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A Review on CFD Analysis of Tubular Heat Exchanger with Ribbed Twisted Tapes for Heat Exchanger Enhancement

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Abstract- A heat exchanger is really a system that transfers heat between two or more fluids. The fluids can also be single-phase or two-phase, so they can be isolated or in close contact, depending on the form of exchanger. In this study, two twisted ribbons are inserted into another heat exchanger tube and heat transfer is studied. The aim of both the ongoing project is to figure out how fast heat transfers in a circular tube with entangled ribbons. For a circular tube, the application of combined double twisted-tapes and V-ribs attached on the tape edge has never been come across in the literature. Considering the merits of both devices, a new enhancement device is offered by incorporating the rib into the twisted-tape edge. The insertion of this compound device is expected to yield stronger turbulence intensity in the near-wall regime by the rib and fast fluid mixing by the double twisted tapes, leading to higher heat transfer augmentation in the tube.

Keywords:-Heat exchanger, single-phase, Nusselt number (Nu), Reynolds (Re), thermal enhancement factor, pressure drop.

I. INTRODUCTION

A heat exchanger is really a system that transfers heat between two or more fluids. The fluids can also be single-phase or two-phase, so they can be isolated or in close contact, depending on the form of exchanger.

While many of the ideas used in their construction are the same, devices containing power sources, including such nuclear fuel pins or burning stoves, really aren't usually called heat exchangers. In heat exchangers.

There seem to be no external relations involving heat and function in most cases. Heating or cooling a fluid stream including evaporating or condensing fluid streams with one and sometimes more components are common applications. Other goals could be to recover or refuse heat, or to sterilize, pasteurize, fractionate, distill, concentrate, crystallize, or monitor a process fluid.

Shell and tube heat exchangers or condenser (cooler) tubes have a high degree of heat energy transfer, making them among the most important, and not the most important, elements of the device. The ability of even a heat exchanger to maximize heat transfer determines its efficiency.

Scale formation of scale significantly decreases the ability of both the heat exchangers and condenser tubes which pass heat, affecting the cooler's overall efficiency. To address this problem despite having to halt operations in order to clean their pipes, cleaning systems for in-line use can be produced. The entangled tape method is one such approach.

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. Depending upon the application, twisted tapes are used with different twist ratio, with varying twist direction, fit and loose

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tape insert, full and short tape insert, perforated insert, insert with peripheral cuts, etc.
Twisted tapes (TT) are also one of the well-known swirl generators due to their easy installation and low cost. In general, swirl flow improves the fluid mixing between the tube walls and core region leading to more effective thermal boundary layer disruption and thus enhances the heat transfer rate.

These benefits associated with thermal performance enhancement have led to developing various modified. To improve the thermal performance of heat exchangers.

II. LITERATURE REVIEW

Farhan, Ammar et al. (2021) The energy and exergic study of a V-shaped corrugated solar air heater (VCSAH) integrated with the woven ribbon insert were investigated analytically and numerically (TTI). The TTI becomes contained in the air ducts created either by absorber and rear surfaces. For abroad variety of Reynolds (Re) numbers in practical weather results, the effect of geometry parameters including such braided belt ratio (Y) and channel number (N) on thermo hydraulic efficiency is investigated.

The findings show that as Y decreases, VCSAH-thermo TTI's order to generate energy first risesto a particular value of Re to achieve its optimum value, then decreases. Whenever the TTI is applied, the optimum number of channels for maximum thermo-hydraulic performance is N=5.

Mashayekhi et al. (2021) Al2O3-water nano fluids used in combination with fixed and rotating twisted tape inserts aim to increase the rate of heat transfer in a flat tube. The simulations are performed by varying the design parameters, including the angular velocity of the twisted web, the Reynolds number and the volume concentration of the nano fluids. It has been found that inserting a twisted ribbon into a tube substantially increases the heat transfer coefficient and the friction factor relative to the smooth tube.

Kulkarni et al. (2021) enhanced heat exchanger thermal efficiency that affects electricity, material, and amperes; cost reductions led to the introduction of the use of several heat transfer enhancement techniques. Through decreasing the thermal resistance in a heat exchanger, augmentation techniques improve convection heat transfer. Twisted ribbons, a type of passive heat transfer enhancement techniques that have shown significantly good results in previous studies.

Tiwari, Arun Kumar et al. (2021) among a double concentric tube heat exchanger, another additional tube was added. The whole thing is done with the conditions with heat transfer from turbulent fluid through fluid in mind. The impact of various thermal parameters, such as total heat transfer or performance, was the subject of the project using the WO3 / water nano fluid with so many different inserts such as twisted tape, rib and porous plate.

Hakim et al. (2021) performed numerical simulations to investigate the improvement of heat transfer in a tube equipped with a rectangular cut braided tape insert and to compare the data with a smooth tube. For this, CFD (Computational Fluid Dynamics) was used to simulate the three-dimensional model with the appropriate boundary conditions. The numerical results show that the flow field can be adjusted and the boundary layer thickness can be reduced by inserting the rectangular cut braided tape insert so that the heat transfer can be improved in the pipe. Water was used as a working fluid.

Paneliya, Sagar et al. (2021) studied and reported the performance of a heat exchanger equipped with an X- shaped ribbon insert. The total heat transfer coefficients, efficiency, friction factor, including decrease in fluid pressure flowing through to the U-tube fitted with an X- shaped ribbon insert were calculated across an experimental investigation. Along with its availability but machine ability, mild steel had been used to make X- shaped ribbon inserts. Two 1m long X-shaped tape inserts the 2.4m long U-shaped tunnel was filled with them.

Liaw, Kim Leong et al. (2021) Underneath a steady wall temperature, numerically analyze the heat transfer of turbulent flow in a helical tube with the twisted ribbon insert.

A three-dimensional computational fluid dynamics model was proposed and verified using experimental data and correlations. Following that, the model was used to evaluate turbulent convection heat transfer in straight or helical tubes with or without a heat

exchanger twisted ribbon insert. The influence of both the torque ratio as well as the Reynolds number at the input are often evaluated to get a full picture of both the heat transfer efficiency.

Bhattacharyya et al. (2021) experimentally and numerically studied the effect of BTT on heat transfer performance in new triangular axial corrugated tubes is. To increase the thermohydraulic performance, a corrugated pipe with inserts is offered.

Farshad et al. (2019) exhibited loss of exergy and heat transfer from a mixture of aluminum oxide and H2O through a solar collector. The finite volume method was used, considering it feasible. Said turbulence model was selected for its best concordance with previous experimental results. To ensure the accuracy of the code, comparisons with numerical and experimental outputs were provided for different Reynolds numbers (Re), number of revolutions (N) and diameter ratio (D *).

Tusar et al. (2019) presented a three-dimensional computational study of conjugate heat and mass transfer performed using the "ANSYS FLUENT Computational Fluid Dynamics (CFD) software package to study the effect of insert torque on heat transfer and fluid flow performance. A survey was conducted for airflow at 300 Kelvin and Reynolds number between 3642 and 21857 through a pipe with a constant wall heat flux of 8000 W/m2. Validating against the Gneilski and Petukhob models," the influence of both the 3.46 and 7.6 torque ratio inserts mostly on Nusselt number, friction factor, and thermal efficiency factor of both the pipe were investigated using the current model.

Nakhchi et al. (2019) "Analyze the thermal performance of the turbulent flow inside the heat exchanger tube equipped with alternating axis braided belt (CCTA). Design parameters include Reynolds number (5000<Re<15,000), cross section width ratio (0.7<b/ D<0.9), cross section length ratio (2<s / D<2.5) and the torsion ratio (2<e / D<4).

Nakhchi et al. (2019) The flow structure and thermo- hydraulic output of turbulent flow through a circular tube filled for twisted belts of various cut shapes were investigated using a numerical analysis. For two sets of specific cuts, the cutting geometries were rectangular for various cutting ratios of 0.25 b/ n 0.75 and 0.25 c/ w 1. (single and double cut). Experimental evidence from the literature was used to test the three-dimensional simulations.

Singh et al. (2019) The thermal properties and flow characteristics of such a fluid in a circular tube containing elliptical inserts were investigated experimentally and computationally. The hydraulic diameter, whichis 6.81cm, is used as main axis. "The height ratio (= b / D) hasalso been considered as a new parameter with three values:0.45, 0.66, and 0.74."

CFD analysis of tubes with circular inserts through vertical twisted tapes (CVTT) and elliptical inserts for vertical twisted tapes (EVTT) When comparing to smooth tube, heat transfer improvements range from 3–8 times for CVTT placed in full length and TPF from 1.19–2.63 times for CVTT placed in TL length."

Tusar et al. (2019) performed a three-dimensional (3D) computational fluid dynamics (CFD) analysis to study heattransfer performance and fluid flow characteristics using a helical screw tape insert in the pipe line flow. The geometry of the inserted tube has been improved by using a helical coil, i.e.wound in wire with a torque ratio of 1.92.

Gorjaei et al. (2019) consider inserting twisted ribbon and turbulent flow of nano fluids (passive techniques) in orderto improve heat flow through the curved tube Copper is used for the curved tubing and braided tape. The evaluation segment (curved tube) is submerged in even a hot water pool. A three-step process is often used to process the water / Al2O3 nano fluid. Influences of volumetric flow rate, nano particle concentration, including twisted ribbon insert onto convective flow heat transfer coefficient, The Darcy friction factor aswell asthe Nusselt number were examined. The curved tube for twisted ribbon insert increases the heat transfer coefficient through convection through upto 31%, according the findings.

Sarviya et al. (2018) described experimental work on increasing heat transfer employing woven tape with continuous cutting edges, a modern form of insert. Thefriction factor and Nusselt number for a current twisted ribbon insert with separate twist ratios of 3 and 5 are being determined. To ensure the validity of the experimental findings, the flat tube and traditional twisted ribbon datawerecross-checked with normal correlations.

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Olenberg et al. (2018) presented CFD simulations to numerically study the performance improvement potential of structured corrugated sheet packaging combined with twisted web inserts. For different configurations of braided belts, the coefficients of pressure drop and mass transfer were determined and the optimal configuration was selected for insertion into structured packaging.

The new structured packaging with integrated twisted ribbons was compared with an equivalent conventional packaging, and finally the first experimental investigations on the optimal configuration were carried out. Based on these investigations, it can be concluded that twisted tape inserts have the potential to increase the overall efficiency of structured packaging.

Hosseinnezhad et al. (2018) numerically investigated the turbulent flow of water / Al2O3 nanofluid in a tubular heat exchanger with two intertwined ribbon inserts in the three-dimensional coordinate. This numerical simulation was performed using FVM and all equations were discretized using the second order wrapping method.

The SIMPLEC algorithm was used for the coupling of the velocity-pressure equations. Reynolds numbers ranging from 10,000 to 30,000, the influence of both the twist ratio of the woven tape inserts ranging from 2.5 to 4, the co-eddy flow and counter-vortex flow of two twisted ribbons within the tube, and volume percentages of the nano fluid ranging from 1 to 4% were all studied in this report.

Sivakumar et al. (2018) presented a numerical survey on heat transfer analysis taken at different flow rates using CFD simulation. The friction factor which heat transfer characteristics were studied using a commercial CFD kit for solid concrete fluid simulation. The heat transfer from hot water to cold water became investigated experimentally using just a double tube heat exchanger for smooth tube but twisted ribbon including triangular cut copper inserts in this research. CFD research was included in this article to enhance heat transfer from a laminar water flow as a working fluid.

Flow analyses were performed in a circular tube for triangular cut braided tape inserts with a Y = 5.4 twist ratio and a 1.2 cm triangular cut depth of cut. A spinning motion was generated by a single twisted ribbon, as well as a triangular cut was used to maximize heat transfer.

Liu et al. (2018) In the paper, the authors used the STAR-CCM + CFD program to perform a numerical analysis of heat transfer efficiency. Whenever the Reynolds number is between 40 and 1050, that local flow dynamics, as well as the local and mean convection heat transfer coefficients, are studied. The impact of the four separate torsion ratios of 2.0, 3.0, 4.0, and ∞ on the heat's efficiency. The Performance Evaluation Criterion (PEC) is used to assess the impact of improved heat transfer with either a specified pumping capacity.

Abed et al. (2018) Forced convection heat transfer studied numerically through built-in horizontal tube with / without twisted ribbon inserts under uniform heat flow conditions. Water is used as a working fluid.

"The governing equations are solved numerically in the domain by a finite volume method (FVM) using the realizable κ - ε (RKE) model. The calculation results are performed for a range of Reynolds number ($4000 \leq Re \leq 9000$), the torsion ratio ($4.0 \leq TR \leq 6.0$) and the heat flux ($5000 \leq q \leq 1000$ W / m^2).

Kumar et al. (2018) "The presented design of the experiments was used to study the effect of thermal parameters in improving heat transfer in a double-tube heat exchanger using a passive technique. Having ribbon diameter, belt pitch, and mass flow rate and input parameters and Nusselt number (Nu) and pressure drop (ΔP) as output variables, a twisted ribbon is known to have been a system what increases heat. For build a mathematical prediction model, the Response Surface Methodology (RSM) is used. The effect of the above input parameters on Nu and ΔP was investigated by ANOVA analysis.

Naveen et al. (2017) Heat transfer, friction factor, and thermal efficiency of concentric tube heat exchangers using twisted ribbons (Plain, V-cut, Jagged V-cut) with various twist ratios (y = 2.0, 4.0) were studied using three-dimensional CFD modeling. Twisted ribbons create instability in the fluid flow, which increases heat transfer.

Akbariet al. (2017) numerically studied the heat transfer of laminar and turbulent water / Al2O3 nanofluid flow in the volume fraction of φ = 0–4% of solid nano particles in Reynolds numbers of 500–

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25,000. A three-dimensional tube with a diameter of 2 cm and a length of 50 cm was examined.

Jalil and Goudarzi Even in evaporator of absorption chillers, wire coils (S1, S2), modified wire coils (GS1, GS2, GS5), modified classic (TW), and butterfly (BT) tube inserts were investigated, with the butterfly tube inserts achieving the highest thermo hydraulic output factor of 1.78.

Keklikcioglu and Ozceyhan Wire coiled inserts were tested in a HET and the maximum total enhancement performance (η) was found to be 1.67 times that of a smooth tube.

Du et al. conducted research on Nurs and frs augmentation of sinusoidal rib tubes (SRTs) and found a 4.89 increase in Nurs.

Singh et al. Heat transfer and friction properties of co-twist HET were studied experimentally. The thermal efficiency factor was discovered to be between 1.46 and 1.61.

Tamna et al. The maximal value of rs=1.4 was discovered in a HET with a double twisted tape (TT) insert with 30° V-shaped ribs.

Bhuiya et al. [16] examined the Nurs and frs properties of a HET in double counter twisted tapes but observed a 1.34 rise in the ηrs.

Promvonge The overall heat transfer coefficient of a quadrangle duct of quadruple TT insert was calculated ηrs of 1.75.

Skullong et al. studied how to improve Nurs in a HET with two pairs of perforated-delta-winglets TT inserts. Nurs and frs improved in a range of 1.97–5.04 and 2.06–35.68, overall, as opposed to smooth tube.

Jang et al. To improve Nurs, researchers looked at the ribs, dimples, even protrusions on inserts, and discovered that the rib-dimple integrated roughness offers the most effectiveness.

Yehia et al. The maximum Nurs, frs, and thermal efficiency was found in a HET with various angle swirl vanes mounted also on inserts, with a 45° blade angle providing the best results.

Omara and Abdelatief The value of Nurs, frs, and rs with rectangular helical wire inserted through elliptic HET were greater than those of circular helical wire inserted in elliptic HET.

S. Eiamsa-ard The results of inserting TT even with a centred rod over which the tape remains placed were investigated experimentally on either a counter flow concentric tube heat exchanger with air and in inner tube and water in the outer tube. The tape with the maximum Nu were recorded to have a space ratio of one without a centred rod.

P. Eiamsa-ard et al The results of discretely positioned TTs at various space ratios and twist ratios were investigated experimentally where computationally, and it was found that the tape with the lowest space ratio and highest twist ratio would be most efficient in improving heat transfer which produced the highest pressure drop.

Hasanpour Experiments were conducted for plain tubing, perforated tube, and tapes with v and u notches embedded in corrugated tube, and it was discovered that the (Nu) and head loss all improved as compared to plain tube. In all cases, a higher rate of heat exchange and the need for further pumping are found as compared to a standard TT, except for the perforated one.

Abdolbaqi 2016, The results of just using clockwise and counter clockwise double TT on heat transfer, pressure drop, and performance were tested experimentally. Throughout terms of thermal performance, double counter TT were observed to be among the most efficient.

Bhuiya The results of someone using twin counter TT with perforations of various porosities and in tape were investigated experimentally. And for the smallest porosity, heat transfer being found to improve with declining porosity. (1.2%).

Piriyarungrod Utilizing various taper ratios and twist ratios, different improvements in thermo fluidics were studied. The tape with the highest taper angle and also the smallest twist ratio where found to have the best thermal efficiency.

Mahipal et al. (2018) the use of swirl flow systems in various configurations as a passive heat transfer augmentation technique is discussed.

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Chen et al. The heat transfer properties of a concentric tube heat exchanger with the a transversely grooved inner tube were investigated. Heat transfer is facilitated by the use of liquid salt in the heat exchanger channel. The inner concentric tube is filled with hot fluid, while the outer tube is filled with cooling oil.

Bartwal et al. At a pitch ratio (PR) of 3 but a grade of metal wire net (G) of 9, an experimentally investigated novel geometry insert yields a maximum TEF of 2.84.

III. METHODOLOGY

1. Model Description:

1.1 Physical Model: Figure 3.1 depicts the heat exchanger's framework with twisted ribbon inserts. To maximize the heat transfer rate, two twisted ribbons are inserted into heat exchanger tube, and air (fluid) with a different Reynolds number is added. The copper pipe is 3000mm long with the a 50.8mm inner diameter (D) and a total length of 1000mm.

The tapes used were twisted aluminum foil tapes with a twist ratio of y / w = 4.24mm wide (w) and 96mm twist length (y). The aim of both the ongoing project is to figure out how fast heat transfers in a circular tube with entangled ribbons. TheReynolds (Re) number as well as the geometry of tube are the parameters of concern. The heat source is provided in the pipe wall and the heat input is kept around 3.5 kW.

a) Dia=50.8, Length=1000

b) Dia=60.8, Length=1000

c) Dia=50.8, Length=2000

d) Dia=80, Length=3000.

Fig 1. Pipe having 2 twisted tape inserts.

2. Boundary Conditions:

Table 1. Boundary conditions and interfaces conceived in the ANSYS-fluent 16 pre-processor.

Sr. No	Solid domain	Fluid domain	Interface/boundary location	Interface/boundary type
1		air	Fluid_Inlet	Velocity Inlet
2		air	Fluid_outlet	Pressure Outlet (0 Gauge Pressure)
3	Copper		Bottom wall	Constant Heat Flux

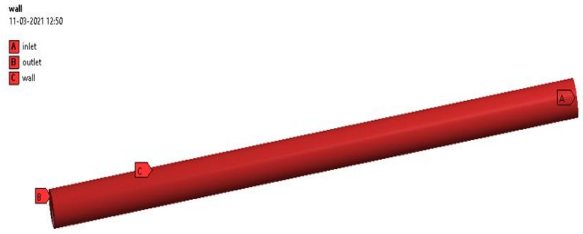

Fig 2. Boundary condition in CFD.

IV. CONCLUSION

In the literature review above, the typical or modified twisted-tapes are frequently introduced in round tubes to enhance the degree of turbulence and the fast fluid mixing whereas the rib/fin/baffle/winglets are often offered in ducts/channels to promote the turbulence intensity.

For a circular tube, the application of combined double twisted-tapes and V-ribs attached on the tape edge has never been come across in the literature. Considering the merits of both devices, a new enhancement device is offered by incorporating the rib into the twisted-tape edge.

The insertion of this compound device is expected to yield stronger turbulence intensity in the near-wall regime by the rib and fast fluid mixing by the double twisted tapes, leading to higher heat transfer augmentation in the tube.

REFERENCES

[1] Farhan, Ammar A., Aljubury Issam M. Ali, and Hamdi E. Ahmed. "Energetic and exergetic efficiency analysis of a v-corrugated solar air

heater integrated with twisted tape inserts." Renewable Energy 169 (2021): 1373-1385.

[2] Mashayekhi, Ramin, Hossein Arasteh, Pouyan Talebizadehsardari, Apurv Kumar, Morteza Hangi, and Alireza Rahbari. "Heat transfer enhancement of nanofluid flow in a tube equipped with rotating twisted tape inserts: A two-phase approach." Heat Transfer Engineering (2021): 1-16.

[3] KULKARNI, KG, SY BHOSALE, and SN SATPUTE. "Experimental Investigation of Heat Transfer Enhancement of Corrugated Twisted Tape Insert with Cfd Analysis." JournalNX 1, no. 2: 1-8.

[4] Tiwari, Arun Kumar, Summaiya Javed, Hakan F. Oztop, Zafar Said, and Naimish S. Pandya. "Experimental and numerical investigation on the thermal performance of triple tube heat exchanger equipped with different inserts with WO3/water nanofluid under turbulent condition." International Journal of Thermal Sciences 164 (2021): 106861.

[5] Hakim, M. U., M. W. Hridoy, M. I. Islam, and M. S. Rayhan. "Numerical study of heat transfer enhancement through a circular tube fitted with and without rectangular cut twisted tape insert." In IOP Conference Series: Materials Science and Engineering, vol. 1017, no. 1, p. 012019. IOP Publishing, 2021.

[6] Paneliya, Sagar, Sakshum Khanna, Jeet Mehta, Vishal Kathiriya, Umang Patel, Parth Prajapati, and Indrajit Mukhopdhyay. "An Experimental and CFD Analysis on Heat Transfer and Fluid Flow Characteristics of a Tube Equipped with X-Shaped Tape Insert in a U-Shaped Heat Exchanger." In Proceedings of the 7th International Conference on Advances in Energy Research, pp. 1331-1348. Springer, Singapore, 2021.

[7] Liaw, Kim Leong, Jundika C. Kurnia, and Agus P. Sasmito. "Turbulent convective heat transfer in helical tube with twisted tape insert." International Journal of Heat and Mass Transfer 169 (2021): 120918.

[8] Bhattacharyya, Suvanjan, Ali Cemal Benim, Rachid Bennacer, and Kunal Dey. "Influence of Broken Twisted Tape on Heat Transfer Performance in Novel Axial Corrugated Tubes: Experimental and Numerical Study." Heat Transfer Engineering (2021): 1-22.

[9] 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.

[10] 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.

[11] 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).

[12] 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.

[13] 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.

[14] 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.

[15] 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.

[16] 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.

[17] 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.

[18] Hossein nezhad, Rahim, Omid Ali Akbari, Hamid Hassan zadeh 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.

[19] Siva Kumar, 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.

[20] 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.

[21] Abed, Azher M., Hasan Sh Majdi, Zainab Hussein, DoaaFadhil, and Ammar Abdul kadhim. "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.

[22] Kumar, Shiva, and P. Dinesha. "Optimization of thermal parameters in a double pipe heat exchanger with a twisted tape using response surface methodology." Soft Computing 22, no. 18 (2018): 6261-6270.

[23] Naveen, S., and S. Bhuvaneshwaran. "CFD analysis of Concentric Tube Heat Exchanger using twisted tapes." International Journal of Advance Research, Ideas and Innovations in Technology 3, no. 1 (2017): 870-879.

[24] Akbari, Omid Ali, Hamid Hassanzadeh Afrouzi, Ali Marzban, Davood Toghraie, Hossein Malekzade, and Abedin Arabpour. "Investigation of volume fraction of nanoparticles effect and aspect ratio of the twisted tape in the tube." Journal of Thermal Analysis and Calorimetry 129, no. 3 (2017): 1911-1922.

[25] Rawani, Atwari, S. P. Sharma, and K. D. P. Singh. "Enhancement in Performance of Parabolic Trough Collector with Serrated Twisted-tape Inserts." International Journal of Thermo dynamics 20, no. 2 (2017).

[26] Bhattacharyya, Suvanjan, Himadri Chattopadhyay, and Ali Cemal Benim. "Simulation of heat transfer enhancement in tube flow with twisted tape insert." Progress in Computational Fluid Dynamics, an International Journal 17, no. 3 (2017): 193-197.

[27] Chaware, Parag, and C. Sewatkar. "Effects of tangential and radial velocity on the heat transfer for flow through pipe with twisted tape insert-turbulent flow." International Journal of Heat and Technology 35, no. 4 (2017): 811-820.

[28] Kaliakatsos, D., M. Cucumo, V. Ferraro, M. Mele, A. Galloro, and F. Accorinti. "CFD analysis of a pipe equipped with twisted tape." International journal of Heat and Technology 34, no. 2 (2016): 172-180.

[29] Singh Suri AR, Kumar A, Maithani R (2017) Effect of square wings in multiple square perforated twisted tapes on fluid flow and heat transfer of heat exchanger tube. Case Stud TherEng 10:28–43. https://doi.org/10.1016/j.csite.2017.03.002

[30] He Y, Liu L, Li P, Ma L (2018) Experimental study on heat transfer enhancement characteristics of tube with cross hollow twisted tape inserts. Appl Therm Eng 131:743–749. https://doi.org/ 10.1016/j. applthermaleng.2017.12.029

[31] Chen YS, Tian J, Fu Y et al (2018) Experimental study of heat transfer enhancement for molten salt with transversely grooved tube heat exchanger in laminar-transition-turbulent regimes. ApplThermEng 132:95–101. https://doi. org/10.1016/j.applthermaleng. 2017.12.054

[32] Bartwal A, Gautam A, Kumar M et al (2018) Thermal performance intensification of a circular heat exchanger tube integrated with compound circular ring–metal wire net inserts. ChemEng Process Intensif 124:50–70. https://doi.org/ 10.1016/j.cep.2017.12. 002

[33] Jalil E, Goudarzi K (2018) Experimental study of heat transfer enhancement in the evaporator of single-effect absorption chiller using new different tube insert. Appl ThermEng 128:1–9. https://doi.org/10.1016/j.applther maleng. 2017. 09.004.

[34] Keklikcioglu O, Ozceyhan V (2018) Experimental investigation on heat transfer enhancement in a circular tube with equilateral triangle cross sectioned coiled-wire inserts. ApplThermEng 131:686–695. https://doi.org/10.1016/j.app lther maleng.2017.12.051.

[35] Du J, Hong Y, Huang S-M et al (2018) Laminar thermal and fluid flow characteristics in tubes with sinusoidal ribs. Int J Heat Mass Transf 120:635–651. https://doi.org/10.1016/j.ijheatm as stransfer. 2017.12.047

[36] Singh V, Chamoli S, Kumar M, Kumar A (2016) Heat transfer and fluid flow characteristics of heat exchanger tube with multiple twisted tapes and solid rings inserts. ChemEng Process Intensif 102:156–168. https://doi.org /10. 1016 /j.cep.2016.01.013

[37] Tamna S, Kaewkohkiat Y, Skullong S, Promvonge P (2016) Heat transfer enhancement in tubular heat exchanger with double Vribbed twisted-tapes. Case Stud TherEng 7:14–24. https:// doi.org/ 10.1016/j.csite.2016.01.002.

[38] Promvonge P (2015) Thermal performance in square-duct heat exchanger with quadruple V-finned twisted tapes. ApplThermEng 91:298–307. https://doi.org/10.1016/j.applthermaleng.2015.08.047.

[39] Skullong S, Promvonge P, Thianpong C, Jayranaiwachira N (2017) Thermal behaviors in a round tube equipped with quadruple perforated-delta-winglet pairs. ApplThermEng 115:229–243. https://doi.org/10.1016/j.applthermaleng.2016.12.082.

[40] Jang HN, Park JS, Kwak JS (2018) Experimental study on heat transfer characteristics in a ribbed channel with dimples, semispherical protrusions, or oval protrusions. ApplThermEng 131: 734–742. https://doi.org/10.1016/j.applthermaleng.2017.12.030.

[41] Yehia MG, Attia AAA, Abdelatif OE, Khalil EE (2016) Heat transfer and friction characteristics of shell and tube heat exchanger with multi inserted swirl vanes. ApplThermEng 102:1481–1491. https://doi.org/10.1016/j.applther malen g.2016.03.095.

[42] Omara M A., Abdelatief M A. (2018) Experimental study of heat transfer and friction factor inside elliptic tube fixed with helical coils. ApplTherEng, 134, 407–4418. Doi:https://doi.org/10. 1016/j. applthermaleng.2018.02.017.ASHRAE Standard 93– 77, Method of testing to determine the thermal performance of solar collector; 1977.

[43] S. Eiamsa-ard, P. Promvonge, Enhancement of heat transfer in a tube with regularly-spaced helical tape swirl generators, Sol. Energy 78 (2005) 483–494.

[44] [P. Eiamsa-Ard, N. Piriyarungroj, C. Thianpong, S. Eiamsa-Ard, A case study on thermal performance assessment of a heat exchanger tube equipped with regularly-spaced twisted tapes as swirl generators, Case Stud. Thermal Eng. 3 (2014) 86–102.

[45] A. Hasanpour, M. Farhadi, K. Sedighi, Experimental heat transfer and pressure drop study on typical, perforated, V-cut and U-cut twisted tapes in a helically corrugated heat.

[46] M.K. Abdolbaqi, W.H. Azmi, R. Mamat, N. Mohamed, G. Najafi, Experimental investigation of turbulent heat transfer by counter and co-swirling flow in a flat tube fitted with twin twisted tapes, Int. Commun. Heat Mass Transfer 75 (2016) 295–302.

[47] M. M. K. Bhuiya, A. K. Azad, M.S.U. Chowdhury, M. Saha, Heat transfer augmentation in a circular tube with perforated double counter twisted tape inserts, Int. Commun. Heat Mass Transfer 74 (2016) 18–26.

[48] N. Piriyarungrod, S. Eiamsa-Ard, C. Thianpong, M. Pimsarn, K. Nanan, Heat transfer enhancement by tapered twisted tape inserts, Chem. Eng. Process. Process Intensif. 96 (2015) 62–71.

[49] Mr. Mahipal, A. Parmar (2018), Numerical Analysis For Effect Of Different Length Combination Of Turbulators On Heat Transfer And Pressure Drop In Double Pipe Heat Exchnager, International Research Journal Of Engineering And Technology, Volume: 05 Issue: 12,Pp 1557-1566.

[50] Chen YS, Tian J, Fu Y et al (2018) Experimental study of heat transfer enhancement for molten salt with transversely grooved tube heat exchanger in laminar-transition-turbulent regimes. ApplThermEng 132:95–101. https://doi.org/10. 1016/j.applthermaleng. 2017.12.054

[51] Bartwal A, Gautam A, Kumar M et al (2018) Thermal performance intensification of a circular heat exchanger tube integrated with compound circular ring–metal wire net inserts. ChemEng Process Intens if 124:50–70. https://doi.org/10. 1016/j.cep.2017.12. 002