PARTICLE SHAPE EFFECT ON THERMO-PHYSICAL PROPERTIES OF NANOFLUIDS

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INTRODUCTION

The thermal conductivity of heating or cooling fluids plays a vital role in the development of energy-efficient heat transfer equipment for many industrial sectors, including electronics, transportation, energy supply and production. However, conventional heat transfer fluids like 50/50 mixture of ethylene glycol and water (EG/H_2O) have poor thermal conductivities compared to most solids. Nanofluids, consisting of nanometer sized solid particles and fibers dispersed in liquids have demonstrated great potential for improving the heat transfer properties of liquids [1].

In our attempt to understand mechanisms of enhanced heat transfer in nanofluids in this work we investigate particle shape effect on thermo-physical properties of nanoparticle suspension.

EXPERIMENTAL

Four types of alumina nanoparticles were used in this study: platelets (9nm), blades (60x10nm); rods (80x10x10nm) and bricks (40nm). Powder XRD characterization confirmed the same boehmite AlO(OH) phase in all powders and approximate crystallite size determined from half width peak by Debye-Sherrer equation indicate that in all powders nanoparticles are mostly single crystallites.

Series of nanofluids with various volume fractions (1-7vol%) were prepared by suspending dry nanopowders into EG/H_2O. Particle size distribution in suspensions was determined with two complimentary techniques Dynamic Light Scattering (determines hydrodynamic radius of suspended particles) and Small Angle X-ray Scattering (sensitive to electronic density change at particle-liquid interface). Thermal conductivity of stable suspension at room temperature was measured using THW technique (KD2Pro) and the temperature and shear rate dependence of relative viscosity were determined using the rotational type viscometer (Brookfield DV-II+).

RESULTS AND DISCUSSION

The macroscopic effective medium theory (EMT) predicts that the effective thermal conductivity (k_{eff}) of solid-liquid suspensions increases with the volume fraction of the solid particles (φ)

$$\frac{k_{eff}}{k_0} = 1 + 3\varphi \frac{k_p - k_0}{k_p + 2k_l - (k_p - k_0)\varphi} \approx 1 + 3\varphi \qquad (1)$$

where k_0 and k_p are the thermal conductivity of the base fluid and particles respectively (Maxwell's model for spherical particles [2]). Corrections for possible effects of nonspherical particle shapes were accounted by Hamilton-Crosser model [3].

Our experimental results show very significant effect of particle shapes and crystallinity on thermal conductivity of nanofluids. Suspension of rod-like and brick-like nanoparticles follow predictions of EMT for cylinders and spheres, while platelets and blades show lower enhancements. Mechanism of enhanced thermal conductivity in nanofluids is not well understood yet and different models are suggested.

Viscosity, on the other hand is a structure sensitive property of a fluid that resists flow. Shapes and concentration of nanoparticles affect the distribution morphology in the nanofluid's structure and further affect the viscosity.

Experimental data show significant increase in viscosity with nanoparticle concentration, much higher then theoretical predictions for suspension of non-interacting spheres (Einstein-Batchleor).

These results indicate great impact of the aspect ratio on the rheological behavior of suspensions and are significant for development of nanofluids for heat transfer applications as heat transfer coefficient depends on the flow behavior. Thus practical nanofluid should have a balance between thermal conductivity and viscosity enhancements.

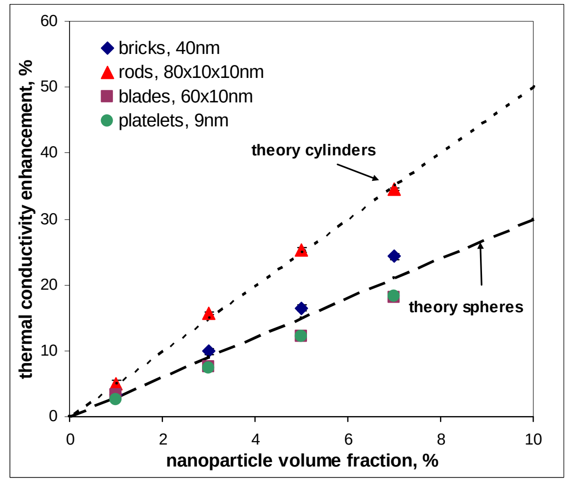

*Figure 1. Thermal conductivity increase as a function of nanoparticle content, (k_{eff}/k_0-1)*100, at room temperature.*

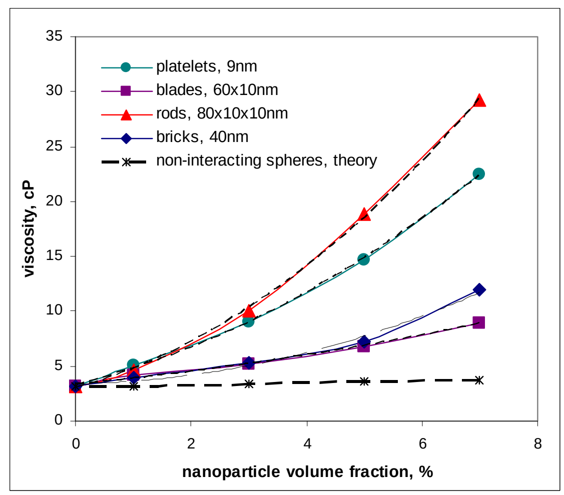

Figure 2. Viscosity increase as a function of nanoparticle concentration, room temperature.

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