NUMERICAL INVESTIGATION OF FERROFLUID BEHAVIOR IN MICRON-SCALE GEOMETRIES

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Some experimental pressure drop results of fluid flows through microchannels and microtubes have shown non-classical behavior. Specifically, some experiments show that as geometries get smaller, pressure drops go higher than expected from classical theory. Models based on an electric double layer, micro polar fluid theory, and even early transition to turbulence, have been proposed to explain this phenomena.

We show that continuum mechanics can predict this anomalous behavior provided one includes the internal angular momentum of a structured media. In that case, the stress tensor has an asymmetric portion. As geometric dimensions decrease, the surface to volume ratio increases, making surface forces and surface couples more important. The stress tensor can only be assumed symmetric if the contiguous surroundings exert no body couples on the system.

Using the constitutive equations from ferrohydrodynamics, two new parameters arise, the spin viscosity and vortex viscosity. The spin viscosity has not yet been measured experimentally, but estimates have been made using Brownian Dynamics simulations of a ferrofluid [1]. The vortex viscosity is related to the dynamic viscosity and hydrodynamic volume fraction of the particles as $\zeta=1.5\mu\phi_h$ [2]. Numerical simulations show that as geometric dimensions decrease, the effect of spin viscosity increases, leading to an increase in pressure drop in the simulations. As dimensions decrease further, the pressure drop approaches an asymptote determined by the vortex viscosity. The behavior of the simulation results is quite similar to the experimental data [3].

References

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