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# Study the effect of axially perforated twisted tapes on the thermal performance enhancement factor of a double tube heat exchanger

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ABSTRACT

The main objective of this numerical study is to investigate the ways to reduce the pressure drop and consequently increase thermal performance enhancement factor (TEF) of a heat exchanger equipped with twisted tapes. For this purpose, axial perforated twisted tapes (PTTs) with various hole diameters are used instead of simple twisted tapes (STTs). Moreover, the variations of the effectiveness with number of transfer units ($NTU$) for different heat capacity ratios ($C_r$) were presented. The numerical model was well validated with the available experimental results. The results indicated that the use of perforated twisted tape leads to a reduction in pressure drop and heat transfer rate, subsequently; a significant increase in TEF was seen compared to simple twisted tapes. In addition, some correlations were formulated to present the numerical results.

## 1. Introduction

Enhancing the heat transfer in heat exchangers leads to an increase in overall system performance and finally it causes reductions in size and cost of the systems. That's why additional techniques are necessary to amplify the heat transfer in heat exchangers. Usually, these techniques are classified either as passive (an external energy is no required) or active (an external energy is required) methods. Some examples of the passive methods include using nanofluids as the working fluid [1–3], using fluted [4], finned [5,6] and micro fined [7] tubes. Moreover, utilizing different turbulators, such as louvered [8], wire brushes [9], coiled wires [10] etc. could be mentioned too. The twisted tape is one of the most important examples of passive methods which are employed extensively in many heat exchanging systems for enhancing the convective heat transfer coefficient on the tube side of the heat exchangers. These kinds of turbulators increase the heat transfer in heat exchangers while they increase the pressure drop. So, to evaluate the quality of enhancement concept, thermal performance enhancement factor (TEF) must be examined.

Fahed et al. [11] examined the thermal characteristics in a double tube heat exchanger equipped with twisted tapes considering various twist ratios. Their results indicated that the heat transfer increases with the increase of the twist ratios. Promvonge et al. [12] investigated the effect of the twist ratio on the heat transfer and pressure drop in a helical-ribbed tube with twin twisted tape inserts. The results indicated that by increasing the twist ratios, heat transfer rate increases. However, the pressure drop increases in the presence of this kind of turbulators. To evaluate the quality of enhancement concept, thermal performance enhancement factor (TEF) was obtained. Chakroun et al. [13] examined the heat transfer and pressure drop of double tube heat exchanger equipped with twisted tapes with various widths. Eiamsa-ard et al. [14] studied the thermal characteristics in a circular tube fitted with serrated twisted tapes. Murugesan et al. [15] introduced v-cuts in the simple twisted tapes (STTs) on both top and bottom alternately in the peripheral region in order to improve the fluid mixing and disrupting the hydrodynamic near-wall boundary layer. Their studies include heat transfer and friction factor analyses of a round tube equipped with simple twisted tapes (STTs) and v-cut twisted tapes

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**Nomenclature**

| | |
|---|---|
| A | surface area of the test tube, $m^2$ |
| $C_p$ | specific heat at constant pressure, $\frac{J}{kg\,K}$ |
| $C_{min}$ | minimum heat capacity, $\frac{W}{K}$ |
| $C_{max}$ | maximum heat capacity, $\frac{W}{K}$ |
| $C_r$ | heat capacity ratio, (dimensionless) |
| NTU | number of heat transfer units, (dimensionless) |
| Nu | Nusslet number, (dimensionless) |
| U | overall heat transfer coefficient, $\frac{W}{m^2K}$ |
| f | Friction factor, (dimensionless) |
| RMSD | root mean square deviation |
| D | hole diameter of PTT, $\frac{W}{K}$ |
| $D_H$ | mean diameter, $m$ |
| d | smooth tube diameter |
| L | length of heat exchanger, $m$ |
| H | Twisted tapes pitch, $m$ |
| $\dot{m}$ | mass flow rate, $\frac{kg}{s}$ |
| Q | heat transfer rate, $W$ |
| $Q_{max}$ | Maximum possible heat transfer rate, $W$ |
| Re | Reynolds number |
| T | water temperature, $k$ |
| p | Pressure, $Pa$ |
| $\overline{U}$ | mean velocity in tube, $\frac{m}{s}$ |
| k | turbulent kinetic energy, $\frac{m^2}{s^2}$ |
| $Y_{exp,i}$ | experimental value |
| $Y_{pre,i}$ | predicted value |
| N | number of observations |
| RMSE | root mean square error analysis |

*Greek symbols*

| | |
|---|---|
| ε | effectiveness, (dimensionless). |
| ρ | density, $\frac{kg}{m^3}$ |
| μ | dynamic viscosity, $\frac{N.s}{m^2}$ |
| Δ | difference operator. |

*Subscripts*

| | |
|---|---|
| ave | average. |
| c | cold. |
| h | hot. |
| i | inner. |
| o | outer. |
| in | inlet. |
| out | outlet. |
| 0 | smooth. |
| w | water. |
| LMTD | logarithmic mean temperature difference. |

(VTT's). Results indicated that the heat transfer rate and pressure drop of heat exchanger equipped with VTT's increases with the decrease of twist ratios and width ratios. The TEF for VTT's were found to be greater than those for the STTs. Ibrahim [16] studied the effects of the helical screw ratio on the pressure drop and heat transfer coefficients in double tube heat exchangers. Consequently, empirical correlations for both friction factor and Nusslet number as functions of Reynolds number, spacer length and twist ratio were proposed. According to their results, the heat transfer increases with the increase of Reynolds number, but it changes dramatically with spacer length and twist ratio. Mashoofi et al. [17] studied heat transfer and pressure drop in a coil double-tube heat exchanger equipped with helical wire.

By taking what was discussed so far, it can be resulted that lots of investigations have been done to study the effect of different types and configurations of TT's on the heat transfer and pressure drop of heat exchangers. Also, the vertical perforated twisted tape is one of the modified TT's studied recently [18]. This kind of turbulators increases the heat transfer in heat exchangers by creating swirling flows, increasing turbulence of flow and disturbing the boundary layer. In addition, pressure drop increases in presence of them due to increase of the fluid flow blockage. The goal of this study is to present a way to decrease the pressure drop in heat exchanger which leads to increase in TEF. So, axially holes are created on twisted tape turbulators with the aim of decreasing pressure drop in heat exchangers. Using PTTs decreases the pressure drop. Also, heat transfer rate and effectiveness decreases, too. To evaluate the quality of enhancement concept of this method, TEF can be calculated in different cases with different hole diameters and can be compared with each other. However, this study attempts to investigate the effect of heat capacity ratios ($C_r$) on the effectiveness was evaluated.

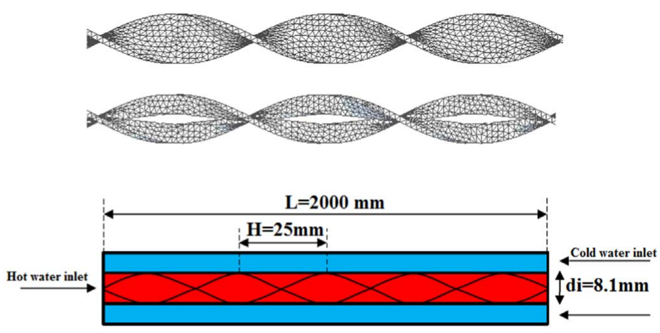


**Fig. 1.** A schematic of the physical model and mesh.