EXPERIMENTAL INVESTIGATION FOR HEAT TRANSFER AND FRICTION CHARACTERISTICS OF HELICAL INSERTS IN A COUNTER FLOW HEAT EXCHANGER BY USING WATER + TiO2 NANO PARTICLES

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ABSTRACT

The objective of the project is to establish the capability of Nano-fluids to enhance the Heat Transfer Coefficient when used on the cold side of a Heat Exchanger and antifreeze is mixed with Water. In the present experimental investigation, an experimental test is to be conducted on a counter flow heat exchanger. For the investigation, Nano-fluids are to be prepared with TiO2 particles of 30 Nano meters size and are to be dispersed in distilled with various volume concentrations. The properties of these Nano-fluids are estimated using method of mixtures. Experiments are planned to be conducted using distilled water on hot fluid side and Nano-fluids on cold side of the Heat Exchanger. Helical inserts of size from 2 mm to 5 mm are to be used to create turbulence on the cold side of heat exchanger so that it helps to absorb more heat. Temperature measurements are made at the inlet and the outlet side of the Heat Exchanger on hot and cold fluids. Mass flow rate measurements are made using the collecting tank and stop clock.

INTRODUCTION

A heat exchanger is a device that is used to transfer thermal energy (enthalpy) between two or more fluids, between a solid surface and a fluid, or between solid particulates and a fluid, at different temperatures and in thermal contact. In heat exchangers, there are usually no external heat and work interactions. Typical applications involve heating or cooling of a fluid stream of concern and evaporation or condensation of single-or multi component fluid streams. In other applications, the objective may be to recover or reject heat, or sterilize, pasteurize, fractionate, distill, concentrate, crystallize, or control a process fluid. In a few heat exchangers, the fluids exchanging heat are in direct contact.

In many heat exchangers, the fluids are separated by a heat transfer surface, and ideally they do not mix or leak. Such exchangers are referred to as direct transfer type, or simply recuperators. In contrast, exchangers in which there is intermittent heat exchange between the hot and cold fluids—via thermal energy storage and release through the exchanger surface or matrix— are referred to as indirect transfer type, or simply regenerators. Such exchangers usually have fluid leakage from one fluid stream to the other, due to pressure divergences and matrix rotation/valve switching. Common examples of heat exchangers are shell-and-tube exchangers, automobile radiators, condensers, evaporators, air preheaters, and cooling towers. If no phase change occurs in any of the fluids in the exchanger, it is sometimes referred to as a sensible heat exchanger. There could be internal thermal energy sources in the exchangers, such as in electric heaters and nuclear fuel elements.

Combustion and chemical reaction may take place within the exchanger, such as in boilers, fired heaters, and fluidized-bed exchangers. Mechanical devices may be used in some exchangers such as in scraped surface exchangers, agitated vessels, and stirred tank reactors. Heat transfer in the separating wall of a recuperator generally takes place by conduction. Heat exchangers are important engineering devices in many process industries since the efficiency and economy of the process largely depend on the performance of the heat exchangers. High performance heat exchangers are, therefore, very much required. Improvement in the performance may result in the 10 reduction in the size of the heat exchangers of a fixed size can give an increased heat transfer rate, it might also give a decrease in temperature difference between the process fluids enabling efficient utilization of thermodynamic availability.

This is particularly true for Laminar flow since the heat transfer coefficients for laminar straight flow through a plain tube is very low. Forced convection heat transfer in doubly connected ducts bounded externally by a circle and internally by a rectangular polygon of various shapes was analyzed using a finite element method. Further Wu and Liu reported experimentally a two – part study for turbulent flow in a horizontal tube with longitudinal inserts. However, the literature on experimental studies dealing with developing laminar convection tube flow with a longitudinal insert is relatively scarce. The purpose of present work is to extend the previous studies for turbulent flow.

LITERATURE REVIEW

Pak and Choi studied the heat transfer performance of Al2O3 and TiO2 nanoparticles dispersed in water flowing in a horizontal circular tube. Alumina (Al2O3) and titanium dioxide (TiO2) nanoparticles with diameters of 13 nm and 27 nm, respectively, were used in their study. They found that the Nusselt number of nanofluids increased with an increase in the Reynolds number as well as the volume fraction. However, they still found that the convective heat transfer coefficient of the nanofluids with 3 vol. % nanoparticles was 12% lower than that of pure water at a given Reynolds number. This may cause the nanofluids to have larger viscosity than that of pure water, especially at high particle volume fractions. Finally, a new heat transfer correlation for predicting the convective heat transfer coefficient of nanofluids in a turbulent flow regime was proposed.

Xuan and Li investigated experimentally the convective heat transfer and flow characteristics for Cu–water nanofluid flowing through a straight tube with a constant heat flux under laminar and turbulent flow conditions. Cu nanoparticles with diameters below 100 nm were used in their study. The results of the experiment showed that the suspended nanoparticles remarkably enhanced the heat transfer performance of the conventional base fluid and their friction factor coincided well with that of the water. Furthermore, they also proposed the new convective heat transfer correlations for prediction of the heat transfer coefficients of the nanofluid for both laminar and turbulent flow conditions.

Tsai investigated gold–DI water nanofluid flowing in a conventional heat pipe with a diameter of 6 mm and a length of 170 mm. Gold nanoparticles of 2–35 nm and 15–75 nm in size were used in this study. Their data showed that the nanofluid causes a significant reduction in the thermal resistance of the heat pipe compared with DI water at given concentrations. The thermal resistance of the circular heat pipe ranged from 0.17 to 0.215 oC/W with various nanoparticle concentrations. The results indicated that the higher thermal potential of nanofluids means that they can 25 be used as working fluids to replace the conventional fluids in vertical circular meshed heat pipes.

Wen and Ding studied the convective heat transfer coefficients in which Al2O3 nanoparticles were suspended in de-ionized water for laminar flow in a copper tube under a constant wall heat flux and focused in particular on the entrance region. Alumina nanoparticles of 27–56 nm in size were used in this study. The results show that the local heat transfer coefficient varied with the Reynolds number and particle concentration. In particular, it was found that the use of nanofluids at the entrance region resulted in a pronounced increase in the heat transfer coefficient, causing a decrease in the thermal boundary layer thickness which decreased with the axial distance. This behavior implied that it might be possible to create a ‘‘smart entrance” region to meet the highest performance of nanofluids. Furthermore, the calculated Nusselt number using the Shah correlation for laminar flow and the Dittus–Boelter equation for turbulent flow did not coincide with the experimental results.

METHODOLOGY

The inner tube is made from smooth copper tubing with a 9.53mm outer diameter and 8.13mm inner diameter, while the outer tube is made from PVC tubing and has a 33.9mm outer diameter and 27.8mm inner diameter. The test section is thermally isolated in order to reduce the heat loss along the axial direction. The J-type thermocouple mounted at both the ends test section to measure the bulk temperature of a nanofluid. The inlet and exit temperatures measured using J-type thermocouples which are inserted into the flow directly. During the test run, the inlet and exit temperatures of the hot water and nanofluids are measured and also mass flow rates of hot water and nanofluid are measured.

Specifications:

Length of the heat exchanger = 1.5m.

Outer Diameter of the Outer Tube,

Do = 33.9mm

Inner diameter of the Outer Tube, Di = 27.8mm

Outer diameter of the Inner Tube, do = 9.13mm

Inner diameter of the Inner Tube, di = 8.53mm

Types of thermocouples used are J-type.

Maximum heater input = 100W

Two collecting tanks of capacity = 50 liters.

Pump Specifications: Discharge: 3200lit/hr

Power: 370 watts/0.5 hp

PREPARATION OF ETHYLENE GLYCOL + WATER (Ethylene glycol + Water):

1. An attempt has been made to study the variation of heat transfer coefficient using different techniques. The first step in the experiment is to determine the overall heat transfer coefficient of base fluid or Ethylene Glycol + Water.

2. Ethylene glycol which acts as an anti-freezing agent is mixed with water. Glycol is commonly used in automobiles as an anti freezing agent in Ethylene Glycol + Water.

3. As concentration of glycol increases the anti freezing properties increases but the heat absorption capacity decreases. So, there is an optimum concentration of mixture to be made.

4. 40%+60% by weight of Ethylene Glycol + Water are taken respectively to form a mixture.

5. After the concentration is fixed the weight of the available Glycol is measured using digital weighing machine. Water is taken 1.5 times the weight of Glycol. Both the fluids are mixed together to form Ethylene Glycol + Water.

6. After the mixture is prepared the next step is to determine the density of the Ethylene Glycol + Water prepared.

7. This Ethylene Glycol + Water mixture thus prepared is passed through the inner tube of the heat exchanger and hot water is passed through the annulus.

8. After attaining steady state, the inlet and outlet temperature readings of hot and nanofluid (cooling medium) are noted and with these readings the overall heat transfer is calculated by using LMTD method. The specific Heat of the nanofluids is estimated based on empirical relations

9. The next step is to put the inserts in to the inner side of the copper tube. This creates turbulence thereby enhancing the heat transfer coefficient.

10.Graphs have been plotted for Overall heat transfer Vs Reynolds number for Ethyl glycol mixture and Mixture with inserts for the values obtained experimentally.

RESULTS

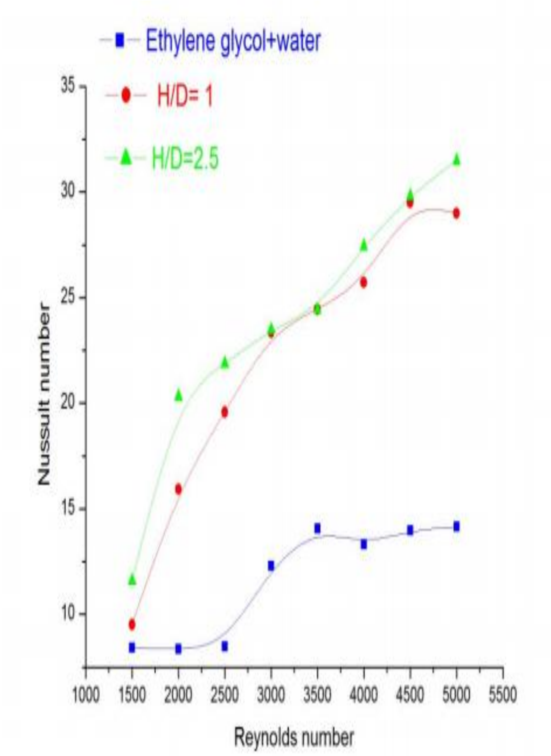
Ethylene Glycol + Water (Ethylene glycol + water)

Ethylene Glycol + Water is prepared mixing ethylee glycol and water in 40:60 ratio respectively. The test fluid is introduced into the cold section of the heat exchanger. The thermal conductivity of the Ethylene Glycol + Water at bulk mean temperature is taken. The variation of Nusselt number with different Reynolds number is shown in Garphs 1.2.3 along with the data of base fluid. It is observed that Nusselt number increases with increase of Reynolds number. The experiments are conducted with helical inserts in the similar way as done with Ethylene Glycol + Water. There is a considerable variation in heat transfer when inserts are used.

The variation of heat transfer for different inserts can be clearly seen in graph??. The helices provided on the core rod creates turbulence and swirl in the flow and hence aids in heat transfer enhancement.

Nano Fluid (TiO2 Nano particles added to Ethylene Glycol + Water)

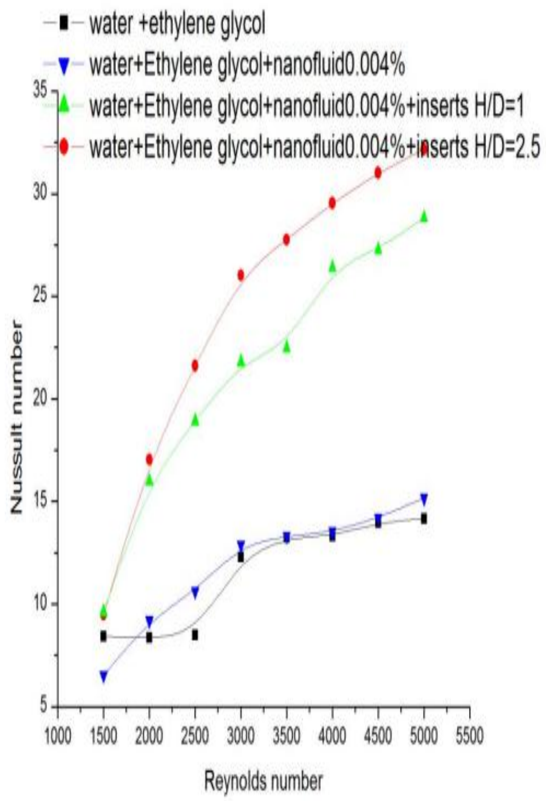
Then TiO2 nanofluid is introduced into the test section and experimental Nusselt number is estimated using the equation .The thermal conductivity of the TiO2 Nanofluid is taken at bulk mean temperature. The variation of Nusselt number with different Reynolds number is shown in Garph6.2 along with the data of base fluid. It is observed that Nusselt number increases with increase of Reynolds number.



Graph Comparison of nussult number when Ethylene Glycol + Water and inserts are used

Friction factor of Ethylene Glycol + Water and nanofluid with helical tape inserts

The experiments are conducted with helical inserts in the similar way as done with base fluid and Nanofluid. Friction factor of the base fluid and also TiO2 nanofluids in plain tube with helical inserts is estimated. The Experimental results are compared with Moody's equation and graphs are plotted accordingly.

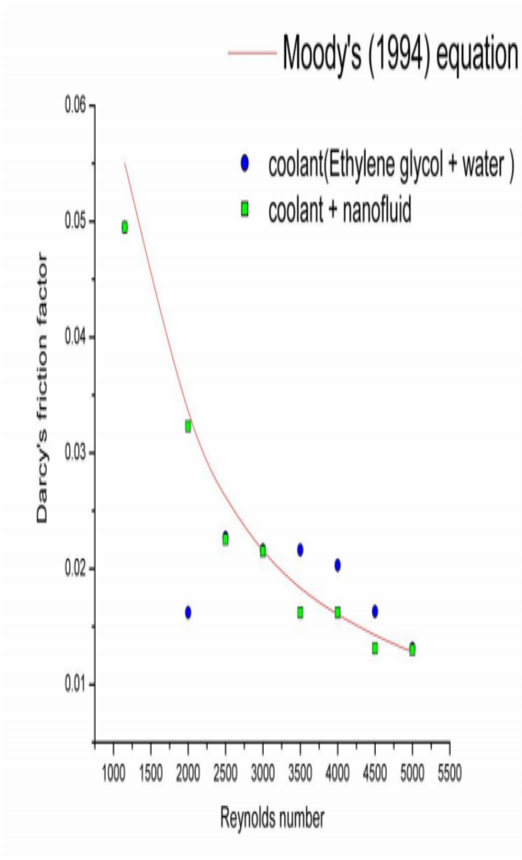


Graph Comparison of nusselt number when nanofluid and inserts are used

Enhancement of heat transfer

From the above experiments the heat transfer between the hot and cold fluid is improved using different techniques. The enhancements of heat transfer coefficient for different methodologies adapted are plotted on a single graph. The comparison of results can be clearly seen from the graph.

$$f = \frac{64}{Re} \qquad f = \text{Darcy's friction factor}$$



Graph Comparison of friction factor of Ethylene Glycol + Water and nano fluid with Moody's equation

CONCLUSION

➢ Suitable experimental test setup has been developed and constructed a new double pipe counter flow heat exchanger.

➢ Ethylene glycol which is commonly used as an anti freezing agent reduces the heat transfer coefficient of water by 15%-20%.

➢ The enhancement of overall heat transfer coefficient compared to the base fluids increases from 5% to10% with use of 0.004 % volume TiO2 nanoparticles concentration.

➢ Nanofluids with relatively small concentration of solid particles exhibited enhancement of Overall heat transfer coefficient.

➢ Use of inserts increases the heat transfer coefficient by 45%-50% with both Ethylene Glycol + Water and Nanofluid as test fluid creating turbulence inside the tube.

➢ With the increase in the pitch of the inserts from 2mm to 5mm the friction factor increased by 15% - 20%.

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