International Journal of Engineering Technology and Applied Science
(ISSN: 2395 3853), Vol. 7 Issue 2 February 2021

# Heat Transfer Enhancement in Tubular Heat Exchanger Using Twisted Tape

Raghvendra Sahu, Prof. Brijendra Kumar Yadav
Department of Mechanical engineering, PCST Bhopal

*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 this study the effect of varying Reynolds number on the different parameters such as pressure drop(Δp), Heat transfer coefficient(h), Nusselt number(Nu), Friction factor (f) on heat exchanger with twisted pipe inserts is studied. 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 source of heat is provided at wall of tube and the heat input is maintained around 10kW. For the numerical simulation, the Reynolds number for each case is varied from 15000 to 25000 in steps of 5000. It is found that the highest pressure drop and heat transfer is find for the Reynolds number 20000 in the heat exchanger with 3 twisted tapes, and also it has highest thermal enhancement factor.

*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<y/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 (γ = 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 ($5000 \leq q \leq 1000$ 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 (y=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.

## 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.

- The inlet air temperature is 300K
- A constant heat flux is assigned to the wall surfaces
- The inlet is velocity and is assumed uniform
- No slip boundary condition is assigned to all the surfaces
- The walls of the pipe are made insulated
- Zero gauge pressure is assigned at the outlet of the heat exchanger.
- The meshing of the pipe was done in ANSYS 16.

## IV. RESULTS AND DISCUSSION

The main objective of the current study is to find the heat transfer in the heat exchanger fitted with tape

**inserts. This is planned to be achieved by considering two cases; first is with three tape inserts, and the second is with four tape inserts.**

**For the numerical simulation, the Reynolds number for each case is varied from 15000 to 25000 in steps of 5000 contributing to three cases for both three and four tape inserts heat exchanger and hence a total of 6 cases are studied and the results are compared.**

**Table 1 Simulation runs corresponding to different Reynolds no.**

**(i) with four tape inserts**

| S. no | Reynolds no. | D(m) | V(m/s) | Tin | Tout | Twall |
|---|---|---|---|---|---|---|
| Case1 | 15000 | 0.0508 | 4.614 | 300 | 345 | 458.4 |
| Case2 | 20000 | 0.0508 | 6.152 | 300 | 343.35 | 422.32 |
| Case3 | 25000 | 0.0508 | 7.690 | 300 | 340.7 | 408.5 |

**(i) with three tape inserts**

| S. no | Reynolds no. | D(m) | V(m/s) | Tin | Tout | Twall |
|---|---|---|---|---|---|---|
| Case1 | 15000 | 0.0508 | 4.614 | 300 | 342.66 | 458.54 |
| Case2 | 20000 | 0.0508 | 6.152 | 300 | 340.083 | 415.29 |
| Case3 | 25000 | 0.0508 | 7.690 | 300 | 335.11 | 412.32 |

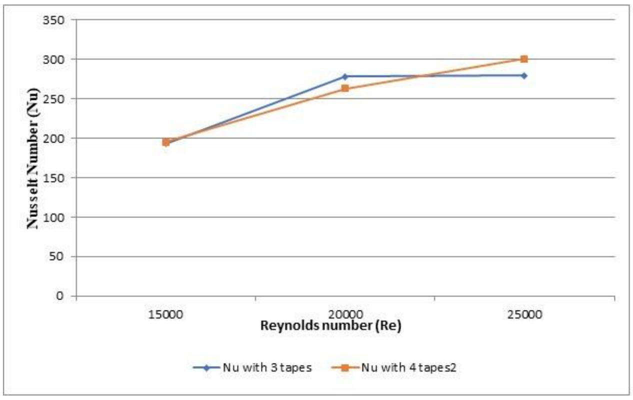


**Fig 1 Variation of Reynolds number with Nusselt Number.**

**The above graph shows that with the increase in number of twisted tapes in the heat exchanger, the Nusselt number also increases with the increase in Reynolds number, but only upto certain velocity. After that, it may decrease.**

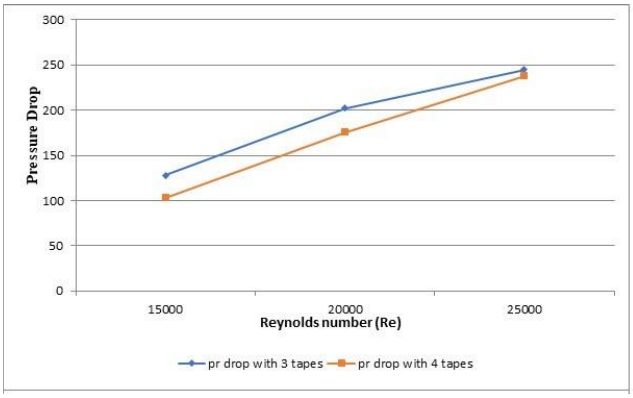


**Fig 2 Variation of Reynolds number with pressure drop.**

**The above graph shows that with the increase in number of twisted tapes in the heat exchanger, the pressure drop starts decreasing with the increase in Reynolds number,**

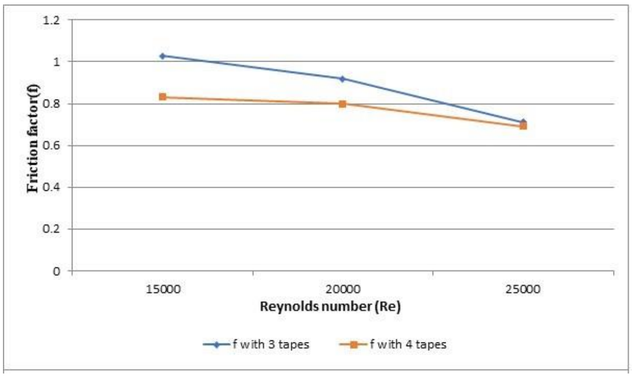


**Fig 3 Variation of Reynolds number with Friction factor.**

**The above graph shows that with the increase in number of twisted tapes in the heat exchanger, the Friction factor increases with the increase in Reynolds number.**

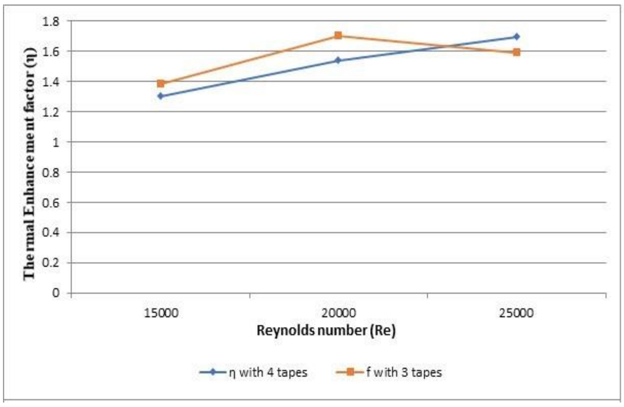


**Fig 4 thermal performance factor with Reynolds number.**

**From the above graph it can be seen that the thermal performance factor of the heat exchanger with 3 tape inserts is more than heat exchanger with 4 tape inserts, however for higher Reynolds number it starts decreasing. Hence, it can be concluded that increasing the number of tapes does not necessarily result in better performance.**

1. Result Validation

**The Nu and f of the inserted tube are, respectively, verified with result tamna et al. [2] .In the figure 5.5 and 5.6, it can be seen that measured data are in good agreement with correlation's data.**

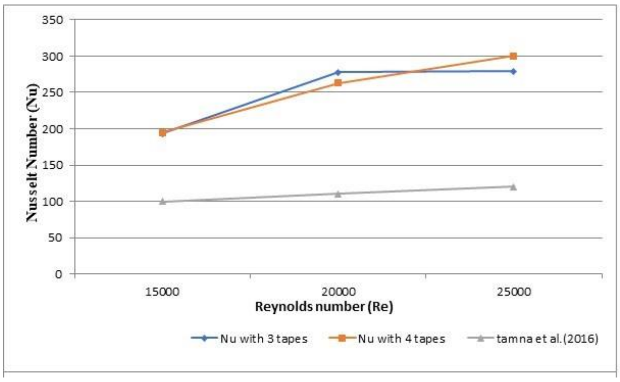


**Fig 5 Variation of Reynolds number with Nusselt Number.**

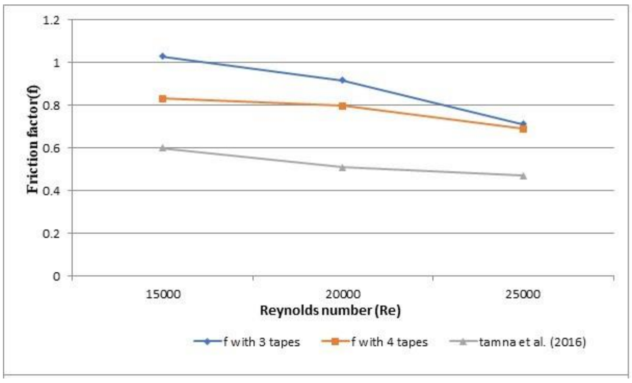


**Fig 6 Variation of Reynolds number with Friction factor.**

## V. CONCLUSION

**In this study, a parametric study is performed 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).**

- **The highest pressure drop and and heat transfer is find for the Reynolds number 20000 in the heat exchanger with 3 twisted tapes, and so it has highest thermal enhancement factor.**
- **It is found that the thermal performance factor of the heat exchanger with 3 tape inserts is more than heat exchanger with 4 tape inserts, however for higher Reynolds number it starts decreasing. Hence, it can be concluded that increasing the number of tapes does not necessarily result in better performance.**

## REFERENCES

[1] Nakhchi, M. E., and J. A. Esfahani. "Performance intensification of turbulent flow through heat exchanger tube using double V-cut twisted tape inserts." Chemical Engineering and Processing-Process Intensification 141 (2019): 107533.
[2] Tamna, Sombat, Yingyong Kaewkohkiat, Sompol Skullong, and Pongjet Promvonge. "Heat transfer enhancement in tubular heat exchanger with double V-ribbed twisted-tapes." Case studies in thermal engineering 7 (2016): 14-24.
[3] http://www.thermopedia.com/content/832/
[4] https://www.explainthatstuff.com/how-heat-exchangers-work.html
[5] https://www.scribd.com/document/253056013/Heat-Exchangers
[6] https://sargenttexas.org/understanding-heat-exchangers/
[7] https://www.watco-group.co/twisted-tape-inserts/
[8] Farshad, Seyyed Ali, and M. Sheikholeslami. "Nanofluid flow inside a solar collector utilizing twisted tape considering exergy and entropy analysis." Renewable Energy 141 (2019): 246-258.
[9] Tusar, Mehedi, Abdullah Noman, Majedul Islam, Prasad Yarlagadda, and Bodius Salam. "CFD study of heat transfer enhancement and fluid flow characteristics of turbulent flow through tube with twisted tape inserts." Energy Procedia 160 (2019): 715-722.
[10] Nakhchi, Mahdi Erfanian, and J. A. Esfahani. "Sensitivity analysis of a heat exchanger tube fitted with cross-cut twisted tape with alternate axis." Journal of Heat Transfer 141, no. 4 (2019).
[11] Nakhchi, M. E., and J. A. Esfahani. "Numerical investigation of rectangular-cut twisted tape insert on performance improvement of heat exchangers." International Journal of Thermal Sciences 138 (2019): 75-83.
[12] Singh, Satyendra, Lokesh Pandey, Himanshi Kharkwal, and Himanshu Sah. "Augmentation of

thermal performance of heat exchanger using elliptical and circular insert with vertical twisted tape." Experimental Heat Transfer (2019): 1-16.

[13] Tusar, Mehedi, Kazi Ahmed, Muhammad Bhuiya, Palash Bhowmik, Mohammad Rasul, and Nanjappa Ashwath. "CFD study of heat transfer enhancement and fluid flow characteristics of laminar flow through tube with helical screw tape insert." Energy Procedia 160 (2019): 699-706.

[14] Gorjaei, Arash Rezaei, and Azadeh Shahidian. "Heat transfer enhancement in a curved tube by using twisted tape insert and turbulent nanofluid flow." Journal of Thermal Analysis and Calorimetry 137, no. 3 (2019): 1059-1068.

[15] Sarviya, R. M., and Veeresh Fuskele. "Heat transfer and pressure drop in a circular tube fitted with twisted tape insert having continuous cut edges." Journal of Energy Storage 19 (2018): 10-14.

[16] Olenberg, Alexander, Wadim Reschetnik, Gunter Kullmer, and Eugeny Y. Kenig. "Optimization of structured packings using twisted tape inserts." Chemical Engineering Research and Design 132 (2018): 1-8.

[17] Hosseinnezhad, Rahim, Omid Ali Akbari, Hamid Hassanzadeh Afrouzi, Mohit Biglarian, Ali Koveiti, and Davood Toghraie. "Numerical study of turbulent nanofluid heat transfer in a tubular heat exchanger with twin twisted-tape inserts." Journal of Thermal Analysis and Calorimetry 132, no. 1 (2018): 741-759.

[18] Sivakumar, K., T. Mohankumar, and K. Rajan. "Numerical analysis of heat transfer characteristics with triangular cut twisted tape inserts." In AIP Conference Proceedings, vol. 2039, no. 1, p. 020059. AIP Publishing LLC, 2018.

[19] Liu, Xiaoya, Chun Li, Xiaxin Cao, Changqi Yan, and Ming Ding. "Numerical analysis on enhanced performance of new coaxial cross twisted tapes for laminar convective heat transfer." International Journal of Heat and Mass Transfer 121 (2018): 1125-1136.

[20] Abed, Azher M., Hasan Sh Majdi, Zainab Hussein, Doaa Fadhil, and Ammar Abdulkadhim. "Numerical analysis of flow and heat transfer enhancement in a horizontal pipe with P-TT and V-Cut twisted tape." Case studies in thermal engineering 12 (2018): 749-758.