HEAT TRANSFER ANALYSIS OF SHELL AND TUBE HEAT EXCHANGER USING AL2O3 NANOFLUIDS

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ABSTRACT

Heat exchanger finds a wide range of applications like power plants, nuclear reactors, refrigeration and air-conditioning systems, chemical processing and food industries. Latest advances in these heat exchangers include the usage of nanofluid that act as coolant that exhibit excellent thermal performance in heat exchanger. In this study heat transfer characteristic of Al2O3-water nanofluid flowing inside the shell and tube heat exchanger has been investigated experimentally. Two different Nanofluids were prepared with 0.2 wt%, and 0.4 wt% of Al2O3 using two step method. Sodium Dodecyl Benzene Sulfonate (SDBS) was used as a surfactant to stabilize the Al2O3 in water. The addition of nanoparticle to base fluid result in significant enhancement of heat transfer characteristics. The experiments were conducted in a shell and tube heat exchanger with Tubeside Reynolds number varying from 1700-9500. Results were compared with conventional cooling fluids (i.e. water) and the two different concentrations (0.2% & 0.4%) which indicate a considerable enhancement of heat transfer due to addition of nanoparticles.

Keywords; Nanofluids, Nanoparticle, Nusselt number, Prandtl number, Reynolds number, Specific heat, Thermal conductivity


1. INTRODUCTION

Heat transfer is a major factor that is involved in wide variety of industrial processes. The enhancement of heating or cooling in an industrial process may create a saving in energy, reduce process time, raise thermal heating and lengthen the working life of equipment. There are several methods to improve the heat transfer efficiency. Some methods are utilization of extended surfaces, application of vibration to the heat transfer surfaces and usage of micro channels etc. Heat transfer efficiency can also be improved by increasing the thermal conductivity of the working fluid. In recent years significant advances in nonmaterial’s
technology, has made it possible to overcome these problems by producing desirable particles in nanometer size ranges. Nanofluids is a new kind of heat transfer medium which are uniformly and stably distributed in a base fluid that enhance the thermal conductivity of the Nanofluids, increase conduction and convective coefficients, allowing for more heat transfer. The feasibility of the usage of such suspensions of solid particles with sizes in the order of millimeters or micrometers was previously researched by several researchers and significant drawbacks were reported. These drawbacks are sedimentation of particles, clogging of channels and erosion of channel walls, which prevented the practical applications of suspended solid particles in the base fluids as advanced technique in heat transfer applications. The better heat transfer rate can be achieved by enhancing the heat transfer capability of the fluid itself.

2. LITERATURE SURVEY

[1]. L. Godsona et al (2010) experimentally investigated the heat transfer characteristics of silver/water nanofluids in a shell and tube heat exchanger The influence of mass flow rate, inlet temperature and volume concentration on the LMTD, effectiveness, convective heat transfer coefficient and pressure drop are studied. The results showed an increase in convective heat transfer coefficient and effectiveness of silver/water nanofluids as the particle volume concentration is increased. A maximum enhancement in convective heat transfer coefficient of 12.4% and effectiveness of 6.14% is recorded.

[2]. B.Farajollahi et al (2009) studied the heat transfer characteristics of Al2O3 / water and TiO2/water Nanofluids in a shell and tube heat exchanger under turbulent flow condition. Adding of nanoparticles to the base fluid causes the significant enhancement of heat transfer characteristics. At different nanoparticle concentrations the heat transfer enhancement of both nanofluid are not the same. TiO2/water and c-Al2O3/ water Nanofluids possess better heat transfer behavior at the lower and higher volume concentration, respectively. For both Nanofluids the experimental result are very close to the predicted values of available correlation at lower nanoparticle volume concentrations.

[3]. S. Mirmasoumi et al (2007) studied the fully developed mixed convection of a nanofluid (water/Al2O3) numerically. Two-phase mixture model has been used to investigate the effects of nanoparticles mean diameter on the flow parameters. The calculated results demonstrate that the convection heat transfer coefficient significantly increases with decreasing the nanoparticles means diameter.

[4]. M.M. Elias et al (2014) studied the effect of different particle shapes (cylindrical, bricks, blades, and platelets) on the overall heat transfer coefficient, heat transfer rate and entropy generation of shell and tube heat exchanger with different baffle angles and segmental baffle An enhancement of overall heat transfer coefficient for cylindrical shape particles with 20° baffle angle is found 12%, 19.9%, 28.23% and 17.85% higher than 30°, 40°, 50° baffle angles and segmental baffle, respectively in corresponding to 1 vol.% concentration of Boehmite alumina (γ-AlOOH).

[5]. Azher M. Abed et al (2015) investigated falling film heat transfer of horizontal shell-side evaporators remains of interest to scientists due to the complexity of these phenomena for practical applications. However, characteristics of heat and mass transfers of spray evaporators are still subject to further enhancement. This study is to review the enhancement techniques and falling film flow especially the effect of nanoparticles suspended with refrigerants in order to confirm their role.

[6]. Smith Eiamsa-ard et al [6], experimentally investigated the heat transfer, friction and thermal performance characteristics of CuO/water nanofluid. The nano fluid was employed in a circular tube equipped with modified twisted tape with alternate axis (TA) and with typical twisted tape (TT). The experiments were performed in laminar regime (Reynolds number
spanned $830 \leq \text{Re} \leq 1990$). It was revealed that the individual uses of TA and TT, Nusselt numbers increase up to 12.8 and 7.2 times of the plain tube, respectively.

[7]. Suresh et al (2006) experimentally determined the comparison of thermal performance of helical screw tape inserts in laminar flow of Al$_2$O$_3$/water and CuO/water nanofluids through a straight circular duct with constant heat flux boundary condition. Thermal performance factor of helical screw tape inserts using CuO/water nanofluid was found to be higher when compared with the corresponding value using Al$_2$O$_3$/water. They concluded that both Al$_2$O$_3$/water and CuO/water nanofluids for a low volume fraction of 0.1% show a very high enhancement in heat transfer rate.

[8]. M.R. Salimpour et al (2008) experimentally investigated the heat transfer coefficient of shell and helically coiled tube heat exchangers. Three heat exchangers with different coil pitches were selected as test section or both parallel –flow and counter –flow configurations. Empirical correlations were proposed for shell and tube side. The calculated heat transfer coefficients of tube-side were also compared to the existing correlations for other boundary conditions and a reasonable agreement were observed.

[9]. Nasser Ghorbani et al (2010) experimentally investigated the mixed convection heat transfer in a coil in shell heat exchanger for various Reynolds number and Rayleigh numbers, various tube to coil diameter ratios and dimensionless coil pitch. It was found that the mass flow rate of tube side to shell side ratio was effective on the axial temperature profiles of heat exchanger. The results also indicate that the Effectiveness –NTU relation of the mixed convection heat exchangers was same as the of a pure counter flow heat exchanger. Their study covered both laminar and turbulent flow regimes inside the coiled tube depending on different mass flow rates.

[10]. Salma et.al (2014) experimentally investigated the measurements of thermal and rheological properties of the nanofluids with operating temperature of a water-based multi-wall carbon nanotubes are measured in a coaxial heat exchanger under laminar regime within the range of Reynolds numbers 500-2500. Higher improvement in thermal conductivity is obtained for nanofluids with higher nanotube aspect ratio and lower thermal conductivity of base fluid. Finally, the results indicate that a low volume fraction of 0.026% in CNT leads to an average convective heat transfer enhancement higher than 12% in comparison with base fluids. Nanotubes aspect ratio increase and base fluid with lower thermal conductivity contribute to better enhance the convective heat transfer of nanofluids.

[11]. Roghayehlofti et.al (2001) experimentally investigated heat transfer enhancement of multi-walled carbon nanotube (MWCNT/water) nanofluid in a horizontal shell and tube heat exchanger. Carbon nanotubes were synthesized by the use of catalytic chemical vapor deposition (CCVD) method over Co–Mo/MgOnanocatalyst with a concentration of 0.015 weight percent, the heat transfer measurement tests were performed. The concentration is selected in a low value to present that the existence of only very low amounts of nanotubes can influence and enhance the heat transfer rate. The results were obtained under two different power of heating section for 280W and 630 W the presence of multi-walled nanotubes enhances the heat transfer rate in a shell and tube heat exchanger.
3. FIGURES AND TABLES

3.1. EXPERIMENTATION

**Nano fluid preparation**

- Two-step method is followed to prepare the Al2O3–water nanofluid at 0.2% and 0.4% volume concentration. Initially the Al2O3 nanoparticle is divided by their weight needed for mixing it with deionized water per litre.

- The magnetic stirrer consists of rotating magnet at the base and a stirrer for glass beaker. The deionized water is taken in 1L glass beaker which is placed on the magnetic stirrer and the nanoparticle is added to the every deionized water while the magnetic stirrer is ON.

  The speed of the magnetic stirrer is maintained at 1200 rpm for 1 hr for 1L deionized water. The same procedures followed for remaining 7L of deionized water. After stirring, the Al2O3-water nanofluid in the no sunlight area to avoid any chemical reaction.

4. EXPERIMENTAL PROCEDURE

The experimental setup consists of a shell and tube heat exchanger of 0.0885m length with counter flow arrangement. Hot water was taken as hot medium flowing in the shell side while the cold water and Al2O3–water nanofluid was taken as cold medium flowing in the tube side. The asbestos rope used as insulating medium. Separate pumps were provided to deliver the fluid from the reservoir tank to the heat exchanger. Two rot meters were used to measure the flow rate of hot and cold fluids.

  Digital temperature indicators were used to measure the temperatures using the K type thermocouples placed at various positions of shell side and tube side. The accuracy of 0.1°C can be achieved by the thermocouples. Radiator arrangement was provided to reduce the outlet temperature of the cold fluid before it enters the reservoir. Reynolds number for the tube side was varied from 1700-9500 while the shell side was varied from 600-1200. Initially the hot water was allowed to enter the shell side at 66°C and the cold water was allowed to enter the tube side at 35°C. A 1500W immersion heater was attached to the hot water bath to deliver hot water at desired temperatures. Surface temperatures were taken at various positions of the tube surface. The outlet temperature of both cold and hot water were noted using digital temperature indicator. The same procedure was repeated for nanofluid of 0.2% and 0.4% volume concentration. The temperature remains same for nanofluid and hot water as in the previous case. Readings were taken and tabulated to determine the overall heat transfer coefficients.
5. SCHEMATIC VIEW OF EXPERIMENTAL SETUP

![Schematic View of Experimental Setup](image)

Figure 1

6. HEAT EXCHANGE SPECIFICATIONS:
- Maximum Flow: 600 lph
- Heat Load: 0.3488 Kw
- Design Temperature: 0 to 100°C
- Shell Material: Galvanized Iron

7. RESULT AND DISCUSSION

Thus the heat transfer analysis on shell and coil heat exchanger was done. The obtained readings were tabulated for water as well as for 0.2% and 0.4% volume concentration. It is also found that the use of nanofluid increases the convective heat transfer coefficient by 7% in laminar flow condition and in turbulent flow condition increases by 22%. It is found that the use of nanofluid increases the overall heat transfer coefficient by 4% compared to that of water.

7.1. GRAPHICAL REPRESENTATION:

![Graphical Representation: Reynolds Number vs. Nusselt Number](image)

Figure 2 REYNOLDS NUMBER vs. NUSSELT NUMBER WITH WATER AS COLD MEDIUM
Figure 2 shows the relationship between Reynolds number and Nusselt number with water as cold medium. It is found that the increase in Reynolds number increases the Nusselt number.

**Figure 3.** REYNOLDS NUMBER vs NUSSELT NUMBER 0.2% Al₂O₃ AS COLD MEDIUM

Figure 3 shows the relationship between Reynolds number and Nusselt number 0.2% Al₂O₃ as cold medium. It is found that the increase in Reynolds number increases the Nusselt number.

**Figure 4.** REYNOLDS NUMBER vs. NUSSELT NUMBER 0.4% Al₂O₃ AS COLD MEDIUM

Figure 4 shows the relationship between Reynolds number and Nusselt number 0.4% Al₂O₃ as cold medium. It is found that the increase in Reynolds number increases the Nusselt number.

**Figure 5.** REYNOLDS NUMBER vs. CONVECTIVE HEAT TRANSFER COEFFICIENT FOR SHELL SIDE

Figure 5 shows the relationship between Reynolds number and convective heat transfer coefficient for shell side.
Figure 5 shows the variation of convective heat transfer coefficient with the Reynolds number for water and different concentration of nanofluid (0.2%, 0.4%). It is found that the increase in Reynolds number increases the convective heat transfer coefficient. It is also found that the use of nanofluid increases 7% in laminar flow condition and 22% in turbulent flow condition.

![Figure 5](image)

Figure 6. REYNOLDS NUMBER vs. OVERALL HEAT TRANSFER COEFFICIENT

Figure 6 shows the variation of overall heat transfer coefficient with the Reynolds number for water and different concentration of nanofluid (0.2%, 0.4%). It is found that the increase in Reynolds number increases the convective heat transfer coefficient. It is also found that the use of nanofluid increases the overall heat transfer coefficient by 4% as compared to that of water. It is also found that the use of nanofluid increases overall heat transfer coefficient under both laminar and turbulent condition.
Figure 7. MASS FLOW RATE vs. CONVECTIVE HEAT TRANSFER COEFFICIENT FOR WATER

Figure 7 shows the relation between mass flow rate and convective heat transfer coefficient for water. The graph says that convective heat transfer coefficient is directly proportional to the mass flow rate.

Figure 8. MASS FLOW RATE vs. CONVECTIVE HEAT TRANSFER COEFFICIENT WITH 0.2% Al₂O₃ AS COLD MEDIUM

Figure 8 shows the relation between mass flow rate and convective heat transfer coefficient for 0.2% Al₂O₃ nanofluid. The graph says that convective heat transfer coefficient is directly proportional to the mass flow rate.
Figure 9. MASS FLOW RATE vs. CONVECTIVE HEAT TRANSFER COEFFICIENT WITH 0.4% Al₂O₃ AS COLD MEDIUM

Figure 9 shows the relation between mass flow rate and convective heat transfer coefficient for 0.4% Al₂O₃ nanofluid. The graph says that convective heat transfer coefficient is directly proportional to the mass flow rate.

8. CONCLUSION

In this project work, the experimental analysis on shell and coil heat exchanger using Al₂O₃-water nanofluid is done. It has been found that use of shell and coil heat exchanger has more performance characteristics when considered with other types of heat exchangers. Also the use of Nano fluids increases the overall heat transfer coefficient by 4%. While increasing the concentration of the nanoparticle has increased the convective heat transfer coefficient on the laminar by 7% and 22% in turbulent region. The notable feature is that with the increase in the concentrations of the Nano fluids the overall heat transfer coefficient also enhances. Thus the application of the nanofluid enhances the overall heat transfer coefficient of shell and tube heat exchanger compared to that of counterpart water.

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