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Thermal Conductivity and Dispersion Stability of Copper Oxide Nanofluid in Kerosene

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ABSTRACT

Kerosene based nanofluids were prepared by involving copper oxide nanoparticle. The optimum level of concentrations of CuO nanoparticle in nanofluid formulations was established by the UV-visible absorbance. The oleic acid based surfactant concentrations in nanofluids were also optimized by UV-visible absorbance. It was found that 0.05 % concentration of copper oxide nanoparticle with 5% concentration of oleic acid surfactant resulting stable dispersion in kerosene. The thermal conductivity enhancement of about 16% was observed of 0.05% CuO nanofluid with surfactant vis-a-vis those of Kerosene. It was also observed that stability of nanofluid was decreased with increasing time.

Keywords: CuO nanofluid, Kerosene, Dispersion stability, Thermal conductivity.

1. INTRODUCTION

Kerosene is used as regenerative coolant in semi-cryogenic engine. The thermal conductivity of kerosene oil is relatively low and it can be enhanced by adding some organic and inorganic nanaoparticles. In recent years, it has been found that dispersing nanoparticles in the fluid at low volume fractions enhances heat transfer properties of the fluid. Thus, an innovative cooling system can be derived for semi-cryogenic engine by improving the heat transfer capacity of kerosene[1]. It can also be used as a cooling agent in metal production and treatment (oxygen-free conditions). Currently, Kerosene is widely used in power jet engines of aircraft (jet fuel) and some rocket engines.

Nanofluid is a suspension of nanoparticles in their base fluids. Nanofluids have unique features different from conventional solid-liquid mixtures in which nm or μm sized particles of metals and non-metals are dispersed. Due to their excellent characteristics, nanofluids find wide applications in enhancing heat transfer[2].

The most attractive property of nanofluids is the enhancement of the thermal conductivity. The thermal conductivity of nanofluids depends on many parameters including the thermal conductivities of the base fluid and the nanoparticles, the volume fraction, the size, the shape, the clustering of the nanoparticles and the temperature[3]. The thermal conductivity of solid particles or nanoparticle is always higher as compared to the base fluids used such as water, ethylene glycol, engine oil, kerosene etc. Solid nanoparticle significantly enhances the thermal properties of base fluid[4]. Propylene glycol based fluids are normally used to lower the freezing point of heat transfer liquids in heat exchangers in cold climatic regions[5].

Copper oxide nnanofluid is most commonly investigated by the researchers. When copper oxide nanoparticle is suspended in aqueous solution[6], its thermal conductivity improved[6]. Several cited literature reveal that with low nanoparticle concentrations (1–5 vol.%) increased the thermal conductivity of nanofluid suspensions by more than 20% [7-10]. Cu based nanofluids possess good suspension in their respective base fluid. Enhanced heat transfer effect of Cu nanofluid was reported earlier[11-14]. It is quite difficult for nanoparticles to maintain suspension stability mainly due to the van der Waals force between small particles resulting into aggregation sedimentation of particles[15]. For example 0.3 vol.% copper nanoparticles dispersed in ethylene glycol is reported to increase its inherent poor thermal conductivity by 40%[9,16].

In our previous studies, it was discussed about the CuO nanofluid in ethylene glycol: water (60:40)[17]. In the present manuscript, we are discussing about the Kerosene based CuO nanofluid with dispersion behaviour of copper oxide nanoparticle, selection of surfactant concentration and thermal conductivity of CuO nanofluids.

2. MATERIALS AND METHODS

Kerosene was used as a base fluid for the preparation of nanofluids. Oleic acid was used as a surfactant. Kerosene was procured from Bayer Material Science LCC, Pittsburgh, USA. Copper oxide nanoparticle (50 nm) was procured from Intelligent Material Pvt. Ltd., USA. All chemicals were used as such without further purification.

Viscosities of nanofluids were measured by Brookfield viscometer (Model RVDV-II+ Pro, Brook field engineering laboratory USA). UV absorbance of nanofluids was recorded by UV-visible spectrophotometer (Model UV-1700 Pharmaspec, Simadzu, Japan).

Thermal conductivity of developed nanofluids was measured by thermal conductivity meter (Model TPS-500, Hot Disk AB, Sweden). It is based on the Transient Plane Source technique (TPS). In this method, the probe comprises a flat sensor with a continuous double-spiral of electrically-conducting nickel (Ni) metal etched out of thin foil and clad between two layers of Kapton. Although only 0.025 mm thick Kapton provides both electrical insulation for the sample and mechanical strength for the probe. The range of thermal conductivity measurement is 0.03-100 W/mK. The temperature range of the instrument is -100^{0}C to 200^{0}C. The 60 ml of liquid sample of different nanofluids were used for thermal conductivity measurement at 25^{0}C. The measurement time was 20 second and heating power was 25 mW.

2.1 Preparation of nanofluids

Copper oxide nanoparticles were dispersed in Kerosene base fluids to prepare nanofluids. The mixture of base fluid and nanoparticles were stirred for 3 hours at 350 rpm using a magnetic stirrer and subsequently sonicated for 2 hours for uniform dispersion.

3. RESULTS AND DISCUSSION

3.1 Dispersion studies of CuO nanoparticles in kerosene

Nine compositions of Kerosene based nanofluids were prepared by dispersing 0.01 to 0.09% CuO nanoparticle. Dispersion behavior of CuO nanoparticle in kerosene base fluid was studied by the UV absorbance. The absorbance values are summarized in Table 1 and the change in absorbance value as a function of percent concentration of CuO have reported in Figure 1. The absorbance values varied from 1.332 to 1.119 for nine CuO nanofluids compositions (Table 1). The absorbance values increase from 1.332 to 1.904 was observed with the increase in concentrations of CuO nanoparticle up to 0.05% (Table 1). It was observed that increasing the CuO concentration beyond 0.05% does not affect much on absorbance value, contrary, when concentrations of CuO increases from 0.06% to 0.09% the absorbance values were dramatically reduced to 1.119. Thus it was inferred that 0.05% concentration of CuO in kerosene oil based nanofluid is the best dispersion as compared to other nanofluids compositions (Figure 1).

3.2 Optimization of surfactant (Oleic acid) concentration in 0.05 % CuO nanofluid

0.05% CuO nanofluids were prepared by varying concentration of oleic acid surfactant from 1% to 9%. The absorbance value of each nanofluids were determined. The absorbance values are given in Table 1 and the effect of oleic acid concentration (%) variation is represented in Figure 2. The absorbance values were found increased with the increase of the percentage of oleic acid from 1% to 5%. The highest absorbance value of 2.720 was observed for 5% oleic acid concentration in nanofluid (Figure2). When the concentration of oleic acid surfactant increased further from 6% to 9% the absorbance value drops to 2.076. So, it is clear from the results that 5% oleic acid surfactant concentration is optimum over the 0.05% CuO Kerosene oil based nanofluid based on the maximum value of absorbance achieved indicating the best dispersion at this concentration.

3.3 Stability studies of CuO nanofluids without surfactant and with Surfactant:

UV absorbance was recorded between 230-700 nm. Stability studies of CuO nanofluids were performed by UV-Visible spectra in time duration of 1 weak to 2 months. The graph of stability studies of nanaofluid without and with surfactant are depicted in figure 3 and 4 respectively. In case of nanofluids without surfactant, it was noticed that the absorbance values were decreases with increasing time period but the values was maximum at 0.05% CuO concentration. The stability of CuO nanofluid without surfactant were decreased with time but it was more stable at 0.05% CuO concentration in compare to other concentration (Figure 3). Similar results have been observed with oleic acid surfactant while the absorbance values were higher in compare to without surfactant. Maximum stability was observed with 5 % oleic acid concentration (Figure 4).

3.4 Thermal conductivity of CuO nanofluids in Kerosene

In our first studies CuO nanopowder was procured from commercial source and prepared nanofluid in water and EG: water (60:40) medium with and without surfactant and observed maximum 20% enhancement in thermal conductivity[17]. In our secund studies, three CuO nanopaticle were synthesized by chemical reduction method (particle size 28-90 nm) and make nanofluid in water and EG: water (40:60) media. In water medium maximum 12% and in EG: water (40:60) medium maximum 60% thermal conductivity enhancements were observed[18]. D. K. Agarwal *et al.*, investigated kerosene-alumina nanofluid and 22% enhancement in thermal conductivity at room temperature was observed for 13 nm particle size nanofluid at 0.5% volume concentration[2].

The kerosene based CuO nanofluid studies are rare and it is also used as coolant, so we choose kerosene as a base fluid.

The thermal conductivity of kerosene base fluid was 0.150 W/mK. Kerosene based nanofluid prepared by dispersing 0.01 to 0.08% CuO nanoparticle using 5% oleic acid as surfactant. The thermal conductivity increases from 0.157 to 0.174 W/mK by loading CuO nanoparticle percentage to 0.05 % (Table 2). When CuO concentration increases further than the thermal conductivity values reduces adversely. Thus, it can be inferred that 0.05% CuO concentration is optimum at which the thermal conductivity of kerosene based nanofluid is found maximum with an increase of 16% (Figure 5). The addition of surfactant is very important from the dispersion stability and thermal conductivity point of view. As surfactant gives an effective dispersion of nanofluids, it is reflected in the improved thermal conductivity of nanofluid. The thermal conductivity enhancement without surfactant was 11% while it was 16% with surfactant (Table 2). The enhancement was some lower may be because of the lower concentration of CuO nanoparticles. In fact the thermal conductivity of nanofluids is depending on the concentration of nanoparticle, temperature, types of nanoparticle used, dispersion medium etc.

Table1: Optimization of Concentration (%) of CuO nanoparticle and Oleic acid surfactant by UV absorbance in Kerosene

S.No.	Concentration of CuO (%)	UV-Absorbance	Concentration (%) of Oleic acid surfactant in 0.05% CuO nanofluids	UV-Absorbance
1	0.01	1.332	1	2.572
2	0.02	1.421	2	2.604
3	0.03	1.638	3	2.665
4	0.04	1.732	4	2.695
5	***0.05***	***1.904***	***5***	***2.720***
6	0.06	1.321	6	2.505
7	0.07	1.317	7	2.516
8	0.08	1.295	8	2.516
9	0.09	1.119	9	2.076

Table 2 : Thermal conductivity of Kerosene, CuO nano fluid (0.01-0.08% CuO concentration) with surfactant and without surfactant of optimized CuO nanofluid (0.05 %) in kerosene

S.No.	Concentration of CuO (%) with surfactant	Thermal conductivity(W/mK)	Enhancement of thermal conductivity (%)
	Kerosene	0.150	-
1	0.01	0.157	4
2	0.02	0.159	6
3	0.03	0.164	9
4	0.04	0.171	14
5	**0.05**	**0.174**	**16**
6	0.06	0.170	13
7	0.07	0.165	10
8	0.08	0.164	9
	CuO nanofluid (0.05%) without surfactant	0.1670	11.0

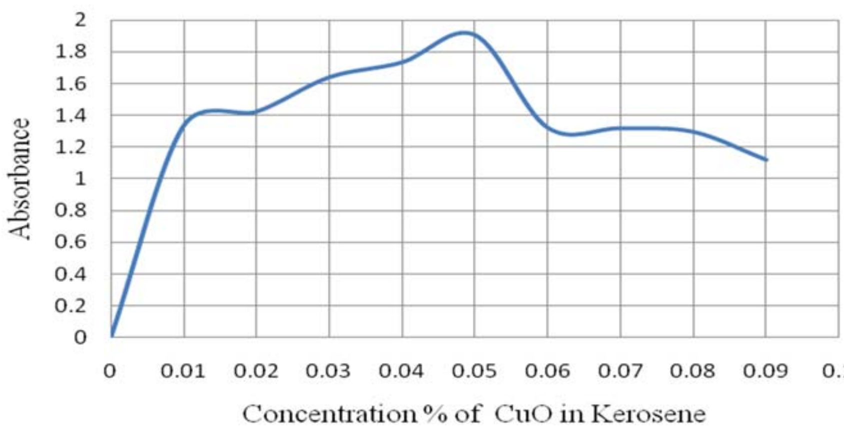

Figure 1 : UV absorbance of nanofluid with varying concentration of copper oxide nano particle in kerosene

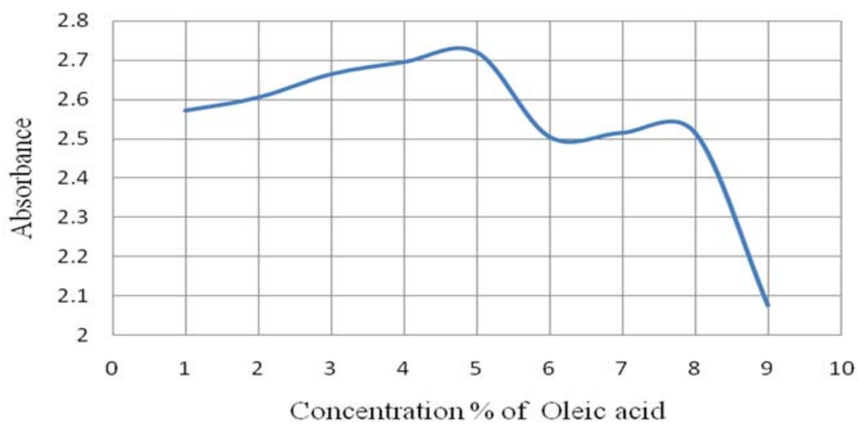

Figure 2: UV-absorbance of 0.05% CuO nanofluids in Kerosene varying the % of oleic acid surfactant

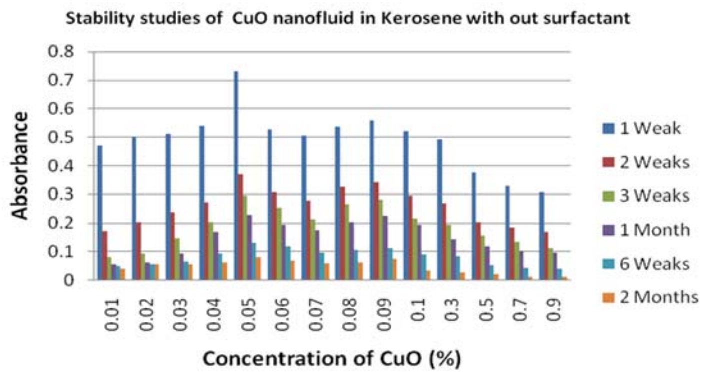

Figure 3: Stability studies of CuO nanofluid in Kerosene without surfactant

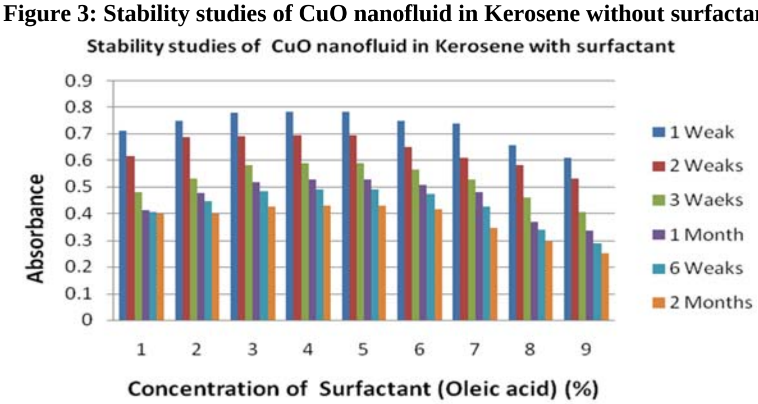

Figure 4: Stability studies of CuO nanofluid in Kerosene with oleic acid surfactant

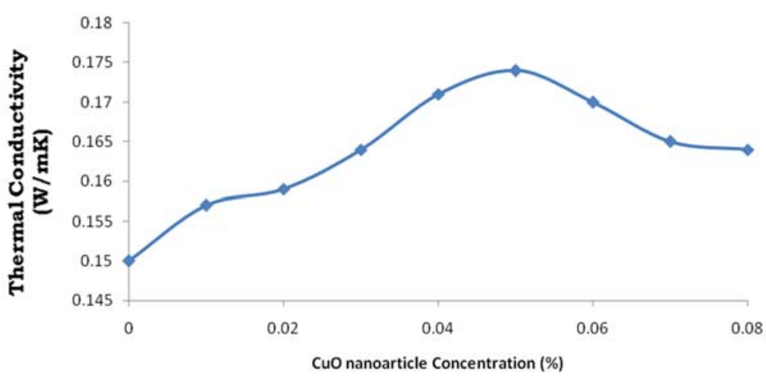

Figure 5: Thermal conductivity of nanofluid with varying concentration of copper oxide nano particle with surfactant in kerosene

4. CONCLUSIONS

On the basis of above discussion it is concluded that 0.05% copper oxide nanoparticle concentration is optimum to achieve best conductivity. The suitable concentration of oleic acid surfactant was 5% for the kerosene based 0.05% CuO nanofluid. The maximum improvement of thermal conductivity was observed as 16% for 0.05% CuO nanofluid with 5% surfactant. In case of nanofluids without surfactant, the absorbance values were decreases with increasing time period but the values was maximum at 0.05% CuO concentration. Similar results have been observed with oleic acid surfactant while the absorbance values were higher in compare to without surfactant. Maximum stability was observed with 5 % oleic acid concentration. It was observed that stability of nanofluid was decreased with increasing time.

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