Asian Journal of Applied Science and Technology (AJAST)
(Open Access Quarterly International Journal) Volume 2, Issue 2, Pages 1005-1012, April-June 2018

Study of Preparation Charaterisation and Thermal Properties of CuO Nanofuids

Keerthi K Pai[1], Nikhil K.S[2], Mohammed Anas[3] and Stalin Joseph[4]

[1,2,3,4]*Department of Chemical Engineering, MVJ College Of Engineering, Bangalore, India. Email: keerthikpai@gmail.com*

Article Received: 27 February 2018 *Article Accepted: 29 April 2018* *Article Published: 08 June 2018*

ABSTRACT

In the present study CuO nanofluids were prepared using two-step method. The nanofluids of 0.1 wt% prepared by dispersing different quantity of CuO nanoparticles i.e. 0.1 gms respectively in base fluid water using a probe sonicator followed by magnetic stirring to disperse the nanoparticles uniformly. Sodium Dodecyl Sulphate was added to the base fluid as surfactant. The important parameters which influence the heat transfer characteristics of nanofluids are its properties which include thermal conductivity, viscosity, specific heat and density. It was noticed that with the increase in concentration the properties such as density, specific heat, viscosity and thermal conductivity also increased. pH was varied by the addition of an acid to the base fluid. As the pH decreased, the stability of the nanofluid increased. The surfactant concentration in the base fluid and the time of Sonication was also increased resulting in a more stable nanofluid. It is concluded that the prepared Nanofluid has thermal conductivity and heat transfer coefficient more than that of water. When used in a heat exchanger more efficient heat transfer takes place when compared to that of water.

Keywords: Component; Nanofluids; Surfactant; Sonication; Thermal conductivity.

1. INTRODUCTION

Nanofluids are fluids prepared by dispersing nanometer-sized materials in base fluids. In other words, nanofluids are nanoscale colloidal suspensions containing condensed Nanoparticles. They are two-phase systems with one phase as solid phase i.e., nano particle in another as liquid phase ie. water or base fluid. Nanofluids have been found to possess enhanced thermo-physical properties such as thermal conductivity, thermal diffusivity, viscosity, and convective heat transfer coefficients compared to those of base fluids like oil or water. It has demonstrated great potential applications in many fields. The nanoparticles used in nanofluids are typically made of metals, oxides, carbides, or carbon nano-tubes. Common base fluids include water, ethylene glycol and oil.

Suspensions of nanoparticles are possible since the interaction of the particle surface with the solvent is strong enough to overcome density differences, which otherwise usually result in a material either sinking or floating in a liquid. The high surface area to volume ratio of nanoparticles provides a tremendous driving force for diffusion, especially at elevated temperatures. For a two-phase system, one of the most important issues is the stability of nanofluids, and it remains a big challenge to achieve desired stability of nanofluids.

Heat transfer enhancement has been shown for jet arrays impingement cooling system using Cu-water nanofluids with SDBS as dispersant [1]. R. Manimaran showed that the copper oxide nanofluid synthesized using wet chemical method, had significant increase (12.4%) in thermal conductivity than water [2]. Stable and well dispersed functionalized graphene –ethylene glycol (EG) + distilled water nanofluids has shown k enhancement of ∼15% for a loading of 0.395 vol. % [3]. Prasad et al [4] reported that for 0.2 wt% PANI nanofluids, 33% increment in heat transfer coefficient was observed and 63% enhancement for 1.2 wt% addition of PANI nanoparticles. The thermal conductivity enhancement of water and glycerol – copper nanofluid investigated by B. A. Suleimanov et al [5] showed enhancement in thermal conductivity about 25% to 35%. They proposed mechanism and mathematical model for this system. The purpose of this paper to study the heat transfer behavior of Cuo-water nanofluid and stability mechanisms.

2. MATERIALS & METHODS

2.1. Materials

2.1.1. Copper Oxide Nanoparticles

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.

Table 1.Chemical properties of CuO Nanoparticles

Chemical Symbol	**CuO**
CAS No.	1317-38-0
Group	Copper 11 Oxygen 16

Table. 2 Physical Properties of CuO Nanoparticles

Properties	**Metric**
Density	6.31g/cm^3
Molar Mass	79.55 g/mol

Table 3.Thermal properties of CuO Nanoparticles

Properties	**Metric**
Melting Point	1201^{o}C
Boiling Point	2000^{o}C

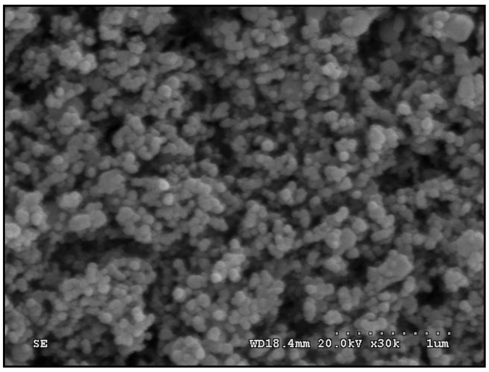

Figure 1. SEM Image CuO Nanoparticles

2.1.2. Surfactant (Sodium Dodecyl Sulfate)

Sodium dodecyl sulfate, synonymously sodium lauryl sulfate, is a synthetic organic compound with the formula CH3(CH2)11SO4Na. It is an anionic surfactant used in many cleaning and hygiene products. The sodium salt is of an organo-sulfate class of organics. SDS is a common component of many domestic cleaning, personal hygiene and cosmetic, pharmaceutical, and food products, as well as of industrial and commercial cleaning and product formulations.

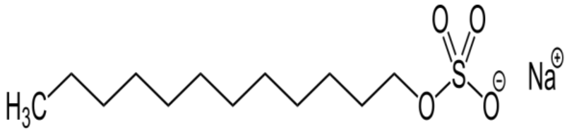

Figure 2. Structure of Sodium Dodecyl Sulfate

Table 4. Properties of Sodium Dodecyl Sulphate

Chemical Formula	**$NaC_{12}H_{25}SO_4$**
Molar Mass	288.372 g/mol
Appearance	White
Odor	Odorless
Density	1.01 g/cm^3
Melting Point	206°C

2.2. Experimental Method

2.2.1. Two step method

Two-step method is the most widely used method for preparing nanofluids where Nanoparticles are first produced as dry powders by chemical or physical methods. Then, the nanosized powder will be dispersed into a fluid with the help of intensive magnetic force agitation, ultrasonic agitation, high-shear mixing, homogenizing, and ball milling. It is most economic method to produce nanofluids in large scale, because nanopowder synthesis techniques have been weel established in industrial levels. Due to the high surface area and surface activity, nanoparticles have the tendency to aggregate. The important technique to enhance the stability of Nanoparticles in fluids is the use of surfactants.

2.2.2. SONICATION

Sonication is the act of applying sound energy to agitate particles in a sample, for various purposes. Ultrasonic frequencies (>20 kHz) are usually used, leading to the process also being known as Ultrasonication. Machine composed of 3 main parts: an amplitude controller, a system test configuration and a probe head. The probe head is cleaned using Ethyl Alcohol. The probe head is dipped in the mixture which is taken in a 250 ml beaker and kept in an ice bath.

3. RESULT AND DISCUSSION

In this study CuO nanofluids were prepared using two-step technique. Then the nanofluids of 0.1 wt.% is prepared by dispersing 0.1gms of CuO nanoparticles in base fluid. 100ml water solution was used as a base fluid to which 0.001ml sodium dodecyl sulphate is added as a surfactant. The nanofluids were sonicated continuously for 1 hour using a probe sonicator to disperse the nanoparticles uniformly. Following this, the nanofluids of different volume concentrations were stirred continuously for 3-4 hours using magnetic stirrer to obtain uniform dispersion of nanoparticles in base fluid.

3.1. Effect of Concentration

Nanofluids of different weight concentrations are prepared by dispersing different amounts (0. 1wt%- 0. 5wt%) of the nanoparticles in the base fluid. The different properties of the prepared Nanofluids are studied. It can be noted that as the weight % of Naonofluid increases it becomes more and more darker.This is due to the increased concentration of CuO nanoparticles suspended in the base fluid.

3.2. Density Model

The density of CuO nanofluids for all the volume concentrations under investigation are measured by using specific gravity method and the density data obtained is compared with the values obtained using the density correlation equation developed by Pak and Cho for nanofluids, which is stated as follows

$$\rho_{nf} = \emptyset\rho_p+(1-\emptyset)\rho_{bf}$$

Where,

$\emptyset$ = The weight concentrations of nanofluid

The error between experimental results and the results obtained correlation shows that the correlations results are very close to the experimental results.

Table 5. Density Variation with Concentration

SL. No.	Weight Percentage	Experimental Density (kg/m^3)	Pak & Cho correlation (kg/m^3)
1	0.1	1025.21	1024.96
2	0.2	1029.96	1028.93
3	0.3	1036.28	1034.21
4	0.4	1042.6	1039.5
5	0.5	1048.98	1044.79

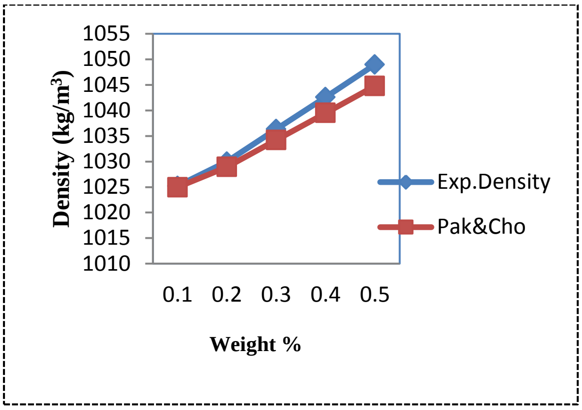

Figure 3:- Density comparison between experimental density and Pak & Cho model

3.3. VISCOSITY MODEL

A few experimental works are reported on the viscosity of nanofluids and correlations were developed to predict the viscosity of nanofluids in terms of particle volume concentration and density of the base fluid. Einstein has developed a viscosity correlation (Drew and Passman- 1999) in terms of nanoparticle weight concentration in the base fluid, when the nanoparticle volume concentration is lower than 5%, and is given by

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

Table 6. Viscosity Variation with Concentration

Sl. No.	Weight Percentage	Experimental Viscosity (kg/ms)	Drew & Passman Correlation(kg/ms)
1	0.1	0.00761	0.00761
2	0.2	0.00765	0.00762
3	0.3	0.0077	0.00768
4	0.4	0.00775	0.00775
5	0.5	0.0078	0.00783

The viscosity of the Nanofluid also increases with the increase in the weight %. The viscosity is measured experimentally using Ostwald viscometer method. The measures viscosity is correlated with the one measured using Drew& Passman model.

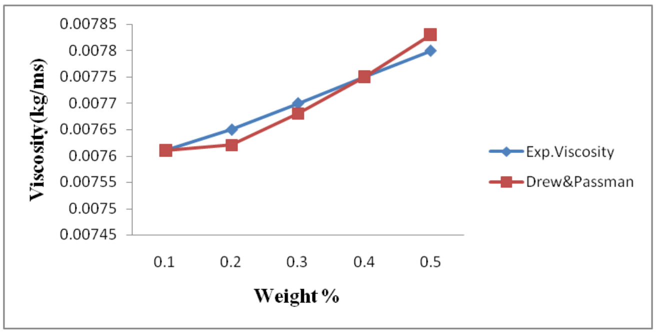

Figure 4:- Viscosity Comparison between Exp. viscosity and Drew& Pass man model

The values between experimental results and the results obtained from Drew & Passman model shows that the correlations results are very close to the experimental results.

3.4. SPECIFIC HEAT MODEL

The specific heat is one of the important properties and plays an important role in influencing heat transfer rate of nanofluids. Specific heat is the amount of heat required to raise the temperature of one gram of nanofluids by one degree centigrade. For a given volume concentration of nanoparticles in the base liquid, the specific heat can be calculated using the mixture formula.

$$Cpnf = \emptyset Cp+(1-\emptyset)Cpbf$$

The specific heat measurement of the Nanofluids done by Pak&Cho model.

Table 7. Specific Heat Variation with Concentration

Sl.No.	Weight Percentage(J/kgK)	Pak & Cho (J/kgK)
1	0.1	3861.1
2	0.2	3858.3
3	0.3	3847.1
4	0.4	3832.1
5	0.5	3823.5

It is observed that the specific heat if the Nanofluid decreases with the increase in the wt% of nano particles.

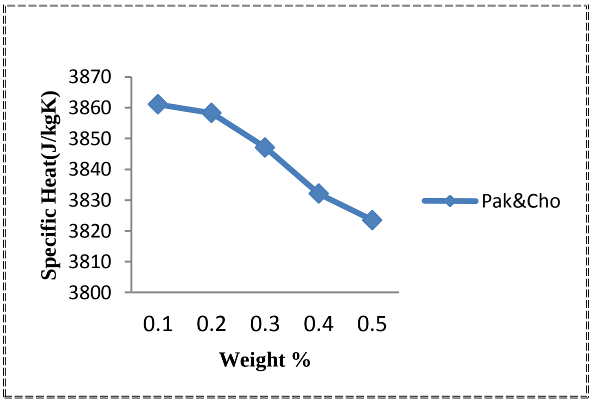

Figure 5. Specific Heat using Pak&Cho model Vs Weight %

3.5. THERMAL CONDUCTIVITY MODEL

Thermal conductivity is the property of a material to conduct heat. It is evaluated primarily in terms of Fourier's Law for heat conduction. It is observed that the thermal conductivity increases with the increase in the concentration of Nanofluid. Several classical models proposed by Maxwell (1881), Hamilton and Crosser (1962), Wasp (Wasp), Bruggeman (2009), are available in the literature to predict the effective thermal conductivities of Liquid-solid suspension. The Maxwell developed a model to predict the effective thermal conductivity of solid-liquid suspension for low volume concentration of spherical microparticles suspensions. The Maxwell-Euken model is given below:

$$Knf = Kbf\{\frac{[(1+2\emptyset\,(1-(Kbf/Kcuo))/(2(Kbf/Kcuo)+1)]}{[(1-\emptyset(1-(Kbf/Kcuo))/((\mathrm{Kbf/KCuO}+1)]}\}$$

Table 8. Thermal Conductivity Variation with Concentration

Sl.No.	Weight Percentage	Maxwell(W/mK)
1	0.1	0.76
2	0.2	1.02
3	0.3	1.32
4	0.4	1.66
5	0.5	2.29

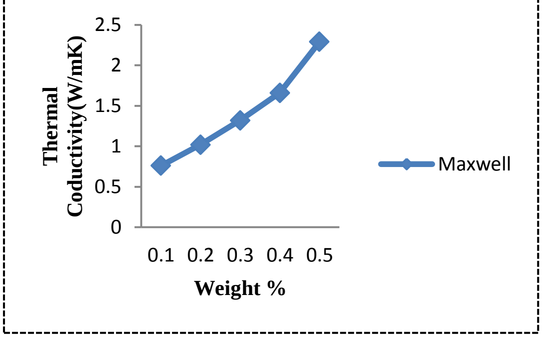

Figure 6. Thermal Conductivity using Maxwell model Vs Weight %

3.6. Effect of Surfactant on stability

The amount of surfactant added to the base fluid during the preparation of Nanofluid affects its Stability. Nanofluids prepared without the addition of surfactant settles down in a matter of hours whereas the one prepared by the addition of one is stable for days. Different concentrations of surfactant is added to the base fluid and the stability is studied.

Table 9. Effect of Surfactant Concentration on Stability

Sl.No	Surfactant Conc.(ml)	Stability(hrs)
1	0.001	24
2	0.0015	36
3	0.002	48
4	0.0025	72
5	0.003	72

 Online ISSN: 2456-883X

It is observed that the stability of Nanofluid increases with the increase in the amount of surfactant i.e. sodium Dodecyl sulphate added to the base fluid. However after a certain amount surfactant addition the stabiltity of the Nanofluid becomes constant concluding uniform distribution of all the nanoparticles.

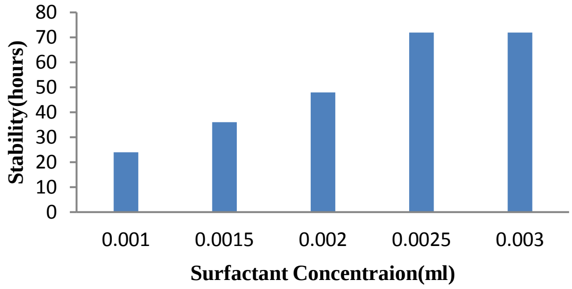

Figure 7. Stability Vs Surfactant Concentration

4. CONCLUSION

1. Based on the experimental findings, the following conclusive remarks can be highlighted.
2. The stability of nanofluid increases with the increase in the surfactant concentration.
3. The density and viscosity of the nanofluid is more than that of water.
4. There is an enhancement in the thermal conductivity of the nanofluid compared to that of water.
5. Nano fluid with good stability and optimal thermo-physical properties.
6. Good thermal conductivity enhancement with minimal impact on viscosity.

From the above results it is concluded that more efficient and effective heat transfer operation is achieved by the use of nanofluids. These characteristics features of Nanofluids make them suitable for next generation heat transfer fluids.

REFERENCES

[1] Peng Tie, Qiang Li*, Yimin Xuan, Heat transfer performance of Cuewater nanofluids in the jet arrays impingement cooling system, International Journal of Thermal Sciences 77 (2014) 199e205.

[2] R. Manimaran et al , Preparation and characterization of copper oxide nanofluid for heat transfer applications , Appl Nanosci (2014) 4:163–167

[3] Madhusree Kole and T. K. Dey, Investigation of thermal conductivity, viscosity, and electrical conductivity of graphene based nanofluids, J. Appl. Phys. 113, 084307 (2013);

[4] Prasad Gurav et al, Heat transfer intensification using polyaniline based nanofluids: Preparation and application, Chemical Engineering and Processing: Process Intensification , Volume 95, September 2015, Pages 195–201.

[5] B. A. Suleimanov et al, Effect of copper nanoparticle aggregation on the thermal conductivity of nanofluids, Russian Journal of Physical Chemistry A February 2016, Volume 90, Issue 2, pp 420–428

 Online ISSN: 2456-883X