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# Heat Transfer Enhancement Of Heat Exchanger Using Nanofluids And Conical Inserts

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***Abstract***
*The integration of nanofluids and conical inserts has garnered significant attention in the pursuit of enhancing heat transfer within heat exchangers. This research delves into the cooperative influences of these two techniques aimed at augmenting heat transfer processes. Nanofluids, comprising base fluids infused with nanoparticles, bring forth improved thermal properties, while the incorporation of conical inserts modifies fluid flow patterns, thereby facilitating more efficient heat transfer mechanisms. The study systematically investigates the repercussions of diverse nanofluid categories and various conical insert configurations on the performance of heat exchangers. By methodically varying parameters such as nanofluids, insert designs, and alterations in flow conditions, the objective is to optimize heat transfer efficiency, all while taking into account the consequential pressure drop. The findings gleaned from this research conical strip with twisted ratio 2.6 is offer valuable insights with 1.25 concentration of $SiO_2$ with Nusselt number, heat transfer rate, convective heat transfer coefficient. Which are 7.3% more compare to base fluid water contributing to the design of more efficient and space-efficient heat exchangers. These insights hold significance across a spectrum of industrial applications, encompassing the likes of automotive cooling systems and power generation plants.*

***Key words:*** *Heat exchanger, Nano fluid, twist ratio, conical inserts*

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## I. Introduction

Heat exchangers play a pivotal role in heat recovery. With the advancements in modern technology, the demand for heat exchangers has surged across various industries, requiring them to handle high heat-flux cooling levels, sometimes reaching megawatts per square meter. Traditional coolants like water and ethylene glycol face significant challenges when dealing with such high heat flux levels. Consequently, there is a pressing need to enhance the heat transfer efficiency of these working fluids within heat transfer devices. To achieve this, various heat transfer augmentation techniques are widely employed in industries spanning from process plants to thermal power generation, air conditioning systems, refrigeration units, and even applications in aerospace and automotive engineering. These techniques fall into three primary categories: passive, active, and compound methods. Passive heat transfer enhancement entails altering the surface area, surface roughness, or changing boundary conditions to naturally boost the rate of heat transfer. This method requires no additional energy input and is often considered a cost-effective approach. Active heat transfer enhancement, on the other hand, involves the introduction of nanosized, highly thermally conductive metallic powders into the base fluid. This modified fluid is commonly referred to as a "nanofluid." The incorporation of nanofluids serves to significantly increase the heat transfer rate within the system.

In comparison to active techniques, passive methods, which utilize inserts within the flow passage to augment heat transfer, are often preferred. This is due to the simplicity of the insert manufacturing process and the ease with which these techniques can be integrated into existing applications. Passive techniques offer an effective means of enhancing heat transfer without complex modifications or the addition of nanoparticles, making them a practical choice for many scenarios.

Oflaz et. al., [1] conducted a study that explored the benefits of combining conical wire inserts with $SiO_2$ nanofluids to enhance the hydrothermal performance of heat exchangers. Their research findings revealed that the conical wire inserts with a pitch ratio of 0 yielded the highest heat transfer efficiency, while the conical wire inserts with a pitch ratio of 4, combined with a 1.25% $SiO_2$ concentration, resulted in the lowest friction losses. Shajahan et. al., [2] investigated the thermal performance of conical strip inserts in conjunction with various volume concentrations of nanofluids. They observed that the thermal performance factor (TPF) for these inserts consistently exceeded 1. Particularly noteworthy was the achievement of a significant thermal performance ratio of 1.62 when using backward-arranged conical strip inserts with a twist ratio of 2.5 and a volume concentration of 0.5% $ZrO_2$/deionized water nanofluid. Furthermore, the research team developed correlations for the Nusselt number and friction factor through rigorous regression analysis, based on their experimental data. Keklikcioglu et. al., [3] conducted a study to investigate the impact of employing a combination of water-graphene nanoplatelet nanofluids and three distinct conical wire coils. Their findings revealed a significant Performance Evaluation Criteria score of 1.73, particularly notable when utilizing the diverging conical wire coil with a pitch ratio of 2, operating at a Reynolds number of 6128, and with a weight fraction of 1% Graphene-Water nanofluid. In a separate study by Mohammed et. al., [4] they proposed that heat transfer rates in heat exchangers can be enhanced by utilizing lowered strip inserts with various nano fluids composed of aluminum, copper, silicon, and zinc. Their research suggested that $SiO_2$ nanofluid demonstrated the highest Nusselt number value, followed by $Al_2O_3$, ZnO, and CuO, while pure water exhibited the lowest Nusselt number. The results further indicated that the Nusselt number tends to increase as the nanoparticle diameter decreases, with a slight increment observed with higher volume fractions of nanoparticles. Bahiraei et al. [5] An experimental study was carried out to assess the thermophysical characteristics and the efficiency of a non-Newtonian nanofluid comprising titanium dioxide nanoparticles within an irregular or disorganized geometric configuration. This investigation revealed that the convective heat transfer coefficient displayed irregular patterns and exhibited periodic behaviour. Heyhat et al., [6] A study was conducted to examine the heat transfer properties of $SiO_2$-water nanofluids within conically coiled tubes under the conditions of constant wall heat flux, as depicted in Figure 1. The investigation revealed that the introduction of nanoparticles led to enhancements in the heat transfer fluid's characteristics, albeit with increased viscosity resulting in elevated pressure drops. The research delved into the influence of cone angle and coil height on heat transfer performance, where it was observed that smaller cone angles were associated with higher heat transfer rates and, simultaneously, greater pressure drops. These observations indicated that the optimal improvements in heat transfer and pressure drop were 26% and 117%, respectively. Within the context of conically coiled tubes, the study further derived empirical correlations for assessing the Nusselt number and friction factor.

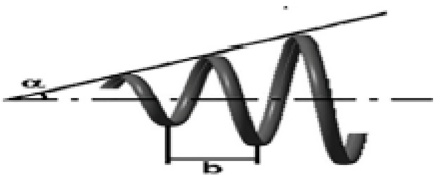

**Figure 1 Conically coiled tubes**

Silicon dioxide ($SiO_2$), commonly referred to as silica, is a naturally occurring compound derived from two abundant substances. Nanofluids containing $SiO_2$ nanoparticles have garnered significant attention from researchers due to their potential advantages and cost-effectiveness.

In a study by Ajeel et. al., [7], the focus was on assessing the heat transfer enhancement within different corrugated channels, including semicircle, trapezoidal, and straight geometries. They utilized $SiO_2$-water nanofluids with weight fractions of 1.0% and 2.0%. Notably, the incorporation of corrugated channels was observed to enhance heat transfer. However, this improvement was accompanied by an unexpected increase in pressure drop. The presence of corrugations in the channels facilitated the formation of secondary flow eddies, consequently enhancing heat transfer by influencing the fluid's path. Across all the channel types investigated, it was observed that the Nusselt number, pressure drop, and enhancement ratio increased as the $SiO_2$ volume fraction was raised. Hashimoto et. al., [8] The study explored the influence of particle diameter and volume concentration on the thermohydraulic efficiency of $SiO_2$-ethylene glycol/water nanofluids. It investigated how these nanofluids affected heat transfer coefficient, friction factor, and $SiO_2$ particle diameter while maintaining constant temperature boundary conditions. Remarkably, it was observed that the heat transfer coefficient of $SiO_2$-water nanofluids exhibited a substantial 25% increase when compared to ethylene glycol/water (EG) solutions. Furthermore, these nanofluids exhibited greater flow resistance and heat transfer coefficients in comparison to the EG solution. The research findings indicated that the enhanced heat transfer effect was closely linked to the particle diameter. In summary, the heat transfer efficiency of these nanofluids was found to be 18% higher than that of the EG solution at equivalent pressure drop levels.

The study also delved into the influence of the geometric parameters of the conical strip. The numerical findings reveal that a larger slant angle and a smaller pitch are effective in enhancing the heat transfer rate, albeit at the expense of increased flow resistance. Additionally, the research highlights that the sensitivity of the Nusselt number and friction factor to changes in the slant angle surpasses their response to alterations in the pitch of the inserts. Overall, a relatively consistent and efficient thermohydraulic performance is achieved at a moderate slant angle of 20° in conjunction with a small pitch of 30 mm [9].

In various literature sources, there is a recurring theme of experimentation involving conical inserts, particularly in the context of investigating the heat transfer characteristics using nanofluids. These experiments are conducted to explore and improve methods for enhancing heat transfer rates without significantly impacting the overall system performance.

The techniques for augmenting heat transfer can be broadly categorized into two groups: passive and active methods. Active methods entail the use of external power input to enhance heat transfer, while passive methods achieve heat transfer augmentation without external power input. Passive approaches aim to increase the effective surface area and residence time of the heat transfer fluid as a means to boost heat transfer performance. This technique introduces swirl into the bulk of the fluids and disrupts the existing boundary layer to increase surface area and residence time, subsequently enhancing the heat transfer coefficient within the existing system.

Inserts, in this context, refer to additional structures or arrangements intentionally placed in the fluid flow path to serve as obstacles. These inserts are strategically designed to augment the heat transfer rate, further contributing to the overall goal of improving heat transfer efficiency. Geometry of conical inserts is shown in below figure.

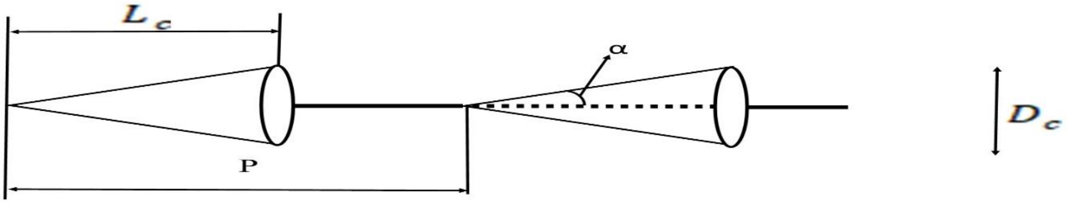

**Figure 2 Geometrical details of Conical inserts**

The ratio between the pitch (P) length to the diameter ($D_c$) of the test section (20 mm) is called the twist ratio (Y = $P/D_c$), as shown in Table1 with three various twist ratios for conical strip inserts. Figure 3 shows the photographic view of three twist ratios of the staggered conical strip inserts, namely Y = 2.6, 3.6, and 4.6, respectively [2].

The conical inserts, as depicted in Figure 3, are meticulously manufactured using a specialized method and constructed from copper material. These inserts possess a diameter ($D_c$) of 20mm and length or height ($L_c$) and slant length of cone is 30mm and 32mm. The length (L) 1m of these conical inserts is purposefully designed to match the inner diameter of the test tube, which measures 20 mm [1]. Notably, the conical shape features a diameter ($D_c$) match with the inner tube's diameter (25 mm). The conical inserts tape placed within the test tube at different pitch ratios such as illustrated in Figure 3 with slant angle 20° [9]. This insertion process is executed in various configurations to comprehensively study their impact on thermohydraulic performance. Apart from the conical inserts' ability to induce turbulence in the fluid flow, their placement close to the wall is instrumental in disrupting the laminar boundary layer, thus facilitating increased heat transfer. Geometric details conical strip is shown in table.

| Strip Name | Twist ratio | Pitch (mm) | Diameter (mm) | Slant angle (°) |
|---|---|---|---|---|
| a | 4.6 | 92 | 20 | 20 |
| b | 3.6 | 72 | 20 | 20 |
| c | 2.6 | 52 | 20 | 20 |

The enhancement of heat transfer in a heat exchanger can be achieved by introducing additional particles, such as nanoparticles, into the base fluid. For instance, the addition of $SiO_2$ nanoparticles to water resulted in an impressive 7.80% increase in thermal conductivity when compared to the thermal conductivity of pure water. However, this enhancement in thermal conductivity came at the cost of a 9.20% increase in viscosity in comparison to pure water.

Similarly, with $Al_2O_3$ nanoparticles, the thermal conductivity improvement varied depending on the nanoparticle size. Specifically, the thermal conductivity of 20 nm $Al_2O_3$ nanoparticles increased by 1.54% compared to the base fluid, while the 50 nm and 100 nm $Al_2O_3$ nanoparticles showed even greater enhancements of 2.43% and 2.43%, respectively, relative to the base fluid.

**Various research studies have examined the effects of nanoparticle size on the properties of nanofluids.** [10-11]

| **Base fluid** | **Nano particle** | **Concentration (%)** | **Size (nm)** | **Temperature (℃)** | **Observation** |
|---|---|---|---|---|---|
| Water | Aluminium oxide ($Al_2O_3$) | 1-1.41 | 20 | 10-50 | The thermal conductivity of 20 nm nanoparticles exhibited a 1.54% increase, which was notably higher than the 2.43% enhancements observed for the 50 nm and 100 nm nanoparticles. |
| | | | 50 | | |
| | | | 100 | | |
| Water | Silicon dioxide ($SiO_2$) | 0.2-1.46 | 15 | 25-65 | The thermal conductivity improvements were 3.80%, 4.90%, and 7.80%, respectively, when compared to the base fluid. In terms of viscosity, the increases were 6.10%, 8.30%, and 9.20% in comparison to pure water. |
| | | | 30 | | |
| | | | 80 | | |

## Experimentation

The technical particulars and the experimental setup procedure have been elucidated in detail. Figure 4 provides a schematic representation of this setup. The test tube consists of three main sections: an inlet section, responsible for establishing hydrodynamic flow and mitigating the initial tube effects; a central test section, which serves as the heated tube; and an outlet section. Each of these sections measures 1000 mm in length. The test tube's inner diameter ($D_i$) is set at 25 mm, while the outer diameter ($D_o$) is 27 mm with copper material. Additionally, the inner tube is enveloped by another tube with a 50mm diameter, constructed from stainless steel. To insulate the tube's external surface, a 6 mm thick layer of glass wool is applied. K type thermocouples are employed to gauge the outer surface temperatures of the test section. Temperature measurements are taken just prior to the beginning of the test section for the inlet and at the conclusion of the test section for the outlet. Liquid flow into the test section is facilitated by a mono pump, and a flow meter is utilized to measure the volumetric flow rate. The pressure drop is quantified using a differential pressure transmitter.

**Figure 4 Experimental setup**

The fluid was driven through the system using a centrifugal pump and controlled by a regulating valve. Flow rates ranged from 0 to 7 liters per minute (lpm), ensuring the establishment of laminar flow conditions. The fluid then passed into a calming section, where it achieved fully developed flow. Subsequently, it traversed the test section, where a constant wall heat flux was applied. Following this, the working fluid underwent cooling in a dedicated cooling unit. To monitor the pressure differential in the fluid, a U-tube manometer with a mercury column was employed. This entire cycle was repetitively executed for experimental runs involving plain tubes, staggered conical strips with varying twist ratios (Y = 2.6, 3.6, and 4.6), and for both water, $Al_2O_3$, and $SiO_2$ nanofluids at a 1.25% concentration level [1].

**Data Processing**

The heat extracted by the fluid in the test section was calculated as follows:

$$Q = M \times C_p \times (T_o \sim T_i)$$

The heat transfer coefficient was utilized in the calculation of the average Nusselt number (Nu):

$$Nu = \frac{hD_i}{k}$$

The pressure drops occurring between the inlet and exit of the test section, maintained under isothermal conditions, was employed to calculate the friction factor (f) using the following equation:

$$f = \frac{64}{Re}$$

The Reynolds number can be expressed as follows:

$$Re = \frac{\rho V D_i}{\mu}$$

## II. Results

The effects of using conical strip inserts with different pitches in a circular tube using different types of nanofluids type and conical inserts with different twisted ratios. Evaluate the performance of coaxial pipe heat exchanger Reynolds number on the Nusselt number, Heat transfer rate, heat transfer coefficient and friction factors are analysed and discussed in this section.

### Effect conical tape on Performance of Co-axial pipe heat exchanger with water

The figure5 depicts the relationship between the Nusselt number and the Reynolds number for plain water. In this graph, both the experimentally obtained Nusselt number and the predicted Nusselt number are plotted. As the Reynolds number increases, the Nusselt number also shows a corresponding increase, as illustrated in the figure. The twist ratio of 2.6 is notably associated with enhanced performance, outperforming other scenarios with an impressive 46% increases compare to without CI. This performance improvement is substantial when compared to cases without inserts.

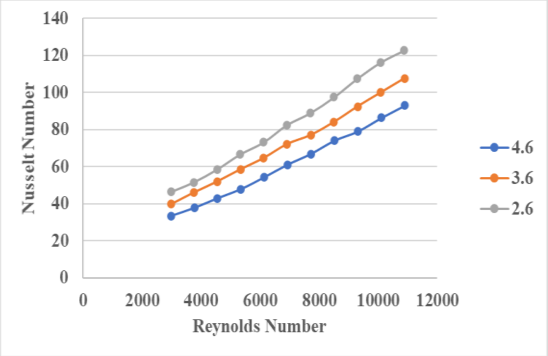

**Figure 5 Variation of Nusselt Number for Plane water**

Based on the information depicted in the figure 6, it is evident that the heat transfer rate varies in accordance with changes in the Reynolds number. Notably, in the present study, a twist ratio of 2.6 emerges as the optimal performer, yielding a heat transfer rate of 1857 w. This enhanced performance can be attributed to the increased turbulence and Nusselt number associated with this specific twist ratio.

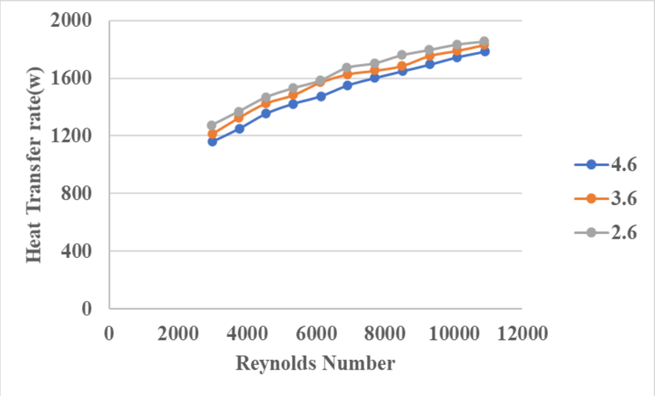

**Figure 6 Variation of Heat Transfer rate for Plane water**

As illustrated in Figure 7, there is a clear relationship between the Reynolds number and the heat transfer coefficient for the configuration involving CI (presumably a type of insert) with water. The trend shows that as the Reynolds number increases, the heat transfer coefficient also experiences an increase. Interestingly, lower Reynolds numbers result in a minimal heat transfer coefficient, as evident from the data presented in the figure. Remarkably, when CI is used in combination with water, the heat transfer coefficient shows a substantial improvement of 48.2% compared to scenarios where water is used without inserts.

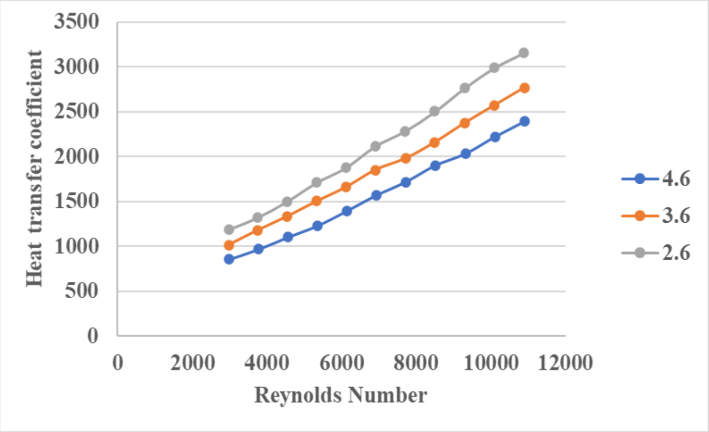

**Figure 7 Variation of heat transfer coefficient for Plane water**

The experimental data of friction factor of friction factor as shown in Figure 8 varies with respect to Reynold's number and results revealed that the experimental value of friction factor 38% is better compare to without inserts. The fitted value of coefficient of correlation is one, which is best value of the friction factor.

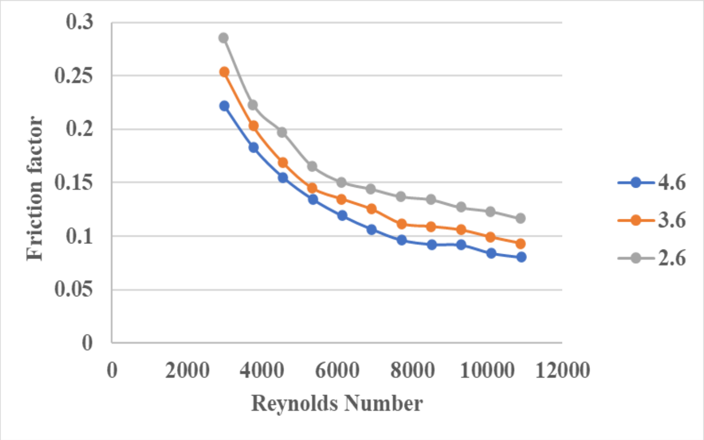

**Figure 8 Variation of friction factor for Plane water**

**Effect conical tape on Performance of Co-axial pipe heat exchanger with $Al_2O_3$ nano fluid**

In the previous chapter, it was examined that the Nusselt number, Heat transfer rate, heat transfer coefficient and friction factor characteristics of the coaxial pipe heat exchanger through conical tape inserts with plane water. In the presence results are presented with $Al_2O_3$ nano fluid.

The Nusselt number of the nanofluid exhibited a notable enhancement of 2.3% when compared to the base fluid, specifically water, during the fluid circulation. This enhancement can be attributed to the considerably higher thermal conductivity of the nanofluid in contrast to plain water.

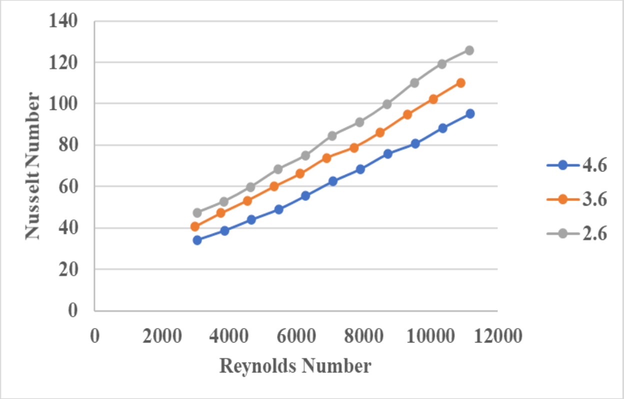

**Figure 9 Variation of Nusselt Number for $Al_2O_3$-water nanofluid**

This phenomenon is a consequence of the increased Reynolds number, which leads to the creation of viscous forces near the fluid wall boundary. These observations serve as compelling evidence, highlighting that the Nusselt number of nanofluids surpasses that of plain water. Furthermore, when considering CI with a twist ratio of 2.6, the Nusselt number is notably higher in comparison to other scenarios, as indicated in Figure 9.

The heat transfer rate within the $Al_2O_3$-water nanofluid demonstrates a remarkable enhancement, specifically 2.42 percentage greater in comparison to plain water when considering the configuration involving CI. The experiments were systematically conducted across a range of Reynolds numbers, achieved by varying the flow rates of cold water. These Reynolds numbers spanned from 3000 to 12000. The experimental procedure was employed to assess the heat transfer rate of the $Al_2O_3$-water nanofluid while concurrently altering the twisted ratios of the inserts. The recorded values for these twisted ratios were 1827.63, 1877.37, and 1902.125 for the respective insert configurations of 4.6, 3.6, and 26, as specified is shown in figure 10.

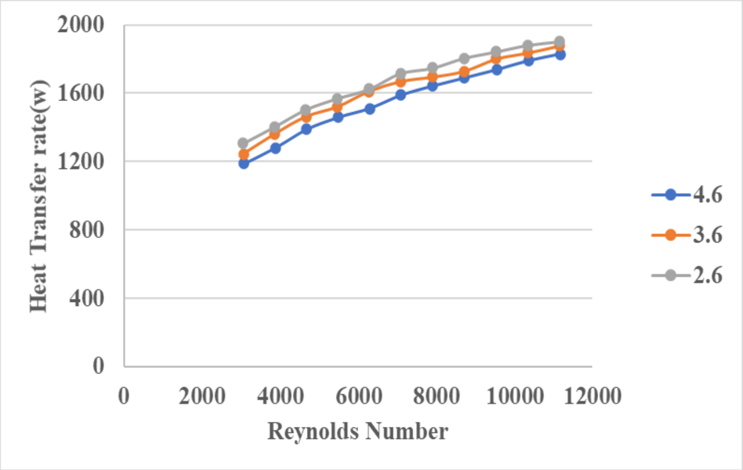

**Figure 10 Variation of Heat transfer rate for $Al_2O_3$-water nanofluid**

The verification of the heat transfer coefficient for $Al_2O_3$ nanofluids, as presented in Figure 11, confirms that the heat transfer coefficient experiences a rise in tandem with an increase in the Reynolds number. Notably, the highest heat transfer coefficient is achieved at higher Reynolds numbers, particularly in conjunction with the configuration featuring the highest twist ratio, as illustrated in Figure 11 In comparison to plain water, the use of $Al_2O_3$ nanofluids results in a significant enhancement of 2.37% in the heat transfer coefficient within the heat exchanger with twist ratio 2.6. Importantly, the experimental results for the heat transfer coefficient closely align with the expected values, attesting to the accuracy of the findings.

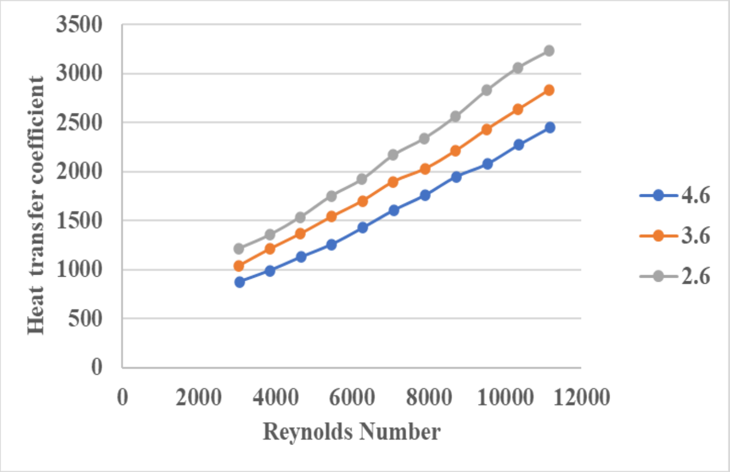

**Figure 11 Variation of Heat transfer coefficient for $Al_2O_3$-water nanofluid**

Figure 12 illustrates the relationship between the Reynolds number and the friction factor. Notably, the data in the graph reveals a consistent trend where the friction factor steadily decreases as the Reynolds number increases. Conversely, the figure also highlights that lower Reynolds numbers correspond to the highest values of the friction factor. This behavior can be attributed to the fact that lower Reynolds numbers and reduced fluid flow rates contribute to higher resistance in the flow, resulting in elevated friction factors.

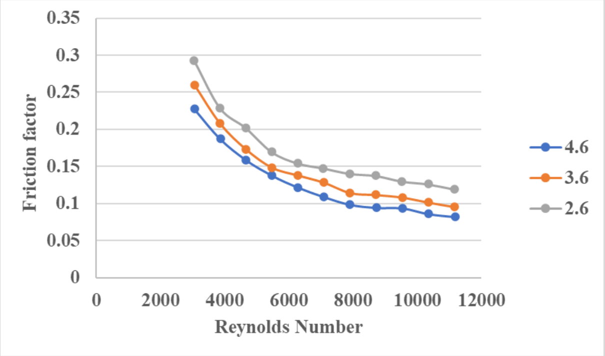

**Figure 12 Variation of Friction factor for $Al_2O_3$-water nanofluid**

**Effect conical tape on Performance of Co-axial pipe heat exchanger with $SiO_2$nano fluid**

In the preceding section, we delved into an exploration of a heat exchanger fitted with CI inserts, where $Al_2O_3$ nanofluid played a pivotal role in conducting experimental assessments. These experiments were aimed at scrutinizing the heat transfer and friction factor attributes of the CI-insert-equipped heat exchanger. The results demonstrated that the heat transfer coefficient of Aluminium oxide was notably superior to that of the base fluids, particularly excelling in its capacity to enhance thermal conductivity throughout the fluid flow, from inlet to outlet conditions. Now, in this subsequent section, we turn our attention to an analysis of heat transfer, Nusselt numbers, heat transfer coefficients, and friction factor characteristics within a heat exchanger that incorporates silicon dioxide nanofluid, all in conjunction with CI inserts.

Within the domain represented in Figure 13, an examination of the differences between the Reynolds number and the Nusselt number, pertaining to the utilization of $SiO_2$ nanofluid in conjunction with water, becomes evident. These investigations unveil a notable outcome: the Nusselt number for this combination, hereinafter referred to as CI with silicon dioxide, surpasses the Nusselt number for the base fluid, which is plain water, by a substantial 7.3%. This enhanced performance is particularly intriguing. The rationale underlying this observation can be traced back to the synthesis of silicon particles, which involves an initial step of particle generation within a solution. The wet particles are subsequently deposited on a substrate using a drop-casting process. Following this, the solvent, surfactants, and other materials are carefully removed from the particles. The resultant particles are characterized and then dispersed in water to create stable nanofluids.

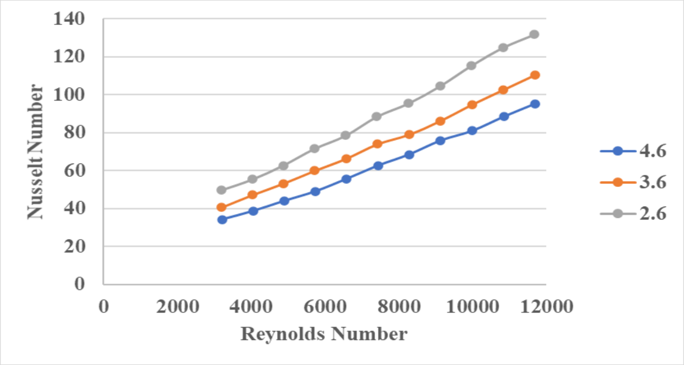

**Figure 13 Variation of Nusselt number for $SiO_2$-water nanofluid**

This silicon nanofluid exhibits a modest yet noteworthy thermal conductivity enhancement, ranging from 1.5% to 7.3% at a temperature of 60°C, particularly when it contains a nanoparticle loading of 1.5 wt.%.

In Figure 14, we can observe the relationship between heat transfer enhancement and the Reynolds number. It's evident that as the Reynolds number increases, the heat transfer rate also experiences a corresponding increase.

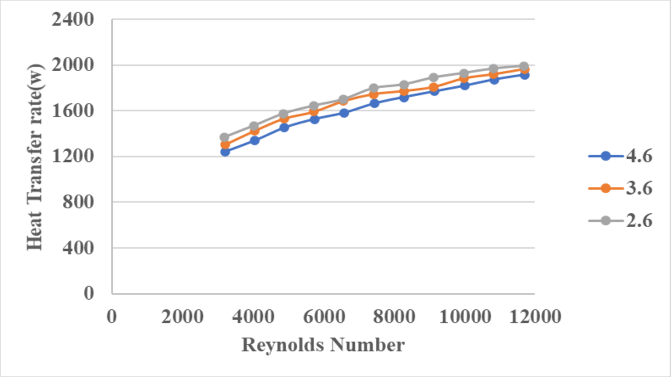

**Figure 14 Variation of Heat transfer rate for $SiO_2$-water nanofluid**

This effect is particularly pronounced in the tubes equipped with CI inserts and nanofluids. In these cases, the combination of CI inserts induces higher flow velocities near the tube wall and imparts a tangential flow pattern. Additionally, the alternating pitch of the twisted tape generates turbulence in the flow. Remarkably, when we consider the heat transfer rate of CI with silicon dioxide nanofluids, it emerges as 7.28 % more efficient than the heat transfer achieved with CI and plain water. Furthermore, the heat transfer coefficient of these nanofluids surpasses that of common base fluids while incurring minimal or negligible pressure drop penalties.

In Figure 15, we can observe the relationship between the Reynolds number and the heat transfer coefficient for CI (presumably a type of insert) with $SiO_2$ nanofluids. The data in the graph demonstrates a clear trend: as the Reynolds number increases, the heat transfer coefficient also experiences an increase. Conversely, the figure also highlights that lower Reynolds numbers are associated with the minimum values of the heat transfer coefficient. Significantly, when we consider the heat transfer coefficient of CI with $SiO_2$nanofluids, it emerges as remarkably enhanced, approximately 7.41 % more efficient than the heat transfer achieved with CI and the base fluid, which is water.

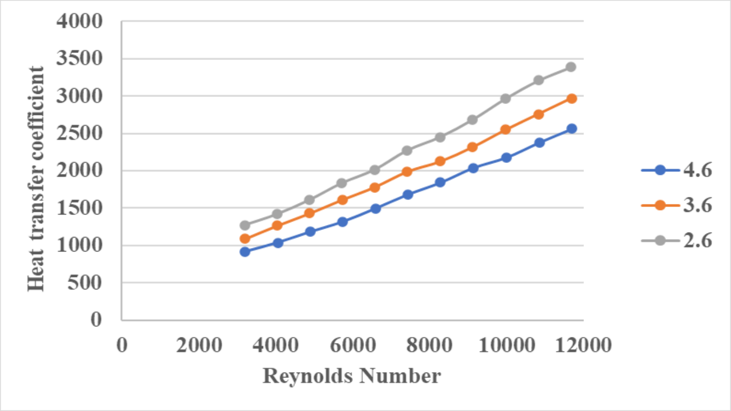

**Figure 15 Variation of Heat transfer coefficient for $SiO_2$-water nanofluid**

Figure 16 illustrates the relationship between the Reynolds number and the friction factor for CI when employing $SiO_2$ nanofluid. The data within the graph demonstrates a distinct pattern: as the Reynolds number increases, the friction factor gradually decreases, as depicted in Figure 16. On the contrary, lower Reynolds numbers are associated with higher friction factor values, and higher Reynolds numbers correspond to lower friction factors. This trend can be attributed to the fact that an increase in the Reynolds number results in reduced fluid flow rates and consequently contributes to increased resistance in the flow, thus leading to higher friction factors.

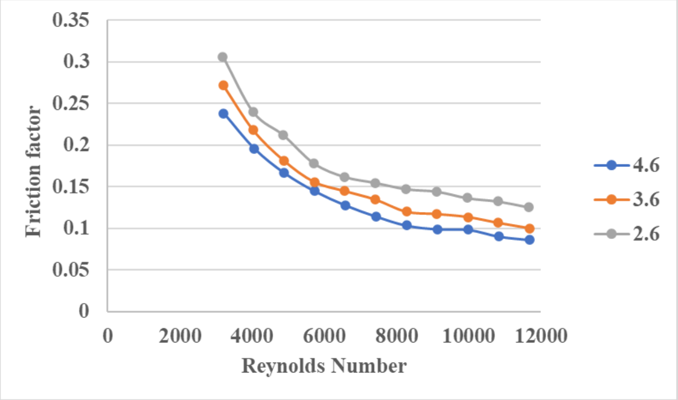

**Figure 16 Variation of Friction factor for $SiO_2$-water nanofluid**

## III. Conclusions

The influence of a conical strip featuring three distinct twist ratios was systematically assessed with respect to the Nusselt number, heat transfer rate, heat transfer coefficient, and friction factor. These evaluations were conducted in comparison to the data obtained from a plain tube across a range of Reynolds number values encompassing the laminar flow region (3000 to 12000).

- The incorporation of conical strip inserts featuring various twist ratios within the test section resulted in elevated Nusselt numbers and friction factors compared to runs conducted without inserts. This enhancement was achieved as the inserts disrupted both the thermal and hydraulic boundary layers, generating a greater swirl flow.
- The utilization of conical strip inserts represents a passive heat transfer enhancement technique that augments fluid turbulence with minimal impact on pressure drop. The even dispersion of highly thermally conductive nanoparticles within the heat transfer fluid further boosts its effective thermal conductivity, attributed to the combined effects of ballistic phonon motion and Brownian motion. In a specific case with a Y = 2.6 twist ratio and 1.25%concentration of $SiO_2$ nanofluid, the maximum heat transfer and Nusselt number were significantly increased by factors of 7.3 and 7.28, respectively.
- The thermal performance factor consistently exceeded unity, underscoring the advantages of employing conical strip inserts in terms of net-energy savings.
- This study opens up opportunities for future exploration, potentially involving the use of hybrid nanofluids and conical strip inserts in various heat exchangers, such as shell and tube heat exchangers and radiators, for applications in industrial heat transfer.

## Nomenclature

| | |
|---|---|
| **CI** | Conical inserts |
| **M** | Mass of water $kg/sec$ |
| **Q** | Heat transfer rate w |
| **h** | Convective heat transfer coefficient $w/m^2k$ |
| **k** | Thermal conductivity $w/mk$ |
| **Re** | Reynold's number |
| **V** | Velocity of fluid $m/sec$ |
| $\boldsymbol{\mu}$ | Viscosity pf fluid |
| $\boldsymbol{T_i}$ | Hot water inlet temperature ℃ |
| $\boldsymbol{T_o}$ | Hot water outlet temperature ℃ |
| $\boldsymbol{C_p}$ | Specific heat of water $kj/kgk$ |

## References

[1]. Fatma Oflaz , Orhan Keklikcioglu , Veysel Ozceyhan , "Investigating thermal performance of combined use of $SiO_2$-water nanofluid and newly designed conical wire inserts, Case Studies in Thermal Engineering, 38 (2022) 102378".

[2]. Mohamed Iqbal Shajahan , Jee Joe Michael , M. Arulprakasajothi , Sivan Suresh , Emad Abouel Nasr and H. M. A. Hussein , " Effect of Conical Strip Inserts and ZrO2/DI-Water Nanofluid on Heat Transfer Augmentation: An Experimental Study" ,Energies 2020, 13, 4554.

[3]. Orhan Keklikcioglu, Veysel Ozceyhan," Thermohydraulic performance evaluation for horizontal tube by using combination of modified coiled wire inserts and graphene nanoplatelet-water nanofluids", International Communications in Heat and Mass Transfer 123 (2021) 105206.

[4]. H.A. Mohammed, Husam A. Hasan, M.A. Wahid," Heat transfer enhancement of nanofluids in a double pipe heat exchanger with louvered strip inserts, Int. Commun. Heat Mass Transf. (2012),

[5]. Bahiraei, M. Mazaheri, N. Alighardashi, M. Development of chaotic advection in laminar flow of a non-Newtonian nanofluid: A novel application for efficient use of energy. Appl. Therm. Eng. 2017, 124, 1213–1223.

[6]. M.M. Heyhat, A. Jafarzad, P. Changizi, H. Asgari, M. Valizade, Experimental research on the performance of nanofluid flow through conically coiled tubes, Powder Technol. 370 (2020) 268–277.

[7]. R.K. Ajeel, et al., Turbulent convective heat transfer of silica oxide nanofluid through corrugated channels: an experimental and numerical study, Int. J. Heat Mass Tran. 145 (2019), 118806,

[8]. S. Hashimoto, K. Kurazono, T. Yamauchi, Anomalous enhancement of convective heat transfer with dispersed $SiO_2$ particles in ethylene glycol/water nanofluid, Int. J. Heat Mass Tran. 150 (2020).

[9]. Fan, A.; Deng, J.; Guo, J.; Liu, W. A numerical study on thermo-hydraulic characteristics of turbulent flow in a circular tube fitted with conical strip inserts. Appl. Therm. Eng. 2011, 31, 2819–2828.

[10]. Kim H., Kim J., Cho H. Experimental study on performance improvement of U-tube solar collector depending on nanoparticle size and concentration of $Al_2O_3$ nanofluid. Energy. 2017; 118:1304–1312.

[11]. Zhang L., Zhang A., Jing Y., Qu P., Wu Z. Effect of Particle Size on the Heat Transfer Performance of $SiO_2$–Water Nanofluids. J. Phys. Chem. C. 2021; 125:13590–13600.