A Review on Experimental and CFD Analysis for Heat Transfer Enhancement in Heat Exchanger Tube using Drilled Twisted Tape Inserts of various Geometries

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Abstract – *Today heat transfer technology is being used in many sector of world, in various heat exchanging applications such as automobiles, refrigerators, air conditioners, process industries etc. The basic goal of enhanced heat transfer is to encourage high heat fluxes. This mainly result in reduction of heat exchanger size, which leads to less capital cost. From the past researches of transferring and saving heat energy has resulted in various heat enhancement techniques like active, passive and compound techniques. Enhancement of heat transfer is of very much significance and important in industries. For tube heat exchangers tubes, the tube insert technology is one of the most common heat transfer enhancement technologies. In this review work main emphasis is given on the research works dealing with enhancement of heat transfer in heat exchanger tubes using various varieties of twisted tape inserts of different twisted angles, twisted ratios, shapes etc. as twisted tapes are very popular heat transfer enhancement tool. The present paper focuses on the CFD and Experimental study of heat transfer and friction factor of heat exchanger tubes fitted with drilled twisted tape inserts of different dimensions.*

Key Words: Heat Transfer Enhancement, Twisted Tape inserts, Heat Exchanger Tube, CFD Analysis, Tube Inserts

1. INTRODUCTION

1.1 Heat Exchanger

The transition of thermal energy from a hotter mass of fluid to a cooler mass is called as "Heat Transfer". Heat exchangers are the devices which are used to transfer the heat from a (hotter mass of fluid to a colder mass) with maximum speed and minimum expenses and running cost.

The fields where heat exchangers are widely used are Power generation, Automobile Industry, Chemical Industry, Thermal power plants etc. To reduce the size and cost of the heat exchanger two important variables are used which are heat transfer coefficient and pressure drop.

Generally, the heat exchanger and mixing chamber both are different things, in mixing chamber the transfer of heat occurs by mixing of two fluids & in case of a heat exchanger two fluids do not get mixes. For example, in a car radiator of an automobile water flows from the radiator tubes and air passes from the thin plates attached outside of the tubes. During the transfer of heat in a heat exchanger the convection occurs between the hot and cold fluid and conduction occurs between the tube walls.

An increase in heat transfer coefficient increases flow resistance & thereby reduces the energy efficiency. The primary task behind heat exchanger configuration is to minimize the flow resistance while upgrading the heat transfer coefficient. In general, the heat transfer enhancement techniques are mainly divided into two categories (a) active technique (need external power source) (b) passive technique (do not need external power source). Some examples of passive techniques are insertion of porous [1] twisted strips and tapes [2] wire coil and helical wire inserts [3] helical screw tapes [4] Regularly spaced twisted tapes and many others.

Amongst the all techniques, the use of tube inserts in heat exchanger has received a lot of attention during the last two decades. The increase in turbulence intensity and tangential flow established by the inserts may be the main reason for heat transfer enhancement induced by tube inserts.

Continuity, momentum and Energy equation are the three main governing equations used to predict the behavior of a fluid flow in a heat exchanger tube.

1.2 Heat Enhancement Techniques

To enhance the heat transfer, rate some techniques are employed which are classified as active techniques, passive techniques and compound techniques.

1.2.1 Active Techniques:

It is the technique which require some external power input for enhancement in heat transfer rate.

1.2.2 Passive Techniques:

It is the technique which does not require any external power source or input to enhance the heat transfer rate, they generally used some additional devices such as twisted tape or porous rod to enhance the heat transfer rate, this technique mainly provides restriction to the fluid flow by using these devices.

ACTIVE	PASSIVE
Mechanical surface	Use of Rough surface
Surface vibration	Use of Extended surface
Fluid vibration	Use of Swirling flow devices
Induced flow	Use of Coiled tubes
Electrostatic field	Use of Additives

Table 1: *Various types of active and passive technique used*

1.2.3 Compound Technique:

Compound Technique involves the combination of both the active and passive method used for enhancement in heat transfer rate. This technique is quite difficult hence it has a limited amount of applications.

1.3 Twisted Tapes

In twisted tape the enhancement is achieved by inducing swirl flow which results in higher near wall velocities and mixing of fluids thereby enhancing the Heat Transfer Coefficient.

Fig 1: *Twisted Tape*

2. LITERATURE SURVEY

The literature survey of the various authors who has worked in this area of heat transfer enhancement is studied and enlisted, the various geometries of the twisted tape used by various author using air or water as a fluid has been discussed for a laminar and turbulent flow region. Numerical analysis performed by different authors was also studied.

Xiaoyu Zhang et.al [1] They have numerically studied the effect of a tube fitted with helical screw tape without core rod inserts, heat transfer enhancement in the core flow of tube is better from that of heat transfer enhancement in a boundary flow of tube.

Helical screw tape inserts with four different widths (w = 7.5 mm, 12 mm, 15 mm and 20 mm) have been investigated for different inlet volume flow rate ranging from 200 L/hr. to 500L/hr. The simulation result shows that the enhancement of heat transfer is obtained in a circular tube with helical screw tape at different width. Physical quantity synergy analysis is also performed to investigate the mechanism of heat transfer enhancement.

S. Eiamsa-ard et.al [2] They used a circular tube consist of loose fitted twisted tape and perform 3D simulation of swirling flow and convective heat transfer coefficient. Effect of clearance ratio is defined as ratio of clearance between the tape edge and tube wall diameter (CR = c/D = 0.0(tight fit), 0.1, 0.2 and 0.3) on heat transfer enhancement (Nu), friction factor (/) and thermal performance factor (77th) are numerically investigated for a twisted tape with two different twist ratios = 2.5 and 5).

CFD was done with total number of elements used are approximately 5474, 8088, 12208 and 22868 for (y/w) = 2.5 and 35520,45736,46750,115162 for (y/w) = 5, the higher number of elements employed for a tape with (y/w) = 5 are due to longer twist length in comparison with tape with (y/w) = 2.5. The heat transfer rate is found to be noticeably decreased with increase in clearance ratio. This is due to the fact that system having larger spacing area generates weaker swirl flow resulting in thicker thermal or hydrodynamic boundary layer.

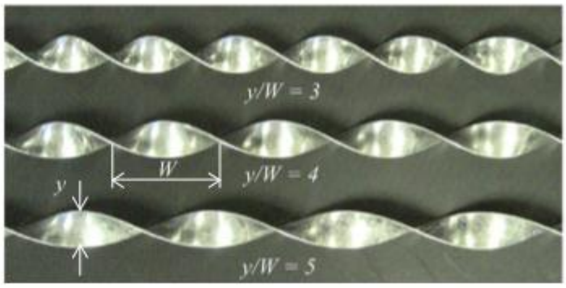

Fig 2: *Twisted Tapes of different twist ratios [2]*

*S. R. Shabanain et.al [*3] They have carried out the CFD study on heat transfer enhancement by using three twisted tape inserts namely butterfly, classical and jagged inserts, they carried out the study within the given range of Reynolds number. The maximum thermal performance was obtained by using the butterfly inserts with an inclined angle of 90°. Here it was concluded that butterfly inserts provide high heat transfer rate as compared to jagged and twisted tape inserts. The reason being the increase in turbulence intensity, decrease in flow cross-sectional area, increase in tangential flow established by the inserts.

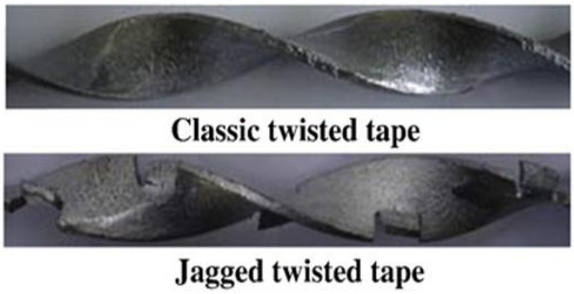

Fig 3: Classic Tw*isted Tapes and Jagged Twisted Tapes [3]*

M.M.K Bhuiya et.al [4] This work shows the experimental study to calculate the heat transfer and friction factor in a circular tube fitted with perforated twisted tape inserts having a different porosity ratio (R_p) of 1.6, 4.5, 8.9 and 14.7%. Air is used as a working fluid within the Reynolds number range from 7200 to 49800, at a constant wall flux temperature, the expansion in Nusselt's number, pressure drop and PEC (Performance Evaluation Criteria) in a tube with wound tape additions was observed to be 110-330, 110-350 and 27-60% higher than those of the plain tube values, the heat transfer & pressure drop were decreased with the increase in twist ratio. They moreover developed co-relations between the Nusselt's number, pressure drop and thermal performance factor.

M.M.K Bhuiya et.al [5] The present study explored the effect of double counter twisted tape on heat transfer and fluid friction characteristics in a heat exchanger tube. The experiments were performed with double counter twisted tape of four different twist ratio (y = 1.95, 3.85, 5.92 and 7.75) using air as testing fluid in a circular tube turbulent flow regime where the Reynolds number varies between 6950 to 50050. The experimental results demonstrate that the heat transfer rate was increased by decreasing the twist ratio.

S. Eiamsa-ard et.al [6] In the present study, the impacts of twin-counter/co-bent tapes (counter tape or co-whirl tape) are tentatively decided. The twin counter curved tapes (CTs) are utilized as counter-swirl stream generators while twin co-twisted tapes (CoTs) are utilized as co-swirl stream generators in a test segment. The tests are directed utilizing the. CTs and CoTs with four distinctive turn proportions (y/w = 2.5. 3.0, 3.5 and 4.0) for Reynolds numbers range between 4000 and 21000 under uniform warmth flux conditions. The tests utilizing the single wound tape (ST) are also performed under comparative operation test conditions, for correlation. The exploratory results demonstrate friction factor (f) and performance criteria increment with decreasing turn proportion (y/w). CT tapes provide more efficient heat transfer rate as compared with the CoT tape.

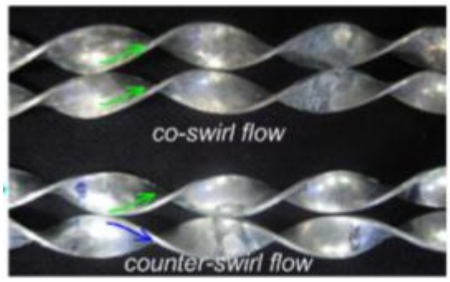

Fig 4: Twin Co-*Twisted Tapes and Twin Counter Twisted Tapes [6]*

CUI Yong-zhang et.al [7] Three-dimensional numerical analysis and tests were completed to concentrate on the heat transfer and the pressure drop of wind current in a round tube with Edge Fold-Twisted Tape (ETT) embeds and with great Spiral-Twisted-Tape (STT) inserts of the same turn proportion. The RNG turbulence model for gently swirling streams and the SIMPLE pressure velocity strategy were embraced to analyze the flow and performance index. Inside the scope of Reynolds number from 2500 to 9500 and the turn proportion y from 5.4 to 11.4.

The Nusselt's number of the tube with ETT inserts is observed to be 4% - 10% higher than that with STT inserts, and the contact variable of the tube with ETT inserts is 8.7% - 74% higher than that of STT tapes.

The heat transfer rate was because of higher tangential speed and uneven speed profile with the expansion and diminishing of the intermittent speed inside an edge fold length. It was found that fundamental components influencing the heat transfer of ETT additions are the turn edge and the crevice width between the tube and inserts A bigger turn point prompts a higher tangential speed, and bigger Nusselt's number and contact variable. The warm pressure driven execution gradually diminishes as the twist angle increments

Yu-Wei Chiu et.al [8] Numerical and trial examinations were completed to think about thermal - hydraulic attributes of wind stream inside a round tube with various tube inserts. Three sorts of tube additions, including longitudinal strip tapes (both with and without gaps) and curved tape inserts with three distinctive wound angles (α = 15.3°, 24.4° and 34.3°) have been explored for various channel frontal speed extending from 3 to 18 m/s. Numerical reenactment was performed by a 3D turbulence examination of the heat exchange and fluid flow. Conjugate convective heat transfer rate in the stream field and warmth conduction in the tube additions are considered also. The investigations were led in a shell and tube exchanger with general counter flow arrangement. The working liquid in the tube side was icy air, while the hot Down herm liquid was on the shell side.

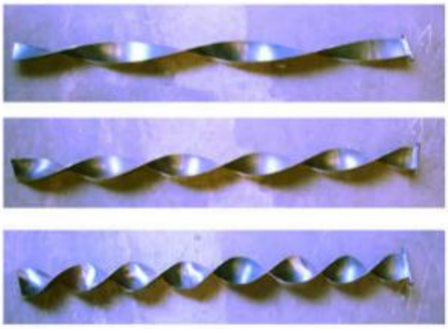

Fig 5: *Twisted Tapes with different twisting angles [8]*

Smith-Eiamsa-ard et.al [9] Test examination of heat transfer rate and friction factor qualities in a twofold pipe heat exchanger fitted with standard separated bent tape components were considered. The inner and outer diameters of tubes are 50.8 and 25.9 mm respectively and cold and hot water were used as a working fluid in shell and tube side. The twisted tape were inserted in a test section at two different cases (a) full length twisted tape at different twist ratio of (y = 6 and 8) & (b) twisted tape with free space tape. The results show that heat transfer coefficient increases with twist ratio (y). Whereas the increase in free space ratio (*S*) would improve both heat transfer coefficient and friction factor. The results are correlated for Nu and f. It was found that Nusselt's number was within +20% and +15% for friction factor

Taiwo O- Oni et.al [10] An examination was done to analyze numerically heat transfer and stream characteristics of water through a round tube prompted with various wound tapes. The point is to know which of the tube plan gives the best execution when contrasted and compared with plain tube. Turbulent stream was viewed as, the mass of the tubes is under uniform divider flux. Reynold's number was between 5000 to 20000 and RNG K-€ model was chosen for simulations. The tube fitted with substitute pivot triangular cut has the best execution as its Nusselt's number and friction factor are 1.63-2.18 and 2.60-3.15 times, individually that of tube with plain curved tape while its thermal performance factor is 1.35-1.43 times that of tube with plain turned tape.

Bodius Salam et.al [11] They have tentatively researched the heat transfer rate in a tube in tube side heat exchanger, for a turbulent stream in a round tube fitted with rectangular-cut bent tape inserts. A copper container of 26.6 mm inward width and 30 mm external distance across and 900 mm test length was utilized. A stainless steel rectangular-cut bent tape addition of 5.25 turn proportion was embedded into the smooth tube. The rectangular cut had 8 mm profundity and 14 mm width. Creator has made a uniform warmth flux condition by wrapping nichrome wire around the test area and fiber glass over the wire. External surface temperatures of the tube were measured at 5 diverse purposes of the test area by T-sort thermocouples. Two thermometers were utilized for measuring the mass temperatures. At the outlet area, the thermometer was put in a blending box. The Reynolds numbers were changed in the reach 10000-19000 with warmth flux variation of 14 to 22 kW/m2 for smooth tube, and 23 to 40 kW/m2 for tube with addition. Nusselt's numbers acquired from smooth tube were contrasted and Gnielinski connection and mistakes were observed to be in the scope of - 6% to - 25% with r.m.s. estimation of 20%. At comparable Reynolds number, Nusselt's numbers in tube with rectangular-cut curved tape supplement were upgraded by 2.3 to 2.9 times at the expense of expansion of rubbing elements by 1.4 to 1.8 times contrasted with that of smooth tube. Heat exchange upgrade efficiencies were found to be in the scope of 1.9 to 2.3 and expanded with the expansion of Reynolds number.

Jaafar Albadr et. al [12] They have experimentally studied the forced convective heat transfer and friction factor in a shell and tube heat exchanger, By using the combination of Nano-fluid and water, the heat exchanger used is of counter flow type in which both the fluids are moving in opposite direction, AI2O3 particle was used as a Nano fluid of about 30nm diameter, They have concluded that nanofluid has high heat transfer rate as compared with water for the same mass flow fate and inlet temperature, Also they have observed that the volume concentration increases the heat transfer rate, but also it increases the viscosity which results in increasing the friction factor.

D G Kumbhar et.al [13] They have presented a review work on heat transfer enhancement in a circular tube having a twisted tape inserts, they focused separately on a thermos-hydraulic performance of a twisted tape inserts under the laminar and turbulent flow conditions and the conclusion was drawn by them.

3. SUMMARY & CONCLUSION

From the above study of various researches on heat transfer enhancement, this can be observed, that many of the authors have used active and passive methods for enhancing the heat transfer rate in a heat exchanger. Most of them have worked on either experimental or numerical analysis but the combined study of both hasn't been performed. In above studies twisted tape inserts of different twisted angles and twisted ratios are taken into considerations. Some of them have also used twin twisted tape inserts inside heat exchanger tubes for heat transfer enhancement. From my review it can be concluded that drilled twisted tape inserts with holes of different geometric shapes like triangular, rhombus & almond can also be used, and a combined study of experimental and CFD investigation of heat transfer and friction factor for these tape inserts can be done.

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