SEDIMENTATION METHOD TO EVALUATE STABLE CuO BASED NANOFLUID FOR HEAT TRANSFER APPLICATIONS

Abstract

Nano fluid is a base fluid in which nanoscale particles are suspended. Nanofluids are tremendous heat transfer applications in the field of thermal engineering such as radiator heat exchanger and solar applications etc. the applications of the CuO-DI water and CuO-EG nanofluids in a area of heat transfer is essential and maintain the stability of CuO-DI water and CuO-EG nanofluids is necessary. In the present study two - step method was used to prepare the CuO-DI water and CuO-EG nanofluids without adding surfactant. The sedimentation method was adopted to check the stability of the nanofluid for the volumetric concentration of 0.2%, 0.4%, and 0.6% of CuO nanoparticles in the DI water and EG. The thermo physical properties such density, specific heat, thermal conductivity, and viscosity of the CuO-DI water and CuO-EG nanofluids were also studied using the appropriate model in the present work.

Keywords: CuO nanoparticles, nanofluid, stability, sedimentation, thermo physical properties.

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I. INTRODUCTION

Nanofluids are most important and innovative fluids in the heat transfer applications due to the higher thermal conductivity then conventional fluids such as water, ethyleneglycol, biofuels, and other oils which are used to transfer the heat from one fluid to another fluids. In order to employee the nano fluids for the heat transfer applications, it is essential to study the thermo physical properties of the CuO-DI water and CuO – EG nanofluids. Focus should also be placed on the production process, nanofluid stability, and heat transmission properties of the CuO-DI water and CuO - EG nanofluids.

Amrut. S. et al [1] discussed optical characterization and synthesis of copper oxide nanoparticles. the authors shown TEM images, for size, tem images to show the rectangular morphology of the CuO nanoparticles. Single phase monoclinic structure is revealed by the X-ray diffraction pattern (XRD). Authors also describe the optical characteristics of the CuO nanoparticles.

Q. Zhang.et al. [2] investigated Synthesis, characterization, growth methods, fundamental properties, and applications of CuO nanostructures and nanoparticles. The author's tells the characteristics of the nanoparticles.

X.Wang .et al.[3] done the research to measured nanofluids thermal conductivity for the different concentration nanoparticles with hot wire method. But the author's does not use the sedimentation method to measure the nanofluids stability for the applications heat transfer.

The plasma evaporation method was adopted to investigate the Copper oxide thin films growth which was studied by K.Santra.et al. [4]. In their study they explain about growth of copper oxide nanofluids which helps to determine the stability of CuO nanofluid for the heat transfer applications.

A. Aslani .et al.[5] discuss the morphology and size control of copper oxide nanostructures by solvo/hydrothermal synthesis, which describes the control of CuO nanostructures without the need of any additives.

As the literature survey suggest that the preparation of the CuO DI water nanofluid for the volumetric concentration of 0.2%, 0.4%, and 0.6% using the two-step method was not available for the 20-nanometre size spherical shape CuO nanoparticles. The sedimentation method was adopted to verify the stability of the CuO DI water nano fluid was scant. Hence in the present work the preparation of nano fluid using the two-step method for the different concentration of the CuO nanoparticles considered and sedimentation method for stability checking was employed. Apart from this the autor's also measured properties of the nanofluids such as density, thermal conductivity, specific heat and viscosity for the different concentration of CuO nanoparticles in DI water.

II. MATERIALS AND METHODS

The CuO selected as nanoparticles and DI water and EG as base fluids were selected based on the study of literature reviews and gap identified for research work. The size of the CuO nano pparticles is 20 nano meter and in spherical in shape the methodology followed for the preparation and stability checking of the nanofluid shown in theFigure 1.

1. **Over view of DI water:** The DI water that has been vaporized condensed back into liquid, and stored in a different container. In the original container, impurities in the water that doesn't boil at or below the water's boiling point are still there. Thus, distilled water is of purified water. The thermo physical properties of distilled water were mentioned in the Table 1.

2. **Overview of EG:** A chemical having the formula (C2H2OH), EG is mostly employed in antifreeze compositions. It is a thick liquid that has no smell, no colour, and is combustible. Although EG has a pleasant flavour, large doses can be harmful. It can occur at neutral pH and melting point and boiling point of the EG are -12.9^{o}C and 198^{o}C respectively. Due its low melting point (freezing) ethylene glycol used in many heat transfer applications. The thermo physical properties of DI water were mentioned in the table 1.

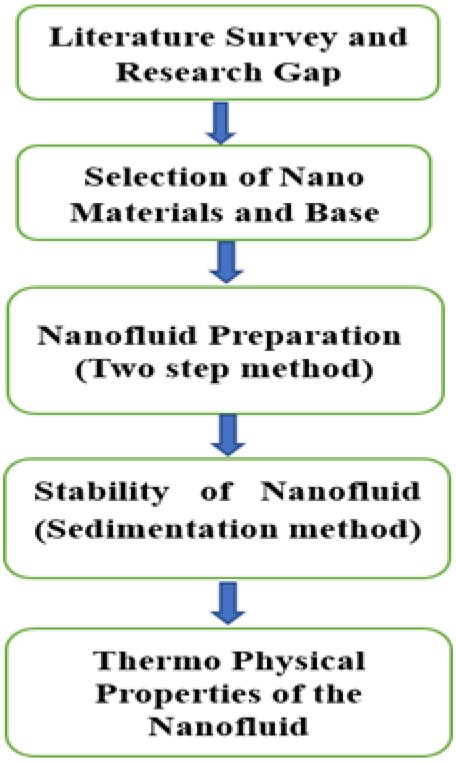

Figure 1: Methodology

Table 1: Properies of DI Water and EG

Specification	SI Unit	DI Water	EG (EthyleneGlycol)
Viscosity	PaS	0.0089	0.0157
Melting point	Celsius	0	-12.9
Boiling point	Celsius	99	198
Density	Kg/m^3	999.875	1114.4
Thermal conductivity	W/m K	0.6	0.252
Specific heat	J/kg K	4182	2415

3. **Over view of Copper Oxide (CuO) Nano Particles:** The powdery form of copper oxide nanoparticles is brownish-black. They can be transformed into metallic copper at high temperatures when exposed to hydrogen or carbon monoxide. They are rated as dangerous for the environment and destructive to aquatic life in addition to being toxic to humans. Chemical composition of copper oxide having copper 79.87% and oxygen 20.10%. The melting point and boiling point of copper oxide are 1201^{o}C and 2000^{o}Crespectively. The density and specific heat of the copper oxide nanoparticles is 6315 kg/m^3 and 540 J/kg K and thermal conductivity of spherical shaped 20 nanometer sized CuO nano particles is 32.9 W/m K which is given by the supplier Nano Research lab Jamshedpur, India.

4. **TEM images of CuO Oxide Nanoparticle:** CuO nanopowder was purchased from Nano research lab Jamshedpur, India. The product maker confirmed that size of the particles was less than 20 nm and surface area was 29 m^2 /g. Before characterization, the CuO nanoparticles were sonified for 5 minutes in DI water (10 mg/L) to prevent agglomeration. Transmission electron microscopy (TEM), the sedimentation method, and particle size analyzers were employed to characterise the size of the nanoparticles. A JEM2100F (JEOL Ltd., Japan) running at 100 kV was used for TEM. CuO nanoparticle powder was dispersed by ultrasonification in water to create the sample for TEM observation, and the dispersion was then allowed to fall onto a copper grid. Figure 2 displays a typical TEM picture of CuO aggregates. CuO nanoparticle sizes were measured and displayed in nm using an ELS-6000 analyzer from Photograph Otsuka Electronics in Japan.

5. **X-RD images of CuO Oxide Nanoparticles:** XRD analysis was done on the CuO NR microcrystalline structure. The graph were prepared using Powder X software. As shown in figure 3, the characteristic X-RD peaks were observed at 33.15, 35.2, 38.8, 48.7, 52.1, 58.45, 62.8, 65.96 and 67.95 corresponding to 110, 002, 101, 202, 020, 202, 123, 331 and 143 reflections respectively which indicate that formation of typical monoclinic CuO NR structure and are in agreement with the standard values reported by the JCPDS card no. 801268 and ICDD card no. 801916 which was in accordance with previous studies reported. The figure 3 does, however, also indicate other peaks. Using Debye Scherrer's equation, the average crystallite size was calculated to be 20 nm**.**

   $$D = K\lambda / (\beta \cos\theta)$$

Where is the diffraction angle (degree), is the full-width at half maximum (FWHM) of the peak in radians, is the wavelength of X-ray radiation, and D is the average particle size (nm).

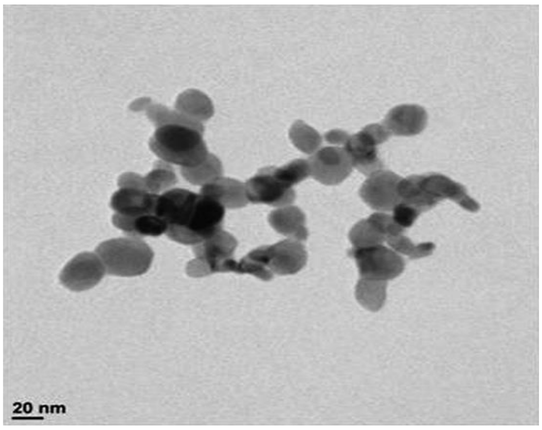

Figure 2: The TEM image of 20 nm CuO Nanoparticles.

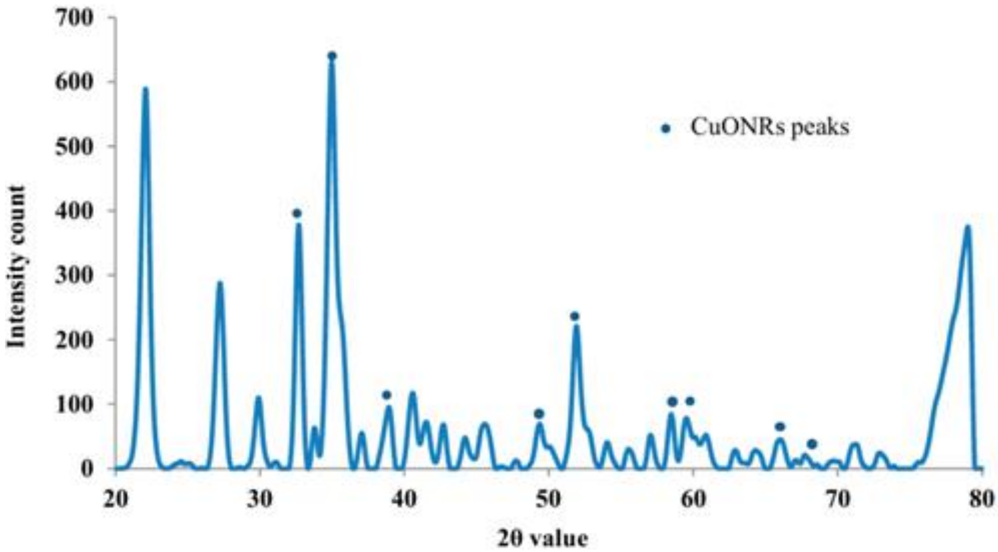

Figure 3: X-RD images of CuO Oxide Nanoparticles

6. **Preparation of the Nano Fluids:** The two step method was adapted to prepared CuO DI water and CuO – EG nanofluids, which is more economical and used for all type of nanofluids preparations. CuO–DI water and CuO – EG nanofluids were prepared with very low concentration and without surfactant.

In this study, a magnetic stirrer with a hot plate was used to disperse CuO nanoparticles with an average diameter of 20 nm in DI water or EG nanofluid at 650 rpm and 30^{o}C temperature (Make: SESW). CuO nanopowder was introduced to DI water or EG and subjected to shear homogenization for 20 min. at 650 rpm speeds, followed by increasing speeds, for each volume fraction required. By combining base fluids with commercially available nanopowders acquired through various mechanical, physical, and chemical pathways, such as milling, grinding, sol- gel, and vapour phase procedures, the two-step preparation process is widely employed in the synthesis of nanofluids. The two step method of preparation shown in figure 4.

7. **Sedimentation Method for Stability checking of Nanofluids:** Due to the high van der Walls force between the nanoparticles, stability is a major concern that is inextricably linked to this procedure. Stability is essential for the nanofluid to possess the same thermophysical characteristics. Van der Waals attraction and electrical double layer repulsive force have an impact on the stability of nanofluid. The Electrical Double Layer Repulsive Force (EDLRF) must be stronger than the Vander Waals attractive forces in order to produce a stable nanofluid. Nanoparticle clustering is caused by the van der Waals attractive interactions that exist between them. If this force is strong, nanoparticles are separated from the base fluid and clustered nanoparticles fall to the bottom of the vessel under the influence of gravity. On the other side, EDLRF acts as just opposite to Van der Waals attractive force which separates the nanoparticles from each other. The sedimentation was adopted for the stability checking of the nanofluids which is basic method and require longer period.

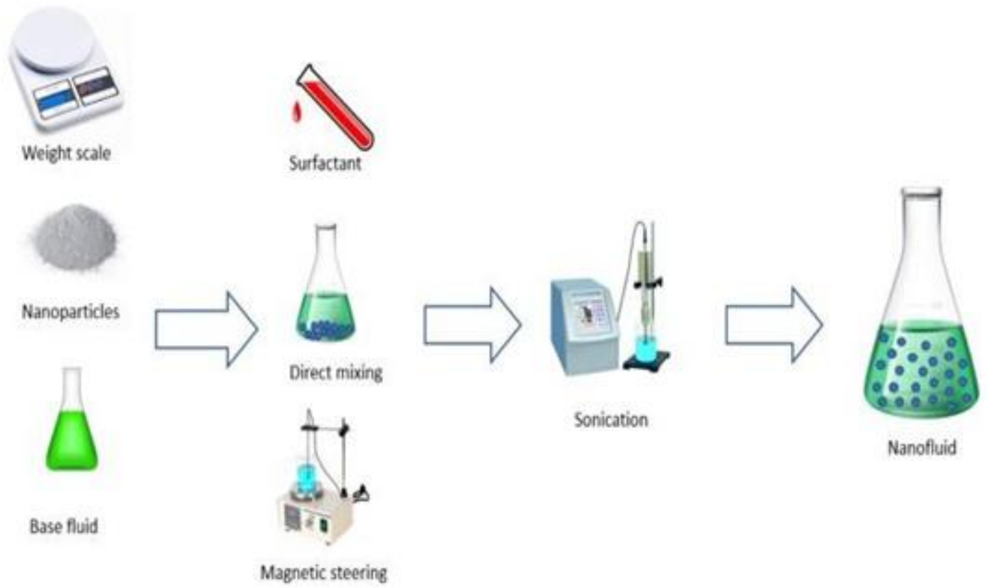

Figure 4: Two Step Method for the Preparation of the CuO-DI Water and CuO-EG Nanofluid.

8. **Thermopysical Properties of the CuO-DI Water CuO-EG Nanofluids**

- **Density of the Nanofluid:** Density can be defined as mass per unit volume, Pak and Chao developed the correlations to measure the density of the nanofluid by taking the account of density of nanoparticles and basefluids.

$$\rho nf = \Phi \rho p + (1-\Phi)\rho f$$

- **Specific heat:** Specific heat represents the capacity of the nanofluids. Specific heat depends on the density, volume concentrations, and specific heat of the nanoparticles and base fluid.

$$\mathrm{CPnf} = \frac{\Phi\ \rho p\ \mathrm{CPnp} + (1 - \Phi)\rho f\ \mathrm{CPf}}{\rho nf}$$

- **Thermal Conductivity:** Thermal conductivity is the properties of materials and function of temperature. Nanofluids found in many heat transfer cooling and heating process applications. The thermal conductivity of nanofluids calculated using the Maxwell correlations of equation.

$$\mathrm{Knf} = \frac{\mathrm{Kp} + 2\mathrm{K_{bf}} + 2\Phi(\mathrm{K_p} - \mathrm{K_{bf}})}{\mathrm{Kp} + 2\mathrm{K_{bf}} - \Phi(K_p - \mathrm{K_{bf}})}\mathrm{Kbf}$$

- **Viscosity:** The Einstein developed the correlations to calculate the viscosity of nanofluid. In the present work viscosity of CuO DI water and CuO-EG nanofluid calculated using the Einstein model.

$$\mu nf = (1 + 2.5\varphi)\mu bf$$

9. **Volumetric Concentrations to Gravimetric Concentrations:** The volumetric concentration of the CuO nanoparticles converted to gravimetric (mass) with the following equation.

$$\frac{Weight}{Volume}\% = \frac{weight\ of\ the\ solute}{Volume\ \ of\ the\ solution}\ x\ 100$$

III. RESULTS AND DISCUSSIONS

The reaserch were carried out to determine the thermophysical properties and stability of the 20 nm sized sperical shaped CuO – DI water CuO-EG nanofluids for the concentrartions of 0.2%, 0.4%, and 0.6% of CuO nanoparticles without adding surfactent. The results were discussed as follows.

1. **Thermo Physical Properties:** The therm0 physical pr0perties of the CuO –DI water and CuO-EG nanofluids such as density, specific heat, tehrmal conductivity and viscosity of the were calculated and discussed**.**

   - **Density of the CuO-DI Water Nanofluids:** The variation of density of the CuO – DI water nanofluid at various concentration shown in figure 5.The densiy of the CuO – DI water nanofluid incresed with incresed concentrations. The concentration of tha CuO – DI water nanofluid vary from 0.2%, 0.4%, and 0.6%. The valeus of density at 0.2%, 0.4%, and 0.6% were 1009.23 kg/m^3, 1019.86 kg/m^3 and 1030.49 kg/m^3 respectively.

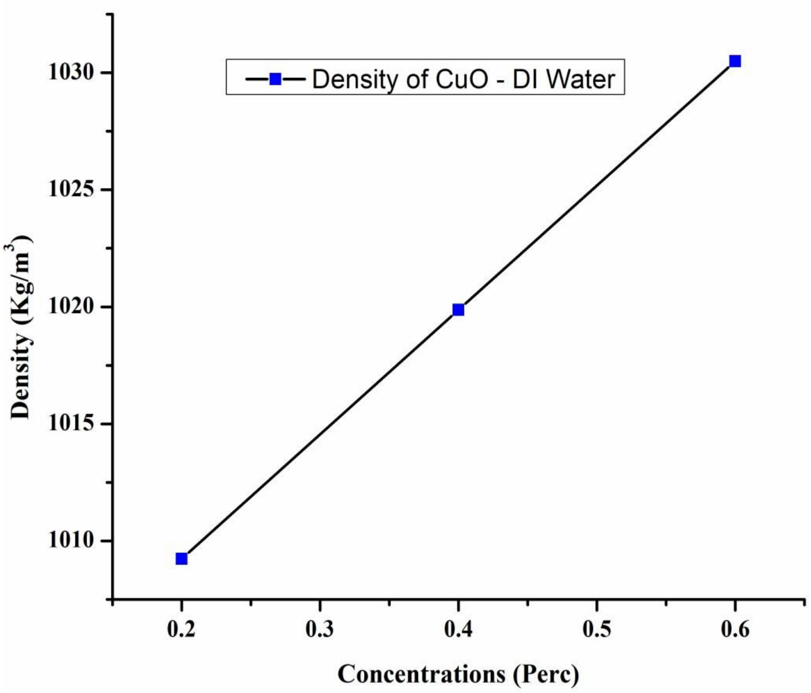

Figure 5: The Density of the CuO – DI Water Nanofluids at Different Concentration

The maximum density occurred at 0.6% and minimum at 0.2% shown in figure 5. Due to increase in the density viscosity increases and clustered of nanoparticles in the DI water increased. The density of the nanofluid was measured with relations (1).

The variation of density of the CuO – EG nanofluid at variuos concentration shown in figure 6.The densiy of the CuO – EG nanofluid increased with increased concentrations. The concentration of tha CuO – EG nanofluid vary from0.2%, 0.4%, and 0.6%. The valeus of density at 0.2%, 0.4%, and 0.6% were 1124.80 kg/m^3, 1135.20 kg/m^3 and1145.60 kg/m^3 respectively.

The maximum density occurred at 0.6% and minimum at 0.2% shown in Figure 6. Due to increase in the density viscosity increases and clustered of nanoparticles in the EG increased. The density of the nanofluid was measured with relations (1).

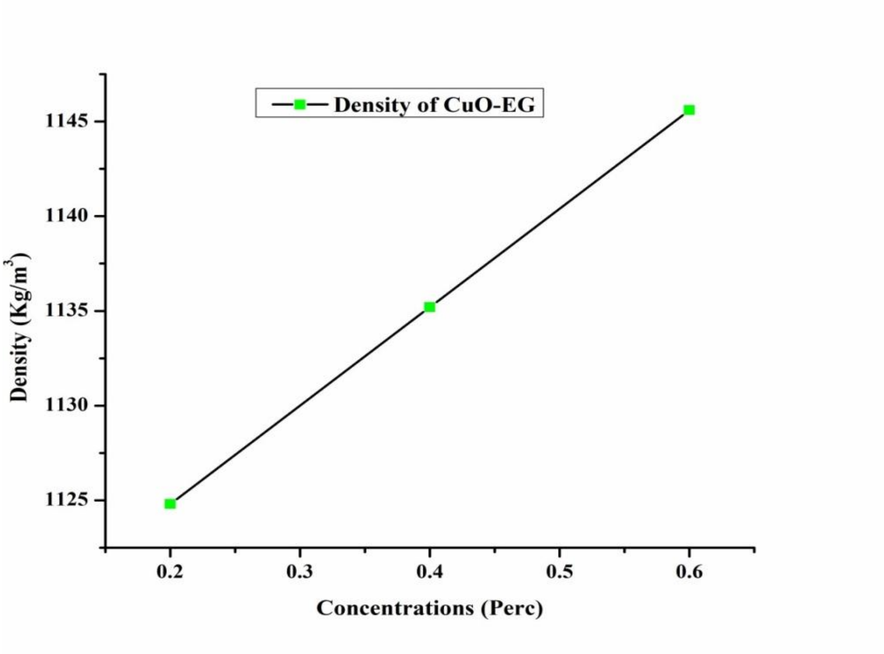

Figure 6: The Variation of Density of the CuO – EG Nanofluids at Different Concentration

- **Thermal Conductivity of the CuO-DI water and CuO – EG Nanofluids:** The changes in thermal conductivity of the CuO – DI water nanofluid at different concentration as shown in figure 7.The thermal conductivity of the CuO – DI water nanofluid incresed with incresed concentrations. The concentration of tha CuO – DI water nanofluids vary from 0.2%, 0.4%, and 0.6%. The values of thermal conductivity at 0.2%, 0.4%, and 0.6% were 0.60342 W/m K, 0.60685 W/m K and 0.61029 W/m K respectively.

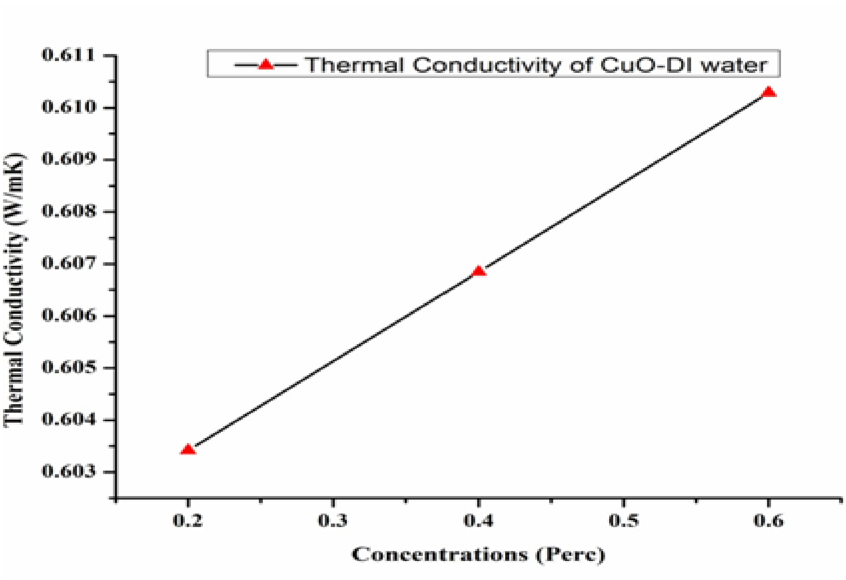

Figure 7: The Changes in Thermal Conductivity of CuO-DI Water Nanofluid at Different Concentration

The maximum thermal conductivity occurred at 0.6% and minimum at 0.2% shown in figure 7. Due to increase in the thermal conductivity, heat transfer through nanofluids increased compared to DI Water. The thermal conductivity of the nanofluids was calculated with relations (3).

The variation of thermal conductivity of the CuO – EG nanofluid at different concentration shown in Figure 8.The thermal conductivity of the CuO – EG nanofluid incresed with incresed concentrations. The concentration of tha CuO – EG nanofluid vary from 0.2%, 0.4%, and 0.6%. The values of thermal conductivity at 0.2%, 0.4%, and 0.6% were 0.2534 W/m K, 0.2549 W/m K and 0.25645 W/m K respectively.

The maximum thermal conductivity occurred at 0.6% and minimum at 0.2% shown in Figure 8. Due to increase in the thermal conductivity, heat transfer through nanofluid increased compared to EG. The thermal conductivity of the nanofluids was calculated with relations (3).

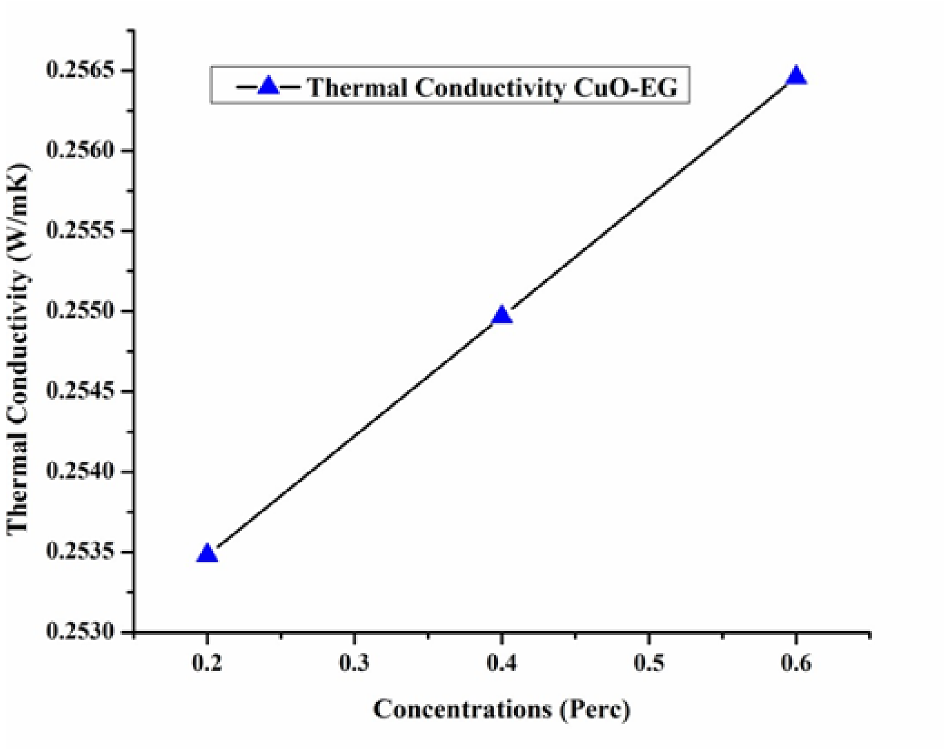

Figure 8: The Changes in Thermal Conductivity of CuO-EG Nanofluid at Different Concentration.

- **Viscosity of the CuO - DI Water and CuO-EG Nanofluids:** The variation of viscosity of the CuO – DI water nanofluid at different concentration shown in Figure 9.The viscosity of the CuO – DI water nanofluid increased with increased concentrations. The concentration of tha CuO – DI water nanofluid vary from 0.2%, 0.4%, and 0.6%. The values of viscosity at 0.2%, 0.4%, and 0.6% were 0.001005 paS, 0.00101 paS and 0.001015 paS respectively.

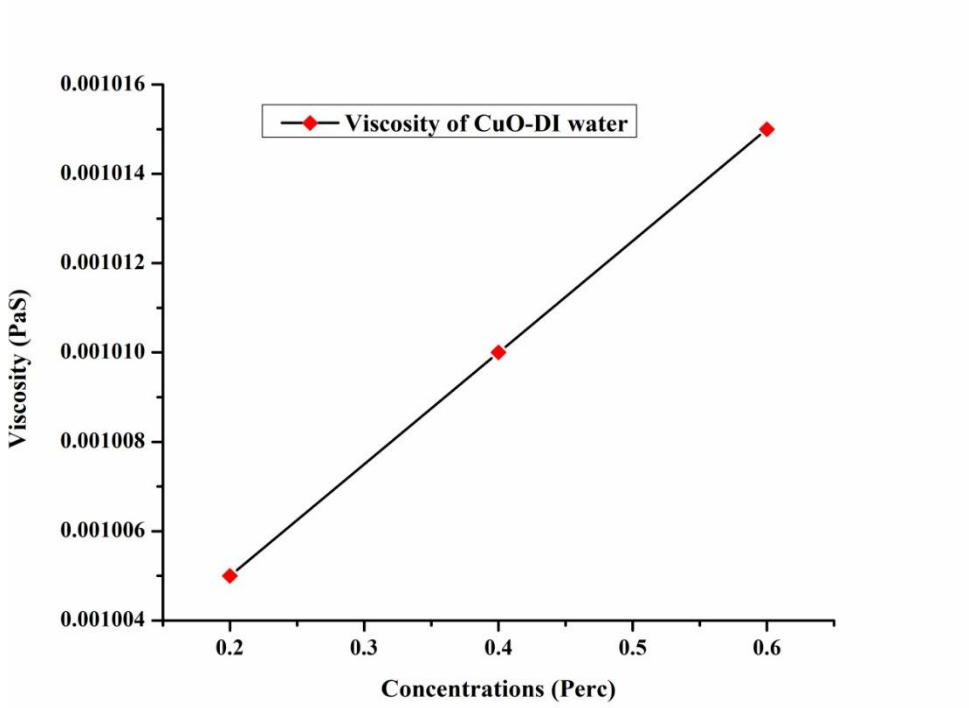

Figure 9: The Changes in Viscosity of CuO-DI Water Nanofluids at Different Concentration

The maximum viscosity occurred at 0.6% and minimum at 0.2% as shown in figure 9. Due to increase in the viscosity, heat transfer through nanofluid increased compared to DI Water. The viscosity of the nanofluid was calculated with relations (4).

The variation of viscosity of the CuO – EG nanofluids at variuos concentration shown in figure 10.The viscosity of the CuO – EG nanofluids increased with increased concentrations. The concentration of tha CuO – EG nanofluid vary from 0.2%, 0.4%, and 0.6%. The values of viscosity at 0.2%, 0.4%, and 0.6% were 0.0157 paS, 0.0158 paS and 0.0159 paS respectively.

The maximum viscosity occurred at 0.6% and minimum at 0.2% shown in figure 10. Due to increase in the viscosity, heat transfer through nanofluid increased compared to EG. The viscosity of the nanofluids was calculated with relations (4).

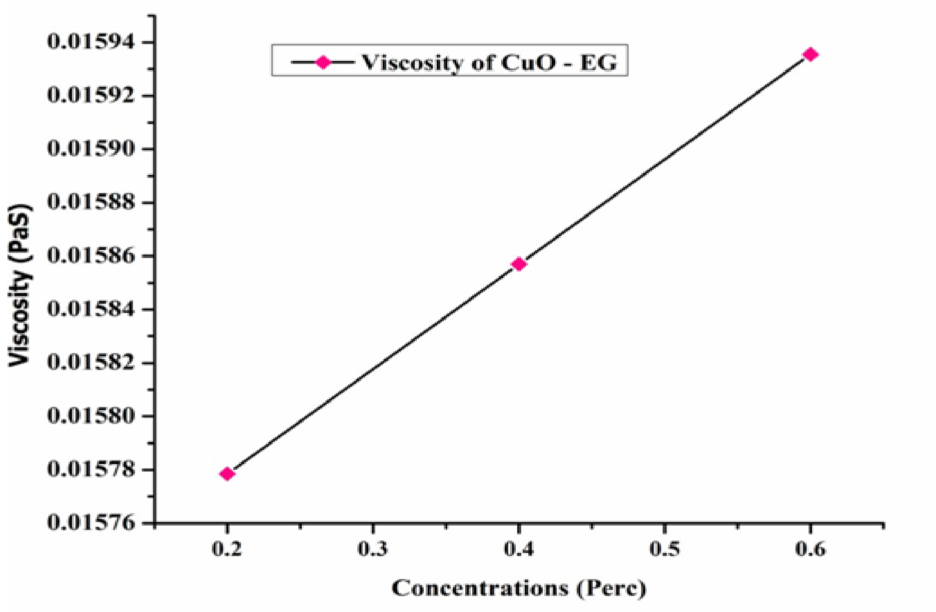

Figure 10: The Changes in Viscosity of CuO-EG Nanofluids at Various Concentrations

- **The Specific Heat of the CuO – DI Water and CuO-EG Nanofluids:** The specific heat of the CuO – DI water nanofluid at various concentration shown in figure 11.The specific heat of the CuO – DI water nanofluids incresed with increased concentrations. The concentration of the CuO – DI water nanofluid vary from 0.2%, 0.4%, and 0.6%. The values of specific heat at 0.2%, 0.4%, and 0.6% were 4140.372 J/kg K, 4095.696 J/kg K and 4051.942 J/kg K respectively.

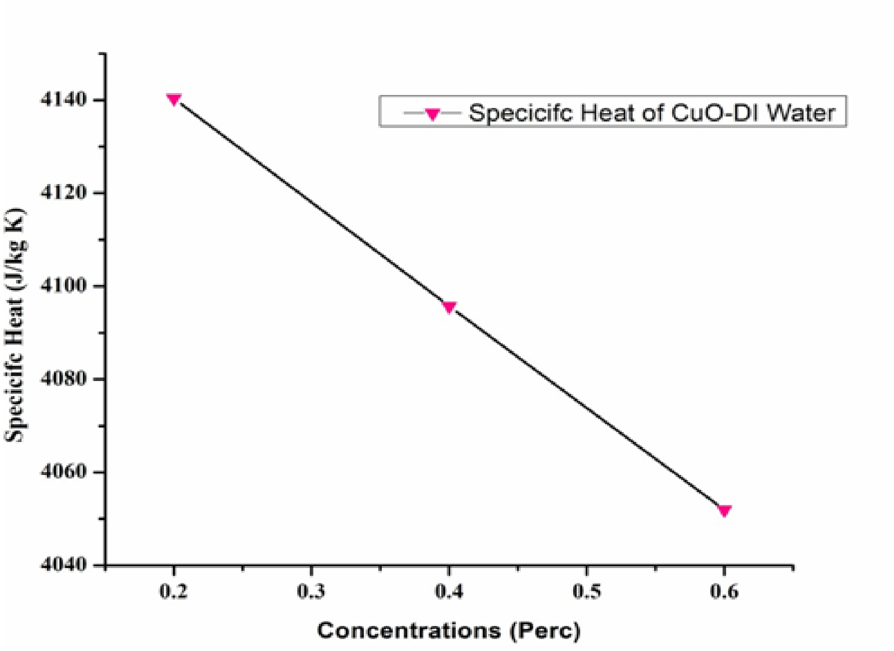

Figure 11: The Changes in Specific Heat of CuO-DI Water Nanofluids at Various Concentrations

The maximum specific heat occurred at 0.2% and minimum at 0.6% shown in figure 11. Due to increase in the specific heat, heat transfer through nanofluid increased compared to DI Water. The specific heat of the nanofluid was measured with relations (2).

The specific heat of the CuO – EG nanofluid at different concentration shown in Figure 12.The specific heat of the CuO – EG nanofluid increased with increased concentrations. The concentration of tha CuO – EG nanofluid vary from 0.2%, 0.4%, and 0.6%. The values of specific heat at 0.2%, 0.4%, and 0.6% were 2393.94 J/kg K, 2373.27 J/kg K and 2352.98 J/kg K respectively.

The maximum specific heat occurred at 0.2% and minimum at 0.6% shown in figure 12. Due to decrease in the specific heat, heat transfer through nanofluid increased compared to EG. The specific heat of the nanofluid was measured with relations (2).

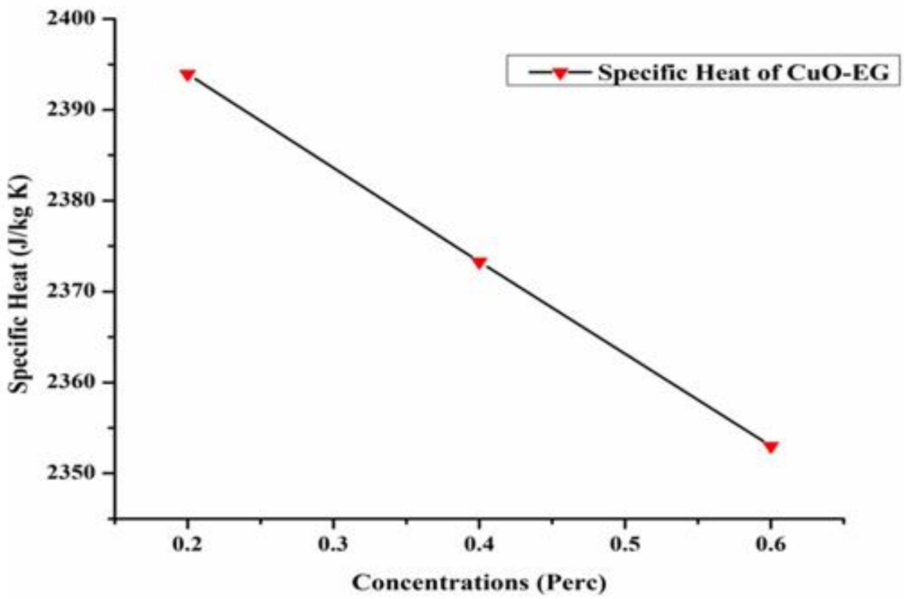

Figure 12: The Changes in Specific Heat of CuO-EG Nanofluids at Various concentrations

2. Prepartion of the Nanofluids:

Table 2: The mass of the CuO nanoparticle in DI water and EG.

SL no	Mass of the solute (gram)	Total volume of thesolution	Concentration
1	0.04	20	0.2
2	0.08	20	0.4
3	0.120	20	0.6

(a) **(b)**

Figure 13: (a) Distilled Water and **(b)** EG.

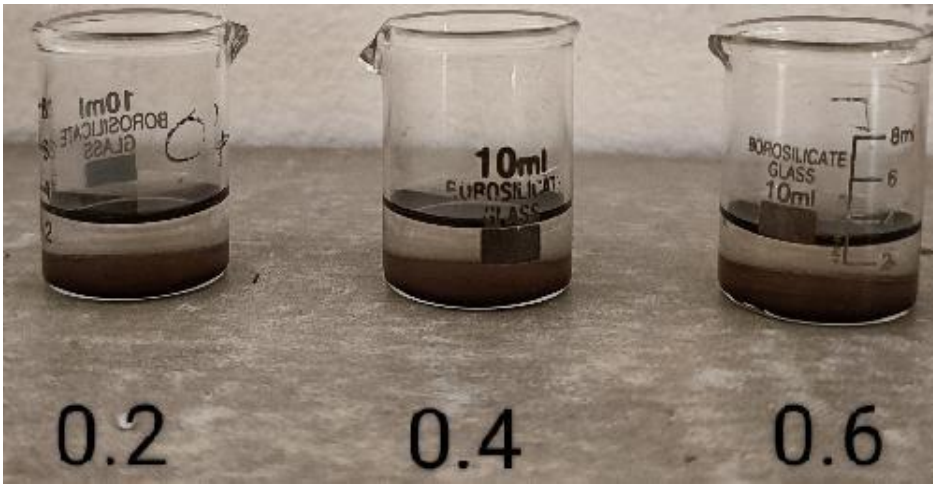

Figure 14: The Prepared CuO-DI Water Nanofluids at Various Concentrations

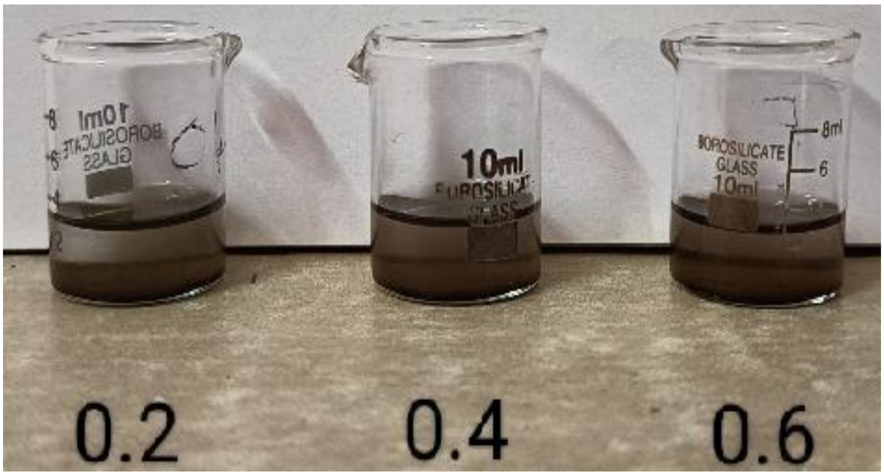

Figure 15: The Prepared CuO-EG Nanofluids at Various Concentrations.

The nanofluid prepared using two step methods without addition of surfactant. The 20 nm sized spherical shaped CuO nanoparticles with concentrations of 0.2%, 0.4%, and 0.6% were converted to mass using equation (5) and tabulated in the table 2**,** mixed with 20 ml of DI water and stirred with magnetic stirrer with hot plate at 650 rpm and $35^{o}C$ for 20 min to avoid the clustering of the nanoparticles and uniform distribution of the nanoparticles in the DI water. The samples were shown in figure 13 (a) & 14. The prepared nanofluids kept for 4 days to study the sedimentation of the nanoparticles.

The nanofluid prepared using two step methods without addition of surfactant. The 20 nm sized spherical shaped CuO nanoparticles with concentrations of 0.2%, 0.4%, and 0.6% were converted to mass using equation (5) and tabulated in the table 2, mixed with 20 ml of EG and stirred with magnetic stirrer with hot plate at 700 rpm and $35^{o}C$ for 20 min to avoid the clustering of the nanoparticles and uniform distribution of the nanoparticles in the EG. The samples were shown in figure 13 (b) & 15**.** The prepared nanofluids kept for 5 days to study the sedimentation of thenanoparticles.

3. **Stability of the CuO – DI Water Nanofluids:** The sedimentation method was adopted to determination Stability of the CuO - DI water nanofluids. The Prepared samples of the nanofluids kept for 4 days to monitor the settlement of the nanoparticles in the DI water. The Digital camera used to take the photos of the samples on daily basis to observe and determine the settlement of the nanoparticles in the DI water. The nanofluid which took more time to settle down is said to be more stable nanofluid used for the heat transfer applications. The stability results of the CuO – DI water nanofluid at different concentration shown in Table 3.

Table 3: The Stability of the CuO – DI Water Nanofluids at Various Concentrations

Sl no	Concentrations	Stability	Remark
1	0.2	Stable for 4 days	More Stable
2	0.4	Stable for 3 days	Less stable
3	0.6	Stable for 2.5 days	Less stable

The stability of the nanofluid more at low concentration i,e at 0.2% and decreases as the concentrations increases to 0.4% and 0.6% due to increase in the density and viscosity of the CuO nanoparticles in the DI water. Hence, the higher concentrations were having less stable compred to lower concentrations. The sedimentation method was adapted to determination Stability of the CuO - EG nanofluids. The Prepared samples of the nanofluids kept for 5 days to monitor the settlement of the nanoparticles in the EG. The Digital camera used to take the photos of the samples on daily basis to observe and determine the settlement of the nanoparticles in the EG. The nanofluid which took more time to settle down is said to be more stable nanofluid used for the heat transfer applications. The stability results of the CuO – EG nanofluid at different concentration shown inTable 4.

The stability of the nanofluids more at low concentration i,e at 0.2% and decreases as the concentrations increases to0.4% and 0.6% due to increase in the density and viscosity of the CuO nanoparticles in the EG. Hence, the higher concentrations were having less stable compared to lower concentrations.

Table 4: The stability of the CuO – EG Nanofluids at Different Concentrations.

Sl no	Concentrations	Stability	Remark
1	0.2	Stable for 4.2 days	More Stable
2	0.4	Stable for 3.3 days	Less stable
3	0.6	Stable for 2.10 days	Less stable

IV. CONCLUSIONS

- The density, thermal conductivity and viscosity of the CuO DI water and CuO – EG nanofluids incresedwith increse in concentrations of the nanoparticles.
- The specific heats of the nanofluids decreses with incresed volume concentrations of the CuO nanoparticlesin the DI Water and EG.
- The two step method was economical and siutable method for the preparation of the nanofluids.
- The CuO – DI water and CuO – EG nanofluid was stable at 0.2% volume concentrations of CuO nanoparticles. The stablity of the CuO DI water and CuO – EG nanofluid decreses with increses in the cancentrations.
- The stability of EG based CuO nanofluids more compared to DI water based nanofluid due to hi viscosity of EG.

Nomeclature:
ρ Density kg/m^3
Cp Specific heat J/kg K
µ Dynamic viscosity PaS
K Thermal Conductivity W/mK.
Φconcentrations Percentage.

Subscript
np nanopartlcesbf Base fluid
nf Nanofluid

Abbreviations:
DI Distilled WaterNP nanoparticles

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