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Impact of Copper Nanoparticle Addition on Thermo Physical Properties of Different Base Fluids

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Abstract: ***In the present work, thermo physical properties of different base fluids (Water, Ethylene Glycol, Propylene Glycol) by suspending various concentrations of copper nanoparticle was evaluated. Initially copper based nanofluid was prepared by two-step method and the concentration of copper nanoparticle was varied at 0.15, 0.2, 0.25 and 0.3 volume. %. The effect of copper nanoparticle concentration on thermo physical properties was evaluated. The result shows that the density, thermal conductivity and viscosity of all the chosen base fluids (Water, Ethylene Glycol, and Propylene Glycol) were increased; however the specific heat of these base fluids decreases while increasing the copper nanoparticle concentration.***

Keywords: copper nanoparticle, thermo physical properties, base fluids.

I. INTRODUCTION

With the improvement in the field of nano technology, the new class of heat transfer fluids called, Nanofluids have been proposed by many researchers and these fluids have higher thermal conductivity compared to that of conventional heat transfer fluids (base fluids). Heat exchangers are often used in many chemical industries and also for engineering applications [1,2]. The enhancement in heating or cooling processes may provide considerable energy savings in process industries. These added nano particles are invented to enhance the thermo-physical properties and hence heat transfer performance of its base fluid. Hence adding nanoparticle in base fluids improves the thermal performance of heat exchanger systems that will save significant energy as well as our environment. Water is widely used as a base fluid in many process industries, however ethylene glycol and propylene glycol also used as a base fluid in various heat transfer equipment. Choi et al. [3] proposed an innovative idea of improving thermal conductivity of base fluids by adding and mixing nanoparticle in a base fluid. This idea creates opportunities for process and thermal engineers. To identify the potential benefit of nanofluid in a heat exchanger, the essential thermo physical properties (viscosity, thermal conductivity, specific heat capacity, density) of nanofluid must have to be studied in the beginning. Nanofluid is a fluid which contains the mixture of base fluids (water, ethylene glycol and propylene glycol) and approximated nano particle size of 100nm[4]. Duangthongsuk et al.[5] Studied thermo physical properties of TiO_2/Water nanofluids and reported that there is a deviation in the thermo physical properties of nanofluid given by different models. Mahian et al. [6] studied the effect on density of ZnO nanoparticle addition in the base fluid of water and reported the maximum density of 1328 kg/m^3 at a temperature of 25 °C for a nanoparticle volume fraction of 4.0%. The density study performed by Kadhim et al.,[7] reported that the density of nanofluid increase with respect to the nanoparticle concentration. They have used MgO nanoparticles suspended with water. Yiamsawasd et al.[8] developed a correlation equation to predict the specific heat of TiO_2 and Al_2O_3 nanofluid. Satti et al. [9] studied the effect of specific heat capacity with respect to CuO, Al_2O_3, SiO_2, ZnO, TiO2 nanoparticles and found that the indirect relationship between specific heat capacity and nanoparticle concentration and the direct relationship between specific heat capacity and temperature. The thermal conductivity study performed by Eastman et al. [10] for Copper nanoparticles dispersed in ethylene glycol base fluid shows that significant improvement in thermal conductivity. Graphene/water nanofluid used by periasamy et al. [11] reported that the nanoparticle concentration has the significant effect on thermal conductivity of base fluids.

Koo & Kleinstreuer [12] were studied the effects of different motion mechanisms with respect to nanofluid thermal conductivity. They considered the effects of osmophoresis and Brownian motion on thermal conductivity. Manikandan et al., [13] studied the heat transfer performance of TiO_2 and ZnO diluted in a mixture of water and ethylene glycol base fluid and reported there is a significant enhancement in the heat transfer rate. The hydrodynamic study conducted by Pak & Cho[14] reported non-newtonian behavior of water in the suspension of Al_2O_3 and TiO_2 nanoparticles. The viscosity study performed by Junming et al [15] observed 15-30% enhancement on viscosity of CuO nanoparticle suspended in water. Several studies related with thermal conductivity and heat transfer identified in literature, however studies related with thermo physical properties are very few.

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Hence the objective was framed to evaluate the effect of copper nanoparticle addition on thermo physical properties of different base fluids such as water, ethylene glycol and propylene glycol.

II. MATERIALS AND METHODS

2.1 Preparation of copper mixed base fluid

Copper mixed base fluid is prepared by two step method [16]. The size of the dried nanoparticles is taken by Scanning Electron microscope and the average size of the particles is found to be 100nm. Figure 1 shows the Preparation method of copper nanoparticle.

Fig -1: Preparation of copper nanoparticle

Figure 2 shows the SEM Image of prepared copper nanoparticle. Then the nanoparticle are dissolved in the 100ml of different base fluids such as water, propylene glycol and ethylene glycol at different concentrations such as0.15%, 0.2%, 0.25% and 0.3% then the nanofluid mixture is stirred in the magnetic stirrer for 5 hours continuously.

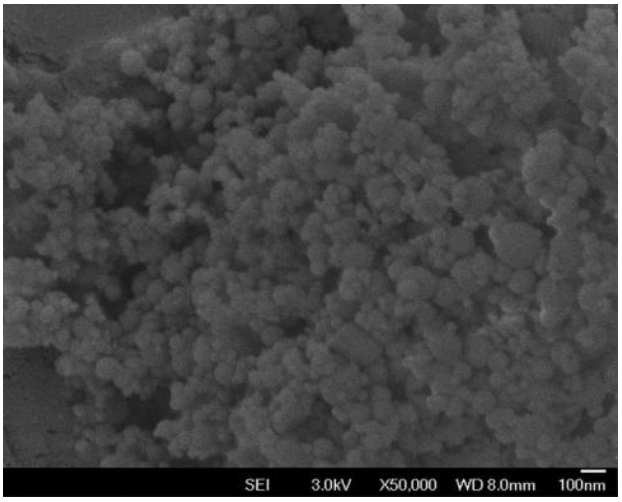

FIG -2: SEM IMAGE OF COPPER NANOPARTICLE

III. RESULTS AND DISCUSION

All the fluid properties are evaluated at room temperatures based on the correlations used in the literatures [17-20].

3.1 Properties of nanofluid:

The addition of nanoparticle will change the properties of the base fluid. The properties of the nanofluids are calculated for the different concentrations like 0.15%, 0.2%, 0.25% and 0.3% for different base fluids such as water, ethylene glycol and propylene glycol at the room temperature of 28°C.

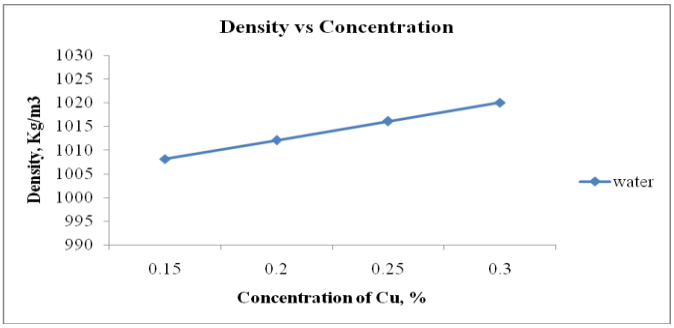

Fig -3: Effect of nanoparticle concentration on Density of water

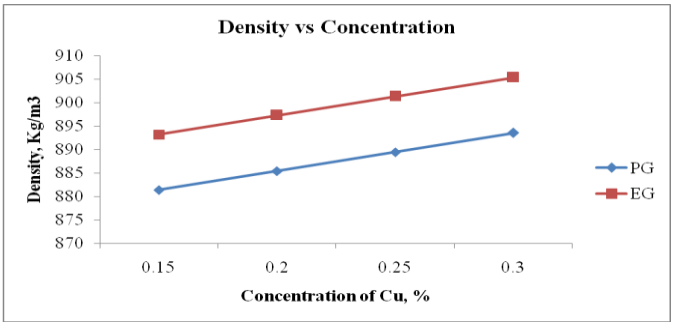

Fig -4: Effect of nanoparticle concentration on Density of Ethylene Glycol and Propylene Glycol

It is noted that the addition of nanoparticles in the base fluid increases the density of base fluids, hence density varies directly with the concentration of copper nanoparticle for all the base fluids (water, ethylene glycol and propylene glycol) as shown in Figures 3 and 4. The maximum Density observed is 910 kg/m^3 and 895 kg/m^3 for a base fluid of ethylene glycol and propylene glycol respectively for the nanoparticle concentration of 0.3%. The effect on copper nanoparticle concentartion with respect to the variations in the specific heat capacity of base fluids is shown in Figure 5**.** It is observed that the specific heat capacity decreased with respect to nanoparticle concentration at all the base fluids in the test temperature. The reason for this is due to the fact that specific heat capacity is a mass specific quantity and these effects depends on the density of components and its mixture

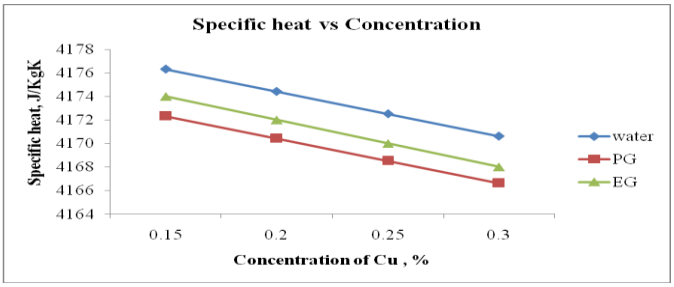

Fig -5: Effect of nanoparticle concentration on Specific heat of base fluids

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The effect of copper nanoparticle addition at a test temperature on thermal conductivity for a base fluid of water, EG and PG was reported in Figure6. We observed that there is a significant increase in thermal conductivity for all the base fluids. This is because of the expanded surface area of dispersed nanoparticle in base fluid .

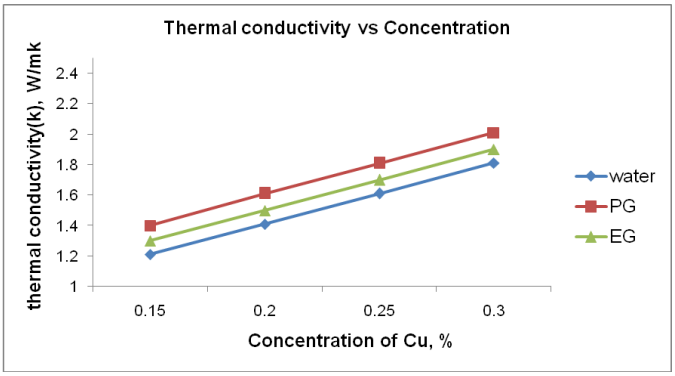

Fig -6: Effect of nanoparticle concentration on thermal conductivity of base fluids

Viscosity is an significant thermo physical property since it indicates the resistance offered by the fluid and estimating the energy requirements for pumping. The variation of viscosity of base fluids on the nanoparticle concentration is shown in Figure 7. Due to increase in viscosity the pumping power and friction factor will also increase. This causes decrease in the heat transfer performance of base fluids above 0.3% concentration of nanoparticle.

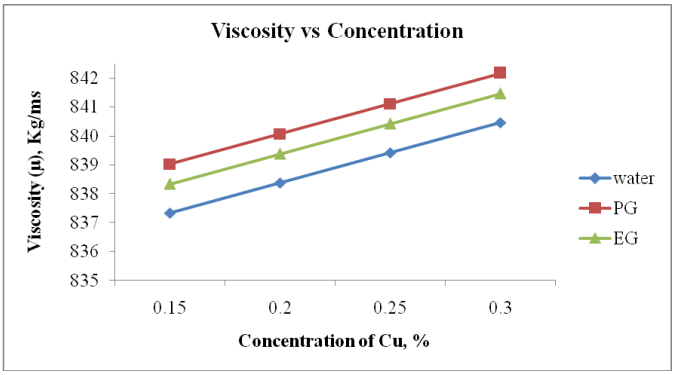

Fig -6: Effect of nanofluid concentration on viscosity of base fluids

4. CONCLUSIONS

Themo physical properties of Cu nanoparticle suspended in different base fluids such as water, propylene glycol and ethylene glycol is observed. The effect of nanoparticle concentration at a given temperature has been determined, which yield the following results.

- It is noted that the addition of nanoparticle in the base fluid will alter the thermo physical properties of the base fluid.
- Due to this change of these properties will alter the heat transfer performance of the base fluids increase the heat transfer coefficient of the nanofluid.
- The thermal property of the fluid will increase which indicates that the heat transferred will also increase. It will show the significant impact on heat transfer coefficient.
- The density of nanoparticle suspensions increases with copper nanoparticle concentration
- With respect to the specific heat, there is a negative trend is observed with the increase in nanoparticle concentration. Hence the dispersed nanoparticle shows lower specific heat than the values of base fluids
- There is an increment in viscosity of all the base fluids with the increase in nanoparticle concentration. Viscosity enhancement in base fluid of propylene glycol is higher than Ethylene Glycol and water.
- the thermal conductivity of the chosen base fluid increases with the increases in copper nanoparticle concentration

Since the heat transfer performance of the base fluid fully dependant on thermo physical properties of the base fluids, this study plays a mojor role in conducting heat transfer studies with the base fluids.

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