A REVIEW ON EXPERIMENTAL INVESTIGATION OF AN INNOVATIVE WATER HEATING SYSTEM

Jyoti V. Patil[1], Mr. Prasad P. Patil[2], Prof .HOD. R.Y.Patil[3]

[1] Student (ME), Mechanical Engineering , SGD COE JALGAON, MAHARASTRA,INDIA.
[2] Guide : Assistant professor, Mechanical Engineering, SGD COE JALGAON, MAHARASTRA,INDIA.
[3] H.O.D, Mechanical Engineering, SGD COE JALGAON, MAHARASTRA,INDIA.

Abstract - *Heat transfer augmentation technique (passive, active or as well a combination of passive with active methods) are normally used in area such as development industries, heating plus cooling in evaporators, thermal power plants, air-conditioning equipment, refrigerators, radiators for space vehicles, automobiles, and so on. Passive technique, anywhere insert be use into the flow passageway toward supplement the heat transfer charge, are beneficial compare by means of active techniques, for the reason that the insert manufacturing method is simple as well as these techniques can be easily working in an obtainable heat exchanger. In design of compact heat exchangers, passive techniques of heat transfer augmentation can take part in an vital task if a appropriate passive insert configuration be able to be preferred according to the heat exchanger functioning position. In the ancient times, a number of studies on the passive techniques of heat transfer augmentation have been reported. The current paper is a review on evolution with the passive augmentation techniques in the recent past and will be helpful to designer implementing passive augmentation techniques in heat exchange. Twisted tapes, wire coils, ribs, fins, dimples, and so on., are the mainly used passive heat transfer augmentation tools. In the current paper, highlighting the specified to works dealing with twisted tapes because, according to current studies, these are identified to be cost-effective heat transfer augmentation tools. The previous insert is set up to be appropriate in a laminar flow regime with the latter is right for turbulent flow. In the current paper stress is set on to work dealing with displaced insert into circular tubes (twist tap insert) and CFD based analysis in laminar plus turbulent flow.*

Key Words: CFD Analysis, Heat transfer enhancement technique, Passive methods, Tape inserts, FrictionFactor*.*

1.INTRODUCTION

The economy of any thermal system mainly depends on efficiency of the Heat Exchangers used in it. The efficiency of Heat Exchanger can be raised by using appropriate method of heat transfer augmentation. The method used for heat transfer enhancement should satisfy the condition of maximum heat transfer and minimum pressure drop.

Heat exchangers be used in various process ranging from conversion, utilization and recovery of thermal energy into different industrial, commercial and domestic applications. Some common example consist of 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 type of fluids. Both the mass and overall dimensions of heat exchangers employed are continuously rising with the unit power and the volume of production. Different techniques are in employment to progress the heat transfer rates, which are commonly referred to as heat transfer enhancement, augmentation otherwise intensification technique. Whereas, the active techniques require a little power externally, for example electric or acoustic fields, surface vibration, mechanical aid, fluid vibration, injection, suction, jet impingement, etc. Some latest techniques like CFD analysis are used for the reason that this provides qualitative and sometimes even quantitative prediction of fluid flows by means of, mathematical modeling, numerical method, software tools (solvers, pre and post processing utilities) CFD enables to carry out numerical experiments.

1.1 TERMINOLOGY USED IN TWISTED TAPE

1.1 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 in general used to match up to the performance of different inserts under a particular fluid flow condition.

1.2 Overall Enhancement Ratio

The overall enrichment ratio is stated as the ratio of the heat transfer enhancement ratio to the friction factor ratio.

1.3 Nusselt Number

The Nusselt number is a measure of the convective heat transfer occurring at the surface and is stated as hd/k, where h is the convective heat transfer coefficient, d is the diameter of the tube and k be the thermal conductivity.

1.4 Prandtl Number

The Prandtl number is stated as the ratio of the molecular diffusivity of momentum to the molecular diffusivity of heat.

1.5 Pitch

The Pitch is stated as the distance between two points that are on the same plane, measured parallel to the axis of a Twisted Tape.

1.6 Twist Ratio

The twist ratio is stated as the ratio of pitch length to inside diameter of the tube.

1.2 CLASSIFICATION OF AUGMENTATION TECHNIQUES

In general, heat transfer augmentation technique is classify as in three broad categories:
(a) Active method,
(b) Passive method,
(c) Compound method.
The active and passive methods are described with examples as following subsections. A compound method is a fusion method in which both active and passive methods. The compound method involve complex design moreover hence has limited applications.

[a] Active method

This method involves some external power input for the improvement of heat transfer and has not revealed to a large extent potential owing to complexity in design. Furthermore, external power is not easy to provide in several applications. Some examples of active methods are induced pulsation via cams and reciprocating plungers, the use of a magnetic field to disturb the seeded light particles in a flowing stream, etc.

[b] Passive method

This method does not necessitate any external power input and the additional power required to improve the heat transfer is taken from the available power in the system, which ultimately leads to a fluid pressure drop. The heat exchanger industry have been determined for better thermal contact (enhanced heat transfer coefficient) and reduced pumping power in order to get better the thermo hydraulic efficiency of heat exchangers. A good heat exchanger design should have an efficient thermodynamic performance, that is minimum
production of entropy or minimum destruction of available work (exergy) in a system incorporating a heat exchanger. It is nearly impossible to stop exergy loss totally, but it can be minimized through an efficient design.

[C] Compound Method

When any two or more of these techniques are employing simultaneously to get enhancement in heat transfer that is greater than that produced by either of them when used separately, is stated as compound enhancement. This method contains complex design and that's why has limited applications.

2. REVIEW

An broad literature review of the entire type of heat transfer augmentation technique with external inserts up to 1985 has been discussed by Bergles [1]. In the following sections, literature involving current work on passive heat transfer augmentation techniques by employing twisted tapes, as an insert has been reviewed.

2.1 Twisted tape in laminar flow

Saha et al. [1] searched that placing twisted tape concentric to the inside tube gives better heat transfer performance than a twisted tape inserted by a loose-fitting. Lokanath and Misal [2] studied twisted tapes in shell and tube heat exchanger for various 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 with 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 inside extended surfaces by using segmented twisted tape insert. 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 variation 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 act of twisted tape inserts in a huge hydraulic diameter annulus was reported by Suresh Kumar et al., [7]. In laminar flow, the main thermal resistance is distributed entirely over the cross section of the tube. Therefore, a twisted tape insert is more efficient 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 on a regular basis 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 as well as 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 in laminar flow conditions. They found that regularly spaced helical screw element can securely 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 with mean Nusselt Numbers for uniform wall temperature heating and cooling of Servotherm oil for flow in a circular tube with twisted tape insert.

2.2 Twisted tape insert in Turbulent flow

Ventisislav D.Zimparov, Plamen J.Penchev and Joshua P. Meyer [11] evaluated the working of angled spiralling tape inserts, a circular tube inside a twisted square tube and spiralled tube inside the annulus for improvement 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 adding 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 going on the mean Nusselt number; friction factor and improvement efficiency characteristics in a circular tube with short-length twisted tape insert under identical wall heat flux boundary conditions for Re 4000 to 20000.

Pongjet Promvonge [14] examined the thermal augmentation in a round tube with twisted tape and wire coil turbulators for Reynolds Number 3000 to 18000.The report indicate that existence of wire coils together by the twisted tape lead to double increase in the heat transfer above the use of wire coil otherwise twisted tape alone. Smith et. al. [15] founded the heat transfer enhancement and pressure failure by placing of single twisted tape, full length dual along with regularly spaced dual twisted tapes as swirl generator in circular tube under axially identical wall heat flux situation. Chinaruk Thianpong et.al. [16] Experimentally researched the friction plus compound heat transfer performance in dimpled tube fitted with twisted tape swirl generator intended for a fully developed flow meant for Reynolds number in the range of 12000 to 44000.

2.3 CFD Based Analysis in Laminar and Turbulent Flow

CFD is a process to numerically calculate heat transfer as well as 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 with the aim for 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 base on the flow inversions by changing way of centrifugal force in helically coiled tubes. Whole flow fields and thermal fields in helical coil and bend coil configuration were studied using CFD Software (FLUENT 6.0). Three dimensional governing equations intended to momentum and energy under laminar flow Conditions be solved with a control volume finite variation method (CVFDM) with second order accuracy. Bent coil design showed a 20-30% growth in heat transfer due to chaotic mixing whereas comparative 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 founded 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% augmentation in heat transfer due to chaotic mixing as relative pressure drop was 5-6%. Under heating condition (temperature-dependent viscosity), heat transfer was found higher in case of chaotic configuration as compare to the cooling condition (constant viscosity).

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

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

3. CONCLUSIONS

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. All achievable research topic related to twisted tape have been summarize in the eview, such as pressure drop and heat transfer studies according to twisted tube, For the heat exchangers working under laminar flow condition where flow rate is low, the twisted tapes with baffles are attractive to increase the heat transfer coefficient and pressure drop. Experimental study were done by using twisted tapes with baffles inclined at 450 to the normal axis of twisted tape fitted in the tubes of shell and tube heat exchanger for the Reynolds number ranging from 200 to 600, and results are. Nusselt number for same flow rate in tubes with TTWB is incesed compared to that of plain tubes as well as tubes with typical twisted tapes. Heat transfer coefficient for tubes fitted with TTWB is highest compared to that of plain tubes as well as tubes with typical twisted tapes for same Re and flow rate. Pressure drop value is found higher in TTWB compared to that of in plain tubes and tubes with typical twisted tapes for same flow rate and Re. So we can conclude that by using twisted tapes with baffles on tubes, the thermal performance of the shell and tube heat exchanger operating under laminar conditions can incresed by 150 to 160% that of plain tube.

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