT). The effects of twist ratios (y/W = 3, 4, 5) on heat transfer and fluid friction were also extensively examined. It is concluded that TA give better fluid mixing and thus higher heat transfer rate than TT which leads to higher heat transfer rate and also friction factor at similar conditions. In addition, swirl number and thus residence time of a fluid flow is promoted as tape twist ratio decreases, this result is consistent with the superior heat transfer at smaller twist ratio. At the same axial distance, the tape with smaller twist ratio provides more swirl number and thus longer residence time which help to prolong heat transfer between tube wall and fluid (Panida Seemawute and Smith Eiamsa-Ard, 2012).

Heat transfer and friction factor characteristics were studied for water flowing through the tube in tube heat exchanger. There were two different configurations, namely twisted tape with pins and Twisted Tape with Pins Bonded (TTPB) to the inner surface of the test section with (y/w = 3.33, 4.29). The effect of twisted tape with pins on the heat transfer for a fully developed turbulent flow by maintaining constant wall temperature, shows that friction factor for the tube fitted with twisted tape pin bonded inserts gives a higher reynolds number when compared with plain tube. It indicates that friction factor for a given Reynolds number increases with the decreasing y/w ratio due to swirl flow generated by TTPB and reaches the maximum for y/w = 3.33. It was observed that the friction factor for y/w = 4.29 are less when compared with y/w = 3.33 (Swaminathan Selvam *et al.*, 2014).

With copper square jagged Twisted tape twisted tape inserts 3 mm with 5.2, 4.2 and 3.2 twists ratio respectively. The inserts when placed in the path of the flow of the fluid, create a high degree of turbulence resulting in an increase in the heat transfer rate and the pressure drop. The results of varying twists in square jagged tape with different pitches have been compared with the values for the smooth tube. The 3 mm thick with 3.2 twists copper insert shows increase in Nusselt number values by 76% however there is increase in friction factor by only 19.5% as compared to the smooth tube values (Gawandare *et al.*, 2014).

Similarly by providing opposite and parallel wings to the at different wing shapes triangle (Tri), rectangular (Rec) and trapezoidal (Tra) wings and on the thermo hydraulic performance characteristics can be improved. By maintaining a constant wall heat flux condition by wrapping nichrome wire around the test section while the Reynolds numbers were varied between 5200 and 20,000 for all tape inserts. The modified twisted tape with three different wing chord ratios (D/W) of 0.1, 0.2 and 0.3 at constant twist ratio (y/W) of 4.0. The thermal performances of the tubes containing the twisted tapes with alternate-axes and wings (as modified twisted tapes) are compared with those of the tube with the typical twisted tape (TT) and also the plain tube. At similar conditions, the heat transfer rate and pressure drop in the tubes with the modified twisted tapes are consistently higher than those in the tube with TT and the plain tube. The thermal performance of the tube with modified twisted tapes with different wing-shape arrangements is superior to that of the tube with TTs. In addition, the tapes with opposite wing arrangement of O-Tra, O-Rec and O-Tri give superior thermal performances to those with parallel wing arrangement of P-Tra, P-Rec and P-Tri around 2.7%, 3.5% and 3.2%, respectively (Eiamsa-ard *et al.*, 2014). By using nanofluid as working medium with twisted-tape in a double pipe heat exchanger, the heat transfer rate can be enhanced. Comparison were made between Water in plain tube, Nanofluid in a plane tube and nanofluid with twisted tape insert in a tube. Titanium dioxide nanoparticles with a diameter of 30 nm and a volume concentration of 0.01% (v/v) were used with twist ratio of y = 3.5. By using twisted tape and nanofluid, heat transfer coefficient was about 10% to 25% higher than water used with plane tube. It was concluded that 0.01% TiO_2/water nanofluid with twisted tape has slightly higher friction factor and pressure drop when compared to 0.01% TiO_2/water nanofluid without twisted tape (Heydar Maddah *et al.*, 2014).

CONCLUSION

This review has considered heat transfer and pressure drop investigations of the various types of twisted tape placed in heat exchangers. By insertion of twisted tape the variation of Nusselt number with Reynold's number in the tube. The values of nusselt number, Reynolds number, prandtl number, pressure drop and friction factor are depends on the geometrics of the twisted tape with different twist ratio, pitch ratio, tape width, space ratio, phase angle, wire diameter, etc.

Heat transfer rate with typical twisted tape is higher than that of plain tube also this device that turns laminar flow into turbulant flow. The conclusions are very useful for the application of heat transfer enhancement in heat exchanger networks.

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