Review of Heat Transfer Enhancement Using Passive Techniques in Different Type of Twisted Tapes in Circular Tube

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Abstract— Heat transfer enhancement techniques refer to different methods used to increase rate of heat transfer without affecting much the overall performance of the system. Heat transfer enhancement is the process of modifying a heat transfer surface to increase the heat transfer coefficient between the surface and a fluid. A majority of heat exchangers used in thermal power plants, chemical processing plants, air conditioning equipment, and processing plants, air conditioning equipment, and refrigerators, petrochemical, biomedical and food processing plants serve to heat and cool different types of fluids. This review paper based on different type of twisted tape and their different orientation or arrangements. In the present paper stress is given on to work dealing with displaced insert into circular tubes (twist tap insert, screw tap insert, helical tap insert, wire mesh tape insert) and CFD based analysis in laminar and turbulent flow. According to recent studies these are known to be economic heat transfer enhancement tools.

Key words: CFD Analysis, Heat transfer enhancement technique, Passive methods, Tape inserts

I. INTRODUCTION

Heat exchangers are used in different processes ranging from conversion, utilization and recovery of thermal energy in various industrial, commercial and domestic applications. Some common examples include steam generation and condensation in power and cogeneration plants, sensible heating and cooling in thermal processing of chemical, pharmaceutical and agricultural products, fluid heating, petrochemical, biomedical and food processing plants serve to heat and cool different types of fluids. Both the mass and overall dimensions of heat exchangers employed are continuously increasing with the unit power and the volume of production. Different techniques are employed to enhance the heat transfer rates, which are generally referred to as heat transfer enhancement, augmentation or intensification technique. Whereas, the active techniques need some power externally, such as electric or acoustic fields, surface vibration, mechanical aid, fluid vibration, injection, suction, jet impingement, etc. Some new techniques like CFD analysis are used because this provides qualitative and sometimes even quantitative prediction of fluid flows by means of, mathematical modeling (partial differential equations) numerical methods (discretisation and solution techniques) , software tools (solvers, pre and post processing utilities) CFD enables to perform numerical experiments.

II. CLASSIFICATION OF ENHANCEMENT TECHNIQUES

- Passive Technique
- Active Technique
- Compound Techniques

A. *Passive Technique:*

Passive techniques do not require any direct input of external power. They generally use geometrical or surface modifications to the flow channel by incorporating inserts or additional devices. Except for the case of extended surfaces, they promote higher heat transfer coefficients by disturbing or altering the existing flow behavior.

B. *Active Technique:*

In these cases, external power is used to facilitate the desired flow modification and the concomitant improvement in the rate of heat transfer. Augmentation of heat transfer by this method can be achieved by mechanical aids, surface vibration, and electrostatic fields, etc.

C. *Compound Technique:*

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. This technique involves complex design and hence has limited applications.

III. REVIEW

A. *Twisted tape swirl generators:*

These include a number of geometric arrangements or tube inserts for forced flow that create rotating and or Secondary flow i.e. inlet vortex generators, twisted-tape inserts and axial-core inserts with a screw-type winding etc. To enhance the heat transfer rate, some kind of insert is placed in the flow passages and they also reduce the hydraulic diameter of the flow passages. Heat transfer enhancement in a tube flow blockages, partitioning of the flow and secondary flow. Flow blockages increase the pressure drop and leads to viscous effects, because of a reduced free flow area.

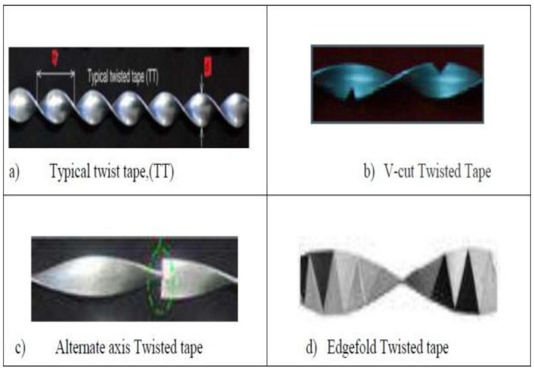

Fig.1: Different types of twisted tapes

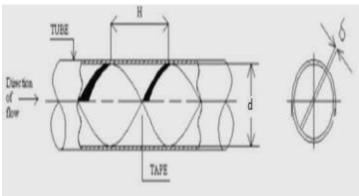

Fig. 2: Diagram of a twisted tape insert inside a tube

B. Twisted tape insert in laminar flow:

Saha et al. [1] found that placing twisted tape concentric to the inside tube gives better heat transfer performance than a twisted tape inserted by a loose fit. Lokanath and Misal [2] studied twisted tapes in shell and tube heat exchanger for different fluids. Their study revealed that twisted tapes of tighter twists are expected to give higher overall heat transfer coefficients. Lokanath [3] investigated the laminar flow experimentally using the tube fitted with half length tapes. He concluded that half length twisted tapes gives better performance than full length twisted tapes on the basis of unit pumping power. AI-Fahed et al. [4] investigated that for high pressure drop and low twist ratio (y = 5.4) and, a loose fit twisted tape is a better option for the heat exchanger owing to it's easy installation and removal for cleaning purposes. For other twist ratios tight fit gives better performance that the loose- fit twisted tapes. Liao and Xin [5] carried out experimental work on compound heat transfer enhancement technique with three dimensional internal extended surfaces by using segmented twisted tape inserts. Results revealed the reduction in the friction factor with small decrease in Stanton number. The Stanton number is the ratio of heat transfer rate to the enthalpy difference and gives a measure of the heat transfer coefficient. Ujhidy et al. [6] proposed a modified dean number for the laminar flow in coils and tubes containing twisted tapes and helical elements. Dean number compensates for the curvature of the coiled tubes or helical elements and gives the measure of the magnitude of the secondary flows. Thermo-hydraulic performance of twisted tape inserts in a large hydraulic diameter annulus was reported by Suresh Kumar et al., [7]. In laminar flow, the dominant thermal resistance is distributed entirely over the cross section of the tube. Thus, a twisted tape insert is more effective than other technique as it mixes the bulk flow. Saha and Chakraborty [8] observed the drastic reduction in the pressure drop compared to the reduction in the heat transfer in their experiment carried out with regularly spaced twisted tapes for laminar flow conditions. It was concluded that for a constant pumping power a large number of turns gives a better thermo-hydraulic performance than the single turn in the twisted tapes. P.Sivashanmugam and S.Suresh [9] investigated heat transfer and friction factor characteristics of circular tube fitted with full length helical screw elements of different twist ratio and helical screw inserts with spacer length 100,200,300,400 mm with uniform heat flux under laminar flow conditions. They found that regularly spaced helical screw elements can safely be used for heat transfer augmentation without much increase in pressure drop than full length helical screw inserts.

S.K.Agarwal and M.Raja Rao [10] experimentally determined 19the isothermal and non-isothermal friction factors and mean Nusselt Numbers for uniform wall temperature heating and cooling of Servotherm oil for flow in a circular tube with twisted tape insert.

C. Twisted tape insert in Turbulent flow:

Ventisislav D.Zimparov, Plamen J.Penchev and Joshua P. Meyer [11] evaluated the performance of angled spiralling tape inserts, a round tube inside a twisted square tube and spiralled tube inside the annulus for enhancement in the annulus side of tube-in-tube Heat exchanger. The results showed that for most of the cases, angled spiralling tube inserts technique is the most efficient.

Watcharin Noothong, Smith Eiamsa-ard and Pongjet Promvonge [12] studied experimentally the effect of twisted tape insert on heat transfer and friction factor characteristics in concentric tube heat exchanger for Reynolds number 2000 to 12000. They found that enhancement efficiency and Nusselt number increases with decreasing the twist ratio and friction factor also increase with decreasing the twist ratio. Smith et. al [13] carried out experimental study on the mean Nusselt number; friction factor and enhancement efficiency characteristics in a round tube with short-length twisted tape insert under uniform wall heat flux boundary conditions for Re 4000 to 20000.

Pongjet Promvonge [14] examined the thermal augmentation in a circular tube with twisted tape and wire coil turbulators for Reynolds Number 3000 to 18000.The report indicate that presence of wire coils together with the twisted tape lead to double increase in the heat transfer over the use of wire coil or twisted tape alone. Smith et. al. [15] investigated the heat transfer enhancement and pressure loss by insertion of single twisted tape, full length dual and regularly spaced dual twisted tapes as swirl generators in round tube under axially uniform wall heat flux conditions. Chinaruk Thianpong et.al. [16] experimentally investigated the friction and compound heat transfer behavior in dimpled tube fitted with twisted tape swirl generator for a fully developed flow for Reynolds number in the range of 12000 to 44000.

D. CFD Based Analysis in Laminar and Turbulent Flow:

CFD is a method to numerically calculate heat transfer and fluid flow. This provides data that is complementary to theoretical and experimental. Computational Flow Dynamics (CFD) investigation for laminar flow and turbulent flow with displaced insert in circular and non circular tubes represented in following section. H.R Rahai and T.W Wong[17] predicted that wire coil with a large pitch spacing increases the mixing, turbulent kinetic energy and half width but decreases the maximum mean velocity. V Kumar and K D P Nigam[18] introduced a device based on the flow inversions by changing direction of centrifugal force in helically coiled tubes. Complete flow fields and thermal fields in helical coil and bent coil configuration were studied using CFD Software (FLUENT 6.0). Three dimensional governing equations for momentum and energy under laminar flow Conditions were solved with a control volume finite difference method (CVFDM) with second order accuracy. Bent coil configuration showed a 20-30% growth in heat transfer due to chaotic mixing while relative pressure drop was found as 5-6%.

S Y Chung and H J Sung[19] investigated a direct numerical simulation for turbulent heat transfer in a concentric annulus (Transverse curvature), and they observed that the thermal structure is more effective near the outer wall than near the inner wall.

V Kumar and K D PNigam[20] studied convective heat transfer in chaotic configuration of circular cross section under laminar flow regime at different values of Dean Number and Prandtl number. Chaotic configuration showed a 25-36% enhancement in heat transfer due to chaotic mixing while relative pressure drop was 5-6%. Under heating condition (temperature-dependent viscosity), heat transfer was found higher in case of chaotic configuration as compared to the cooling condition (constant viscosity).

I Conte and X F Peng[21] performed computer simulations for four rectangular coiled pipes with different angles of straight tube inclination (90, 15, 30 & 45°) at different inlet velocities. Better heat transfer performance was observed for the coil with smaller angle of straight tube inclination.

M Mridha and K P D Nigam[22] investigated turbulent forced convection in a new device of coiled flow inverter and found 4-13% enhancement in heat transfer as compared to straight helical coil while relative pressure drop was found to be 2-9%.

B Zheng et al.[23], studied combined convection and thermal radiation heat transfer in three-dimensional turbulent flow through a helical pipe with finite pitch simulated with CVFDM method. Thermal radiation had no significant influence for flow and temperature fields, especially in a fully developed region but it substantially enhanced total heat transfer in helical pipe. T H Ko[24] studied on laminar forced convection and entropy generation in a helical coil suggested optimal Reynolds number to be chosen as the flow operating condition so that thermal system could have the least irreversibility and best energy utilization Eiamsa-ard et al[25] numerical study in circular tube with turbulent flow and found heat transfer rates for the tube with twisted tape inserted for y/w=2.5 and CR=0.0,0.1,0.2 and 0.3 were respectively,73.6%, 46.6%,17.5% and 20.1% higher than for the plain tube. S.Gulia and A.Parinam[26] numerical study in circular tube with turbulent flow and found heat transfer rates for the tube with twisted tape inserted for y/w=4. The twisted tapes with LR=0.29,0.43,0.57 and 1, heat transfer rate increases 15%,18.8%,22.6% and 31% more than plain tube(fluid-Air). The maximum thermal performance for using LR=0.29, 0.43, 0.57 and 1 is found to be 1.23, 1.3, 1.32 and 1.37,

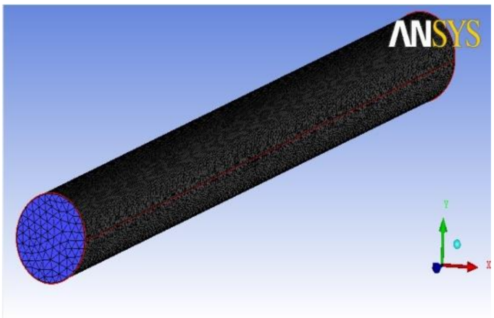

Fig. 3: ICEM Meshing of Plain tube geometry

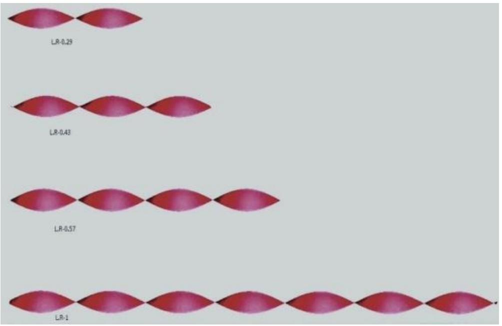

Fig. 4: Diagram of Different-2 length ratio twisted tapes

IV. Conclusion

This review paper discuses the considerable experimental, Numerical and CFD work which has been done on heat transfer augmentation through internal inserts in circular tube.

(1) In Full length twisted tape, Heat transfer rate increases increase in friction factor also observed.
(2) In Short length twisted tape, Low friction factor and low Nusselt number observed As the length of the tape reduces, friction factor reduces and heat transfer co-efficient also reduces.
(3) Twisted tape with uniform pitch, Performs better than gradually decreasing length tape
(4) Twisted tape with gradually decreasing pitch, Poor performance as compared to uniform pitch tape.
(5) 5 Baffled twisted tape with holes, Better Heat transfer rate is observed but as turbulence increases, increase in friction factor is also observed.
(6) Tight fit and lose fit tapes, Tapes having tight fittings give more frictional loss, whereas reduced Width and centrally located loose fit tape gives better result.

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