Sedimentation Method to Evaluate Stable CuO Based Nanofluid for Heat Transfer Applications

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ABSTARCT

Nano fluid is the suspension of nano sized particles in the base fluid. 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 heat transfer area 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 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.

1. 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. The preparation method, stability of the nanofluids and heat transfer characteristics of the CuO-DI water and CuO – EG nanofluids are also essential to focus.

Amrut. S. et al [1] discussed Synthesis and optical characterization of copper oxide nanoparticles Author shoes TEM images, for size, tem images to show the rectangular morphology of the CuO nanoparticles. Xray diffraction pattern (XRD) reveals single phase monoclinic structure.Authors also describe the optical characteristics of the CuO nanoparticles.

Q. Zhang.et al. [2] studied Characterization of nanoparticles and CuO nanostructures: synthesis, characterization, growth mechanisms, fundamental properties, and applications. The authors tells the characteristics of the nanoparticles.

X.Wang .et al.[3] done the research to measure the Thermal conductivity of the nanofluids for the different concentration nanoparticles using the hot wire method. But the authors does not use the sedimentation method to measure the stability of the nanofluids for the applications heat transfer.

The Growth cycle of copper oxide which describes the Copper oxide thin films grown by plasma evaporation method was studied by K.Santra.et al. [4]. In their study they Explain about growth of copper oxide nanofluids which helps to determine thestability of CuO nanofluid for the heat transfer applications.

A. Aslani .et al.[5] discuss the Controlling system of copper oxide nanostructure which explains Controlling the morphology and size of CuO nanostructures with synthesis by solvo/hydrothermal method without 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 check 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 thermo physical properties of the nanofluids such as density, thermal conductivity, specific heat and viscosity for the different concentration od CuO nanoparticles in DI water were studied and discussed.

2. MATERIALS AND METHODS.

The CuO selected as nano particles and DI water as base fluids were selected based on the literature reviews and gap identified. 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 the Figure 1.

A. Over view of DI water

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

B. Overview of EG

EG is an organic compound with formula (C_2H_2OH), it’s mainly used as antifreeze formulations. It is an odorless, colorless, flammable, viscous liquid. EG has a sweet taste, but it is toxic in high concentrations. It can occur at neutral pH and melting point and boiling point of the EG are -12.9ºC and 198ºC 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.

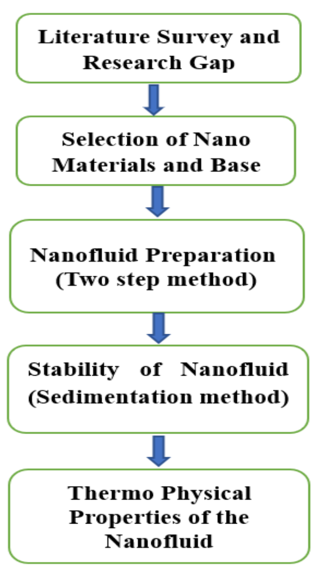

Fig.1: Methodology

Table 1: Properies of DI Water and EG

Specification	SI Unit	DI water	EG (Ethylene Glycol)
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

C. Over view of copper oxide (CuO) nano particles.

The powdery form of copper oxide nanoparticles is brownish-black. When exposed to hydrogen or carbon monoxide at high temperatures, they can be converted to metallic copper. 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. the thermal conductivity of the spherical shaped 20 nano meter sized CuO nano particles is 32.9 W/m K which is given by the supplier Nano Research lab Jamshedpur, India.

D. TEM images of CuO oxide nanoparticles

CuO nanopowder was purchased from Nano research lab Jamshedpur, India Company. The product manufacturer confirmed that size of the particles was less than 20 nm and surface area was 29 m^2 /g. The CuO nano particles were placed in DI water (10 mg/L) and subjected to sonification for 5 minutes to reduce agglomeration before characterization. Nanoparticles size was characterized using transmission electron microscopy (TEM) and sedimentation method used for stability checking and particle size analyzers. TEM was done on a JEM2100F (JEOL Ltd., Japan) operating at 100 kV. The sample for TEM observation was prepared by dispersing the powder of CuO nanoparticles by ultrasonification in water and allowing the dispersion to drop on a copper grid. A representative TEM image of CuO aggregates is shown in Figure 2. The particle sizes of CuO nanoparticles were measured with an ELS-6000 analyzer (Photal Otsuka Electronics, Japan) and shown in nm.

E. X-RD images of CuO oxide nanoparticles

XRD analysis was done on the CuO NR microcrystalline structure. The graph was prepared using Powder X software. As shown in Fig 3, the characteristic XRD peaks were observed at 32.65, 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 Fig.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 D is an average particle size (nm), K is the constant and equals to 0.94, λ is the wavelength of X-ray radiation, β is full-width at half maximum (FWHM) of the peak in radians and θ is the diffraction angle (degree).

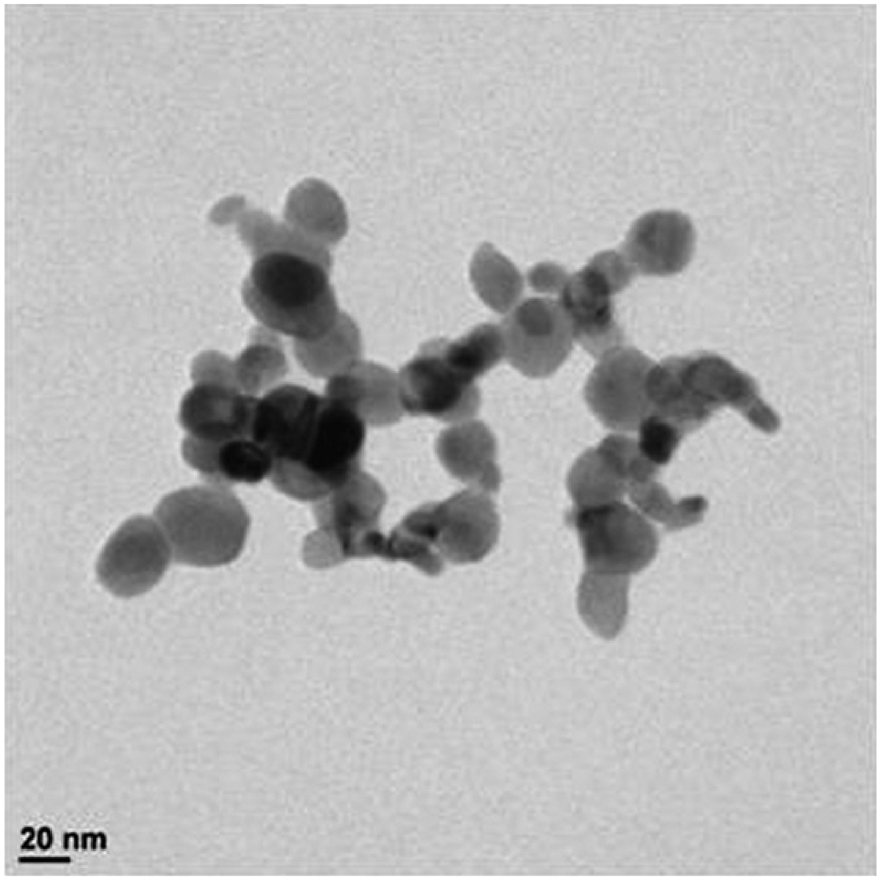

Fig 2: The TEM image of 20 nm CuO nanoparticles.

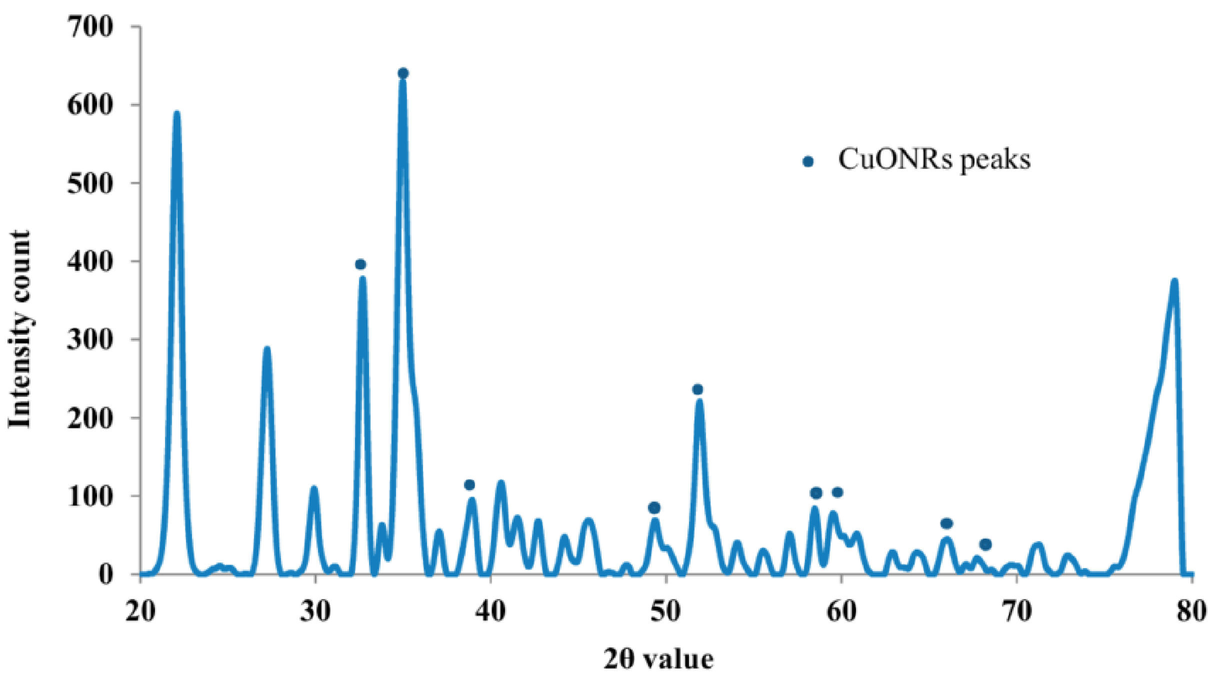

Fig 3: X-RD images of CuO oxide nanoparticles

F. Preparation of the nano fluids

The CuO DI water and CuO – EG nanofluids prepared using the two step method, 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 work CuO nanoparticles with average diameter of 20 nm were dispersed in DI water or EG nanofluid using magnetic stirrer with hot plate at 650 rpm and 30ºC temperature (Make: SESW). For each volume fraction required CuO nanopowder was added to DI water or EG and exposed to shear homogenization for 20 min at 650 rpm speeds and followed by higher speeds. Two-step preparation process is extensively used in the synthesis of nanofluids by mixing base fluids with commercially available nanopowders obtained from different mechanical, physical and chemical routes such as milling, grinding, and sol-gel and vapor phase methods. The two step method of preparation shown in Figure 4.

G. 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. For the nanofluid to have the same thermophysical properties, stability is crucial. Electrical double layer repulsive force and Van der Waals attractive force influence the stability of nanofluid. To produce a stable nanofluid, the Electrical Double Layer Repulsive Force (EDLRF) must be greater than the Vander Waals attractive forces. 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.

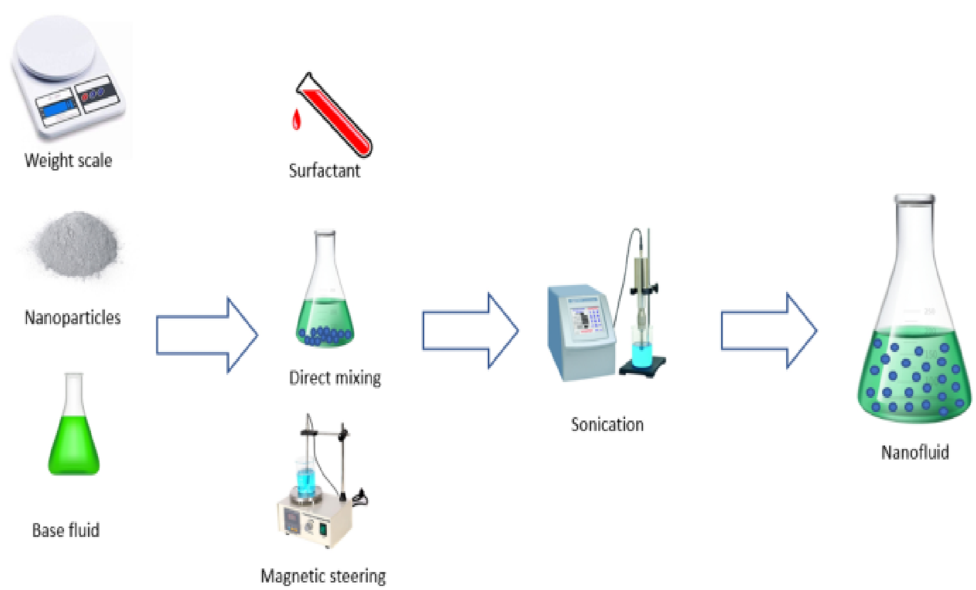

Fig 4: Two step method for the preparation of the CuO-DI water and CuO-EG nanofluid.

H. Thermopysical properties of the CuO-DI water CuO-EG nanofluids

1. Density of the nanofluid

Density is mass per unit volume, Pak and Chao developed the correlations to calculate the density of the nanofluid by taking the account of density of nanoparticles and basefluids.

$$\rho_{nf}=\Phi\rho_p+(1-\Phi)\rho_f \quad (1)$$

2. *Specific heat*

Specific heat is the capacity of the nanofluid. Specific heat is the depends on the density, volume concentrations, and specific heat of the nanoparticles and base fluid.

$$CPnf = \frac{\Phi\,\rho p\;CPnp + (1-\Phi)\rho f\;CPf}{\rho nf} \tag{2}$$

3. *Thermal Conductivity*

Thermal conductivity is the property of the materials and function of temperature. Nanofluid found in many heat transfer applications. The thermal conductivity of the nanofluid calculated using the Maxwell correlations of equation.

$$Knf = \frac{Kp + 2K_{bf} + 2\Phi(K_p - K_{bf})}{Kp + 2K_{bf} - \Phi(K_p - K_{bf})} Kbf \tag{3}$$

4. *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.

$$\mu_{nf} = (1 + 2.5\varphi)\mu_{bf} \tag{4}$$

I. *Volumetric concentrations to gravimetric concentrations*

The volumetric concentration of the CuO nanoparticles converted to gravimetric (mass) with the following equation.

$$\frac{Weight}{Volume}\% = \frac{weight\ of\ the\ solute}{Volume\ of\ the\ solution}\ x\ 100 \tag{5}$$

3. RESULTS AND DISCUSSIONS.

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

A. Thermo physical properties

The thermo physical properties of the CuO –DI water and CuO-EG nanofluids such as density, specific heat, tehrmal conductivity and viscosity of the were calculated and discussed.

1. *Density of the CuO-DI water nanofluids*

The variation of density of the CuO – DI water nanofluid at different 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.

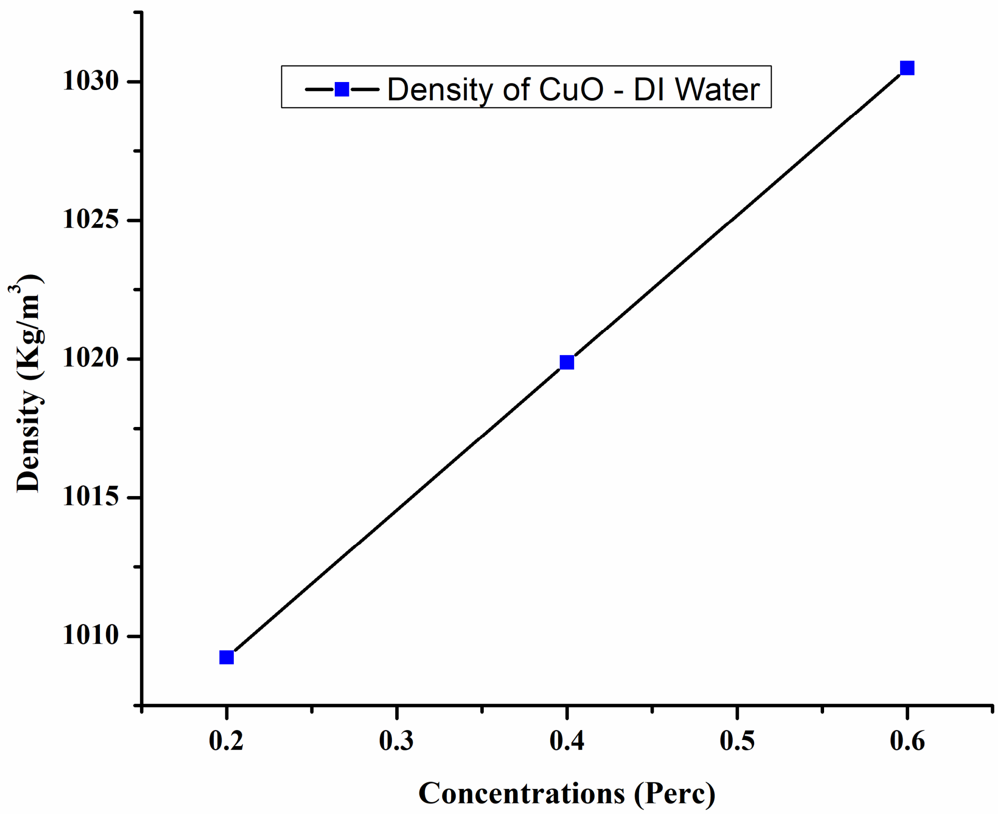

Fig 5: The variation of density of the CuO – DI water nanofluid at different concentration

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 different concentration shown in Figure 6.The densiy 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 valeus of density at 0.2%, 0.4%, and 0.6% were 1124.80 kg/m^3, 1135.20 kg/m^3 and 1145.60 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).

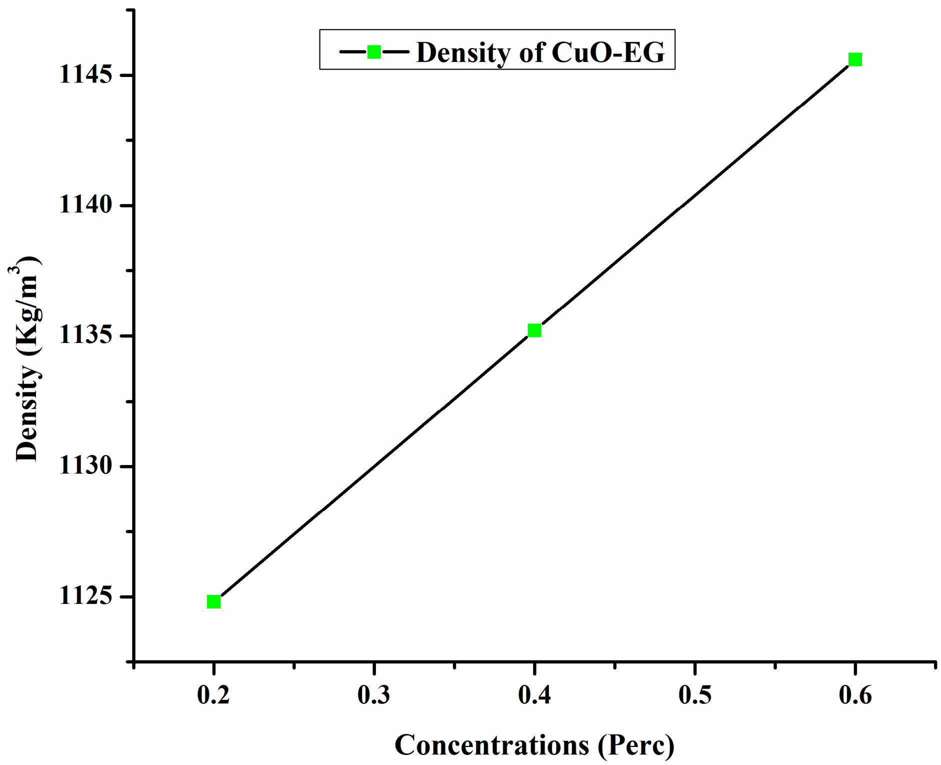

Fig 6: The variation of density of the CuO – EG nanofluid at different concentration

2. Thermal Conductivity of the CuO-DI water and CuO – EG nanofluids

The variation of thermal conductivity of the CuO – DI water nanofluid at different concentration shown in Figure 7.The thermal conductivity 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 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.

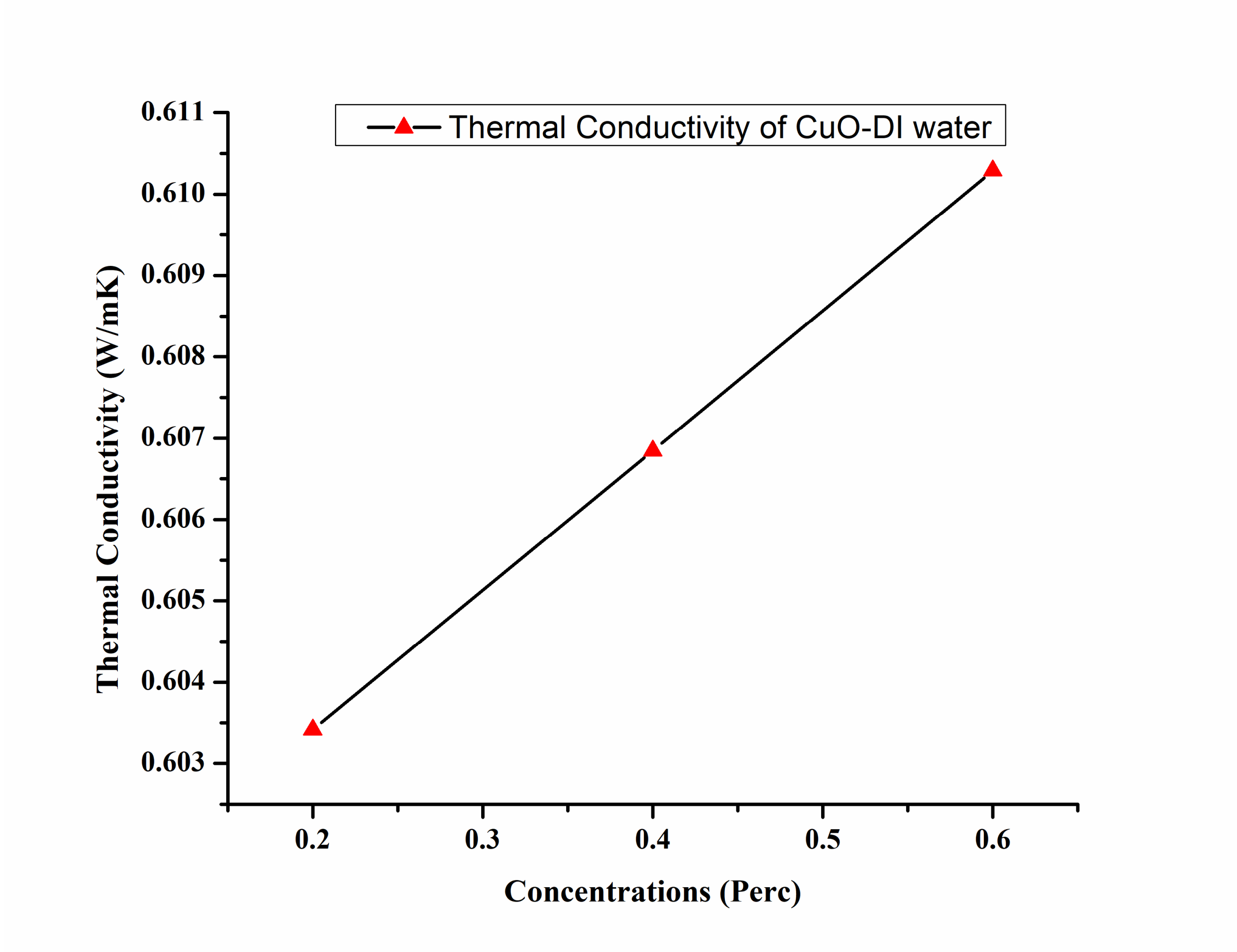

Fig 7: The variation of thermal conductivity of CuO-DI water nanofluid at different concentration

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 nanofluid increased compared to DI Water. The thermal conductivity of the nanofluid was measured 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 nanofluid was measured with relations (3).

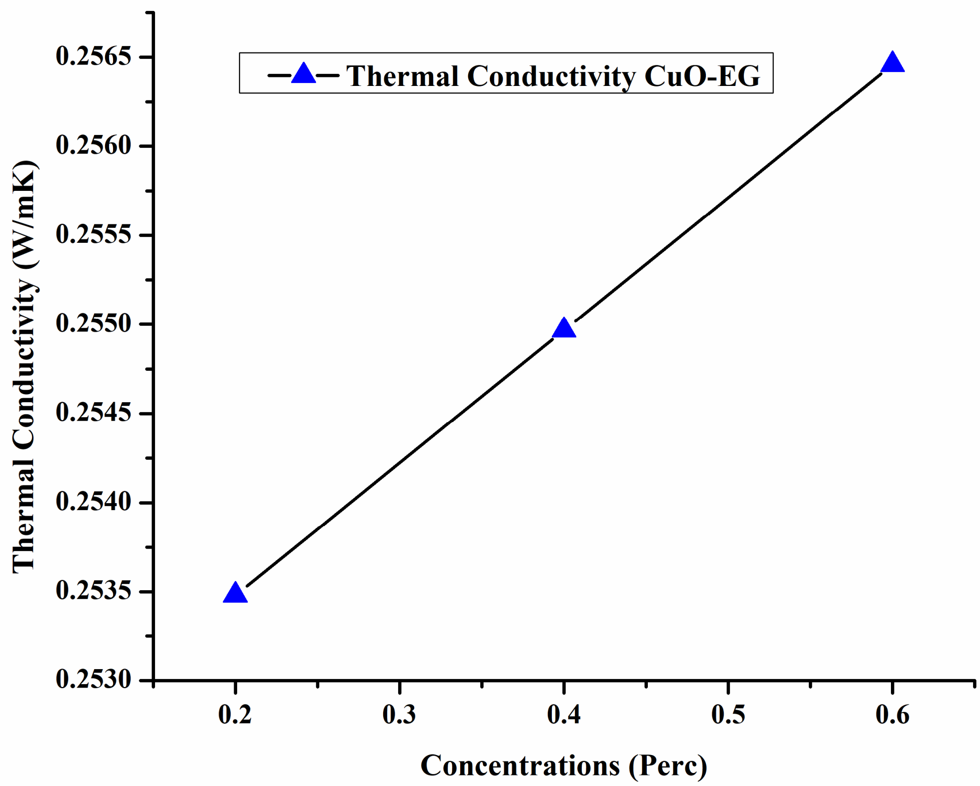

Fig 8: the variation of thermal conductivity of CuO-EG nanofluid at different concentration.

3. 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 incresed with incresed 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.

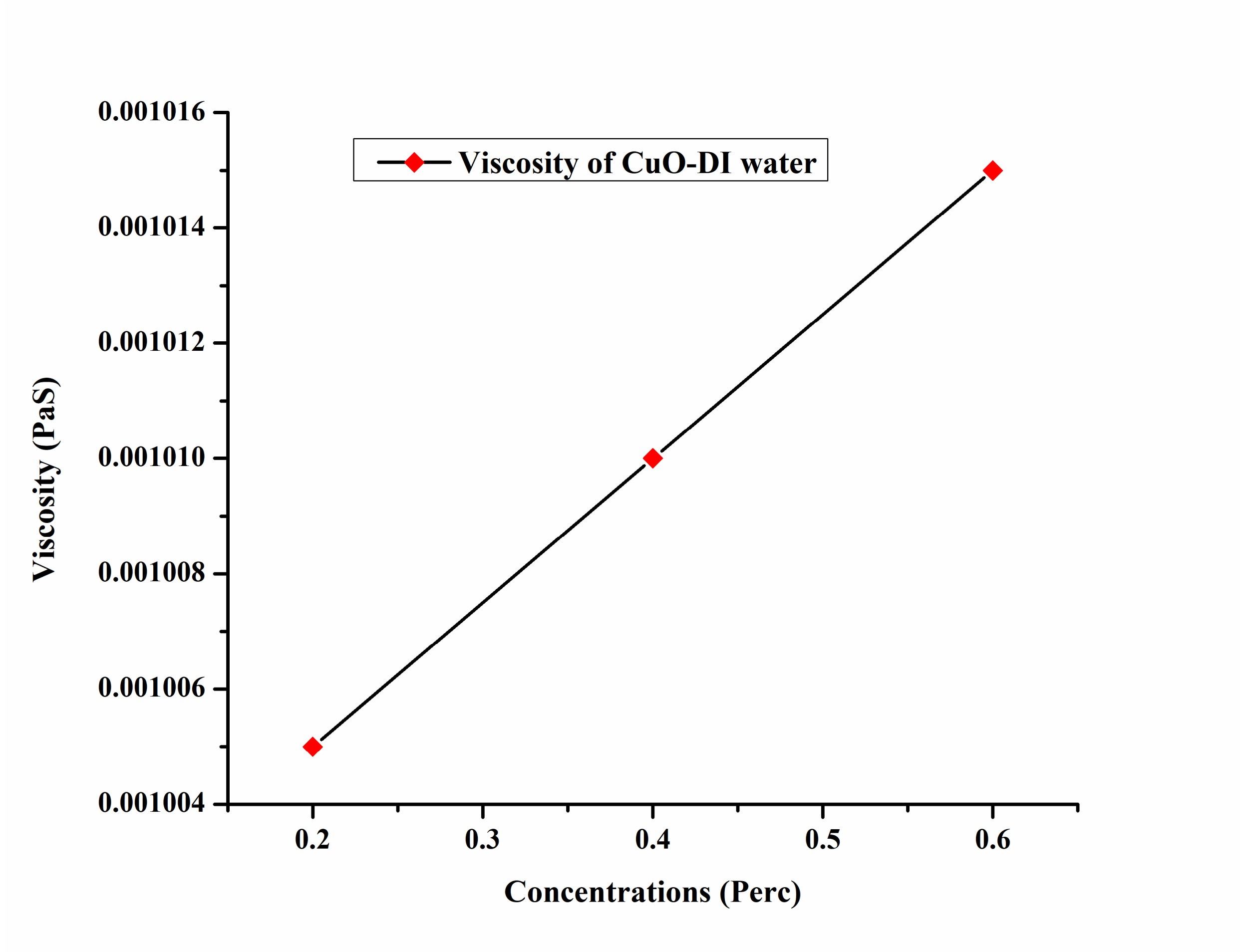

Fig: 9. The variation of viscosity of CuO-DI water nanofluid at different concentration

The maximum viscosity occurred at 0.6% and minimum at 0.2% 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 measured with relations (4).

The variation of viscosity of the CuO – EG nanofluid at different concentration shown in Figure 10.The viscosity 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 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 nanofluid was measured with relations (4).

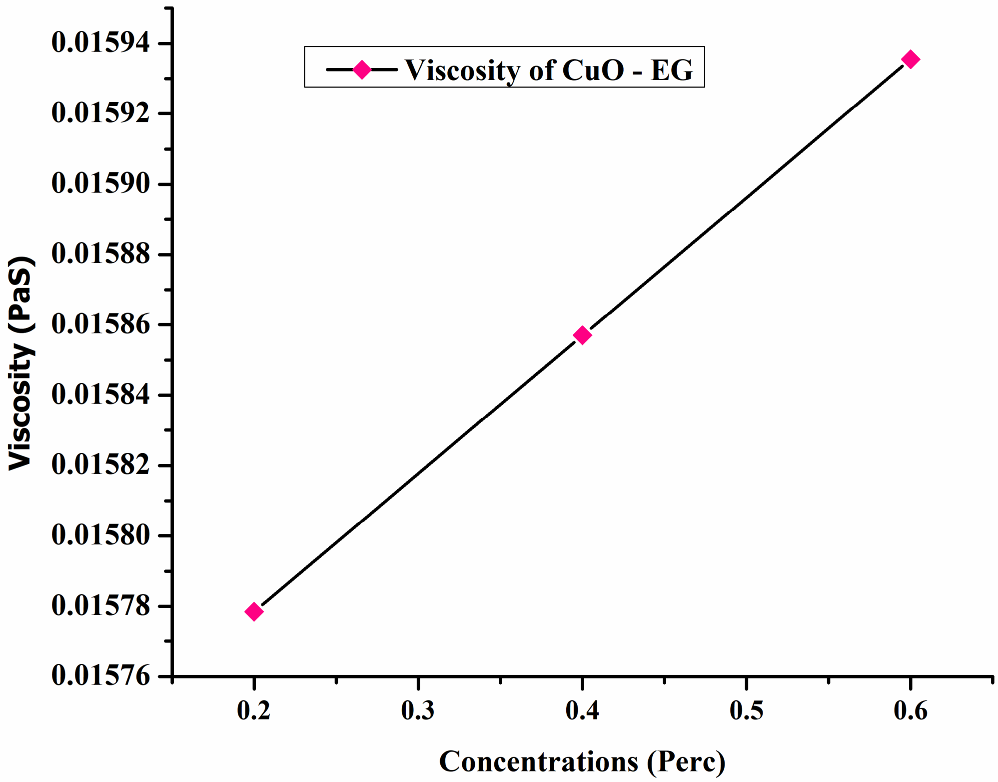

Fig 10: the variation of viscosity of CuO-EG nanofluid at different concentration

4. The Specific Heat of the CuO – DI Water and CuO-EG

The specific heat of the CuO – DI water nanofluid at different concentration shown in Figure 11.The specific heat 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 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.

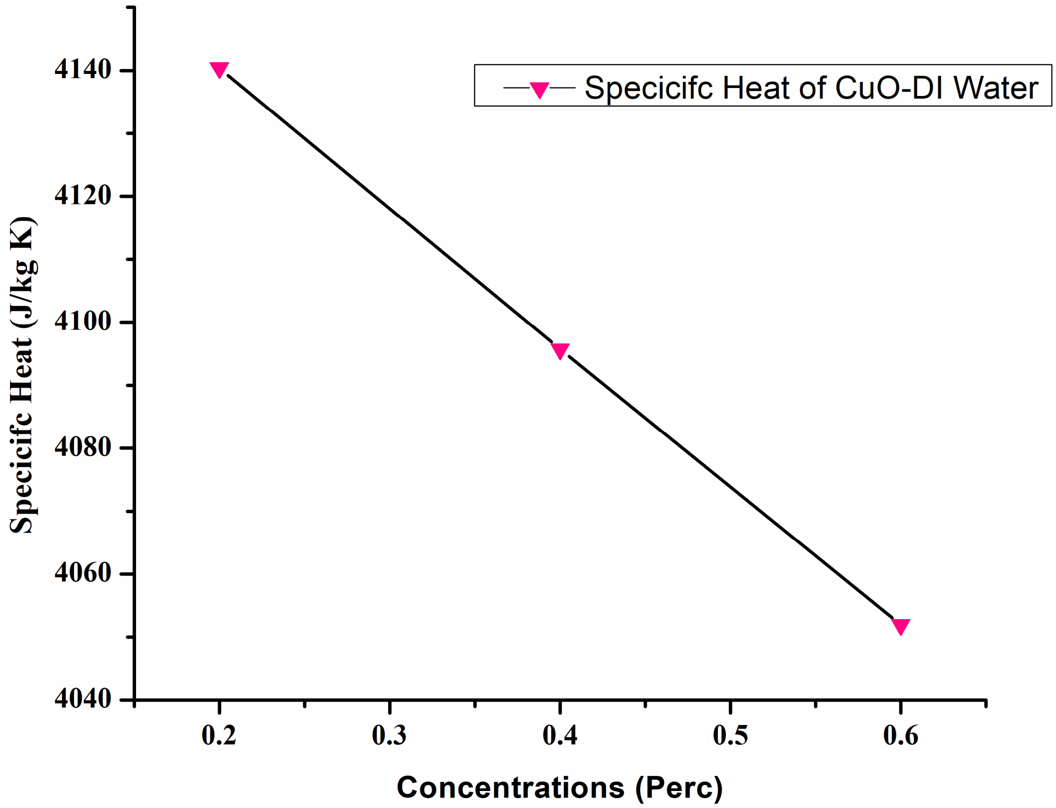

Fig. 11: The variation of specific heat of CuO-DI water nanofluid at different concentration

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 incresed with incresed 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).

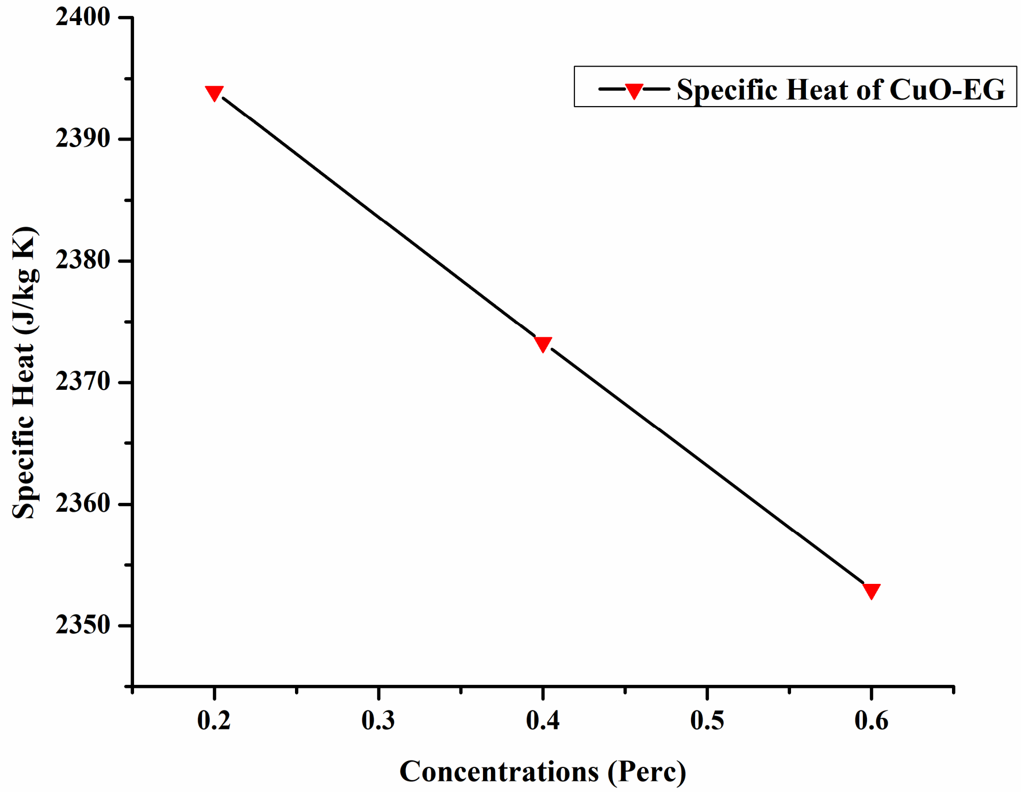

Fig 12: the variation of specific heat of CuO-EG nanofluid at different concentration

B. Prepartion of the nanofluid

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

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

(a) **(b)**

Fig 13: (a) Distilled water and (2) EG.

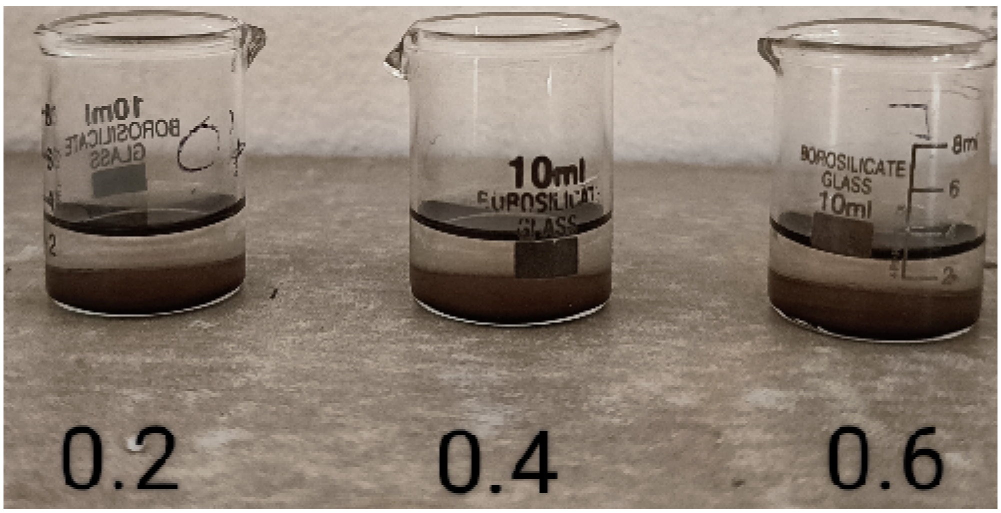

Fig 14: The prepared CuO-DI water nanofluids at different concentrations

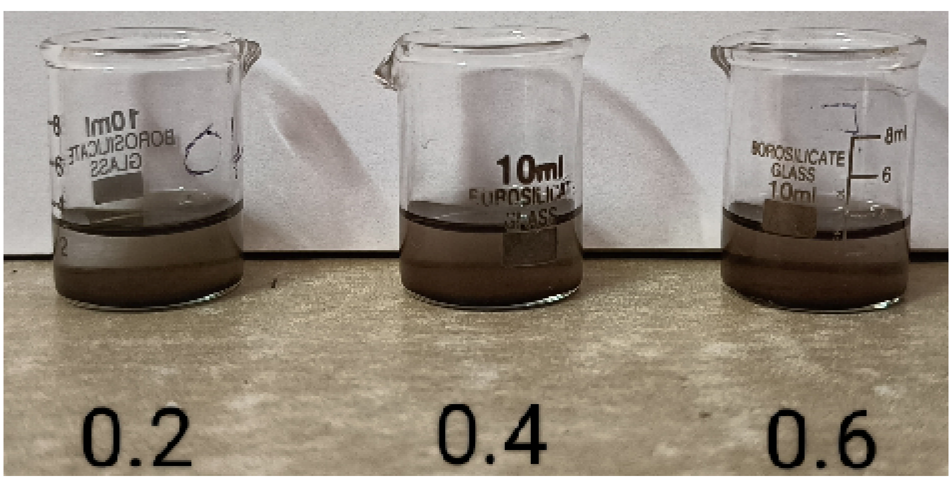

Fig 15: The prepared CuO-EG nanofluids at different concentrations

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 35ºC 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 35ºC 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 the nanoparticles.

C. 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 different 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 in Table 4.

The stability of the nanofluids 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 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

4. CONCLUSIONS:

1. The density, viscosity and thermal conductivity of the CuO DI water and CuO – EG nanofluids incresed with increse in concentrations of the nanoparticles.
2. The specific heat of the nanofluid decreses with incresed volume concentrations of the CuO nanoparticles in the DI Water and EG.
3. The two step method was economical and siutable method for the preparation of the nanofluids.
4. 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.
5. 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.
Φ concentrations Percentage.

Subscript

np nanopartlces
bf Base fluid
nf Nanofluid

Abbreviations:

DI Distilled Water
NP nanoparticles

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