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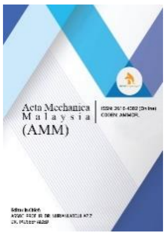

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REVIEW ARTICLE

COMBINED TWISTED TAPE AND NANOFLUIDS IMPROVEMENT HEAT TRANSFER TECHNIQUES IN HEAT EXCHANGERS: REVIEW ARTICLE

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ABSTRACT

Recently, the nanofluid using has led to development of enhanced heat transmission. A nanofluid is a kind of fluid made by dispersing 100 nm-sized metal, oxide, or carbide nanoparticles into water, ethylene glycol, or oil. The ultimate goal of the analysis is to identify the best way to modify twisted tape inserts while maintaining the ideal nanoparticle volume fraction for the turbulent flow regime. Lastly, several issues including pressure drop and agglomeration that need to be resolved for further study are covered. This review article presents a number of numerical and experimental studies that looked into effects of nanoparticles usage in hybrid and single nanofluid to enhance heat rate in heat exchangers of double pipe type, taking into account nature the heat exchange process and the relative directions of motion of the fluids (counter and parallel flow). This article discussed the important system's efficiency factors as the concentrations of nanoparticles, the Re, and the inserts configurations of, and summarized 41 papers published between 2000 and 2023 on the nanofluid improvement with inserts.

KEYWORDS

heat exchanger; nanofluid; inserts; twisted tape

1. INTRODUCTION

In many different commercial, industrial, and residential contexts, heat transfer devices like heat exchangers are utilized extensively for energy conversion and recovery. There are several ways to increase heat transmission that may be used to optimize double pipe heat exchanger DPHE operation and design. Because of its outstanding thermal performance, twisted tape is one of the most used swirl flow technologies in real-world applications (Ponnada et al., 2019; Eiamsa-Ard et al., 2013). Eiamsa-ard and Wongcharee surveyed the interactions between two micro-fin tube (MF), twisted tapes (DTs), and nanofluids on the heat transfer rate properties, thermal performance factor and friction factor (Eiamsa-ard and Wongcharee, 2013). CuO-water nanofluids with concentrations (0.3- 1.0 % vol.) as working fluids with Re = 5650 -17000. The heat rate increased with increasing the nanoparticles concentration. The dual twisted-tapes using in micro-fin tube will delivered a higher thermal performance factor than the micro-fin tube with a single twisted-tape or the micro-fin tube by itself micro-fin tube.

A study numerically a variety of nanofluid types, the impact of employing louvered strip inserts in a circular DPHE on the flow and heat fields (Mohammed et al., 2013). The (FVM) is used to explain the equations for continuity, momentum, and energy. A pipe's top and bottom walls are heated under a boundary condition of uniform heat flux. The forward and backward louvered strip insert configurations with a Re =10,000 to 50,000 are used. Investigations are also conducted into the impact of changed strip slant pitches and angles. Four distinct kinds of nanoparticles with varying diameters and volume fractions between 1% and 4% are Al_2O_3, CuO, SiO_2, and ZnO. The results showed that at the lowest pitch of S=30 mm and the highest slant angle of α=30°, the arrangement of forward louvered strip will increase the heat rate by around 367% to 411%. The enhanced in coefficient of tube skin friction is ten times greater than that of the smooth tube. The performance evaluation criterion (PEC) of the tube falls to 1.28 and 1.56.

Finally, the results concluded that the water give the lowest Nusselt number but the SiO_2, Al_2O_3, ZnO, and CuO has the greatest values respectively. Experimental research was done on the DPHE with inner and outer diameters of 8 and 16 mm, respectively with twisted-tape and TiO_2 nanofluid (Maddah et al., 2014). The aluminum sheet used to create the twisted tapes had dimensions of 1 mm for tape thickness, 5 mm for tape width, and 120 cm for tape length. 30 nm-diameter titanium dioxide nanoparticles with a 0.01% (v/v) volume concentration were created. The heat rate coefficient increased by roughly 10 to 25 percent when twisted tape and nanofluid were employed, compared to when they weren't. Additionally, it was noted that the mass flow rate and operating temperature both raise the heat transfer coefficient. The friction factor empirical correlations that have been suggested match the experimental results quite well. Maddah et al. investigated DPHE with modified twisted tapes the fluid flow of the Al2O3 nanofluid under turbulent flow conditions in an experimental setting (Maddah et al., 2014).

Under comparable operating conditions, studies were carried out using varying geometrical progression ratios (GPRs) of new modified twisted tapes and varying nanofluid concentrations. When RGPR twists and nanofluids are combined, heat transmission and friction factor tend to rise by 12% to 52% and 5% to 28%, respectively, in comparison to tubes with standard twisted tapes and nanofluid, according to experimental results. To gauge overall improvement in thermal behavior, the heat exchanger's thermal capabilities with improved twisted tapes and nanofluid were

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assessed. The proposed correlations are validated by a satisfactory match between the collected experimental data and the current correlations. Eiamsa-ard and Kiatkittipong investigated numerous twisted tapes and TiO_2 nanofluid to advance the thermal characteristics in a DPHE (Eiamsa-ard and Kiatkittipong, 2014). Furthermore, twisted tape arrangements in countercurrent were better energy-saving devices for real-world applications, especially at low Re. Particularly true for counter tapes in cross directions.

It was justified to boost heat transmission at the expense of comparatively little friction loss. The thermal presentation factor was maximum up to 1.45. A greater thermal performance was obtained while employing water containing TiO2 nanoparticles as the working fluid as opposed to pure water. Al2O3 nanofluid was employed to increase the heat exchangers' heat transfer rate (Prasad et al., 2015). This paper presents an experimental investigation employing an Al2O3 water-based nanofluid on a trapezoidal-cut twisted tape insert in a twin pipe U-tube heat exchanger. Data from experiments are produced at flow of 0.0333 and 0.2667 kg/s. as using water and Re = 3000-30000, experimental data is produced. The total pipe's Nusselt number is increased by 34.24% as compared to water. When using trapezoidal twisted tape with a H/D = 5 friction factor of the entire system of pipes is increased by 1.29 times at a concentration of 0.03% nanofluid in comparison to water. According to the investigation's results, the heat exchanger's performance parameters the friction factor and heat transfer coefficient improve with an increase in the volume concentration of the nanoparticle.

A group researcher used Al2O3 nanofluid to increase heat rate in heat exchangers. This paper presents an experimental investigation employing an Al_2O_3 water-based nanofluid on a trapezoidal-cut twisted tape insert in a twin pipe U-tube heat exchanger (Prasad et al., 2015). Data from experiments produced at range of flow of 0.0333 - 0.2667 kg/s. The Nu of the entire pipe for 0.03% nanofluid with trapezoidal twisted tape about 34.24 % in comparison to water for range 3000<Re<30000. At a concentration of 0.03% nanofluid, the friction factor of the complete system of pipes with trapezoidal-cut twisted tape inserts of H/D=5 is enhanced 1.29 times relative to water. The results of the investigation indicate that the performance parameters of the heat exchanger, namely the friction factor and heat transfer coefficient, improve with an increase in the volume concentration of the nanoparticle.

Convective (HTE) approaches have been developed over years of research in the heat transfer field. In order to properly optimize thermal engineering systems, both the exegetic efficiency and the heat transmission must be minimized in their design and operation. A group researchers offered a theoretical, numerical, and experimental examination of the exergy analysis in a twin pipe heat exchanger (Mmohammadiun et al., 2016). For this purpose, metal oxide-water nanofluids and twisted tapes (TTs) are considered as model fluids and turbulators. Results are confirmed using established relationships. The results show that the exergetic efficiency may be increased by 30–100% using nanofluids and TTs in place of an empty tube and water as the base fluid. Moreover, the exergetic efficiency rises with a nanoparticle concentration and decreases with a reduction in twist ratio. Compared to other nanofluids, CuO nanofluid offers a higher increase in energy efficiency under the same circumstances.

In addition to the structural alterations of the tape inserts, some researchers found an additional heat transfer improvement of base fluid (polyvinyl alcohol) and twisted tape (RWTT) inserts (Hazbehian et al., 2016). A base fluid and nanoparticles were selected to be TiO_2 and polyvinyl alcohol as TiO2/PVA nanofluid up to 2.0 % volume fraction and Re= 800–30000. As the breadth of the tape grows, the rate of heat transfer for twisted tapes with a smaller width falls. The average Nusselt numbers for the plain tube in the tube equipped with the RWTT of 16, 14, and 12 are 170-290%, 190-320%, and 210-390%, respectively. RWTT with bigger width length create a stronger thermal enhancement factor than RWTT with less width, based on the same tendency previously established. Maddah and Ghasemi examined the heat efficiency of iron oxide-water nanofluid flow in DPHE with standard twisted tape (Maddah and Ghasemi, 2017).

The concentration of the nanofluid was 0.01, 0.02 and 0.03 weight percent, and the experiments were carried out in both laminar and turbulent flow conditions for Reynolds numbers between 1000 and 6000. An artificial neural network was employed to model and predict the heat transfer efficiency. Heat transfer is the network's output or aim. Heat transfer efficiency increases by 30% when 0.03 weight percent nanofluid is present and by 60% when 0.03 weight percent nanofluid and twisted tape with a twist ratio of two are used combined. The most optimal configuration was found to be a 1–10–6 configuration with a correlation coefficient of 0.99181 and a normal root mean square error of 0.001621, after experiments with various neural network topologies and middle layer neuron counts. Performance of the heat exchanger is impacted by the fluid's Nusselt number. The fluid's nusselt number will increase with increasing heat transfer. Using nanofluids as working fluids and twisting tape within a tube are two techniques that may be used to improve the Nusselt number. Nevertheless, using the method previously mentioned might potentially result in a greater pressure drop along the pipes.

Therefore, it must be ascertained if the increase in pressure drop that results is justified by the improvement in heat transmission. Suhanan et al. is connected to the modeling of parallel heat exchangers employing twisted tape with twist ratios of 7.35, 5.25, and 4.72 and nanofluids with volume percentages of 0% (base fluid), 0.1%, and 0.3% (Suhanan et al., 2017). According to current theories, nanofluid is a homogeneous fluid with characteristics that have been studied in previous research. A simulation using ANSYS Fluent showed that the Nusselt number increases by 131.88%, 142.271%, 145.82%, and the pressure drop increases by 232.52%, 280.23%, and 304.50%, respectively, when twisted tapes with twist ratios of 7.35, 5.25, and 4.72 are used in place of plain tubes with base fluid. Additionally, the Nusselt Number increases by 6.72%, 13.85%, and the pressure drop increases by 14.01%, 37.09%, and so on when nanofluids with fraction volumes of 0.1% and 0.3% are utilized in place of simple tubes with base fluid.

A group researcher conducted the flow of nanofluids TiO2/TermoXT 32 in twin DPHE with twisted tape insert (Prayitno et al., 2018). The working fluid, nanofluids, was continually pumped and maintained at a low temperature of 20°C. Ten LPM, twelve LPM, fourteen LPM, sixteen LPM, eighteen LPM, and twenty LPM were the eight distinct flow rates. Three distinct twist ratio variations of aluminum twisted tape insertions were used in the experiment: 7.35, 5.25, and 4.72. The nanofluid TiO2/TermoXT 32 has three volume fraction variations: 0% (base fluid); 0.1%); and 0.3%. The results showed that the twisted tape insertions were what contributed to the increased heat transfer rate. This increment was shown by an increase in the Nusselt number for each measurement planned. A group researchers studied the twisted tape insertion in twin U-bend DPHE with Fe3O4/water nanofluids flow by using (NTU), effectiveness, heat transfer coefficient and friction factor (Ravi et al., 2018).

The test conditions included particle volume concentrations between 0.005% and 0.06%, Reynolds numbers between 16,000 and 32,000, and twisted tape inserts with H/D values of 10, 15, and 20. When Reynolds number and particle volume concentrations increase, so does the Nusselt number of nanofluids; it increases even more when the twist ratio of twisted tape inserts falls. Similarly, in comparison to the water data, the friction factor penalty at a Reynolds number of 30,000 was 1.092 times (no insert) and 1.251 times (with twisted tape inserts of H/D = 10). New correlations between the friction factor and the Nusselt number have been reported, based on the experimental data. An experimental investigation was conducted by to look into the hydrothermal properties of an agitated-vessel U-tube heat exchanger (Aliabadi et al., 2018). Three metallic nanofluids (Cu/water, Fe/water, and Ag/water) and three twist ratios (α=0.33, 0.67, and 1) with varying width/depth values for peripheral cuts (β=0.33, 0.5, 0.67, 1, 1.5, 2, and 3) with Re of 7000-18,000 are conducted. The results show that both spiky twisted tapes and metallic nanofluids significantly enhance heat transfer in the agitated-vessel U tube heat exchanger. Spiky twisted tapes have an 11%–67% higher heat transfer coefficient when compared to the smooth state. Based on the performance factor, the most efficient configuration is the spiky twisted tape configuration with α=β=0.33.

Nakhchi and Esfahani used numerical examination to study the Cu-water nanofluid with cross twisted tape (Nakhchi and Esfahani, 2018). Nine different CCTA geometries and plain tubes with width ratios (b/w) and length ratios (s/w) between 0.7 and 0.9, Reynolds numbers between 5000 and 15,000, and nanoparticle volume fractions between 0 and 1.5% are used in all simulations. Based on computed results, the swirl flow produced by CCTA, which starts in the tube core, reaches the near wall parts. Improved heat transmission and the friction factor at the tube wall are thus enhanced by increased fluid mixing. According to the results, the heat transfer coefficient may reach 23.20% when the volume percentage of nanoparticles grows from 0% to 1.5%.

A group researcher conducted a quantitative study on the turbulent flow of water/Al_2O_3 nanofluid in a tubular heat exchanger with two twisted-tape inserts in the three-dimensional coordinate (Hosseinnezhad et al., 2018). In this numerical simulation, which was conducted using FVM for Re 10,000–30,000, the impact of twisted-tape insert twist ratios between 2.5 and 4, co-swirl and counter-swirl flow of two twisted-tapes inside the tube, and volume fractions of nanofluid between 1 and 4% were all discretized using the second-order upwind method. For twist ratios of 3.25 and 2.5, respectively, the maximum values of the performance evaluation criterion (PEC) are 1.55 and 1.6. Moreover, the PEC improvement of the counter-swirl flow state is substantially higher than that of the co-swirl flow state. A group researchers provided the heat transmission and frication factor characteristics of a heat exchanger tube using self-rotating twisted tapes (SRTTs) (Zhang et al., 2019).

In order to compare SRTTs with stationary twisted tapes (STTs) and look into the effects of SRTTs with different twist ratios (Y = 2.2, 3, 4, and 6) on the thermal properties, experimental study was carried out in turbulent flows (12000 < Re < 45000). The results of the experiment showed that SRTTs working in a rotating environment might enhance the heat exchanger's thermal performance in contrast to STTs. It was found that the SRTTs with lower twist ratios rotated faster and that the twist ratios had less of an effect on the early stages of the spinning behavior under the same operating circumstances. The maximum thermal performance factors of 1.03, 0.9444, 0.924, and 0.898 could be reached at the beginning of rotational behavior for Y = 2.2, 3, 4, and 6, respectively. In the end, some correlations between the Nusselt number and the frication factor were discovered, within ±10% variation of the experimental data. A group researchers performed an experimental study that examined the thermal properties of a double-pipe heat exchanger equipped with perforated self-rotating twisted tapes with six perforation ratios of 0%, 1.16%, 3.63%, 6.46%, 10.1%, and 14.49% (Zhang et al., 2019).

The results of the experiment showed that the perforation ratio has a significant impact on both rotational speed and the initial stage of rotation behavior. Experiments showed that in terms of thermal performance, perforated self-rotating twisted tapes perform better than perforated stationary twisted tapes. Moreover, the rise in perforation ratios was accompanied by an increase in the Nusselt number and pressure drop. PR = 10.1% was shown to be a greater thermal performance factor under rotating settings than PR = 14.49%. When the self-rotating twisted tapes went from a stationary to a spinning state, the thermal performance factor rose from 0.862 to 0.924, 0.987 to 1.025, 1.04 to 1.078, 1.084 to 1.101, and 1.042 to 1.055 for perforation ratios of 0%, 1.16%, 3.63%, 6.46%, and 10.1%, respectively. The thermal performance factor of perforated twisted tapes and perforated self-rotating twisted tapes was assessed, and it was discovered that several correlations relating to perforation ratios might predict the friction factor and Nusselt number. A group researcher examined the effect of using TiO_2-water nanofluid with ϕ = 0.05, 0.1, and 0.15 vol.% fluid flow in dimpled tubes with twisted insert (Eiamsa et al., 2019). The testing results showed that the dimpled tubes with twisted tapes had greater heat transfer rates than the dimpled tube without tapes. The results also shown that dimple angle, twist ratio, and TiO2-water nanofluid concentration all significantly impacted thermo-hydraulic performance.

Among the dimpled tubes under examination, the one with the greatest improvement in heat transmission had a dimple angle of 45°. Heat transmission (Nu) rose as the concentration of nanofluid increased and the twist ratio (y/W) dropped. It is imperative to enhance heat transmission in heat-exchanging devices in today's heat exchanger design. One of the best methods for passive heat transmission is to employ twisted tape inserts. A group researchers examined the thermal performance of a twin pipe heat exchanger in the Reynolds number range of 5000 to 15000 using water and SiO2/water nanofluid, both with and without the insertion of serrated twisted tape (STT) (Karthik et al., 2019). STT has a pitch to width ratio of 0.2. As a result of adding 1% of STT-containing nanoparticles, the friction factor increases by 90%, but the maximum amplification of heat transfer is only around 49%. An Al2O3+MgO hybrid nanofluid moving in turbulent settings was examined for its hydrothermal characteristics by Singh and Sarkar (Singh and Sarker, 2020). According to the research, D-type wire coil inserts provide better hydrothermal performance than C-type and C-D kinds. The hybrid nanofluid produces less entropy than the basic fluid in every circumstance. Every insert has a thermal performance factor greater than one for the hybrid nanofluid. The highest thermal performance factor for the D-type coil is claimed to be 1.69.

Among others, Gnanavel Industries such as power plants and automobiles have required improved heat transfer for applications involving heating, cooling, and evaporation, facilitated by appliances like air conditioners, freezers, and radiators (Gnanavel et al., 2020). Depending on the need, either active or passive methods, or combinations of both, are used. The passive technique is commonly used to improve heat transfer in the heat exchanger's pipes since it is simple. In common with plain water as the base fluid, the titanium dioxide, beryllium oxide, copper oxide, and zinc oxide nanofluids are added. The thermal performance is being examined by the numerical analysis. Using a twisted tape turbulator, a group research examined the Al2O3-H2O nanofluid in DPHE (Arjmandi et al., 2020). In this method, the behavior of the pressure drop and heat transfer rate of a twin pipe heat exchanger is examined. As a result, the central composite design (CCD)-based response surface methodology (RSM) is used to find the twisted tape turbulator. Gnanavel and associates made thermal devices to work more effectively by increasing the heat transfer (Gnanavel et al., 2020).

In order to heat, cool, or evaporate on machinery like air conditioners, radiators, freezers, condensers, and other similar devices, some industrial industries, including power plants and autos, need a greater amount of heat transmission. Passive and active procedures are the two categories into which the currently available techniques may be separated. The goal of the effort is to use passive strategies to improve heat transmission in twin pipe heat exchangers. Numerous fluid media, such as water, titanium dioxide nanofluid, beryllium oxide or beryllia nanofluid, zinc oxide nanofluid, and copper oxide nanofluid, are considered for investigation in order to boost the fluid medium's thermal conductivity. The spiral spring insert distributes the fluid on the surface and offers flow resistance to enhance heat transfer. The heat exchanger's thermal and flow fields are analyzed numerically through the use of a spiral spring insert and many types of nano-fluid. The finite volume approach was used to solve the continuity, momentum, and energy equations, and ANSYS 15.0 was used for the numerical analysis.

A group researchers proposed a novel approach that improves convective heat transfer in heat exchangers while minimizing the pressure drop penalty as compared to other conventional enhancement solutions (Bezaatpour et al., 2020). The method relies on providing an external magnetic field to induce a swirling flow in the magnetic working fluid. A three-dimensional numerical simulation has been used to assess the efficacy of the proposed method in a double pipe small heat exchanger at different magnetic nanofluid concentrations, flow rates, and magnetic field strengths. According to the findings, using an external magnetic field can enhance heat transfer by as much as 320% while just slightly increasing pressure drop. The resulting spinning flow enhances flow mixing and upends the thermal barrier layer, which speeds up heat transmission. Furthermore, when there isn't an extra obstruction in the flow path, the pressure drop is decreased and flow resistance is also decreased.

It is demonstrated that low Reynolds numbers, strong magnetic fields, and high nanofluid concentrations are ideal for the operation of nanoscale heat exchangers. According to the continuous and discontinuous twisted tapes turbulator (perforated and non-perforated) on the inner side of the internal tube in the double heat exchangers had experimental impacts on heat transfer, the friction coefficient, and thermal performance (Vaisi et al., 2020). Nine distinct geometries, including square, rectangular, circular, and triangular with a triangle arrangement, have been generated on the flat surfaces of a discontinuous twisted tape turbulator. Examined is the Reynolds range from 5500 to 100000, with hot and cold water in the annular gap and working fluids on the inner tube side, respectively. Experimental results show that the heat transfer and pressure drop of a discontinuous turbulator are superior than those of a continuous turbulator. Subsequently, the effect of perforation on the turbulator of discontinuous twisted tapes was studied. The experimental findings showed that the perforated discontinuous turbulator with circular, square, rectangular, diamond, and triangular perforation increased heat transmission by 20.8%, 15%, 11%, 8.7%, and 5% and decreased it by 27.7%, 22.8%, 17.3%, 12.1%, and 5.5%.

The power plant, automobile, and process industries—more especially, air conditioning, radiators, refrigerators, condensers, and heating and cooling—are the principal users of heat transfer augmentation. In this approach, it is possible to boost heat transport through both passive and active ways. A group researcher used the passive approach for heat rate intensification in DPHE (Gnanavel et al., 2020). For the study, four different nanofluids—zinc oxide, copper oxide, zinc oxide, and titanium dioxide, also known as beryllium oxide or beryllia—are taken into account. The round fin insert distributes the fluid on the surface and offers flow resistance to enhance heat transfer. The numerical study investigates the thermal and flow fields in the system using a circular fin insert and many types of nanofluid.

In a twin pipe heat exchanger fitted with GO-Water nanofluid and different turbulators at (500 ≤ Re ≤5000) and (0.05%–0.15%) of GO-H2O nanofluid, Murthy and Hegde investigated the effects of a combined passive method on thermal performance factor, friction factor, and heat transfer (Murthy and Hegde, 2020). Utilizing helically twisted inserts and circular finned twisted tape, research was conducted. The results of the experiment showed that helices and nanofluid volume concentration increased along with a decrease in twist ratio, which was also correlated with an increase in Nu and TPF. A group researchers presented experimental investigation on an $Al_2O_3+TiO_2$ hybrid nanofluid volume concentration of 0.1% flowing turbulently in a double-tube heat exchanger with a range of modified V-cuts twisted tape inserts to examine the hydrothermal characteristics (Singh et al., 2021). The impacts of using twisted tape turbulators (with and without V-cuts) and hybrid nanofluid on the heat transfer and pressure drop characteristics are evaluated for different twist ratios, V-cut depth ratios, V-cut width ratios, and hybrid nanofluid inlet temperatures.

The results show that the Nusselt number and friction factor decrease with decreasing twisting ratio, depth ratio, width ratio, and nanofluid inlet temperature. Comparing to the water in the experiment, maximum increases of 55% for the friction factor and 132% for the Nusselt number are obtained. The thermal performance factor for hybrid nanofluid and the entropy generation ratio for all modified twisted tape inserts are more than unity. A numerical investigation aimed at investigating the flow characteristics and thermal performance of CuO–water was published (Nakhchi and Esfahani, 2021). The numerical study utilizes the turbulent model of (RNG) k – α since the flow is completely turbulent. The results indicate that increased vortex flow via the incisions in the twisted tapes and turbulent kinetic energy are the main factors responsible for improved fluid mixing and greater heat transmission. The heat transfer is increased by around 14.5% when =1.5% is present. Thermal performance reaches its maximum value (=1.99) at Re = 5000 when nanofluid with =1.5% and b/c = 1.8 is used.

Singh and Sarkar looked into this using an Al_2O_3+MWCNT hybrid nanofluid (Singh and Sarkar, 2021). The research is carried out using a Reynolds number of 8000–40000, a volume concentration of 0.01%, and a nanofluid flow velocity of 5–25 lpm. Hybrid nanofluid is combined with a range of enhancers, such as V-cut twisted tapes and tapered wire coils, to assess the impact of various enhancer configurations, such as wire coil, on the hydrothermal properties. The test indicates that an increase in the heat transfer coefficient is caused by a lowering twist ratio, a rising depth ratio, and a decreasing width ratio. At the cost of a pressure drop, the D-type wire coil offers superior heat transfer performance as compared to other arrangements. Twisted tape that has been V-cut with a minimum twist ratio and maximum depth and breadth ratios yields the highest PEC and FOM. The tapered wire coil has a lower performance index than the V-cut twisted tapes, which show a little larger pressure drop. With regard to entropy creation, the D-type wire coil has the least amount of any arrangement.

The base fluid in the twisted tube system used was nanofluid (NF), which was calculated theoretically using CuO-water with 0.5 mass percent carboxymethyl cellulose passing between the annulus side and the tube side in a steady-state laminar flow (Shahsavar et al., 2021). The performance measures are examined in connection with the twist pitch, nanoparticle volume concentration (φ), and Reynolds number (Re). The findings showed that an increase in Re has both favorable and unfavorable effects, such as increased pumping power and pressure drop as well as improved heat transfer and heat exchanger performance. Moreover, it was shown that everywhere except for $\varphi \leq 1.5\%$ and Re=500, the NF performs better than the base fluid.

The increasing global energy demand will need double pipe heat exchangers (DPHEX), which are used in many thermal and energy engineering applications, to function better in terms of heat transmission. Das et al.'s evaluation of the thermophysical and rheological characteristics of a new formulation at different weight percent concentrations of 0.01, 0.05, and 0.10 was conducted (Das et al., 2021). Using zeta potential analysis, the stability of the dispersion is assessed, and an optimal concentration is selected. By adding different geometric incisions, such triangular, rectangle, and circular ones, to the surface of the conventional twisted tape (TT) insert, it is modified. As compared to the basic fluid, the Io-nanofluid characterization shows that 0.10 weight percent. The rectangular-cut TT increases heat since it has more additional vortices than other cut inserts.

The effectiveness of the heat exchanger is influenced by several aspects, such as the cut geometry, twist orientation, and twist ratio of twisted tapes. In order to optimize heat transmission and reduce friction, work focused on constructing DPHE inserted with variable cross-section cut twisted tapes (Kola et al., 2021). The mass flow rate, radius of cut, and angle of cut were all taken into account as input factors. The response variables are the coefficient of friction factor and heat transmission. The input values required for the analysis were supplied using CFD. The impact of the aforementioned features on the response variables was investigated using ANOVA. Both the interaction and the linear terms have an impact on the replies. The optimal parameters within the investigated range are a mass flow in order to produce a higher HTC and a lower friction factor. The work by looked at the numerical assessment of how utilizing two different types of nanofluids and adding a unique curved insert affected a DPHE's thermal performance (Karouei et al., 2021).

Two examples of hybrid nanofluids that are taken into account are silver (Ag) and graphene (HEG) nanoparticles in water and multi-wall carbon nanotubes–iron oxide nanoparticles in water (MWCNT-Fe_3O_4/s). This turbulator is considered groundbreaking since it has 12 blades to create secondary flows. Additionally, care is given to a hole at the end of the turbulator. This study is divided into two parts: The first compares the results utilizing hybrid nanofluids and pure water (φ = 0.3%). In the second section, the nanofluid from the first was selected and applied. The volume concentration of the selected hybrid nanofluid was analyzed. The results show that the present new turbulator provides a greater heat transfer rate. Thus, the Ag-HEG/water hybrid nanofluid performs better thermally at low mass flow rates. Moreover, the analyzed helical heat exchanger has the lowest thermal efficiency at φ = 0.1%. When the volume concentration is at its greatest (φ = 0.7%), the thermal performance peaks at low mass flow rates. Kundan and Darshan employed a twisted tape insert to circulate a TiO_2-H_2O nanofluid (0.05% by vol.) in DPHE (Kundan and Darshan, 2022).

The TiO_2-H_2O turbulent flow of nanofluid has been constructed for Re=5000–25000 in terms of heat transfer and friction factor coefficient. Moreover, the heat transfer coefficients for the 0.05%, 1%, 2%, and 3% volume concertation of TiO_2 nanoparticles increase to 6%, 10.9%, 17.4%, and 23.4%, according to numerical data. Based on simulation results, the heat transfer coefficient values of the TiO_2-H_2O nanofluid at a volume concentration of 0.05% are not significantly affected by the size of the TiO_2 nanoparticles (30 nm and 50 nm). Thianpong et al. created a hybrid method that combines the use of delta-wing twisted tape (LTT-W) with TiO_2-H_2O nanofluid to improve heat transfer (Thianpong et al., 2022). The results of the experiment demonstrated that the system using the combined enhancement method had a much higher heat transfer capacity than the system without using the enhancement technique. This is brought on by the interplay between the working fluid's increased thermal conductivity and the spinning flow. As the loose-fit ratio decreased and the concentration of nanofluid increased, the rate of heat transmission and thermohydraulic performance both improved.

The thermohydraulic performance (TPF) reached its optimum at φ = 0.15% and c/D = 0.0. Moreover, GMDH models and NSGA II algorithms were employed in Multi-Objective Optimization (MOO) to investigate the best thermohydraulic performance. Bantan et al. [40] investigated the effect of employing a porous zone on the behavior of a hybrid nanofluid flowing through a duct using the FVM approach. Momentum equations have incorporated related factors and used the Darcy model in three-dimensional steady flow forms. Testing fluids were hybrid nanofluids, which were created by combining H_2O and nanoparticles (MWCNT + Al_2O_3). To improve heat absorption, helical tape was applied. The test section is the middle 40 cm of the duct, where the porous zone and helical tapes were inserted. For the lowest computing cost, the most accurate outputs are obtained by analyzing the grid and utilizing the validation basis of previous published work. Da, ϕ, and Re's impact on working fluid.

Finaly, employed twisted tape as inserts together with a recently created perforated conical ring in an experimental investigation on a heat exchanger tube (Kumar et al., 2023). The investigation examines a wide range of geometric and flow parameters in the experimental setup, such as the following: a ring pitch ratio (RP/DED) of 1.41-2.51, a ratio of the ring's inner print dia to inlet flow dia (DIR/DBR) of 1.33-2.33, fixed values for other parameters like relative ring height ((DED/ WR) of 2.33 and nanoparticle diameter (dnp) of 30 nm. The best results are obtained with the thermal-hydraulic performance parameter (ηTT) at DIR/DBR = 1.83, TL/WT = 3.50, and RP/DED = 1.45.

2. Conclusion

The present study indicates the following research gaps and suggests other research directions: The ideal modification for twisted tape has to be determined by more thorough tests and simulations that take a wide variety of geometrical parameters into account. Dispersion and random movement of nanoparticles must be studied in order to comprehend how swirl flow resulting from twisted tape influences the total enhancement ratio. The greatest overall enhancement ratio value of 1.8 is provided by RGPR, but low-to-high twisted tape shows rising values of overall enhancement ratio with Reynolds number. Therefore, in order to create a system that functions for higher Reynolds numbers, further study is needed on the increase and reduction of PR twisted tape from the tube's intake to output. Further studies on the kind, concentration, and shape of nanoparticles are required to identify which nanoparticles are most suited for turbulent flow regimes since turbulent and swirl flow result in increased heat transfer. The impact of twisted tape alteration on the total enhancement ratio is more noticeable (30% more effective) when compared to the nanofluid volume percentage. Nonetheless, the total enhancement ratio is 20% higher when both of these passive strategies are used at the same time as twisted tape alone.

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References

Aliabadi, M., Davoudi, S., Dibaei, M.H., 2018. Performance of agitated-vessel U tube heat exchanger using spiky twisted tapes and water based metallic nanofluids. Chemical Engineering Research and Design, 133, Pp. 26-39.

Arjmandi, H., Amiri, P., Pour, M.S., 2020. Geometric optimization of a double pipe heat exchanger with combined vortex generator and twisted tape: A CFD and response surface methodology (RSM) study. Thermal Science and Engineering Progress, 18, Pp. 100514.

Bantan, R., Abu-Hamdeh, N.H., AlQemlas, T., Abd Elmotaleb A.M.A. Elamin, 2023. Heat transfer improvement of hybrid nanofluid with use of twisted tapes within a heat exchanger. Alexandria Engineering Journal, 70, Pp. 673-684.

Bezaatpour, M., Goharkhah, M., 2020. Convective heat transfer enhancement in a double pipe mini heat exchanger by magnetic field induced swirling flow. Applied Thermal Engineering, 167, Pp. 114801.

Das, L., Rubbi, F., Habib, F., Saidur, R., Islam, N., Saha, B.B., Aslfattahi, N., Irshad, K., 2021. Hydrothermal performance improvement of an inserted double pipe heat exchanger with Ionanofluid. Case Studies in Thermal Engineering, 28, Pp. 101533.

Eiamsa-ard, S., Kiatkittipong, K., 2014. Heat transfer enhancement by multiple twisted tape inserts and TiO2/water nanofluid. Applied Thermal Engineering, 70 (1), Pp. 896-924.

Eiamsa-Ard, S., Somkleang, P., Nuntadusit, C., Thianpong, C., 2013. Heat transfer enhancement in tube by inserting uniform/non-uniform twisted-tapes with alternate axes: effect of rotated-axis length, Appl. Therm. Eng., 54, Pp. 289–309.

Eiamsa-ard, S., Wongcharee, K., 2012. Single-phase heat transfer of CuO/water nanofluids in micro-fin tube equipped with dual twisted-tapes, International Communications in Heat and Mass Transfer, 39 (9), Pp. 1453-1459.

Eiamsa-ard, S., Wongcharee, K., Kunnarak, K., 2019. Heat transfer enhancement of TiO_2-water nanofluid flow in dimpled tube with twisted tape insert. Heat Mass Transfer, 55, Pp. 2987–3001.

Gnanavel, C., Saravanan, R., Chandrasekaran, M., 2020. Heat transfer enhancement through nanofluids and twisted tape insert with rectangular cut on its rib in a double pipe heat exchanger, Materials Today: Proceedings, 21 (1), Pp. 865-869.

Gnanavel, C., Saravanan, R., Chandrasekaran, M., 2020. Heat transfer augmentation by nano-fluids and Spiral Spring insert in Double Tube Heat Exchanger – A numerical exploration. Materials Today: Proceedings, 21 (1), Pp. 857-861.

Gnanavel, R., Saravanan, M., Chandrasekaran, 2020. Heat transfer augmentation by nano-fluids and circular fin insert in double tube heat exchanger – A numerical exploration, Materials Today: Proceedings, 21 (1), Pp. 934-939.

Hazbehian, M., Maddah, H., Mohammadiun, H., 2016. Experimental investigation of heat transfer augmentation inside double pipe heat exchanger equipped with reduced width twisted tapes inserts using polymeric nanofluid. Heat Mass Transfer., 52, Pp. 2515–2529.

Hosseinnezhad, R., Akbari, O.A., Hassanzadeh Afrouzi, H., 2018. Numerical study of turbulent nanofluid heat transfer in a tubular heat exchanger with twin twisted-tape inserts. *J Therm Anal Calorim.,* 132, Pp. 741–759.

Karouei, H., Ajarostaghi, S.H., Gorji-Bandpy, M., 2021. Laminar heat transfer and fluid flow of two various hybrid nanofluids in a helical double-pipe heat exchanger equipped with an innovative curved conical turbulator. *J. Therm Anal Calorim.,* 143, Pp. 1455–1466.

Karthik, A., Hanumanth, K.S., Kumar, R.J.V., 2019. Experimental investigation of silica oxide/water nanofluid in a double pipe heat exchanger with serrated twisted tape insert. AIP Conf. Proc., 2128, Pp. 050020.

Kola, P., Pisipaty, S.K., Mendu, S.S., Ghosh, R., 2021. Optimization of performance parameters of a double pipe heat exchanger with cut twisted tapes using CFD and RSM. Chemical Engineering and Processing - Process Intensification, 163, Pp. 108362.

Kumar, A., Ali, M.A., Maithani, R., Gupta, N.K., Sharma, S., Kumar, S., Sharma, L., Thakur, R., Alam, T., Dobrota, D., Eldin, S.M., 2023. Experimental analysis of heat exchanger using perforated conical rings, twisted tape inserts and CuO/H2O nanofluids. Case Studies in Thermal Engineering, 49, Pp. 103255.

Kundan, L., Darshan, M.B., 2022. Performance investigation of a concentric double tube heat exchanger using twisted tape inserts and nanofluid. An International Journal, 40 (3).

Maddah, H., Aghayari, R., Morshed, F., Shabnam, J., Khatere, A., 2014. Effect of Twisted-Tape Turbulators and Nanofluid on Heat Transfer in a Double Pipe Heat Exchanger. Journal of Engineering, Article ID 920970, 9 pages, 2014.

Maddah, H., Alizadeh, M., Ghasemi, N., Alwi, S.R.W., 2014. Experimental study of Al2O3/water nanofluid turbulent heat transfer enhancement in the horizontal double pipes fitted with modified twisted tapes, International Journal of Heat and Mass Transfer, 78, Pp. 1042-1054,

Maddah, H., Ghasemi, N., 2017. Experimental evaluation of heat transfer efficiency of nanofluid in a double pipe heat exchanger and prediction of experimental results using artificial neural networks. *Heat Mass Transfer.,* 53, Pp. 3459–3472.

Mmohammadiun, M., Dashtestani, F., Alizadeh, M., 2016. Exergy Prediction Model of a Double Pipe Heat Exchanger Using Metal Oxide Nanofluids and Twisted Tape Based on the Artificial Neural Network Approach and Experimental Results. J. Heat Transfer. Jan, 138 (1), Pp. 011801.

Mohammed, H.A., Hasan, H.A., Wahid, M.A., 2013. Heat transfer enhancement of nanofluids in a double pipe heat exchanger with louvered strip inserts, International Communications in Heat and Mass Transfer, 40, Pp. 36-46.

Murthy, H.M.S., Hegde, R.N., 2020. Investigations on thermal characteristics in a double pipe fitted with circular finned and frequently spaced helical twisted inserts and Graphene oxide nanofluid. Heat Mass Transfer., 56, Pp. 2667–2679.

Nakhchi, M.A., Esfahani, J.A., 2018. Cu-water nanofluid flow and heat transfer in a heat exchanger tube equipped with cross-cut twisted tape, Powder Technology, 339, Pp. 985-994.

Nakhchi, M.E., Esfahani, J.A., 2021. Numerical investigation of turbulent CuO–water nanofluid inside heat exchanger enhanced with double V-cut twisted tapes. *J. Therm Anal Calorim*., 145, Pp. 2535–2545.

Ponnada, S., Subrahmanyam, T., Naidu, S.V., 2019. A comparative study on the thermal performance of water in a circular tube with twisted tapes, perforated twisted tapes and perforated twisted tapes with alternate axis, Int. J. Therm. Sci., 136, Pp. 530–538.

Prasad, P., Gupta, A., Deepak, K., 2015. Investigation of Trapezoidal-Cut Twisted Tape Insert in a Double Pipe U-Tube Heat Exchanger using Al2O3/Water Nanofluid, Procedia Materials Science, 10, Pp. 50-63.

Prasad, P., Gupta, A., Deepak, K., 2015. Investigation of Trapezoidal-Cut Twisted Tape Insert in a Double Pipe U-Tube Heat Exchanger using Al2O3/Water Nanofluid. Procedia Materials Science, 10, Pp. 50-63.

Prayitno, Y., Wiranata, A., Pradecta, M.R., Nugraha, M.V.A., 2018. Suhanan, Improvement performance of the double-concentric pipes heat exchanger using twisted tape insertions and nanofluids TiO2/TermoXT 32, AIP Conf., 020011.

Ravi, N.T., Bhramara, P., Sundar, K.L.S., Singh, M.K., Sousa, A.C.M., 2018.

Effect of twisted tape inserts on heat transfer, friction factor of Fe3O4 nanofluids flow in a double pipe U-bend heat exchanger, International Communications in Heat and Mass Transfer, 95, Pp. 53-62.

Shahsavar, A., Bakhshizadeh, M.A., Arici, M., 2021. Numerical study of the possibility of improving the hydrothermal performance of an elliptical double-pipe heat exchanger through the simultaneous use of twisted tubes and non-Newtonian nanofluid. *J. Therm Anal. Calorim.,* 143, Pp. 2825–2840.

Singh, S., Sarkar, J., 2020. Improving hydrothermal performance of hybrid nanofluid in double tube heat exchanger using tapered wire coil turbulator. Advanced Powder Technology, 31 (5), Pp. 2092-2100.

Singh, S., Sarkar, J., 2021. Hydrothermal performance comparison of modified twisted tapes and wire coils in tubular heat exchanger using hybrid nanofluid. International Journal of Thermal Sciences, 166, Pp. 106990.

Singh, S.K., Sarkar, J., 2021. Improving hydrothermal performance of double-tube heat exchanger with modified twisted tape inserts using hybrid nanofluid. J. Therm Anal Calorim., 143, Pp. 4287–4298.

Suhanan, R.H.P., Wiranata, A., Ardean, Y., Prayitno, K., Pradecta, M.R., 2017. Study on the Heat Transfer Improvement of Double Pipe Concentric Heat Exchanger Enhancement Using Twisted Tape And Nanofluids, Proceedings of the 9th International Conference on Thermofluids, (THERMOFLUID 2017), AIP Conf., 020010-1–020010-6.

Thianpong, C., Wongcharee, K., Safikhani, H., Chokphoemphun, S., Saysroy, A., Skullong, S., Eiamsa-ard, S., 2022. Multi objective optimization of TiO2/water nanofluid flow within a heat exchanger enhanced with loose-fit delta-wing twisted tape inserts. International Journal of Thermal Sciences, 172, Part A, Pp. 107318.

Vaisi, R.M., Moslem, L.M., Mohsen, S., 2020. Experimental investigation of perforated twisted tapes turbulator on thermal performance in double pipe heat exchangers, Chemical Engineering and Processing - Process Intensification, 154, Pp. 08028.

Zhang, S., Lu, L., Dong, C., Cha, S.H., 2019. Performance evaluation of a double-pipe heat exchanger fitted with self-rotating twisted tapes. Applied Thermal Engineering, 158, Pp. 113770.

Zhang, S., Lu, L., Dong, C., Cha, S.H., 2019. Thermal characteristics of perforated self-rotating twisted tapes in a double-pipe heat exchanger, Applied Thermal Engineering, 162, Pp. 14296.

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