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Studies on Thermal Conductivity and Zeta Potential of Cuo-Nanofluids at Different Temperatures

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ABSTRACT

The purpose of the present investigation is to study the effect of adding copper oxide nano powder to the conventional heat transfer fluids for their comparative thermal conductivity properties. CuO nano powder was synthesized and subsequently different nanofluids were prepared in two base fluids such as water and tri-ethylene glycol by ultrasonication technique. Synthesized CuO nano powder was characterized for its shape and size from XRD, EDX and SEM analysis. Thermal properties of prepared nanofluids have been studied from thermal conductivity at different temperature. In addition, particle size analysis, zeta potential studies, viscosity and density of the nanofluids were carried out. The thermal conductivities of all nanofluids were found to be enhanced, whereas the density and viscosities of nanofluids were less in comparison to their base fluids.

Keywords : CuO Nanofluids, Thermal Conductivity, Tri-Ethylene Glycol

I. INTRODUCTION

In industries Heat management and automobile sectors is becoming a challenging process. Heat transfer fluids have been an integral part of this process for many years. Enhancement of heat transfer capacity of a fluid can be expected by increasing the thermal conductivity.Varieties of heat transfer fluids both Aqueous and organic were being used to meet the operating needs of various applications. Other than water, ethylene glycol has better capacity of heat transfer properties including high density and low viscosity in comparison to many other fluids. However, TEG is non-toxic and more eco-friendly to be used as heat transfer fluid [1]. Study is being carried out by using nano particles in heat transfer fluids, where these nano particles found to boost the heat transfer capacity of basefluids [2]. Review of literature shows that metals and metallic oxides in their nano scale are utilized for the preparation of nanofluids [3-5]. Based on their physical, chemical, thermal and structural properties from bulk materials, these nanoparticles have plenty of applications in various frontier areas like optoelectronics [6,7], sensing [8], catalysis [9], solarcells etc,. In the area of nano research, investigations on nanofluids are quite demanding field apart from nanoparticles. These are the most modern class of fluids engineered by Choi et al [10].

Out of different metal oxides nano particles, CuO nanoparticles are the promising materials due to their applications in various technologies both as solid form as well as in fluids. CuO nanoparticles dispersed with fluids have many applications in the industries and instruments especially with heat transfer systems.

In present work, CuO nano particles were synthesized and different nanofluids were prepared with base fluids such as water and TEG to study different thermo and rheological parameters. All these parameters shed light on the molecular environment as well as the dispersed phase of the nanofluids with respect to the temperature.

II. MATERIALS AND METHODS

The reagents used for the synthesis and preparation were of AR grade and procured from Merck, India. These reagents were used as it is without further purification. Deionized double distilled water was used throughout the experiment.

A. Synthesis of CuO Nano Particles and Preparation of Nanofluids

Copper oxide nanoparticles are prepared from copper chloride dihydrated and sodium hydroxide pellets as precursors in aqueous media maintaining pH of the solution from 4 to 11 and temperature 60-70^{0}C [11]. A brownish-black precipitation of copper hydroxide was obtained after stirring continuously for one hour to complete the precipitation reaction. Hydrochloric acid was used to neutralize the solution. The precipitate was centrifuged and washed with deionized water and was dried in oven at 90^{0}C for 4hour to get Copper Oxide nanoparticles. The synthesized nanoparticles were then characterized for their properties using XRD, EDX and SEM.

B. Preparation of Nanofluids

Nanofluids have been prepared by using the synthesized CuO nano particles in water and Triethylene glycol [0.005% (w/V)]. These two different solutions were properly stirred for 30mins by a magnetic stirrer before subjecting to ultra-sonication for 2 hr using Ultrasonic Processor. After dispersing, the nanofluids were carried out for Zeta potential, electrical conductivity, thermal conductivity along with rheological properties studies.

C. Characterization of CuO Nanoparticles and Nanofluids

The prepared nanoparticles have been characterized for structural determination from XRD by using X-ray Diffractometer with CuK alpha radiation (λ= 1.5405 Å). Both, the elemental composition (EDX analysis) and the particle shapes (SEM morphology) of CuO nanoparticles and nanofluids have been carried out. In addition, zeta potentials and particle size of nanofluids were determined.

D. Rheological Properties of Nanofluids

In the present study, the kinematic viscosities of the solutions were measured with a calibrated Ostwald viscometer immersed in a constant temperature water bath maintained within ±0.01K. It was followed by determine the time of flow at three different temperatures. Apart from this, the thermal conductivity of all the fluid samples were measured experimentally using KD-2 Pro KS-1 sensor instrument, where it uses transient hot wire source method for the conductivity measurement.

III. RESULTS AND DISCUSSIONS

From XRD diffractogram, it is observed that the intensity and position of peaks are indicative of the presence of copper oxide in the sample and the particles are of monoclinic crystal system (literature: JCPDS, File No 01-

080-1916). The average crystallite size (D) has been calculated from the line broadening using the following Debye-Scherrer's relation [12] and the average crystal size is found to be 11.23nm

$$D=\frac{K\lambda}{\beta\cos\theta} \quad (1)$$

where K is the crystallite shape factor and a good approximation is 0.9, λ is the wavelength of X-ray, β is full width at half the maximum (FWHM) in radians of the X-ray diffraction peak and θ is the Braggs angle.

The images of EDX analysis for the samples show the presence of copper and oxygen elements in the prepared nano powder with the % weight composition of copper and oxygen are 67.73 and 25.60, respectively. The SEM images are the evidence for the nanoscale sizes of CuO particles in range of 43 to 73nm. It also reveals that, the shapes of copper oxide particles were found to be spherical.

Zeta potential is an important property and it shows the difference between the dispersion medium and the stationary layer of fluid attached to the dispersed particle. Larger the values of zeta potential better will be the dispersion. pH of a colloidal solution is found to be one of the main parameters influencing the particle aggregation and the stability of the suspension. In the present investigation, zeta potential has been studied with the variation of pH of the nanofluids and it has been observed that the potentials of all the nanofluids increase with pH values. However, it decreases after pH 8 in most of the fluids with negative mV. This variation may be due to more anionic dispersant [13]. In the present study, there is increment of thermal conductivity for all the nanofluids from their respective base fluids. It increases with temperatures appreciably for the CuO nanofluids in water, though there is not any remarkable change in TEG. Electrical conductivity is another parameter that is related to the ability of charged particles or ions in the suspension to carry the charges towards respective electrodes when an electric potential is applied [14]. There is no such appreciable variation in electrical conductivity with pH except for the nanofluid with water, where the conductivity shows maxima at pH 4. This enhanced conductivity is assumed to be presence of more charged particles at this range.

Viscosity is an essential parameter that describes the internal resistance of a fluid to flow and, in case of a nanofluids, it depends on the morphology and size of nanoparticles. The kinematic viscosities of nanofluids are more than that of their base fluids and it decreases with temperature (Table1). This might be due to the increased disturbance in particles with temperature that makes the fluids to move fast. The enhanced viscosity is indicative of increased particulate-solvent association in fluids. It also shed light on better dispersion of CuO nanoparticles [15].

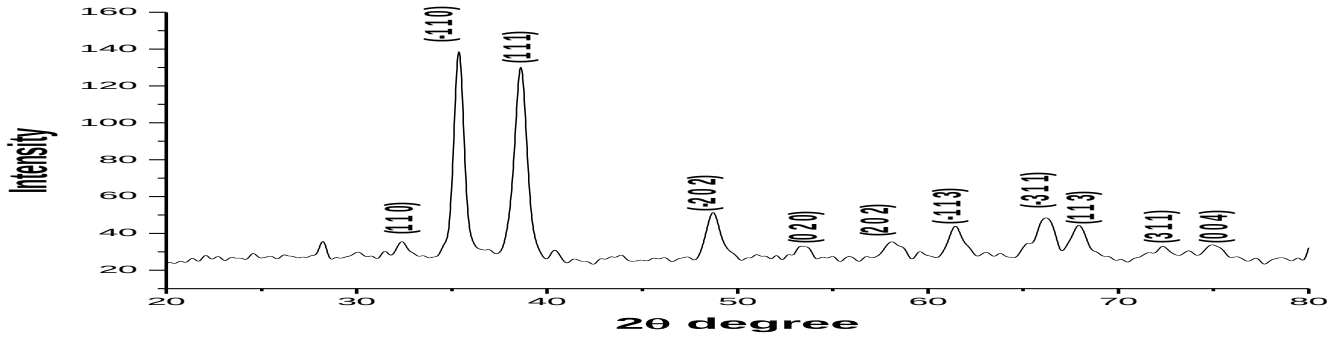

Fig.1. X-ray diffractograms of CuO Nanoparticles

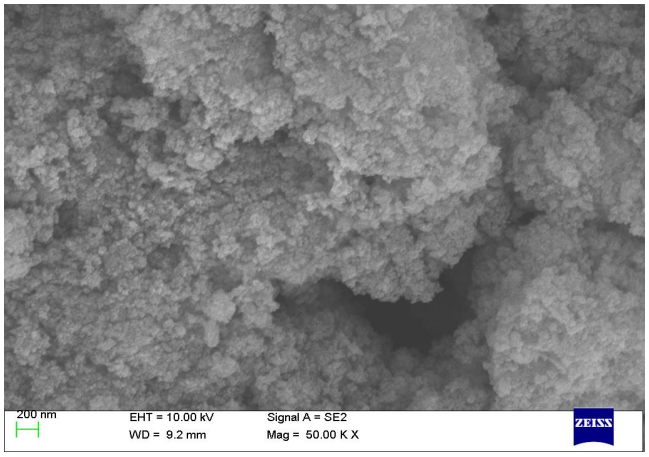

Fig.2. SEM Morphologies of CuO Nanoparticles

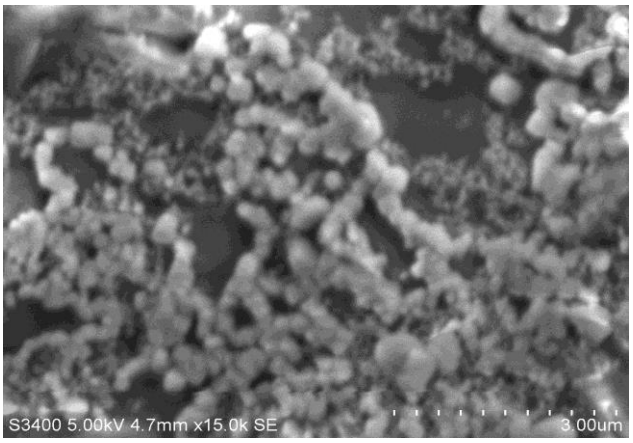

Fig.3. SEM Morphologies of CuO Nanofluid in Water

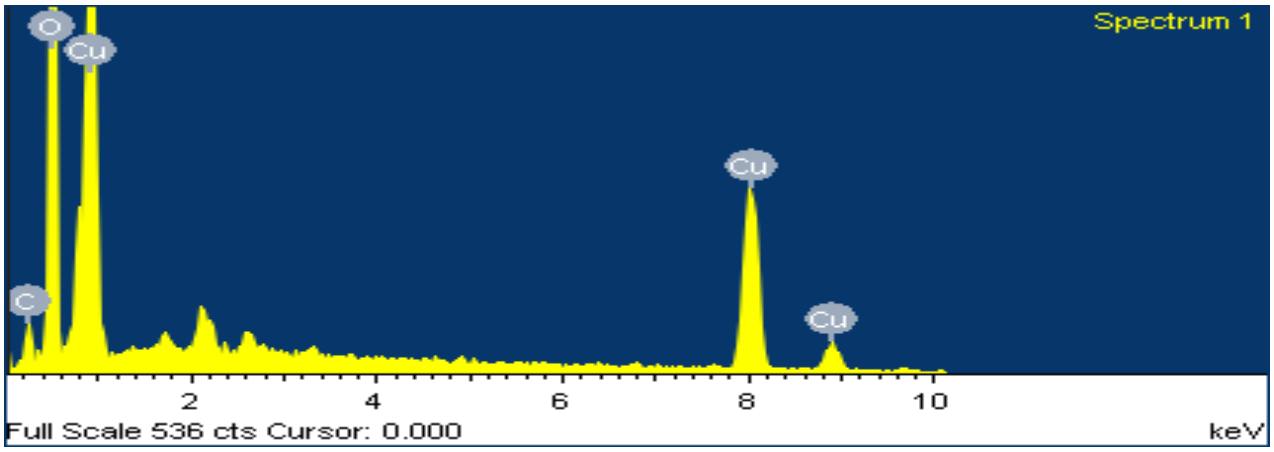

Fig. 4. EDAX images of CuO Nanoparticles

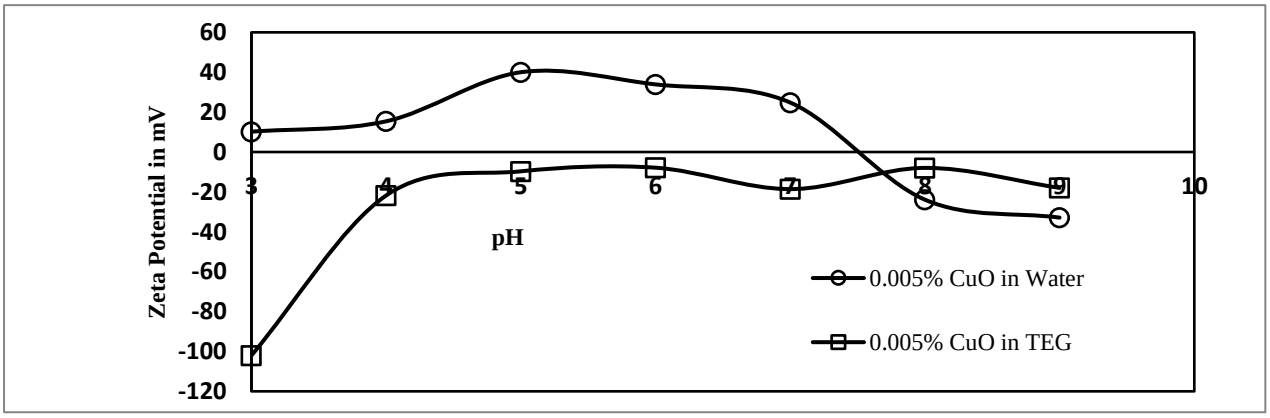

Fig.5. Plot of Zeta Potential of CuO Nanofluids in Water and TEG

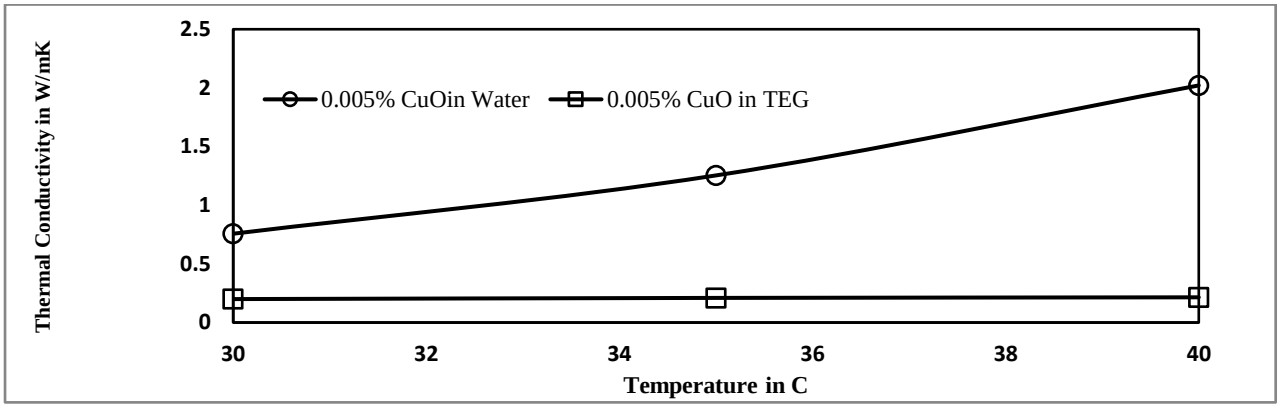

Fig.6. Plot of Thermal Conductivity of CuO Nanofluids in Water and TEG

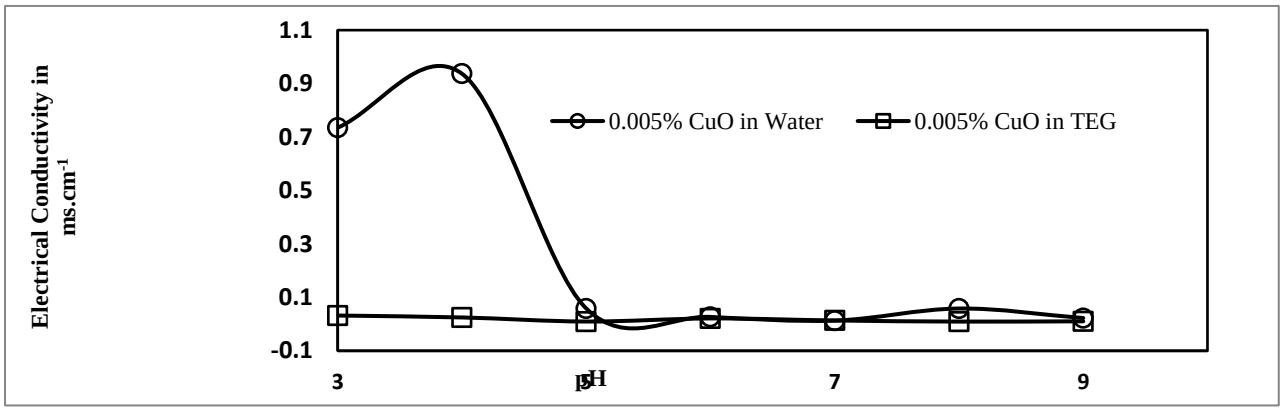

Fig.7. Plot of Electrical Conductivity of CuO Nanofluids in Water and TEG

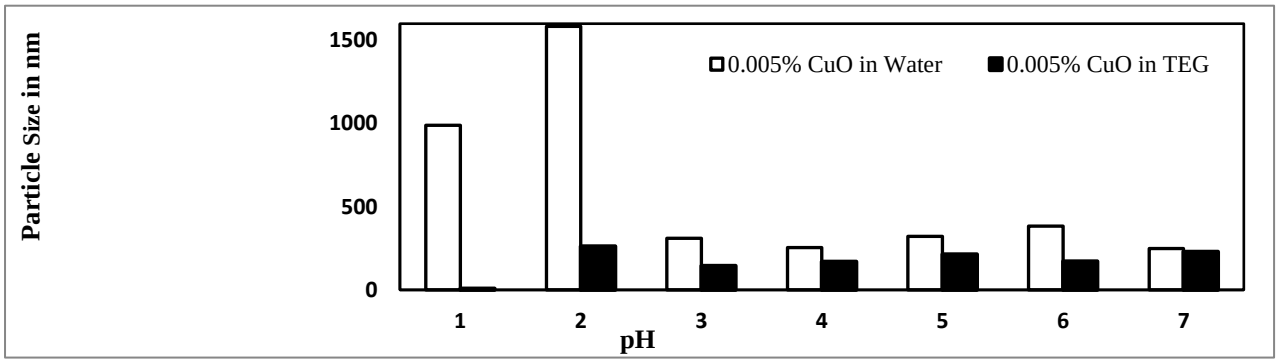

Fig.8. Particle sizes for 0.005% CuO nanofluid in Water and TEG at different pH

Table 1: Experimentally determined density, ρ and viscosity, η of Water, TEG (basefluid) & 0.005% CuO nanofluids in Water and TEG at 303.15K, 308.15K and 313.15K

Solvents	ρ x 10^{-3} kg.m^{-3}			η x 10^{3} kg.$m^{-1}s^{-1}$		
Basefluids						
	303.15K	**308.15K**	**313.15K**	**303.15K**	**308.15K**	**313.15K**
Water	0.9945	0.9943	0.9931	0.7877	0.7112	0.6531
TEG	1.1121	1.1091	1.1071	21.1615	18.0889	13.6685
0.005% CuO in different basefluids						
Water	0.9953	0.9942	0.993	0.7952	0.726	0.6603
TEG	1.1135	1.1133	1.1125	29.6908	21.8496	18.8393

IV. CONCLUSION

From the present investigation, the following conclusions have been drawn:

- Copper oxide nanoparticles have been successfully prepared by chemical precipitation technique and stable CuO nanofluids have been prepared by taking base fluids such as water and TEG.
- Noticeable changes that, there was enhancement in thermal conductivity for the nanofluids from their respective base fluids.
- The studies of zeta potential, which is the important parameter for the stability and dispersibility also shows enhancement even with the variation of pH

V. Acknowledgement

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