

A Review on Heat Transfer Enhancement in Tubular Heat Exchanger Using Twisted Tape

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Abstract- The twisted tape inserts have been used as a heat transfer enhancement device in last few decades and particular most widely used in heat exchangers to reduce their size and cost. Twisted tapes (TT) are also one of the well-known swirl generators due to their easy installation and low cost. In addition, the existing studies almost focused on the effect of heat transfer enhancement in the tube side, and there are limited studies about the heat transfer enhanced results on the shell side of the corrugated tubes, especially the outward convex corrugated tube. Furthermore, there are few relevant articles on comparing the heat transfer performance of the tube and shell side. In this paper, the studies done related to twisted tape inserts are reviewed.

Keywords- Reynolds number, twisted tape inserts, Nusselt number, Friction factor, Heat transfer coefficient, pressure drop.

I. INTRODUCTION

Heat exchangers are widely used in different types of industries and engineering applications such as chemical reactors, heat exchangers, petrochemical and oil industries, refrigeration, etc. Thermal performance intensification plays an important role in the design of heat exchangers from an economic point of view. Twisted tape enhances heat transfer in heat exchanger tubes by modifying the flow channel of the cooling fluid. In fluid dynamics, two main types of flows exist: laminar and transverse. In laminar flow, fluid particles travel in a longitudinal direction, and the only mode of heat transfer is conduction. When twisted tape is inserted, it causes a turbulent, transverse flow inside the tube. This kind of flow activates the fluid particles and forces heat transfer through both convection and conduction. Twisted tape geometries divide the flow within the tube, creating spiral flow paths resulting in higher velocity at the tube wall. For many conditions they also induce swirl flow which increases local velocities and promotes mixing. While twisted tape has been built as an advanced online tube cleaning system, its effectiveness in heat exchanger / condenser tube cleaning has its shortcomings such as the spiral ties of the twisted tape are made of a polymer material that wears out with time. When this happens, the

Width of the ties reduces, thereby weakening the rotation torque of the twisted tape. Ultimately, the twisted tape cannot meet its cleaning obligations. Its surface will instead become fouled and scaled. The turbulent water flow can have an increasing effect on the pressure drop of the system. If not compensated for this, the flow volume decreases, which can negatively impact the overall effectiveness of the system. This aspect needs to be factored in when considering the tape cleaning technology for retrofitting. The twisted tape is relatively easy to install and maintain both in new systems and in retrofits. The fact that it can clean your condenser tubes while in operation means no standstill production loss. However, the drawbacks highlighted above could cause less-than-optimal production cycles.

II. LITERATURE REVIEW

Farshad et al. (2019) presented exergy loss and heat transfer of mixture of Aluminum oxide and H₂O through a solar collector. Finite volume method has been employed with considering realizable. Such turbulence model has been selected because of best agreement with previous experimental outputs. To assure the accuracy of code, comparisons with numerical and experimental outputs have been

provided for different Reynolds number (Re), number of revolution (N) and diameter ratio (D^*).

Tusar et al. (2019) presented three-dimensional computational conjugate heat and mass transfer study carried out using computational fluid dynamics (CFD) software package ANSYS FLUENT to investigate the effect of insert's twist ratio on the heat transfer and fluid flow performance. Investigation was carried out for air flow at 300 Kelvin and Reynolds number ranging from 3642 to 21857 through a tube with constant wall heat flux of 8000 W/m². Validating against Gneilski and Petukhob models, the current model has been used to investigate the effect of insert with twist ratio 3.46 and 7.6 on Nusselt number, friction factor and thermal performance factor of the tube.

Nakhchi et al. (2019) analyze the thermal performance of turbulent flow inside heat exchanger tube fitted with cross-cut twisted tape with alternate axis (CCTA). The design parameters include the Reynolds number ($5000 < Re < 15,000$), cross-cut width ratio ($0.7 < b/D < 0.9$), cross-cut length ratio ($2 < s/D < 2.5$), and twist ratio ($2 < \gamma/D < 4$).

Nakhchi et al. (2019) presented numerical analysis performed to investigate the flow structure and thermal hydraulic performance of turbulent flow through circular tube equipped with twisted tapes with different cut shapes.

Singh et al. (2019) presented the experimental and computational investigation of thermal properties and fluid flow characteristics on circular tube with elliptical inserts. The major axis is taken equal to hydraulic diameter i.e. 6.81cm. A new parameter, height ratio ($\gamma = b/D$) has been defined with three values - 0.45, 0.66, and 0.74. The test section is 1.5 m long which is provided with a constant heat flux of 1000 W/m² along with air as working fluid at Reynolds number ranging from 3,000 to 21,000.

Tusar et al. (2019) performed a three-dimensional (3D) computational fluid dynamics (CFD) analysis to investigate the heat transfer performance and fluid flow characteristics using a helical screw tape insert in pipe flow. An inserted tube geometry was improved using a helical coil i.e., wire-wrapped with 1.92 twist ratio. The simulated results showed that the heat transfer rate in terms of Nusselt number increased 1.34-2.6 times, whereas, the friction factor

also increased 3.5-8 times for wire-wrapped-tube i.e., the tube with helical screw tape insert in comparison to the plain tube.

Gorjaei et al. (2019) considered twisted tape insert and nanofluid turbulent flow (passive techniques) to increase the heat transfer in the curved tube. The curved tube and twisted tape are fabricated from the copper. The test section (curved tube) is submerged inside a pool filled with hot water.

Sarviya et al. (2018) presented The experimental work on heat transfer augmentation using a new kind of insert called twisted tape with continuous cut edges. The work includes the determination of friction factor and Nusselt number for new twisted tape insert having different twist ratios of 3 & 5. The experimental data obtained from plain tube and conventional twisted tape were verified with the standard correlations to ensure the validation of experimental results.

Olenberg et al. (2018) presented CFD simulations to numerically investigate performance enhancement potential of corrugated sheet structured packings combined with twisted tape inserts. For different twisted tape configurations, pressure drop and mass transfer coefficients were determined and the optimal configuration was selected to be inserted into structured packings.

Hosseinnezhad et al. (2018) numerically investigated the turbulent flow of water/Al₂O₃ nanofluid in a tubular heat exchanger with two twisted-tape inserts in the three-dimensional coordinate. This numerical simulation has been done by using FVM, and all of the equations have been discretized by second-order upwind method. For coupling velocity-pressure equations, SIMPLEC algorithm has been used.

Sivakumar et al. (2018) presented Numerical investigation of heat transfer analysis taken with different flow rates using CFD simulation. A commercial CFD package of fluid simulation in solid works was used to analyses the heat transfer and friction factor characteristics. In this present study the double pipe heat exchanger for a plain tube and twisted tape with the triangular cut copper material inserts, the heat transfer from hot water to cold water by was experimentally investigated. In this paper CFD analysis was used for heat transfer

enhancement of laminar flow of water as a working fluid.

Liu et al. (2018) presented The numerical analysis of the heat transfer performance in the article using CFD software STAR-CCM+. The local flow characteristics, and local and average convective heat transfer coefficients are analyzed, when the Reynolds number ranges from 40 to 1050. The effects of the four different twist ratios of 2.0, 3.0, 4.0 and ∞ on the heat transfer performance are also investigated

Abed et al. (2018) numerically studied forced convection heat transfer through a horizontal pipe built-in with/without twisted tape-inserts under a uniform heat flux condition. Water is used as a working fluid. The governing equations are numerically solved in the domain by a finite volume method (FVM) using the Realizable κ - ϵ (RKE) model. The computational results are performed for a range of the Reynolds number ($4000 \leq Re \leq 9000$), the twisted ratio ($4.0 \leq TR \leq 6.0$), and heat flux ($5000 \leq q \leq 1000 \text{ W/m}^2$). Two type of twisted tape which inserts across a circular pipe (P-TT) and (V-cut) are carried out

Kumar et al. (2018) presented design of experiments has been used to study the effect of thermal parameters on heat transfer enhancement in a double pipe heat exchanger using a passive technique. A twisted tape is considered as the heat augmentation device with tape width, tape pitch and mass flow rate as the input parameters and Nusselt number (Nu) and pressure drop (ΔP) as the output variables. Response Surface methodology (RSM) is used to develop a mathematical prediction model.

Naveen et al. (2017) presented the three dimensional CFD modeling studies on heat transfer, friction factor and thermal performance of concentric tube heat exchanger using twisted tapes (Plain, V-cut, , Jagged V-cut) with different twist ratios ($\gamma=2.0, 4.0$). Twisted tapes are used to augment the heat transfer by creating turbulence in the fluid flow. Various 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. Out of these twisted tape method is used to increase the thermal performance.

Akbari et al. (2017) numerically investigated the heat transfer of laminar and turbulent flow of water/Al₂O₃ nanofluid in the volume fraction of $\phi = 0-4\%$ of solid nanoparticles in Reynolds numbers of 500–25,000. The studied geometrics is a three-dimensional tube with the diameter of $D = 2 \text{ cm}$ and the length of $L = 50 \text{ cm}$ The results indicate that, in the turbulent flow, the use of solid nanoparticle in higher volume fractions and Reynolds numbers, comparing to the laminar flow, improves heat transfer.

Rawan et al. (2017) investigate the performance of parabolic trough collector (PTC) with serrated twisted tape insert in the absorber tube. The heat transfer equations for fully developed flow under quasi-steady state conditions have been developed in order to analyze entropy generation, exergy efficiency, thermal efficiency, rise in fluid temperature and to study the effect of system and operating parameters on performance. A computer program, based on mathematical models is developed in C++ language to estimate the temperature rise of fluid for evaluation of performances under specified conditions

Bhattacharyya et al. (2017) investigated numerically the heat transfer behaviour in a tube with inserted twisted tape swirl generator, for different values of the twist ratio and diameter ratio and for Reynolds numbers within the range 100-20,000. The transition-SST model is used as the turbulence model.

Chaware et al. (2017) presented Numerical analysis of heat transfer improvement in a pipe with the twisted tape in the turbulent regime carried out for twist ratios of 4, 5, 6, 8 and 10 at $4000 \leq Re \leq 30000$. The velocity field in terms of axial, tangential and radial velocity and temperature field are studied with the twist severity and Reynolds number as governing parameters. The numerical results are correlated for the friction factor and Nusselt number. The correlations show good resemblance with the experimental data.

Kaliakatsos et al. (2016) presented a pipe provided with twisted tape inserts. This system allows a significant increase of convective heat transfer coefficient by introducing a swirl motion which determines greater heat removal from the solid surface, by improving the fluid mixing.

III. METHODOLOGY

Three twisted tapes in case 1 and four twisted tapes in case 2 are inserted inside the pipe of the heat exchanger to increase the heat transfer rate and the air (fluid) is entered having different Reynolds number. The 3000 mm-long copper tube with inner diameter (D) of 50.8 mm is made with overall length 500 mm. twisted-tapes made of aluminum sheet was used having twist ratio, $y/w = 4$, 24mm wide (w) with 96mm twist-length (y). The purpose of the current work is to determine the heat transfer rate in a circular tube fitted with twisted-tapes. The parameters of interest are Reynolds number (Re) and no of tape inserts. The source of heat is provided at wall of tube and the heat input is maintained around 10kW. The fluid used in this numerical analysis is air and its corresponding thermo physical properties are obtained at 300K, similar to those of experimental investigations.

IV. CONCLUSION

In this paper a pipe provided with inserts of twisted tape type will be analyzed by CFD analysis and by varying the Reynolds. Using this system it is possible to increase the convective heat transfer coefficient due to the induced swirl motion which improves the mixing of the fluid and allows a greater heat removal. The analysis will be carried out on a 500 mm long pipe provided with tape inserts showed a significant increase in the convective heat transfer coefficient compared to the case of pipe without an insert. In this study, a parametric study is proposed to investigate the effects of twisted tapes inside the heat exchanger on the different parameters such as pressure drop(Δp), Heat transfer coefficient(h), Nusselt number(Nu), and Friction factor (f).

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