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Microstructural effects on the rheological behaviour of nanofluids

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Addition of a small amount of nanoparticles to a base fluid is a promising strategy to increase heat conductivity and specific heat of base fluids used as either thermal energy storage (TES) materials or heat transfer fluids (HTF) in solar thermal power plants. Indeed, research shows substantial enhancements in both properties, well in excess of predictions from classical effective medium theories of well dispersed systems. Thermal conductivity enhancements are attributed to nanoparticle aggregation and formation of fractal structures that span regions larger than their volume equivalent spheres. Likewise, detrimental increases in suspension viscosity due to the effect of the microstructure are reported. However, a good understanding of the rheological behaviour of nanofluids is still lacking.

Here we follow a volume-averaging approach to obtain the effective rheological response of a dilute suspension of non-interacting, non-colloidal fractal-like aggregates. First, we use a tunable Cluster-Cluster Aggregation algorithm [1] to generate large populations of fractal aggregates with specified fractal dimension. Then, Stokesian Dynamics simulations are used to obtain effective stresses in the suspension from ensemble and orientation averages of cluster stresslets [2]. Hydrodynamic interactions between primary nanoparticles within a cluster are fully considered in the simulations. Finally, we summarize our results with scaling laws that relate effective suspension viscosity with mean aggregate size and fractal dimension.

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