Jabirian
Journal of Biointerface Research in Pharmaceutics and Applied Chemistry
ISSN: 2584-2536 (Online)
Vol.1(05), Dec 2024, pp, 7-10
Journal homepage: https://sprinpub.com/jabirian

Research article

# Twisted-Tape Inserts: A Method for Improving Heat Transfer Efficiency in Heat Exchangers

S. T. Patil[1], Omkar Phalle[2], Prashant B Dehankar[3]*

Department of Chemical Engineering, TKIET, Warananagar, Kolhapur, Maharashtra, India

ARTICLE INFO

**Keywords:**
heat exchanger; twisted tape; swirl flow; passive techniques; NTU Method

**Article History:**
Received: 23-05-2024
Accepted: 20-11-2024
Published: 13-12-2024

ABSTRACT

Heat transfer augmentation procedures, such as Heat Transfer Enhancement and Intensification, are commonly used in heat exchanger systems to enhance thermal performance by decreasing thermal resistance and increasing convective heat transfer rates. Swirl-flow devices, such as coiled tubes, twisted-tape inserts, and other geometric alterations, are commonly used to create secondary flow and improve the efficiency of heat transfer. This study aimed to explore the performance of a heat exchanger by comparing its performance with and without the use of twisted-tape inserts. The setup consisted of a copper inner tube measuring 13 mm in inner diameter and 15 mm in outer diameter, together with an outer pipe measuring 23 mm in inner diameter and 25 mm in outer diameter. Mild steel twisted tapes with dimensions of 2 mm thickness, 1.2 cm width, and twist ratios of 4.3 and 7.2 were utilised. The findings indicated that the heat transfer coefficient was 192.99 W/m$^2$°C when twisted-tape inserts were used, while it was 276.40 W/m$^2$°C without any inserts. The experimental results closely aligned with the theoretical assumptions, demonstrating a substantial enhancement in heat transfer performance by the utilisation of twisted-tape inserts. The study provides evidence that the utilisation of twisted-tape inserts resulted in a nearly two times increase in the heat transfer coefficient, hence demonstrating their efficacy in augmenting heat transfer.

**Cite this article:**
Patil ST, Phalle O., Dehankar PB. Twisted-Tape Inserts: A Method for Improving Heat Transfer Efficiency in Heat Exchangers. Jabirian J. Biointerface Res. Pharmaceut. Appl. Chem. 2024 Dec. 13;1(5):7-10. https://doi.org/10.55559/jjbrpac.v1i5.408

## Introduction

Heat exchangers are used in many processes to convert, utilize, and recover thermal energy in industrial, commercial, and residential settings. Enhancing the efficiency of heat exchangers can yield more economical designs, hence leading to reductions in energy consumption, material usage, and total expenses related to the heat exchange [1-5] procedure. Improved thermal efficiency in heat exchangers can also result in decreased dimensions, resulting in reduced expenses for materials and production.

Various strategies, such as heat transfer augmentation, heat transfer enhancement, or intensification, are employed to enhance the thermal performance of heat exchangers. These strategies aim to decrease thermal resistance and enhance convective heat transfer rates. By implementing these techniques [6-8], the pressure drop is enhanced, resulting in an improvement in the rate of heat transfer. It is essential to examine the balance between pressure drop and heat transmission rate. In conclusion, these augmentation strategies have the potential to reduce the size and enhance the efficiency of heat exchangers [9-10].

Enhancing heat transport is crucial in a wide range of technical applications. Due to increasing energy and material expenses, there has been a notable effort to develop heat exchange systems that are more efficient [11]. Enhancing heat transmission is essential for achieving miniaturization of heat exchangers in specific instances, such as space applications.

Implementing augmentation techniques to enhance the efficiency of heat exchangers can result in significant reductions in material costs.

Heat transfer improvement can be classified into three main categories [12]: passive approaches, active techniques, and compound techniques. They are widely used in diverse industries including process engineering, thermal power plants, air-conditioning, refrigeration, evaporators, and even in radiators for space vehicles and automobiles.

The concept of swirl flow [13-15] is commonly used in heating and cooling systems to enhance the efficiency of heat transmission. Passive techniques, such as enhancing surface area, roughness, or altering boundary conditions, can enhance heat transmission without requiring extra energy input. In contrast, active approaches entail the incorporation of nano-sized particles or metallic powders with superior thermal conductivity into the base fluid to augment heat transfer. Among these options, passive approaches, particularly those that utilize inserts in flow passageways, are frequently favored due to their high efficacy and straightforward implementation.

---

* **Corresponding Author:**
Email: dehankarpr@gmail.com (P.B. Dehankar)

https://doi.org/10.55559/jjbrpac.v1i5.408

## METHODOLOGY

This method improves heat transfer in heat exchangers by modifying the flow pattern without relying on external power. Altering the flow pattern disrupts the thermal boundary layer, leading to a decrease in pressure, which eventually enhances the rate of heat transfer [16-17]. Illustrations of this methodology encompass the utilisation of coarse textures, outside exteriors, contorted tapes, and ridged surfaces.

Treated surfaces encompass minute modifications in surface texture or coatings, which may be uninterrupted or fragmented. They are mostly employed in boiling and condensing applications, where the roughness height remains below the threshold that would impact single-phase heat transmission. These coarse surfaces are available in several arrangements, ranging from randomly distributed sand grains to distinct projections. The primary objective of these arrangements is to perturb the viscous sub layer, rather than to augment [18] the surface area. Irregular surfaces are mostly used in situations when there is just one phase of fluid flow.

Extended surfaces, which are frequently employed in several heat exchangers, are also altered to optimize heat transfer. One common method to accomplish this is by modifying the surface through shaping or perforating, which enhances the heat transfer coefficients. Displaced enhancement devices, inserted into the flow channel, indirectly enhance energy transmission [19] at the heated surface, and are commonly employed in forced flow systems.

Swirl-flow devices are frequently used to generate rotating or secondary flow in forced flow systems. These devices employ different geometric designs or tube inserts to achieve this effect. Some examples of these include coiled tubes, twisted-tape inserts, inlet vortex generators, and screw-type axial core inserts.

Surface-tension devices utilize wicking or grooved surfaces to regulate the movement of liquid in boiling and condensing operations.

## OBJECTIVES

One may consider the use of augmentation techniques to satisfy any of the following thermo hydraulic objectives:

(1) To reduce prime surface area

(2) To increase heat transfer capacity

(3) To reduce the approach temperature difference for the process streams

(4) To reduce pumping power.

Having defined a basic objective, the designer will establish the parameters that are fixed and the basic constraints that must be satisfied. Through manipulation of the data or correlations for heat transfer coefficients and friction factors, performance ratios can be calculated, for example, the ratio of the prime surface area of the enhanced heat exchanger to that of the normal or reference exchanger at constant pumping power.

## EXPERIMENTAL SETUP

In this experimental setup (Figure 1 and Table 1) the inner tube is consist of the copper with inner diameter 13 mm and outer diameter of inner pipe with 15 mm with length 100 mm and the outer pipe having the inner diameter 23 mm and the outer diameter 25 mm with 76 mm length. For The twisted tape thickness is 2 mm with length 90 cm. the material of construction for the twisted tape is mild steel the width of twisted tape is 1.2 cm with the twist ratio 4.3 and 7.2.

For the measurement of flow rate the rotameter which has operated at 0.2 to 2 LPM, 0.5 to 50 LPM and two storage tanks having the 500 lit capacities has taken into the consideration and the eight thermocouples are used to measure the temperature of inner and outer pipe. Four thermocouples for the inner pipe and four for the outer pipe for lifting the non-Newtonian fluid 2 hp centrifugal pump is used.

Table 1: Specification of Experiment Instruments

| | | |
|---|---|---|
| Inner tube of DPHE | Copper tube (20mm) | 2 mt. test section |
| Outer tube of DPHE | S.S.314 tube (35mm) | 2 mt . Test section |
| Two storage tanks | S.S. 314 | 500 Lit. Capacity |
| Rotameter | Ureka made | 0.2 to 2 LPM ,0.5 to 50 LPM |
| | | 1 to 5 LPM, 5 to 50 LPM |
| Manometer or DPT | | |
| Centrifugal pump | Kirloskar make | 2 HP ( 2 pump) |
| Fluid | Water and viscous | |

Figure 1: Experiment Setup

### Data Reduction

There are number of methods for designing double pipe heat exchanger [20] in which LMTD method and NTU method are mostly used. The LMTD method is used when we know both inlet temperature and outlet temperature of both hot and cold fluid (Table 2). But, in present case inlet temperature were known so for the calculation of this outlet temperature of fluid we use NTU method [21] which is simpler than other method.

Table 2: Intel and outlet flow temperatures

| *Hot fluid in temp* | *Hot fluid out temp.* | *Cold fluid in temp.* | *Cold fluid out temp.* |
|---|---|---|---|
| $60^{0}c$ | $43^{0}c$ | $30^{0}c$ | $32^{0}c$ |

In NTU method inlet temperature of both fluids as well as heat transfer coefficient are known so from that easily calculate outlet temperature of both the fluids. In present case assumed that volumetric flow rate for both the fluids are same 3 LPM and the overall heat transfer coefficients have 240 watt/m$^2$k.

The standard design procedure for the design of double pipe heat exchanger [22-23] but it is lengthy and it’s required to collect data so used the data reduction method that is NTU Method for the calculations.

## NTU Method

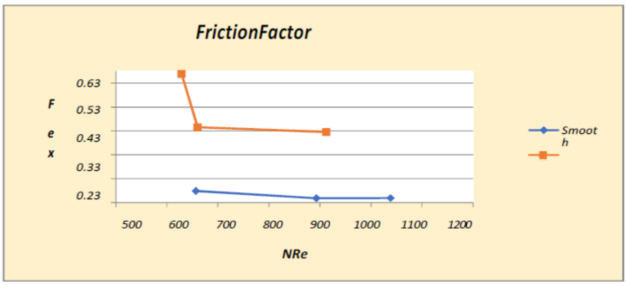
The number of transfer unit (NTU) method is use d to calculate the rate of heat transfer in heat exchanger s when there is insufficient information to calculate the log-Mean Temperature Difference (LMTD). In heat exchanger analysis, if the fluid inlet and outlet temperatures are specified or can be determined by simple energy balance [12], the LMTD method can be used; but when these temperatures are not available the NTU or Effectiveness method is used.

## Effectiveness

It is a ratio between the actual heat transfer rate to the maximum possible heat transfer rate effectiveness is the dimensionless quantity between 0 to 1 To define the effectiveness of heat exchanger of we need to find the maximum possible heat transfer that can be hypothetically achieved in co-current or counter-current. Some assumption for the calculation of NTU Method,

1) Constant heat flux,
2) Constant temperature gradient and
3) Same volumetric flow rate

## RESULTS AND DISCUSSION



The above Figure shows the variation of friction factor (f exp) with Reynolds Number for Smooth tube, twisted tape (Yl =4.6). As the twist ratio decreases, a higher degree of swirl is created which leads to higher pressure drop & hence higher friction factor [22]. In case of twisted tape (Yl= 4.6) a much higher friction factor is observed because of increase in degree of turbulence created by the respective tapes.

The graph presents the variation of the friction factor (Fex) with respect to the Reynolds number (NRe) for two different flow conditions: smooth surface (denoted by blue diamonds) and an enhanced or treated surface (denoted by orange squares).

Smooth Surface Behavior: The friction factor for the smooth surface remains relatively constant as the Reynolds number increases. This is expected, as in laminar or mildly turbulent flow regimes, a smooth surface [14] does not introduce significant additional resistance to the flow. The values are lower than those for the enhanced surface throughout the range.

Enhanced Surface Behavior: The friction factor for the enhanced surface starts significantly higher compared to the smooth surface, especially at lower Reynolds numbers. This indicates the increased flow resistance caused by surface modifications (e.g., roughness or inserts). However, as the Reynolds number increases, the friction factor drops steeply and then stabilizes, suggesting that at higher flow rates, the relative impact of the surface enhancements on friction diminishes.

Friction Factor and Reynolds Number: The friction factor is inversely related to the Reynolds number for both smooth and enhanced surfaces. However, the enhanced surface initially exhibits much higher friction, implying that techniques such as rough surfaces, twisted tapes, or similar augmentation devices are increasing [11] flow resistance, especially in lower flow regimes.

Impact on Heat Transfer Enhancement: The increase in friction factor for enhanced surfaces typically correlates with improved heat transfer due to the disruption of the boundary layer [5]. While the smooth surface offers lower friction (and thus lower pumping power), the enhanced surface offers a trade-off: higher friction (and thus greater energy expenditure for fluid movement) but significantly improved heat transfer.

Design Considerations: For applications where heat transfer is critical and the increased friction can be compensated by energy efficiency improvements (e.g., in reduced surface area or better thermal performance), enhanced surfaces may be preferred. However, if minimizing energy consumption for pumping is a priority; smooth surfaces may be the better choice.

The designer must balance the increase in heat transfer with the added frictional losses when choosing between smooth and enhanced surfaces for heat exchanger applications.

## CONCLUSION

The theoretically calculate the values of outlet temperature of both fluids and from considering that result we expect that same result we can achieve in experimental work by using passive heat transfer augmentation technique, with twisted tape and without twisted tape the heat transfer coefficient is calculated

1) The inlet temperatures of the hot fluid that is CMC is maintained at the 60$^0$C
2) The inlet flow rate of water is content and by changing the CMC flow rate.

The heat transfer coefficient with twisted tape is 192.99 watt/m$^2$ $^0$C the heat transfer coefficient without twisted tape is 276.40 watt/ m$^2$ $^0$C. the heat transfer coefficient as assumed earlier is 243 whatever assumption we taken for the theoretical calculation and experimental calculation value getting is nearly matches the heat transfer coefficient getting from twisted tape is doubled.

## References

### References

[1] Stone KM. Review of Literature on Heat Transfer Enhancement in Compact Heat Exchangers. ACRC TR-105. 1996;1–19. https://www.ideals.illinois.edu/items/11576

[2] Eiamsa-ard S, Promvonge P. Enhancement of heat transfer in a tube with regularly-spaced helical tape swirl generators. Sol Energy.2005;78(4):483–94. http://dx.doi.org/10.1016/j.solener.2004.09.021

[3] Eiamsa-Ard S PP. Enhancement of Heat Transfer in a Circular Wavy-surfaced Tube with a Helical-tape Insert. International Energy Journal. 2007;8(1):29–36. http://www.rericjournal.ait.ac.th/index.php/reric/article/view/174/136

[4] Dehankar PB, Patil NS. Heat transfer augmentation -A review for helical tape insert. International Journal of Scientific Engineering and Technology. 2014;3(10):1236–8. http://dx.doi.org/10.13140/2.1.2899.9361

[5] Murugesan P, Mayilsamy K, Suresh S. Heat transfer in tubes fitted with trapezoidal-cut and plain twisted tape inserts. Chem Eng Commun. 2011;198(7):886–904. http://dx.doi.org/10.1080/00986445.2011.545294

[6] Ray S, Date AW. Laminar flow and heat transfer through square duct with twisted tape insert. Int J Heat Fluid Flow. 2001;22(4):460–72. http://dx.doi.org/10.1016/s0142-727x(01)00078-9

[7] White CM. Streamline flow through curved pipes. Proc R Soc Lond A Math Phys Sci. 1929;123(792):645–63. http://dx.doi.org/10.1098/rspa.1929.0089

[8] Saha SK, Dutta A. Thermohydraulic study of laminar swirl flow through a circular tube fitted with twisted tapes. J Heat Transfer. 2001;123(3):417–27. http://dx.doi.org/10.1115/1.1370500

[9] Prabhanjan DG, Raghavan GSV, Rennie TJ. Comparison of heat transfer rates between a straight tube heat exchanger and a helically coiled heat exchanger. Int Commun Heat Mass Transf. 2002;29(2):185–91. http://dx.doi.org/10.1016/s0735-1933(02)00309-3

[10] Saha, S. K. and Bhunia, K. Heat transfer and pressure drop characteristics of varying pitch twisted-tape-generated laminar smooth swirl flow. In: 4th ISHMT– ASME Heat and Mass Transfer Conference. 2000. p. 423–8.

[11] Kern DQ. Process heat transfer, Indian edition. In McGraw Hill Eduction, India PVT Delhi; 2017. p. 102–10.

[12] Kapatkar AVN, Padalkar A, Kasbe CS. Experimental Investigation on Heat Transfer Enhancement in Laminar Flow in Circular Tube Equipped with Different Inserts. In: Proc of Int Conf on Advances in Mechanical Engineering 2010. 2011. p. 58–63.

[13] Chang SW, Yang TL, Liou JS. Heat transfer and pressure drop in tube with broken twisted tape insert. Exp Therm Fluid Sci. 2007;32(2):489–501. http://dx.doi.org/10.1016/j.expthermflusci.2007.06.002

[14] Manglik, R. M., and Bergles, A. E. Heat Transfer and Pressure Drop Correlation for Twisted-Tape Inserts in Isothermal Tubes: Part I—Laminar Flows. Enhanced Heat Transfer, ASME HTD. 1992;68:89–98.

[15] Manglik RM, & Bergles, A E. Swirl flow heat transfer and pressure drop with twisted-tape inserts. In: In: Hartnett JP, Irvine TF, Cho YI, Greene GA (eds), Advances in heat transfer. 2002. p. 183–266.

[16] Chakroun WM, Al-Fahed SF. The effect of twisted-tape width on heat transfer and pressure drop for fully developed laminar flow. J Eng Gas Turbine Power. 1996;118(3):584–9. http://dx.doi.org/10.1115/1.2816688

[17] Dewan A, Mahanta P, Raju KS, Kumar PS. Review of passive heat transfer augmentation techniques. Proc Inst Mech Eng A: J Power Energy. 2004;218(7):509–27. http://dx.doi.org/10.1243/0957650042456953

[18] Lopina RF, Bergles A. Heat transfer and pressure drop in tape generated swirl flow. ASME, J Heat Transfer. 1967;91:434–41. https://dspace.mit.edu/handle/1721.1/61495

[19] Hong, S. W. and Bergles, A. E. Augmentation of laminar flow heat transfer in tubes by means of twisted-tape inserts. In: Trans ASME J Heat Transfer. 98; 1976. p. 251–6.

[20] Ray S, Date AW. Friction and heat transfer characteristics of flow through square duct with twisted tape insert. Int J Heat Mass Transf. 2003;46(5):889–902. http://dx.doi.org/10.1016/s0017-9310(02)00355-1

[21] Saha SK, Gaitonde UN, Date AW. Heat transfer and pressure drop characteristics of turbulent flow in a circular tube fitted with regularly spaced twisted-tape elements. Exp Therm Fluid Sci. 1990;3(6):632–40. http://dx.doi.org/10.1016/0894-1777(90)90080-q

[22] Saha SK, Dutta A, Dhal SK. Friction and heat transfer characteristics of laminar swirl flow through a circular tube fitted with regularly spaced twisted-tape elements. Int J Heat Mass Transf. 2001;44(22):4211–23. http://dx.doi.org/10.1016/s0017-9310(01)00077-1

[23] Wang L, Sundén B. Performance comparison of some tube inserts. Int Commun Heat Mass Transf. 2002;29(1):45–56. http://dx.doi.org/10.1016/s0735-1933(01)00323-2