International Journal of Computational and Experimental Science and ENgineering (IJCESEN)

Vol. 11-No.2 (2025) pp. 3582-3585
http://www.ijcesen.com

ISSN: 2149-9144

Research Article

Investigation of turbulent flow of water through converge and diverge pipes with twisted tapes inserted

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Article Info:

DOI: 10.22399/ijcesen.1656
Received : 29 March 2025
Accepted : 25 May 2025

Keywords :

Solar
Converge
Diverge
Twisted Tape
Fully Developed And Turbulent

Abstract:

In most cases, convective heat transfer can normally be improved by active or passive methods. The former (active methods) utilize power external to the system to cause enhancement, whereas an external power source is not utilized by the latter. The passive method is almost centered upon the hypothesis that a decrease in the thermal boundary layer (TBL) thickness will undoubtedly create an increase in the rate of convective heat transfer. Some of the passive techniques are: geometry modification, e.g., inserting a twisted tape in the pipe, converging pipe, corrugated pipe, helically coil tube, and wavy channel. For geometry modification to increase convective heat transfer, twisted tape insert is more preferable since it possesses a relatively high thermal enhancement compared to other modified geometry designs explored so far. Following is a summary of recent research on heat transfer efficiency and EPR in twisted tape inserts for pipes.

1. Introduction

Dagdevir and Ozceyhan [1] under persistent thermal flux and turbulent flow conditions, an experiment was made to study the influence of water/CuO nanofluid flow in a heat exchanger tube fitted with a RITT and RIST. Experiments are carried out under the parameters of a nanofluid mass fraction (wt) of 0%, 1%, and 2%, and a Re that ranges from roughly 5000 to 29,000, respectively. The results with a Reynolds number of 6572, a nanofluid mass fraction of 2.0%, and a ratio of $RITTL/p$=40 exhibited the greatest thermohydraulic (PEC) of 1.377 and the best entropy efficiency of 0.439.

Xie, Mansir [2] carried out experimental work to investigate the thermal, frictional, and performance parameters affected by twisted tape of varying pitch on the various characteristics of a helical tube reliant on constant heat flux. The findings show an increase of 66% in Nusselt number when increasing water flow rate and decreasing twist degree when compared to the plain coaxial pipe.

Nithiyesh Kumar and Ilangkumaran [3] conducted an trial examination of the performance improvement ratio and exergy efficiency assay of TCTTs in an IG tube. The studies were performed with TCTT in the turbulent zone (Re = 3000-14,000) and with varying values corresponding to twist rate (y = 3.5, 5.3, and 6.5) and attacking angle (β= 90° and 45°). The experimental findings demonstrate that for internally grooved tube incorporated with TCTT shows an improvement in thermal and exergy efficiency by 1.12 and 1.85, respectively.

the hydraulic and thermal properties and entropy production rate of copiously advanced turbulent flows within the twisted U-tube are studied by Feizabadi, Khoshvaght-Aliabadi [4]. The experiment is conducted for Reynolds numbers extending from 3843 to 11,436 in an adiabatic external fluid environment. The impacts of various twisted-tape and tube sides are investigated. The data achieved indicate a positive correlation between the friction factor and the Nusselt number, as the twist rate goes up. Research showed that a reduction in the twist leads to a drop in the entropy created via heat transfer, while simultaneously resulting in a rise in the entropy produced due to loss of friction. The U-tube, equipped with a twisted-tape insert, exhibits significant enhancements in friction factor and the Nusselt

number relative to the flat U-tube. Specifically, the Nusselt experiences a remarkable increase of 122.4%, while the friction factor demonstrates a substantial increase of 78.4%.

Kumar, Patil [5] investigate the process of entropy formation in a rounded tube that has been prepared with solid twisted-tape and perforated twisted-tape (PTT) insert that has several V incisions. Empirical data relevant to heat transfer and loss of friction are obtained by altering the twist rate from 2–6 for the Reynolds number range of 2000–25,000. In common situations, it has been shown that the insertion of a heated tube results in a lowered rate of entropy formation in comparison to a flat pipe when subjected to comparable operating circumstances. The smallest value of the entropy production number is seen when the PTT (Perforated twisted-tape) has a twist rate of 3.

Bas and Ozceyhan [6] By using the Taguchi design approach, the researchers were able to identify the ideal values for all of the design criteria, including those pertaining to transfer of heat and drop of pressure, in a tube that had twisted tape inserts. The clearance rate (c/D), the twist (y/D), and the Reynolds number (Re) were all taken into consideration throughout the design process.

Chu, Tsai [7] Shows the impact of various V-cut twisted tape inserts in pipe on thermohydraulic performances at Re range 4000 – 10000. The consecutive TT with the twisted rate of 4 may attain its greatest all-inclusive heat performance (CTP) by 1.08–1.10. However, more gaps from 0.043 to 0.135 drops Nu and f by 6.7% and 11.6%, respectively. The CTP is substantially decreased and can doubtedly be poorly inverted than the flat pipe at the area of turbulent transition.

Suri, Kumar [8] The study presents an experimental analysis of the thermal transfer and fluid flow properties of several rectangular perforated twisted tape with wing insertions installed in a heat exchanger tube at Re range 5000 – 27000. The study revealed that the thermal transmission and friction factor increase reached a maximum value of 6.96 and 8.34 times more than that of a normal pipe.

Sun, Yang [9] The study investigates the heat transmit and fluid properties of a various nano-fluids via twisted belt external threads tubes for Re range from 2000 to 12000 with nano-fluid fraction range 0.1%-0.6%. the findings indicated that Cu nanofluid exhibit the most favorable convective thermal effect and the heat transfer features reaches their optimal state at 0.5% Cu nanofluid mass fraction. Also, the system showed a significant improvement of 50.32% when contrasted with flat pipe. Durga Prasad and Gupta [10] The experimental is conducted to explore the potential enhancement of heat transmission using U- tube with Al2O3 nano-fluid for Re between 3000 and 30000. Findings revealed that Nusselt (Nu) was enhanced by 31.28% while employing 0.03% nano-fluid mass fraction and a rise in friction factor by 1.23 when contrasted to water.

Kaood, Abou-Deif [11] investigate corrugated tubes with diverse transverse geometrical corrugated forms, including rectangle, trapezoid, curve, and triangle. The investigation focused on tubes with distinct corrugation directions, either inside or outward. The Reynolds number (Re) range in this paper was through 5000 to 61,000. The findings demonstrate that the orientation and geometry of grooves significantly influence heat transport, as shown by the Nusselt (Nu), and pressure drop, as indicated by the friction factor (f) which is higher than flat tube.

Abed, Sh. Majdi [12] The study investigates the numerical analysis of thermohydraulic parameters for various twisted tapes, namely Vcut and PTT, installed in a horizontal pipe. The study focuses on twisted ratios of 4.0 and 6.0. The findings indicate that there is a positive correlation between the twisted ratio and both the average Nusselt number and friction factor, regardless of the Reynolds number. Moreover, the factor of thermal performance exhibited an upward trend as the Reynolds-No went up and the tape twist ratio decreased. Evidently, the use of twisted-tapes relating to V-cut and P-TT configurations with a twist ratio (TR) of 4 resulted in significantly higher average thermal performance factors of 4.45 and 4.19, respectively, compared to those with a TR of 6.

Khanmohammadi and Mazaheri [13] investigated the impacts of heat transmission elements in a circular tube by numerical analysis on entropy generation, thermal and hydraulic performance. Two varieties of twisted tape, single and double (coaxial), were chosen to study their effects. The findings indicate that the coefficient of convective thermal transfer is positively influenced by an increase in the Reynolds number across whole scenarios. The findings indicate that the coaxial tape with a decreased twisted rate (TR) exhibits greater efficiency compared to a single tape, but larger pressure drop. Also It may be inferred that the decrease in overall entropy production is a result of the decreased thermal resistance seen in both kinds of inserts.

Bahiraei, Mazaheri [14] investigate the effect of doubled counter twisted tapes insert in circular tube on entropy production, heat transfer and fluid dynamics characteristics for hybridnanofluid flow. In the scenario involving doubled counter twisted tape, it is seen that the overall thermal entropy

production rate experiences a decrease of around 10%. Additionally, the findings indicate that the use of nanofluid in place of the main fluid reduces total entropy creation, hence resulting in a drop in overall irreversibility.

Nakhchi and Esfahani [15] analyzed the creation of entropy in the flow of nanofluid via a thermal exchanger tube that was fitted with porous helical rings. The findings show that thermal irreversibility is the prevailing factor in the majority of the tube. However, the observed trend indicates a reduction in the measured variable as the volume percentage of nanoparticles increases. The reduction in frictional entropy formation is seen when the number of holes increases from 4 to 10. The Bejan number exhibits a decreasing trend as the Reynolds number goes up.

Hassan, Kassem [16] a focus in this work directed to conduct multi-criteria assessments and improvements of the absolute and relative thermal hydraulic performances of tube heat exchangers (HEXs) with different cross-sections, both with and without twisted tape inserts. The findings indicated that traditional straight tubes have superior fluid performance, as shown by a extreme friction factor of just 0.042. Convergent tubes have superior thermal performance, as seen by their high Nusselt values, which may reach up to 475.9. Divergent tubes often have no significant potential for enhancing heat transmission, if they are fitted with a tape insert. Adopting twisted tapes had been revealed to significantly enhance the thermal efficiencies of various system configurations, but it is critical to note that this improvement is accompanied by a substantial rise in the factor of friction. The thermal performance of a baseline design consisting of an hollow straight tube may be enhanced by as much as 74.8%.

Ju, Zhu [17] The study aimed to explore the improvement of thermals transfer and the features of friction factor in laminar nanofluid flow (namely Al2O3/water) in a three-dimensional circular tube that is combined with numerous semi-twisted tapes. The study revealed that augmenting the quantity of semi-twisted tapes results in an improvement in both (Nu) and (f) from 15.13 to 28.42 and 0.022 to 0.052, respectively. For the rising number of semi-twisted tape through 0 to 4, for Re = 1000. Maximum (PEC) value is 1.66 which is observed at Re = 750 when using 4 semi-twisted tape for 3% nano-fluid concentration.

Kaood, Aboulmagd [18] investigate the effect of including dimples on helical tube on heat transfer and fluid characteristics using 3D computational fluid dynamics (CFD) approach. The research demonstrated that the convergent pipe with hollows, having a diameter rate (DR) of 1.5, had the highest value of PEC (Performance Evaluation Criterion) with a notable boost of 29.54% when matched to the plain geometry with a DR of 1. And enhancement of Nu by 121.4 % at Re = 3000 compared to plain pipe.

Kaood and Fadodun [19] This study examines the rate of turbulent entropy generation in water flow inside tubes have multiple configurations (plain, convergent and divergent) with and without the presence of TTs inserts numerically using CFD for Re range 3000 – 45000 with many diameters ratio. The findings indicate that the application of a perverted tape insert leads to a rise in the rate of viscous entropy generation (VEPG), while simultaneously reducing the rate of thermal entropy generation (TEPG). Moreover, it should be noted that the Total Energy Pressure Ratio (TEPR) exhibits a greater value in the diverging pipe as compared to the convergent pipe.

Zheng, Xie [20] The study investigates the effect of dimpled turbulator inserts in straight pipe on thermohydraulic and entropy generation by using nano-fluid numerically. The findings showed a growing heat transfer coefficient by 25.53% and maximum deviation in total entropy production 29.10%.

2. Objectives

1. Find the impacts of inserted twisted tape in flat, conical tubes with circular cross section on thermal and hydraulic performance.
2. Find the effect of inserted turbulator on the entropy generation rate.

3. Conclusions

- There are no studies in this region
- No evidence for twisted tape inserted inside the converge and diverge pipes in solar energy applications

Author Statements:

- **Ethical approval:** The conducted research is not related to either human or animal use.
- **Conflict of interest:** The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper
- **Acknowledgement:** The authors declare that they have nobody or no-company to acknowledge.
- **Author contributions:** The authors declare that they have equal right on this paper.

- **Funding information:** The authors declare that there is no funding to be acknowledged.
- **Data availability statement:** The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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