Investigation the Stability of the Copper Oxide-Distilled Water Nanofluids

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Abstract - 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 nanofluid in a heat transfer area is essential to maintain the stability of CuO-DI water nanofluid is necessary. In the present study two step method was used to prepare the CuO-DI water nanofluid 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. The thermo physical properties of the CuO-DI water nanofluid was also studied using the appropriate model in the present work.

Key Words: CuO-DI water, 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 nano fluids. The preparation method, stability of the nanofluids and heat transfer characteristics of the CuO-DI water nanofluidsare 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 heat transfer applications.
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 of the nanofluid such as density, specific heat, thermal conductivity and viscosity for the different concentration of 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.

2.1 Over view of DI water

The Distilled water is water that has been boiled into vapor and condensed back into liquid in a separate container. Impurities in the original water that do not boil below or near the boiling point of water remain in the original container. Thus, distilled water is a type of purified water. The thermo physical properties of distilled water were mentioned in the Table 1.

Table -1: Properties of DI water.

Specification	SI unit	Values
Clarity	Percentage	99.5
Melting point	Celsius	0
Boiling point	Celsius	99.974
Density	Kg/m^3	999.975
Thermal conductivity	W/m K	0.6
Specific heat	J/kg K	4187

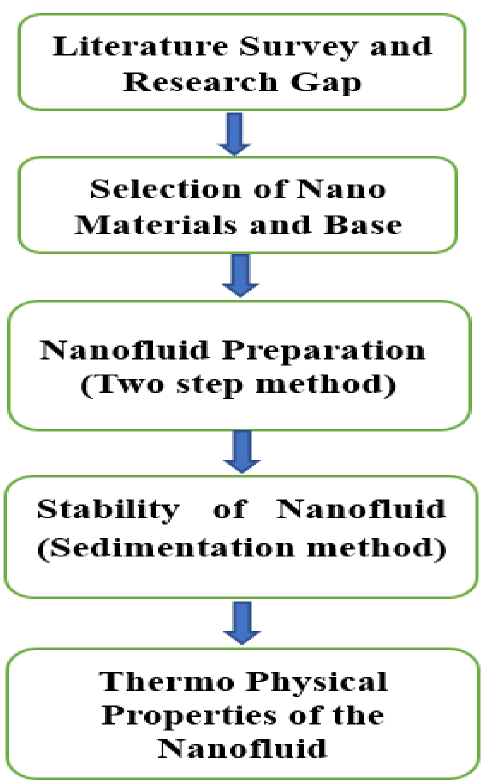

Fig -1: Methodology

2.2 Over view of copper oxide (CuO) nano particles

Copper oxide nanoparticles appear as a brownish-black powder. They can be reduced to metallic copper when exposed to hydrogen or carbon monoxide under high temperature. They are graded harmful to humans and as dangerous for the environment with adverse effect on aquatic life. 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 $2000^{o}C$ respectively. The density and specific heat of the copper oxide nanoparticles is 6315 kg/m3 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.

2.3 TEM images of CuO nanoparticles

CuO nanopowder was purchased from Nano research lab Jamshedpur, India Company. The manufacturer confirmed that particle size was less than 50 nm and surface area was 29 m2 /g. The CuO particles were placed in distilled water (10 mg/L) and subjected to sonification for 5 minutes to reduce agglomeration before characterization. Particle size was characterized using transmission electron microscopy (TEM) and sedimentation method 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.

2.4 X-RD images of CuO nanoparticles

The microcrystalline structure of CuO NR was analyzed using the XRD technique. The graph was prepared using Powder X software. As shown in Figure 3, the characteristic XRD peaks were observed at 32.64, 35.1, 38.9, 48.9, 52.0, 58.46, 62.9, 65.94 and 67.96 corresponding to 110, 002, 111, 202, 020, 202, 113, 311 and 113 reflections respectively which indicate the 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. However, other peaks are also denoted in the figure. The average crystallite size was calculated to be 20 nm using Debye Scherrer's equation

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

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).

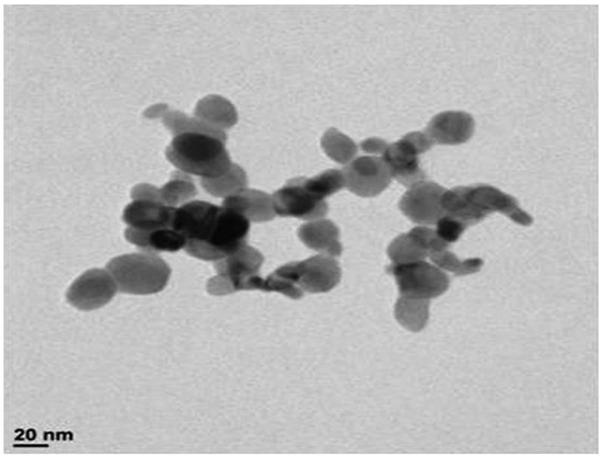

Fig -2: The TEM image of 20 nm CuO nanoparticles.

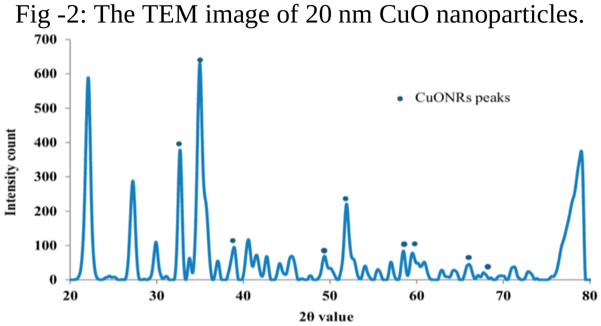

Fig -3: X-RD images of CuO oxide nanoparticles

2.6 Preparation of the nano fluids

The CuO DI water nano fluids prepared using the two step method, which is more economical and used for all type of nano fluids preparations. CuO–DI water nanofluid was prepared with very low concentration of surfactant-less. In this work CuO nanoparticles with average diameter of 20 nm were dispersed in DI water nanofluid using magnetic stirrer with hot plate at 650 rpm and 30°C temperature (Make: SESW). For each volume fraction required CuO nanopowder was added to DI water 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.

2.7 Sedimentation method for stability checking of nanofluids.

Stability is a big issue that inherently related to this operation as the powders easily aggregate due to strong van der Walls force among nanoparticles. Stability of nanofluid is important to get the same thermophysical properties. Stability of nanofluid is related to electrical double layer repulsive force and Van der Waals attractive force. Electrical Double Layer Repulsive Force (EDLRF) must be higher than the Vander Waals attractive forces to get stable nanofluid. Van der Waals attractive forces between nanoparticles causes to get clustered because of attraction forces. If this force is high, nanoparticles get separated from base fluid and these clustered nanoparticles settle down at the bottom of vessel because of gravitational force. On the other hand, EDLRF acts as opposite to Van der Waals attractive force which separates the particles from each other. The sedimentation was adopted for the stability checking of the nanofluid which is basic method and require longer period.

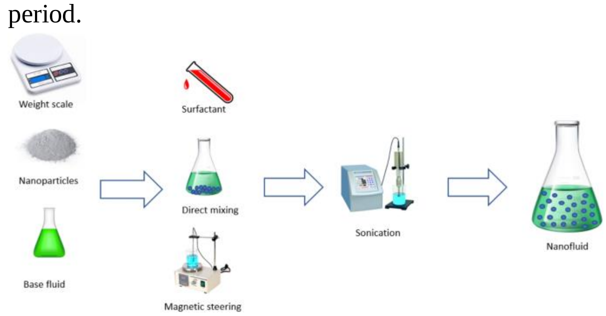

Fig -4: Two step method for the preparation of the CuO-DI water nanofluid

2.8 Thermo physical properties of the CuO-DI water nanofluids.

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.

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

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.

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

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.

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

Viscosity

The Einstein developed the correlations to calculate the viscosity of nanofluid. In the present work viscosity of CuO DI water nanofluid calculated using the Einstein model.

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

2.9 Volumetric concentrations to gravimetric concentrations.

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

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

3. RESULTS AND DISCUSSIONS

The research was carried out to determine the thermo physical properties and stability of the 20 nm sized spherical shaped CuO – DI water nanofluid for the concentrations of 0.2%, 0.4%, and 0.6% of CuO nanoparticles without adding surfactant. The results were discussed as follows.

3.1 Thermo physical properties.

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

Density of the CuO-DI water nanofluids

The variations of density of the CuO – DI water nanofluid at different concentrations shown in Figure 5. The density of the CuO – DI water nanofluid increased with increased concentrations. The concentration of tha CuO – DI water nanofluid varies from 0.2%, 0.4%, and 0.6%. The values of density at 0.2%, 0.4%, and 0.6% were 1009.23 kg/m3, 1019.86 kg/m3 and 1030.49 kg/m3 respectively. 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).

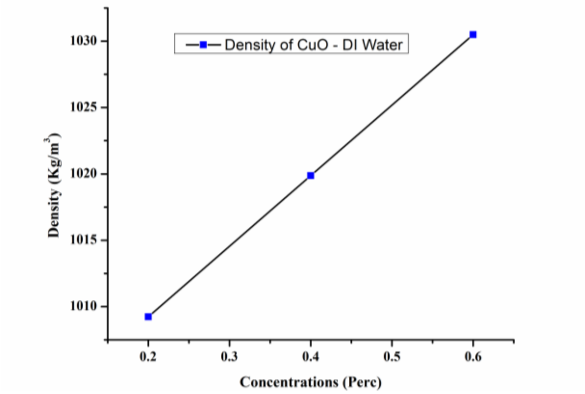

Fig -5: The variation of density of the CuO – DI water nanofluid at different concentration

Thermal Conductivity of the CuO-DI water nanofluids

The variation of thermal conductivity of the CuO – DI water nanofluid at different concentration shown in Figure 6. 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. The maximum thermal conductivity occurred at 0.6% and minimum at 0.2% shown in Figure 6. 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).

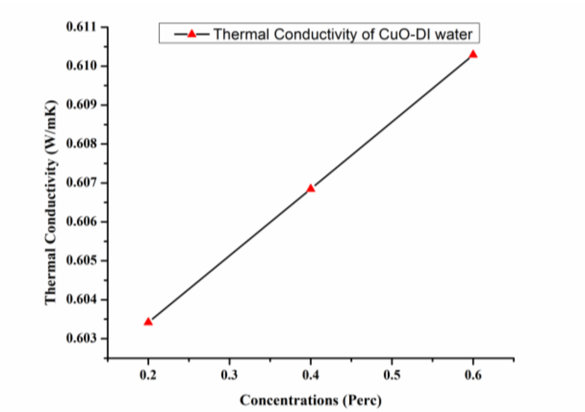

Fig -6: The variation of thermal conductivity of CuO-DI water nanofluid at different concentration

Viscosity of the CuO - DI water nanofluids

The variation of viscosity of the CuO – DI water nanofluid at different concentration shown in Figure 7.The viscosity of the CuO – DI water nanofluid increased with increased concentrations. The concentration of tha CuO – DI water nanofluid varies 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. The maximum viscosity occurred at 0.6% and minimum at 0.2% shown in figure. 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).

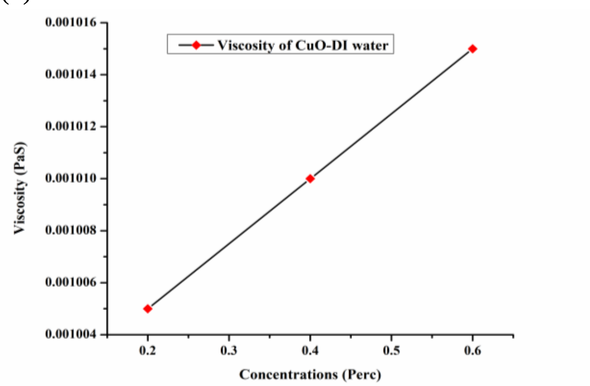

Fig -7: The variation of viscosity of CuO-DI water nanofluid at different concentration.

The Specific Heat of the CuO – DI Water

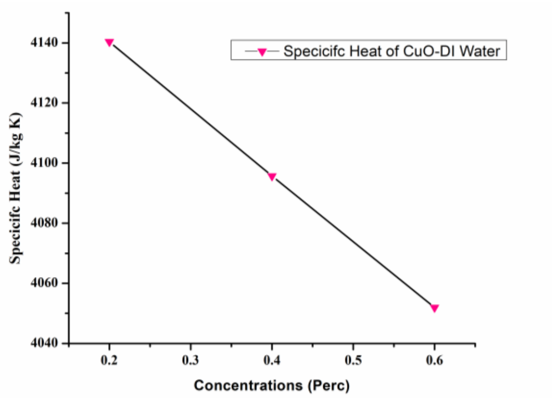

Fig -8: The variation of specific heat of CuO-DI water nanofluid at different concentration

The specific heat of the CuO – DI water nanofluid at different concentration shown in Figure 8. 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.

The maximum specific heat occurred at 0.2% and minimum at 0.6% shown in figure. 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).

3.2 Preparation of the nanofluid.

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

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

Fig – 9: Distilled water.

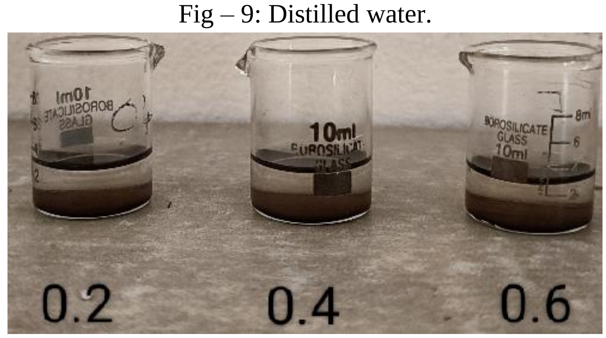

Fig – 10: The prepared CuO-DI water nanofluids at different concentrations

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 9 & 10. The prepared nanofluids kept for 4 days to study the sedimentation of the nanoparticles.

3.3 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.

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 are having less stable compared to lower concentrations.

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

4. CONCLUSIONS

1. The density, viscosity and thermal conductivity of the CuO DI water nanofluids increased with increase in concentrations of the nanoparticles.
2. The specific heat of the nanofluid decreases with increased concentrations of the CuO nanoparticles in the DI Water.
3. The two step method was economical and suitable method for the preparation of the nanofluids.
4. The CuO – DI water nanofluid was stable at 0.2% volume concentrations of CuO nanoparticles. The stability of the CuO DI water nanofluid decreases with increases in the concentrations.

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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