**Abstract:**
This article reports viscosity data on a series of colloidal dispersions collected as part of the International Nanofluid Property Benchmark Exercise (INPBE). Data are reported for seven different fluids that include dispersions of metal-oxide nanoparticles in water, and in synthetic oil. These fluids, which are also referred to as 'nanofluids,' are currently being researched for their potential to function as heat transfer fluids. In a recently published paper from the INPBE study, thermal conductivity data from more than 30 laboratories around the world were reported and analyzed. Here, we examine the influence of particle shape and concentration on the viscosity of these same nanofluids and compare data to predictions from classical theories on suspension rheology.

**Viscosity Measurements on Colloidal Dispersions (Nanofluids) for Heat Transfer Applications**

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than predicted: measured stronger dependence on particle concentration with spherical particles in Figure 7 show a slightly dependence of spherical and rod-shaped particles show a linear as with the viscosity data, nanofluids with both spherical and rod-shaped nanoparticles show a linear dependence of $\eta/\eta_0$ versus particle concentration $\phi$. The data for the fluids with spherical particles in Figure 7 show a slightly stronger dependence on particle concentration than predicted: measured $[k] = 4.0$, and predicted $[k] = 3.1$. This observation is consistent with the presence of particle agglomeration in these systems, and suggests that particle clustering has a large effect on viscosity than thermal conductivity in nanofluids with spherical particles. The situation is different for the nanofluids with rod-shaped particles as shown in Figure 8. Here, the observed dependence on particle concentration is weaker than predicted: measured $[k] = 5.6$, and predicted $[k] = 13.3$. Apparently, particle agglomeration can significantly reduce the effective thermal conductivity of nanofluids with rod-shaped particles. A second explanation for the reduction in effective thermal conductivity in these nanofluids is interfacial thermal resistance [16].

4 CONCLUSIONS

Viscosity data have been collected as part of an International Nanofluid Property Benchmark Exercise (INPBE). These data are from approximately 10 different laboratories around the world on a series of 10 different nanofluids and their base fluids. In general, the agreement between different laboratories was good with variations of approximately ±20%, which, in part, could be explained by lab-to-lab temperature variations. Two of seven nanofluids showed shear-thinning behavior; the remaining five showed Newtonian behavior. For nanofluids with both spherical and rod-shaped nanoparticles, the dependence of viscosity (relative to the base fluid viscosity) on particle concentration (volume fraction) was significantly stronger than predicted by dilute suspension theory. This discrepancy was attributed to particle agglomer-
tion. In contrast, the observed enhancement in thermal conductivity was slightly larger for the spherical particle fluids, and significantly lower for the rod-shaped particle fluids, than predicted by effective medium theory. As noted in the introduction, criteria for the overall effectiveness of nanofluids as heat transfer fluids have been proposed [9, 12], which suggest \[ h \] should be 4 - 5 times smaller than \[ k \]. Clearly, the nanofluids considered in this study would fail; this suggests that the overall effect of adding nanoparticles to the base fluid is negative in terms of heat transfer performance.

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