



Performance of Thermal Solar Collector with Incorporation of the Nanoparticle in Nanofluid

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Abstract: An adverse effect of changing titanium dioxide nanoparticle shapes and concentrations on the amount of friction and Nusselt number ratio of improvement for thermal solar collectors (TSCs) has been examined. Several nanoparticle shapes (PD = 20–50 nm) and varying concentrations of TiO₂ nanoparticles (NC = 1-4%) have been used for preparation of nanofluid via stirrer mechanism. Both pure water and water/TiO₂ flow under diverse Reynolds numbers, spanning from 5,000 to 30,000. The permitted amount Nusselt number is found in the water/TiO₂ mixture with nanoparticle concentration (NC = 4%) and nanoparticle diameter (PD = 20 nm). With water/TiO₂ nanofluid flow at Re = 5,000 and 15% flow at Re = 30,000, the average Nusselt numbers climb by 23% and 13%, respectively. It has been observed that for both fluids, the skin friction factor diminishes as the Reynolds number rises. The skin friction factor of a water/TiO₂ nanofluid is higher than that of pure water. Employing water/TiO₂ nanofluid as the working fluid and adjusting the concentration of TiO₂ nanoparticles from (NC = 1%) to (NC = 4%), the average Nusselt numbers improved by 29% at the lowest Reynolds number and by 39% at the highest Reynolds number of 30,000. Across all Reynolds principles, the Nusselt number increased as the nanoparticle diameter shrank. The maximum Nusselt number is synthesized by TiO₂ nanoparticles with the smallest dimension (PD = 20 nm). The most important ratio of improvement for the Nusselt number in TSC is offered by the smallest size TiO₂ nanoparticles (PD = 20 nm). This investigation showed that infusing 5% nanoparticles to water/TiO₂ (diameter of 20 nm) leads to significant heat transfer development, which raises TSC's thermal performance.

Index Terms - Solar Collector; Nanoparticle; Nanofluid; Parameters; Performance.

I. Introduction

In recent decades, solar energy has been accustomed to heat water. Optimizing solar heat absorption may be attainable through the use of nanofluid as a beneficial fluid. For the purpose to improve solar thermal performance, one approach is to use nanofluids as circulating liquids. For the production of nanofluid, conventional heat transfer fluids have been paired with metallic particles at the nanoscale [1, 2]. Nanometer-sized metals, oxides, carbides, or carbon particles in a base fluid form a nanofluid. The efficient functioning of solar heater collectors was investigated in connection with the combination of corrugated barriers and nanofluids. Numerous concentrations of nanoparticles have been studied. Water-based nanofluids are occurred using metal oxide nanoparticles and carbon nanoplatelets. The researchers discovered that employing nanofluids improved solar heating systems' performance [3-5].

An influence of adding carbon nanotube particles to the working fluid (water) on the thermal performance of the refrigeration cycle has been researched experimentally. The outcomes of the testing demonstrated that the performance of refrigerators is affected differently by changing fractions of volume of nanoparticles. In contrast to pure water, a rise in carbon nanotube particles will result in a significant

temperature gradient in the charging and discharging evaporator. As a result, nanoparticles can greatly improve the transmission of heat in the process of refrigeration [6-8].

Employing alumina nanofluids with volume fractions of 0, 0.03, and 0.06% to the distilled base fluid, researchers evaluated the thermal performance of an ETC with an annular coil in a manifold with a water flow rate of 20 - 60 L/h in Malaysian conditions of climate. They observed that when the water flow rate was 60 L/h and the nanoparticles had volume fractions of 0.06%, the system's highest thermal efficiency was 57.63%. In addition, the collector's thermal efficiency improved when the volume percentage of nanoparticles and the rate of water flow climbed [9, 10].

The proportion of energy consumption resulting from solar energy has increased due to modern designs, including thermal solar collector technology. The thermal solar collector is an exchange of heat in which solar radiation is absorbed by the selected material and then transferred to a working fluid (such as water, oil, air, or nanofluid) for use in other applications [11]. Even though these collectors' thermal efficiency usually rises over time, these collector systems' thermal efficiency has to keep growing better until it reaches the highest possible system efficiency. There is an exceptional opportunity to increase these heat collection systems' thermal performance with a nanofluid [12].

The ultimate goal of this research study is to quantitatively evaluate the impact of various titanium dioxide nanoparticle concentrations and shapes on facilitating the transfer of heat in thermal solar collectors (TSCs). Pure water and water/TiO₂ have been used as circulating fluids in the tube with homogeneous heat flux on top of the TSC tube. Their Reynolds numbers are fluctuated among 5,000 to 30,000.

II. MATERIALS

Pure water and water/TiO₂ flow rate of the Reynolds number are fluctuates among 5,000 to 30,000. The tube TSC has been covered with the heat flux. Numerous titanium dioxide nanoparticle volume fractions (concentrations) with diameters that varied from PD = 20 nm to PD = 50 nm have been examined using an outlet pressure-outlet state. The turbulence rate was preserved at 1% at the inlet. **Fig. 1** display the schematic diagram of the thermal solar collector. Water based nanoparticle with different concentration is prepared using magnetic stirrer as shown in **Fig. 2**.

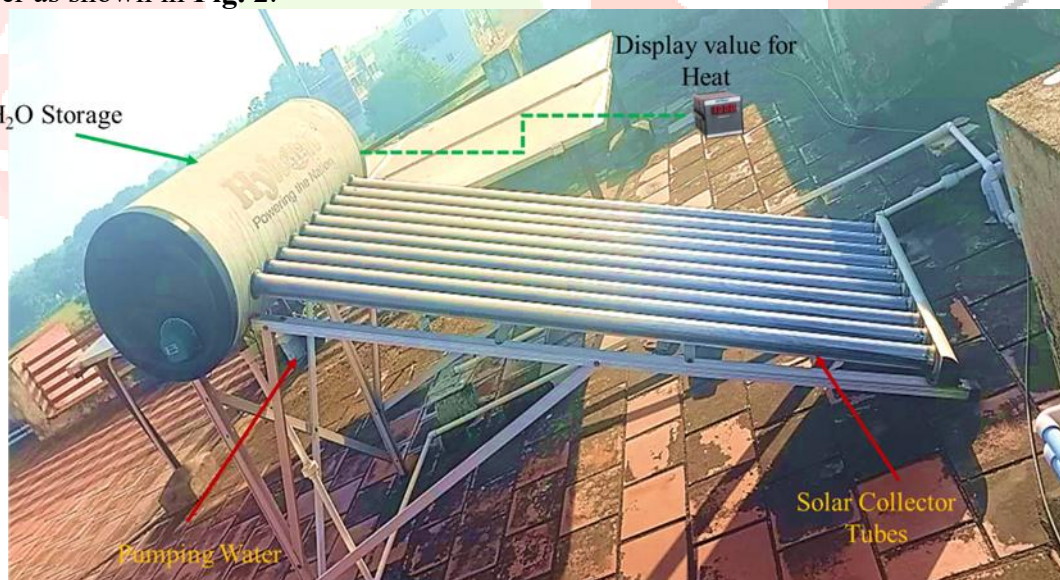


Figure 1. Schematic representation of the thermal solar collector system.

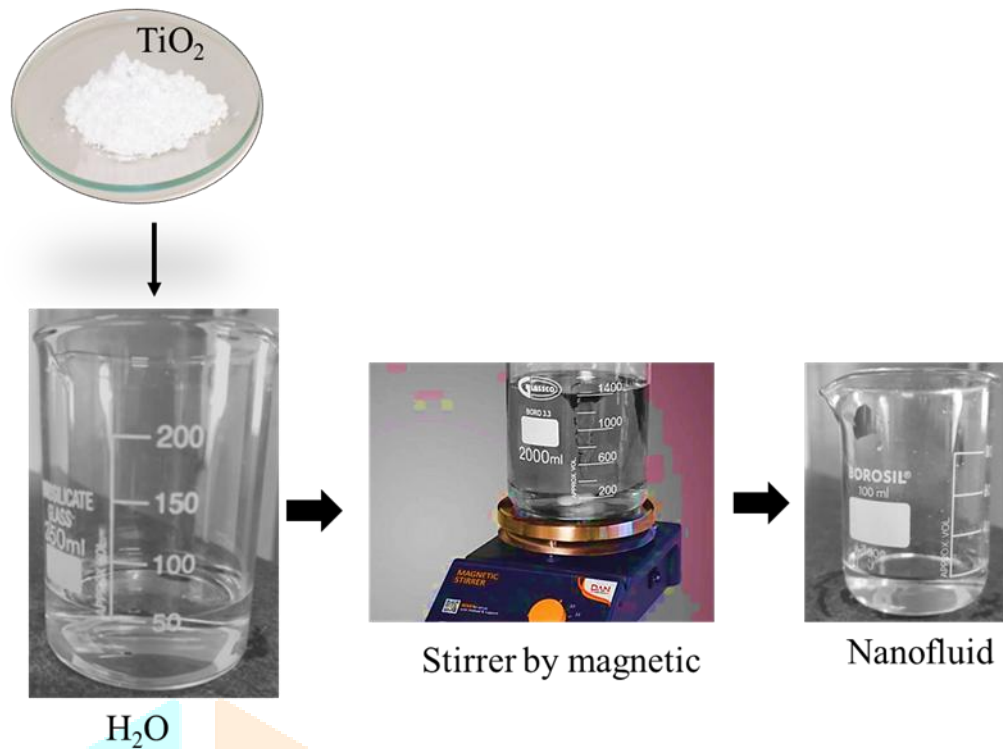


Figure 2. Nanofluid preparation using stirrer mechanism.

III. RESULTS AND DISCUSSION

3.1 Coefficient of Transfer heat

The consequences of utilizing pure water and water/ TiO_2 as working fluids on the TSC's capabilities to enhance heat transfer examined statistically in this section. **Fig. 3** illustrates the association between different Reynolds numbers and Nusselt numbers. In light of the high thermal conductivity of the nanofluid, the Nusselt numbers of TSC containing water/ TiO_2 are higher than the base fluid (water) for all Reynolds numbers [13]. The collision between titanium dioxide nanoparticles and the tube wall, which results in increased energy rate of exchange, also has a connection to the improvement in the transfer of heat. As the Reynolds number expands, so rise the Nusselt numbers. The flow of water/ TiO_2 promotes the transfer of heat more than pure water among test fluids. Employing water/ TiO_2 nanofluid as the working fluid increases the median Nusselt numbers by 23% at $Re = 5,000$ and 13% at $Re = 30,000$. The variation in Reynolds number with skin friction coefficients using pure water for TSC and a water/ TiO_2 nanofluid is displayed in **Fig. 4**. It can be seen that for both fluids, the skin friction factor diminishes as the Reynolds number goes up. The skin friction factor of a water/ TiO_2 nanofluid is higher in contrast of pure water [14].

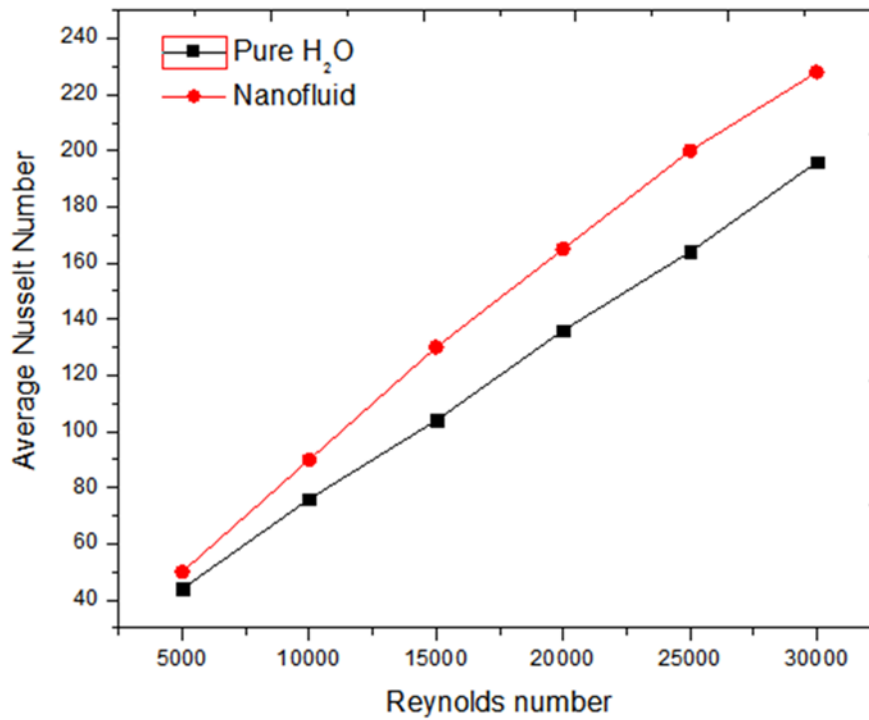


Figure 3. Median nusselt number of nanofluids.

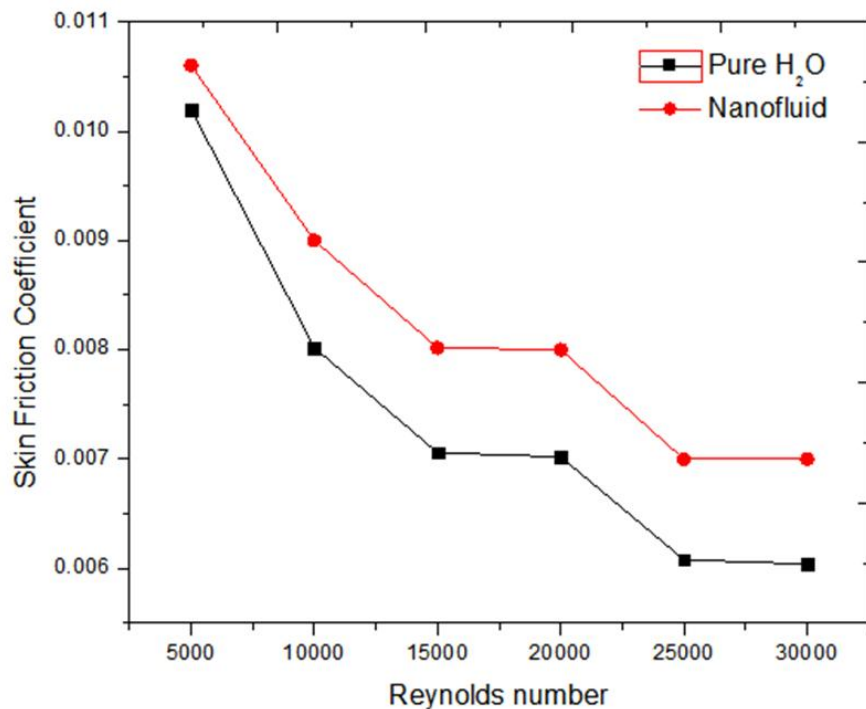


Figure 4. Coefficient of friction for prepared nanofluids.

3.2 Influence of TiO₂ Proportion

The consequence of titanium dioxide nanoparticle levels on frictional coefficient and transfer of heat enhancement in TSC will be addressed in this section. **Fig. 5** demonstrates the effects of different TiO₂ nanoparticle proportions (NC = 1–4%) on the skin friction coefficients and Nusselt number. Reynolds numbers in the present investigation are fluctuated among 5,000 to 30,000. The average Nusselt number rises in concordance with the Reynolds number. As a result of the strong thermal insulation of TiO₂ nanoparticles, it becomes apparent that all Reynolds numbers employing volume fractions of 4% water/TiO₂ yield the maximum Nusselt number [15].

Adopting a water/TiO₂ nanofluid to lower the proportion of TiO₂ nanoparticles from (NC = 1%) to (NC = 4%), the median Nusselt numbers improve by 29% at the least Reynolds number and 39% at the biggest

Reynolds number of 30,000. The skin friction coefficient vs Reynolds number for a variety of concentrations of TiO₂ nanoparticles with PD = 20 nm is shown in **Fig. 6**. The skin friction coefficient grows as the nanofluid concentration grows [16].

An increased the density of the fluid which restricts fluid movement, is usually the result of increasing nanofluid concentration. The Nusselt number enhancement ratio vs Reynolds number for distinct metal oxide nanoparticle volume fractions, NC of water/TiO₂ nanofluid with PD = 20 nm, is displayed in **Fig. 7**. The highest possible score ratio of improvement for the Nusselt number in TSC is obtained with the highest concentration of TiO₂ nanoparticles (NC = 4%) [17].

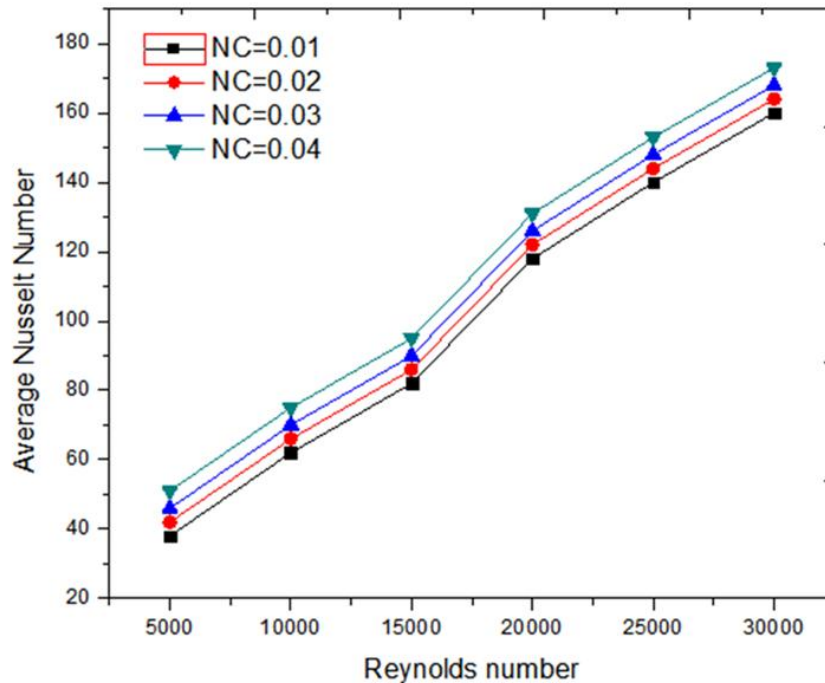


Figure 5. Performance of nusselt number with different proportion of TiO₂.

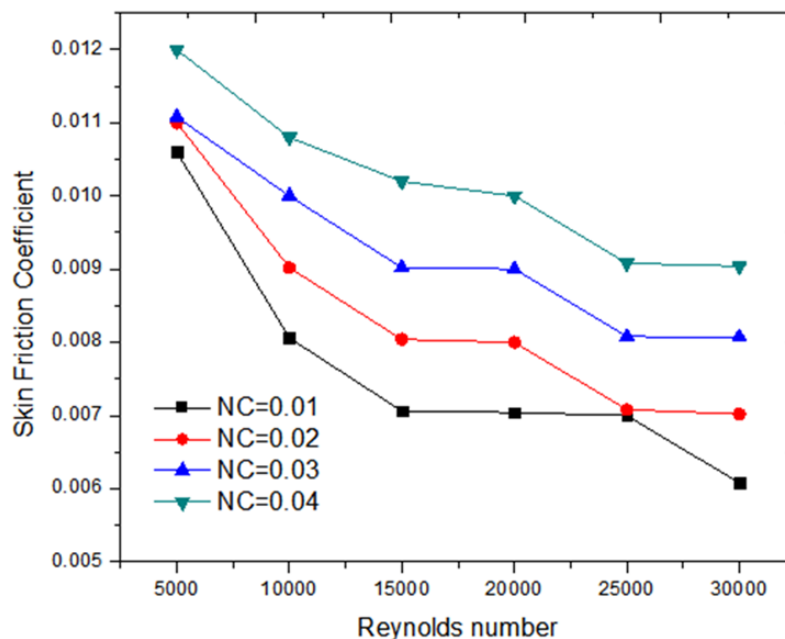


Figure 6. Friction performance of different concentration of particle.

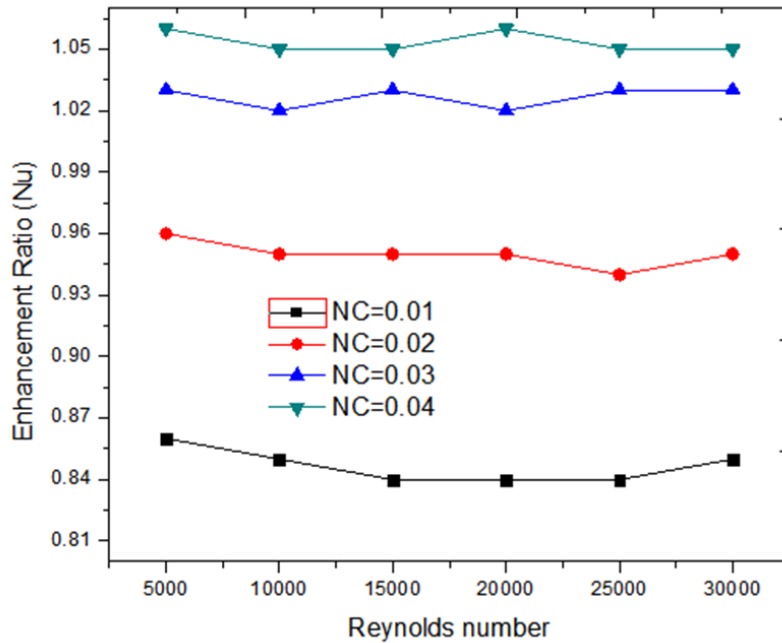


Figure 7. Improvement of nusselt number with particle concentration.

3.3 Influence of Shape of TiO₂ Proportion

The present research presents the effects of titanium dioxide nanoparticle dimensions on friction factor and heat transfer enhancement. At an established concentration of 4%, the diameters of a variety TiO₂ nanoparticles (PD = 20–50 nm) were evaluated. **Fig. 8** illustrates the Nusselt number increased for all Reynolds values when the nanoparticle diameter declined. The highest possible score Nusselt number is obtained from TiO₂ nanoparticles with the smallest size (PD = 20 nm). As the diameter of the nanoparticles decreases, the active dynamic viscosity of the nanofluid rises, improving transmission of heat. Applying water/TiO₂ nanofluid at the smallest size TiO₂ nanoparticles (PD = 20 nm) at Re = 5,000 and 15% at Re = 30,000 in TSC boosts the average Nusselt numbers by 33% and 13%, correspondingly [18].

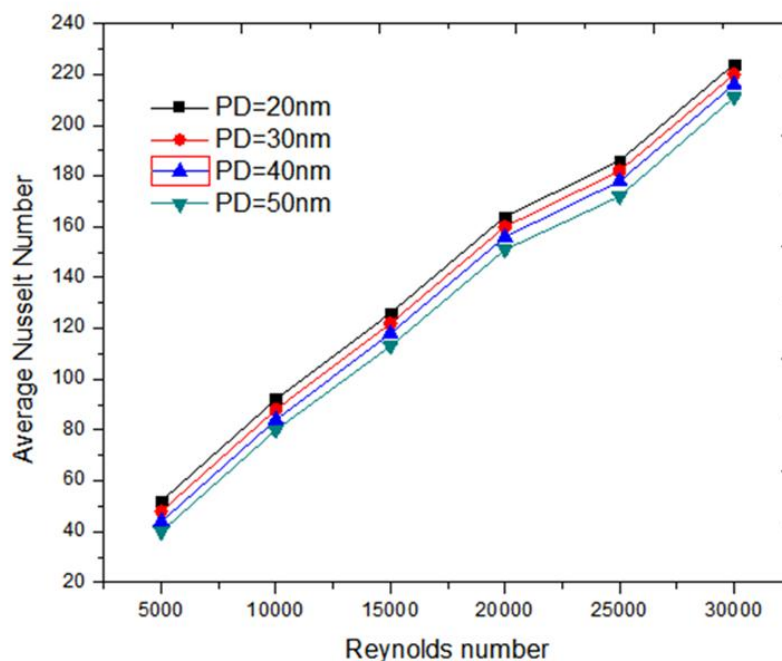


Figure 8. Average performance of nusselt with different size of particle.

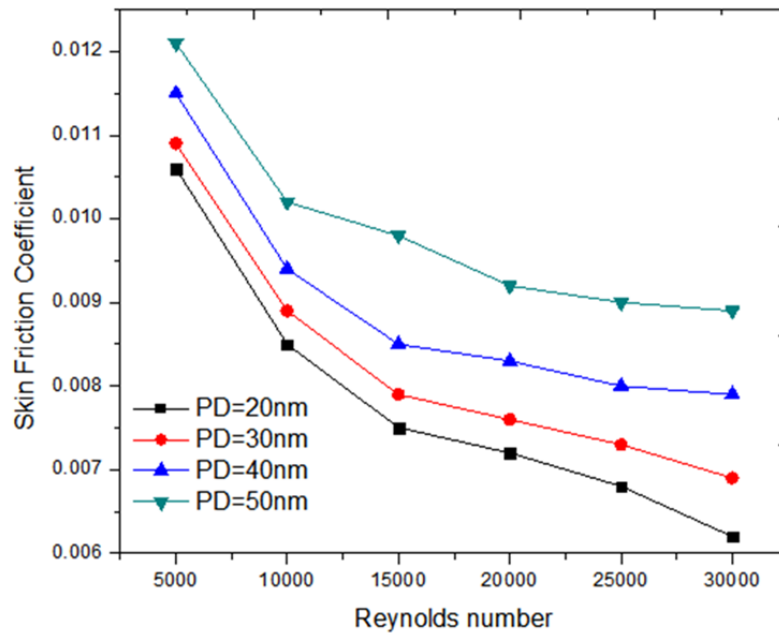


Figure 9. Coefficient of friction performance with particle size.

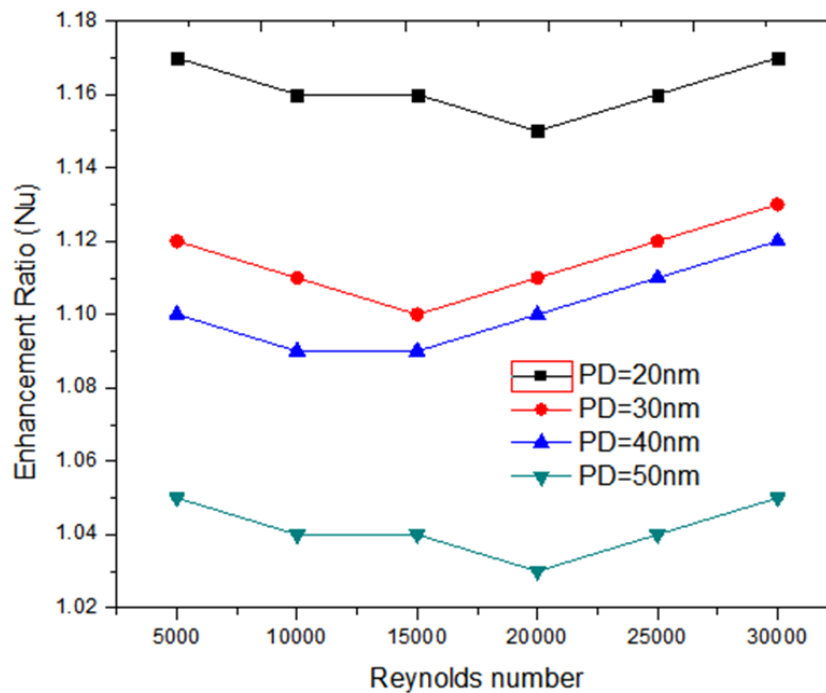


Figure 10. Ratio of enhancement with various size of the nanoparticle.

The Reynolds numbers with various metal oxide nanoparticle shapes of water/TiO₂ nanofluid with NC = 4% are depicted against skin friction coefficients in **Fig. 9**. It becomes apparent that when the diameters of TiO₂ nanoparticles shrink, so do the skin friction coefficients [19]. The Nusselt number the enhancement rate vs Reynolds number for various shapes of TiO₂ nanoparticles (NC = 4%) is shown in **Fig. 10**. The greatest ratio of expansion for Nusselt number in TSC can be obtained by the smallest size TiO₂ nanoparticles (PD = 20 nm) [20].

IV. CONCLUSION

The consequence of titanium dioxide nanoparticle shape and concentration on the heat conveyance enhancement ratio and friction factor for TSC has been investigated in the present experimental analysis. The adverse effect of water/TiO₂ and pure water flow within the pipe on improving the TSC's performance can be seen by the experiment results. Several nanoparticle sizes (PD = 20–50 nm) and varying concentrations of TiO₂ nanoparticles (NC = 1-4%) are employed. The flow the rates of pure water and water/TiO₂ vary from 5,000 to 30,000 Reynolds numbers. The following points should be emphasized:

- The mean Nusselt frequencies increasing the Reynolds amounts across both fluids improved the average Nusselt numbers.
- As the concentration of TiO₂ nanoparticles expands, so do the median Nusselt measurements.
- The maximum Nusselt number can be found in water/TiO₂ with nanoparticle levels of NC = 5% and nanoparticle shape of PD = 20 nm.
- Implementing water/TiO₂ nanofluid as the working fluid boosts the median Nusselt numbers by 23% at Re = 5,000 and 13% at Re = 30,000.
- For comparable fluids, the skin friction factor reduces as the Reynolds number climbs. The skin friction factor of a water/TiO₂ nanofluid can be greater than that of pure water.
- Through the high amount of TiO₂ nanoparticles of NC = 4, the median Nusselt numbers grow by 29% at Re = 5,000 and 39% at Re = 30,000.
- For all Reynolds standards, the Nusselt number climbed as the nanoparticle dimension declined.
- The maximum Nusselt number is synthesized by TiO₂ nanoparticles with the smallest size possible (PD = 20 nm).

Data Availability Statement

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Ethics Declaration

This study did not involve any experiments on human participants or animals, and therefore no ethical approval was required.

Conflict of interest

The authors are declaring no competing interests.

CRedit author statement

C. Ayyanar, P. Kathirvel and N. Selva Karthik: Conceptualization, Data curation, Methodology, Visualization, Investigation, Software, Supervision, Validation, Writing- Original draft preparation, Writing-Reviewing and Editing.

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