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Short Communication

Viscosity and Rheological Behavior of Ethylene Glycol-Maghemite Nanofluids

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Abstract:
This work is devoted on the rheological behavior of ethylene glycol based nanofluids containing maghemtite nanoparticles. The size of these maghemite nanoparticles was measured using XRD and found to be about <50 nm. Major factors that influence on viscosity and rheological behavior, such as, temperature and particle mass concentration, were investigated over 25–80°C and 0.2 and 2% respectively. It was found that the nanofluids show shear-thinning behavior particularly at particle concentrations in excess of 0.2%. Temperature imposes a very strong effect on the rheological behavior of the nanofluids at higher temperatures. For a given particle concentration, there exists a certain shear rate below which the viscosity decreases by increasing the temperature.
Keywords: *Viscosity, Nanofluid, Ethylene glycol,* Fe_2O_3*, Nanoparticle*

1. INTRODUCTION

In traditional heat transfer fluids, properties that mainly determine the thermal performance of a liquid for heat transfer applications are the thermal conductivity, viscosity and density [1]. Recently a class of heat transfer fluids containing dispersed metallic nanoparticles with typical size scales in the order of 1-100 nm has attracted great interests. Most attention has been paid in the past decade to this new type of heat transfer materials due to their enhanced properties and behaviors associated with heat transfer, mass transfer, wetting, spreading and antibacterial activities. These enhanced characteristics implies an enormous potential of nanofluids in device miniaturization and process intensification which could have an impact on many industrial sectors including chemical processes, transportation, electronics, energy and environment [1,2].

Most published studies on nanofluids deal with the heat transfer behavior including thermal conductivity [2], phase change (boiling) heat transfer [3] and convective heat transfer [4], which have been reviewed recently [5]. Very few studies, however, have been reported on the rheological behavior of nanofluids. Key requirements for nanofluids include low solids loading but with high thermal properties, favorable rheological properties and flow behavior, and great stability over a wide range of temperatures to meet the industrial needs. Clearly, there is a gap in the literature for studies on the rheological behaviors of these fluids.

Here in, the rheological behavior of a nanofluid material is investigated. The focus will be on the nanofluids containing spherical particles. We used ethylene glycol based Maghemite (EG-Fe_2O_3) nanofluid. The reasons for the use of EG-Fe_2O_3 nanofluid can be summarized as: both EG and γ-Fe_2O_3 are generally regarded as a safe material for humans and animals although it may change in the future with more fundamental research on their nano-toxicology and γ-Fe_2O_3 nanoparticeles can be produced on large industrial scales [6-8].

2. MATERIALS AND METHODS

2.1. Analytical Methods

In this study, all chemicals are reagent grade and deionized distilled water was used to prepare nanoparticles. Anhydrous $FeCl_3$ and $FeCl_2.4H_2O$ were obtained from Sigma–Aldrich (USA). Ammonia and ethylene glycol were purchased from loba. Chem.

2.2. Batch Experiment

The nanoparticles (γ-Fe_2O_3) were prepared according to previously reported procedures [9]. Briefly, anhydrous $FeCl_3\cdot$ (3.25 g) and $FeCl_2.4H_2O$ (1.99 g) were separately dissolved in 20 mL of deionized water, followed by the mixing of the two iron salt solutions under vigorous stirring (800 rpm). Then, 30 mL of 25 w/w % aqueous ammonia was added to the solution. The color of the bulk solution changed from orange to black immediately. The magnetic precipitates were washed twice with deionized water. The size of the nano particles was obtained with an X-ray diffraction.

The analysis was carried out on the ethylene glycol (EG) based nanofluids containing 0.2 and 2 Vol % spherical γ-Fe_2O_3 nanoparticeles at 25-80°C. The viscosity of nanofluids (γ-Fe_2O_3/EG) was measured with fungilab F.A. instrument.

3. RESULTS AND DISCUSSION

The crystal structure of the synthesized nanoparticles was investigated using XRD measurement using Cu Kα radiation (Philips, PW1800). It was found that the size distribution of the prepared maghemite nanoparticles is around 40 nm with a good monodispercity (Figure 1).

Figure 2 shows the viscosity of pure EG and EG-Fe_2O_3 nanofluids as a function of shear rate at 25°C. It can be seen that the EG-Fe_2O_3 nanofluids exhibit highly shear-thinning behavior particularly when the γ-Fe_2O_3 concentration exceeds 2%. Such behavior is different from the observed Newtonian behavior of EG-TiO_2 nanofluids containing spherical nanoparticles over similar shear rate range [10] where the base liquid (EG) is the same as that used in the current work. This behavior also is similar to the observations of carbon nanotube nanofluids [11] and CuO nanorod nanofluids [12], although there are important differences between them such as temperature dependence.

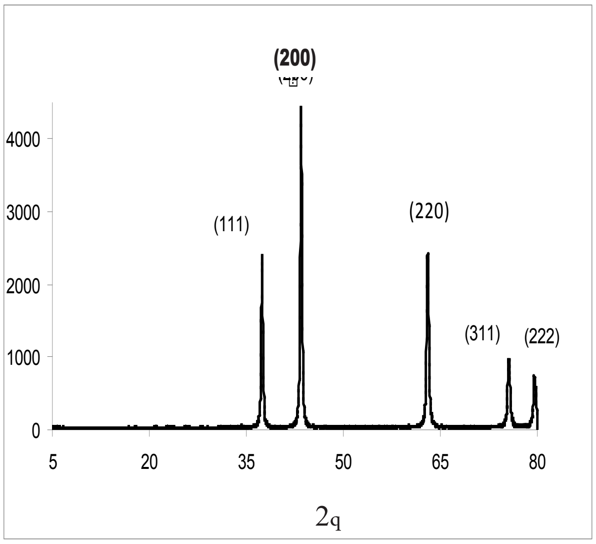

Figure 1: *XRD patterns of Maghemite nanoparticles*

Figure 3 shows the measured viscosity at different temperatures for 0.2 and 2 Vol. % nanofluids at high shear rates. It can be seen that the temperature has a very strong effect on the rheological behavior of nanofluids.

The temperature dependence of the entitled nanofluids can be interpreted as follows. Given the base liquid and nanoparticles, the functional dependence of viscosity on shear rate is determined by the relative importance of the Brownian diffusion and convection effects. The contribution from the Brownian diffusion becomes increasingly important by increasing the temperature particularly above 40°C due to the exponential dependence of the base liquid viscosity on temperature (Figure 3). At very high-shear rates, the Brownian diffusion plays a negligible role in comparison with the convective contribution and hence independent of the high-shear viscosity on the temperature.

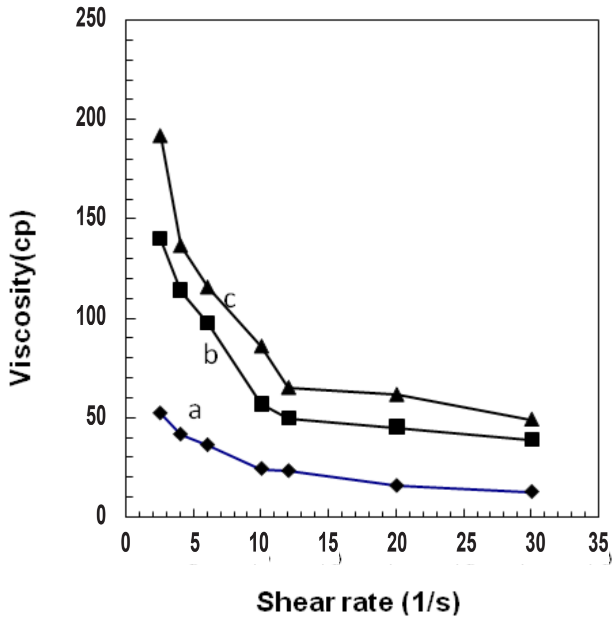

Figure 2: *Viscosity as a function of shear rate for different nanoparticle concentrations at 25°C. (a) 0 Vol. % ; (b) 0.2 Vol. % ; (c) 2 Vol. %*

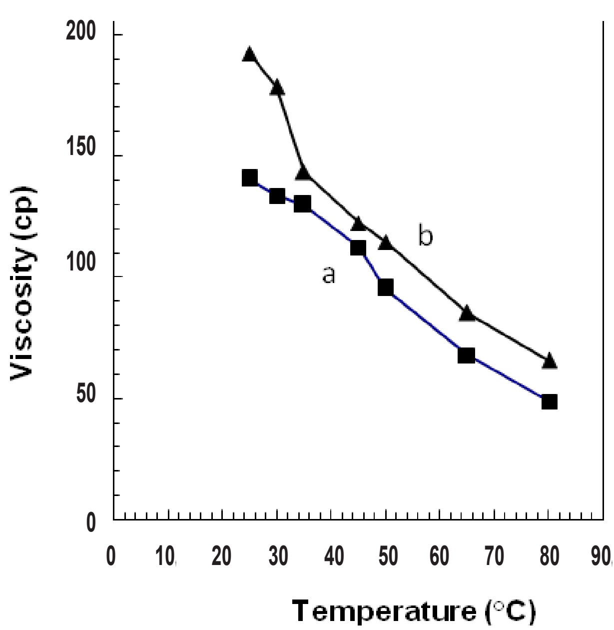

Figure 3: *Viscosity as a function of temperature for different nanoparticle concentrations at the constant shear rate (a) 0.2 Vol. % ; (b) 2 Vol. %*

4. CONCLUSIONS

It was determined that the viscosity of Ethylene glycol solutions increased by increasing Maghemite nanoparticle concentrations. Also the viscosity of EG-Fe_2O_3 nanofluids was very sensitive to the temperature since its rheological properties were significantly affected. This nanofluids show non-Newtonian behavior under the conditions implied in this work. The non-Newtonian shear-thinning behavior becomes stronger at lower temperatures or higher concentrations.

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