THERMOPHYSICAL CHARACTERIZATION OF ETHYLENE GLYCOL-BASED ZnO NANOFLUIDS

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Introduction: The main factor influencing heat transfer efficiency of thermal convection is the thermal conductivity of the employed heat transfer fluids. Concerning this fact, a new type of materials, termed nanofluids and consisting of nano-additives dispersed on a base fluid, represent a promising possibility because their thermal transport capacities is significantly higher than those of conventional liquids [1]. Although the thermal conductivity has a huge importance in heat transfer fluids, properties as density or viscosity could become as critical as thermal conductivity in engineering systems that require fluid flow [2-4]. The use of nanofluids in practical applications requires a previous exhaustive analysis of their thermophysical properties. In spite of the experimental and theoretical studies on nanofuids lately published, there is still a remarkable lack of reliable experimental data. The discrepancy existent between some of these is believed to be due to the combination of several factors as the diversity of preparation processes, particle size dispersion, stability, non uniformity of the particle shape, clustering, sedimentation, etc [5]. This work studies the influence of particle size, concentration and temperature on thermal conductivity, viscosity and density of ethylene glycol-based ZnO nanofluids. Homogeneous and stable nanofluids were prepared consisting of synthesized and commercial ZnO. The influence of pressure in density data was also measured. Some data available in the literature [6-9] were used to compare the results presented in this work. In addition, experimental thermal conductivity and viscosity were evaluated with some theoretical models.

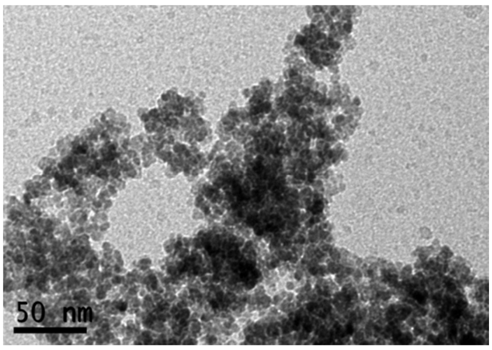
Experimental: *Synthesis of nanoparticles and preparation of nanofluids.* ZnO nanoparticles were prepared from Zn Acetate in alcoholic solution under basic conditions. This procedure is a modification of the method developed by Haase et al. [10]. Two different sets of ZnO in EG were studied in this work at concentrations up to 1% vol for density measurements, up to 4.7% vol for viscosity and up to 6.2% vol for conductivity measurements. The first sample (S1) was prepared from commercial ZnO nanopowder supplied by NanoTek while the second (S2) was prepared from ZnO nanopowder synthesized as described above.

Characterization. The commercial ZnO nanoparticles were analyzed using the scanning electron microscopy (SEM) technique. The images were obtained with a JEOL JSM-6700F field emission gun-SEM operating at an acceleration voltage of 20 kV in backscattering electron image (Yttrium Aluminium Garnet type detector). This device incorporates an energy dispersive X-Ray Spectrometer (EDS), which was used to chemically characterizer the sample. X-Ray Difracción (XRD) measurements were performed for the dry syntesized ZnO nanoparticles on a Siemens D-5000 diffractometer, using Cu(Kα) radiation, without finding impurities. The morphology of the samples is presented in figure 1a and it was observed on a JEOL JEM-1010 FEG (100 kV) transmission electron microscope (TEM) and a Philips CM20 microscope, equipped with an EDAX DX4mDX EDS. With the aim to evaluate the stability of the nanofluids, the optical absorption of the samples was measured using an UV-Visible spectrophotometer.

Thermophysical properties. The thermal conductivity of five different concentrations (between 1% and 6.2% vol) of S1 sample were measured using a device based on the hot-wire method (KD2 Pro Thermal Properties analyzer). Viscosity measurements were performed at atmospheric pressure and temperatures from 283.15 to 323.15 K, using a Schott rotational viscometer equipped with a spindle of coaxial cylindrical geometry (LCP) and enclosed in a stainless steel flow jacket. The volumetric behaviour of the analyzed nanofluids has been studied from the experimental density data (measured from 283.15 K to 323.15 K and up to 45 MPa) obtained with an Anton Paar DMA 512P/4500 vibrating tube densimeter.

Results and discussion: It has been found that thermal conductivity increases with the volume fraction of nanoparticles, reaching enhancements up to 45%. The improvements are also higher with particles of lower size according to literature data [8]. Experimental values have been evaluated with Maxwell, Jeffrey, Bruggeman, Turian and Hamilton-Crosser models reaching deviations of 6.1%, 6.0%, 5.3%, 2.1% and 1.9%, respectively.

For concentrations from 0.35% to 4.7% vol. with S1 samples and for concentrations up to 2.1% vol. with S2 samples, the nanofluids have presented a Newtonian behaviour (with an operating shear rate value of 123 s^{-1}). As usual, viscosity decreases significantly with temperature and increases with volume fraction as it is observed in figure 1b. The Vogel-Tamman-Fulcher method was applied to the experimental viscosity data, finding good agreements and showing that this correlation with temperature is also suitable for nanofluids.



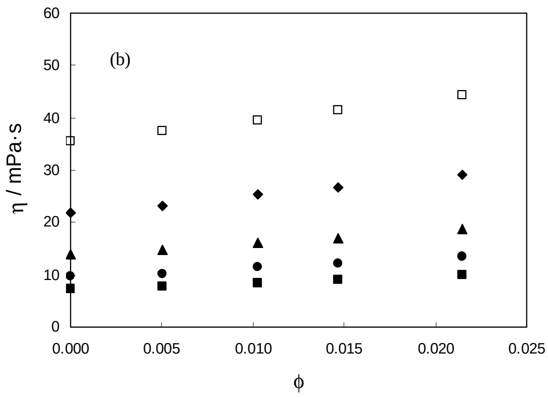


Figure 1. (a) TEM image of Synthesized ZnO (JEOL JEM-1010) nanoparticles in Ethylene Glycol (0.005% v/v); (b) Dynamic viscosity versus volume fraction, ϕ, for S2 samples at different temperatures: (□) 283.15 K; (◆) 293.15 K; (▲) 303.15 K;(●) 313.15 K; (■) 323.15 K.

The density behaviour of these nanofluids is coincident with the standard trend shown by the base fluid. In both cases, density increases with the concentration of nanoparticles although the enhancements are higher in S1 samples than S2 samples. The increments might be attributed to the interface effects on the bulk fluid properties produced by the solid nanoparticle surface, and to the interaction among the nanoparticles themselves, which are usually considered negligible.

Conclusions: Different ZnO/EG nanofluids were prepared by dispersing of synthesized and commercial ZnO nanoparticles in EG. The behaviour of the density as function of temperature and pressure has been experimentally determined up to 1% volume fraction. It has also been shown that as concentration increases the interactions between nanoparticles have an effect on the volumetric trend. The nanofluids studied are Newtonian for the shear stress used in the determination of the viscosity determination. The viscosity increases with concentration and decreases with temperature. Viscosity increases as particle size and decreases following the expected classical behaviour for dispersions. Thermal conductivities of commercial nanoparticles in ethylene glycol have been determined experimentally as a function of temperature and concentration. The enhancement of the thermal conductivity increases with the concentration, reaching the highest value of 45% for 343.15 K and 6.2% volume fraction.

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