Heat Transfer Studies Of Copper Nanoparticle Suspended Water-Ethylene Glycol Base Fluid In A Plate Heat Exchanger

A.S.Periasamy Manikandan, K.Kalaivani, R.Balasubramani

ABSTRACT: IN THE PRESENT STUDY, THE HEAT TRANSFER BEHAVIOR OF COPPER NANOPARTICLE SUSPENDED WATER- ETHYLENE GLYCOL (50:50) BY VOLUME WAS EXPERIMENTALLY ANALYZED. IN ORDER TO ANALYZE THE HEAT TRANSFER BEHAVIOUR OF COPPER NANOPARTICLE, REYNOLDS NUMBER, PRANDTL NUMBER, NUSSELT NUMBER AND CONVECTIVE HEAT TRANSFER COEFFICIENT (H) WERE DETERMINED BY OBSERVING THE EFFECTS OF COPPER NANOPARTICLE VOLUME FRACTION (0.3, 0.6, 0.9, 1.2 AND 1.5%) AND HOT FLUID INLET TEMPERATURE (55°C, 65°C AND 75°C). FROM THE RESULTS IT WAS NOTED THAT THE REYNOLDS NUMBER AND NUSSELT NUMBER INCREASES WITH RESPECT TO THE HOT FLUID INLET TEMPERATURE AND NANOPARTICLE VOLUME FRACTION. THE PRANDTL NUMBER SHOWS DECREASING PATTERN, HOWEVER THE HEAT TRANSFER COEFFICIENT WAS INCREASED SIGNIFICANTLY BY THE ADDED NANOPARTICLE. THE OBTAINED RESULT INFERS THAT THE NANOPARTICLE HAS THE SIGNIFICANT CONTRIBUTION IN ENHANCING THE HEAT TRANSFER BEHAVIOR OF BASE FLUID.

Keywords: Copper, heat transfer, Nusselt number, plate heat exchanger, water, Ethylene Glycol, base fluid

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1 INTRODUCTION

With the advancement of a nanotechnology, the new type of heat transfer fluids With the advancement of a nanotechnology, the new type of heat transfer fluids (Nanofluid) was derived by researchers because of its enhanced thermo physical and heat transfer enhancing properties. This topic gives energy saving idea, which could be used in Heat exchangers used in many process and allied industries [1,2]. The conventional heat transfer fluids such as water, ethylene glycol, propylene glycol, oil etc, have the deficiency in their thermo physical properties, which can be improved by the addition of even a small quantity of nanoparticle. The main concept was initiated by Choi et al. [3] to improve thermal conductivity of conventional fluids is by dispersing metal and metal oxide nanoparticle in it. This concept provide eye opening for the researchers working in this area. The study performed to assess the thermal conductivity on copper nano particle was done Eastman et al. [4] in ethylene glycol base fluid and reported the significance of nanofluid in the improvement in thermal conductivity. Periasamy et al. [5], used Graphene nanoparticle suspended water and observed that the nanoparticle volume fraction directly proportional to the thermal conductivity of base fluids. The study performed with oxides of copper and alumina by Putra et al [6] observed the deterioration in heat transfer behaviour due to the deposition of the nanoparticle and particle-fluid slip. They have done the experiment in the fluid flowing in a horizontal tube. Kulkarni et al.[7] Studied the Heat transfer behaviour of SiO2 suspension in water-ethylene glycol mixture under turbulent flow regime. They have considered the effect of particle size on heat transfer behaviour and observed that heat transfer increases with increasing particle size. Pantzali et al [8] studied the efficacy of nanofluid in plate heat exchanger. They concluded that in micro-scale equipment with increased thermal duties the use of a nanofluid instead of a conventional fluid seems advantageous. The heat transfer study conducted by Hwang et al.[9] by suspending 35 nm nano Aluminium oxide at low volume fractions. According to their results, there is a considerable enhancement (10%) was observed in heat transfer coefficient. They also reported t that increasing Reynolds number did not increase even though the heat transfer rate increases significantly. The pressure drop and heat transfer behaviour of aluminium oxide nanoparticle was studied by Chandrasekar et al.[10] Their results are in the fully developed laminar region of pipe flow with constant heat flux, the Nusselt number has enhanced up to 12. % in comparison with base fluid. The heat transfer study conducted in plate heat exchanger by Manikandan et al., [11] with the oxides of Zinc and Titanium shows that mixture of water and ethylene glycol base fluid with nanoparticle has highest heat transfer coefficient than the mixture without nanoparticle. Zamzamian et al. [12] prepared Al2O3 and CuO nanoparticle and suspended in ethylene glycol. The stability and heat transfer behavior was evaluated by them. According to the results, the heat transfer coefficient is rising greatly with the nanoparticle suspension. The heat transfer is high in plate heat exchanger than the double pipe heat exchanger. They also concluded that if the temperature and nanoparticle concentration increases, the convective heat transfer coefficient also increases linearly. The copper oxide-water suspension made in an equilateral triangular duct by Edalati et al. [13] to study the heat transfer behavior of a nano particle suspension. The flow is laminar flow and the results shows that the heat transfer coefficient of the nanoparticle suspended base fluid is more than that of base fluid. Different metal oxide nanoparticle (Al2O3, CuO, SiO2) was used by Ray et al. [14] to study the heat transfer behaviour of prepared nanoparticle suspension in ethylene glycol-water mixture in a plate heat exchanger. They observed that suspended nanofluid shows higher overall and convective heat transfer coefficient than the base fluid without nanoparticle. Based on the literature survey, several studies related with thermal conductivity were identified in literature; however studies related with heat transfer properties are very few [15,16]. Hence in this study, the heat transfer behavior of copper nanoparticle suspended ethylene glycol-water base fluid was studied in plate heat exchanger and the results are presented.

2 MATERIALS AND METHODS

2.1 Preparation of copper nanofluid:

The two step method was used to prepare Copper nanofluid [17]. Then the prepared nanoparticle is mixed in the base fluid (ethylene glycol-water) and different volume fractions such as 0.3, 0.6, 0.9, 1.2 and 1.5%. The prepared nanoparticle were stirred well and kept for 6 hours to maintain nano fluid stability. The preparation method is shown in Figure 1.

***Figure -1**: Copper nanoparticle preparation*

The fluid properties were calculated at the average of inlet and outlet temperature of hot and cold fluids. The dimensionless numbers (Reynolds Number, Prandtl number, Nusselt Number) and heat transfer coefficient were calculated based on the literature [18-21].

2.2 Experimental setup and calculation:

Figure. 2 shows the experimental setup consists of plate heat exchanger, thermocouples, flow meters, pumps and fluid containers. The prepared nanofluid was studied for the heat transfer behavior in plate heat exchanger.

***Figure -2**: Experimental setup*

3 RESULTS AND DISCUSSION

3.1 Effect of nanoparticle volume fraction on Reynolds number:

The Reynolds number is a significant number which is the ratio of internal to viscous forces in the fluid Figure 3 provides the effects of copper nanoparticle volume fraction on Reynolds number for base fluid volume fraction of 50:50 (EG: W) and at a hot fluid inlet temperatures of 55, 65 and 75°C.

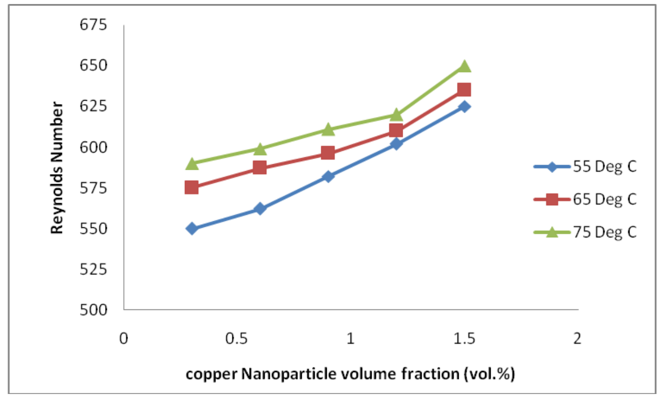

***Figure3.** Effect of nanoparticle volume fraction on Reynolds number*

From the figure it was observed that Reynolds number increased linearly at all the nanoparticle volume fractions. However if hot fluid inlet temperature is low, the increase in Reynolds number is high, due to proportionate increase in density of fluid with respect to viscosity. If the temperature is increased further, the enhancement in Reynolds number also increased, which shows the applicability of nanofluid in heat transfer processes.

3.2 Effect of nanoparticle volume fraction on Prandtl number:

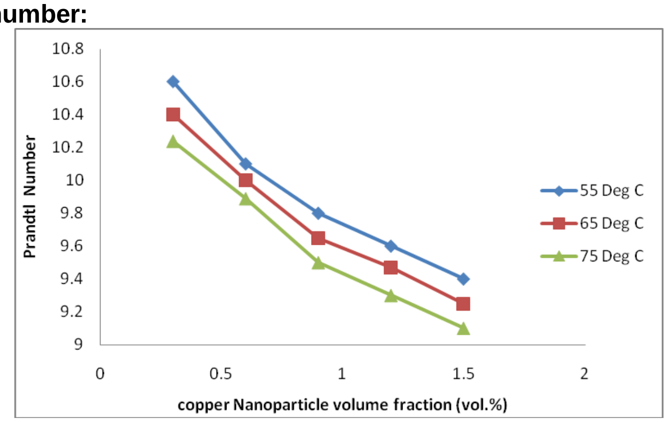

***Figure4.** Effect of nanoparticle volume fraction on Prandtl number*

The Prandtl number relates the momentum and thermal transport ability of a process fluid. The changes in Prandtl number with respect to hot fluid inlet temperatures and nanoparticle concentration is shown in Figure 4 for the base fluid concentration of 50:50 (Ethylene Glycol: Water). From the figure it was noted that the Prandtl number decreases with respect to both factors i.e., temperature and volume fraction. Because of the increment in thermal conductivity of nanofluid, the molecular transfer of heat transport dominates over the molecular transfer of momentum transport, Hence the Prandtl number decreases at all the temperatures.

3.3 Effect of nanoparticle volume fraction on Nusselt number:

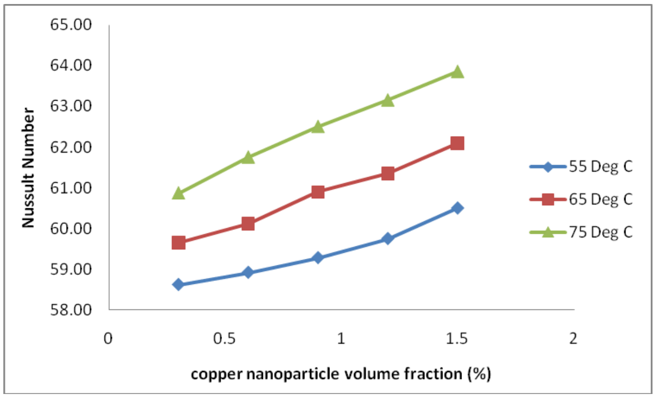

Figure 5. *Effect of nanoparticle volume fraction on Nusselt number*

One of the significant factor to assess the heat transfer performance is Nusselt number. Figure 6 presents the effects of copper nanoparticle suspension on Nusselt number for base fluid concentration of 50:50 (EG: W) and at a hot fluid inlet temperatures of 55, 65 and 75°C. The increase of Nusselt number was observe at all the volume fraction, which shows that the heat transfer is enhanced significantly. The same trend was obtained at all the temperatures viz., 55, 65 and 75° C. Since there is a significant changes in thermo physical properties, which alters the heat transfer behavior of the base fluid.

3.4 Effect of nanoparticle volume fraction on heat transfer coefficient:

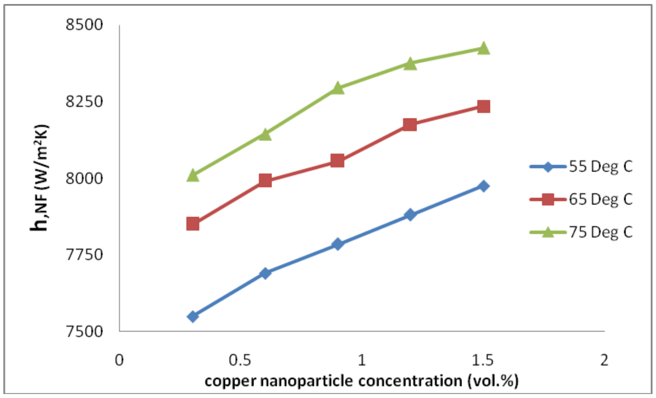

Figure 6. *Effect of nanoparticle volume fraction on heat transfer coefficient*

Figure 6 describes the variations in heat transfer coefficient by the added copper nanoparticle. From the figure it was noted that, the nanoparticle increases the heat transfer coefficient and maximum enhancement was noted at 1.5 volume% with the heat transfer coefficient value of 8350 W/m2K. The reason for the enhancement in heat transfer rate is due to the Brownian motion created by the added nanoparticle. At all the temperature the same effects was observed with the prepared base fluid.

4. CONCLUSIONS

In this research the heat transfer behavior of Ethylene Glycol-Water (50:50 vol%) mixture with the copper nanoparticle addition was studied in a plate heat exchanger. In order to assess the performance of added base fluid, Reynolds number, Prandtl number, Nusselt Number was determined. The convective heat transfer coefficient was also determined at various hot fluid inlet temperatures and different nanoparticle volume fractions. Study reveals that the Reynolds and Nusselt number increases, where as Prandtl number decreases because of the changes in thermo physical properties. However, the convective heat transfer coefficient increases with respect to copper nanoparticle concentration as well as the hot fluid inlet temperature. From the study it is suggested that the nanoparticle suspended possess the enhanced capability of heat transfer behavior.

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