Special Program in Applied Mathematics and Applied Mechanics

Analytical modeling of negative electrorheological suspension liquid flows

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Negative electrorheology (ER) describes the reduced effective viscosity responses of liquid-particle suspensions when the suspension liquid is subjected to externally applied electric fields. Mechanisms responsible for negative ER may be due to the separation of the solid and liquid phases of the suspension or to the spontaneous Quincke electrorotation of the suspended micro-particles when the electric field is applied. In this talk, our discussions shall be focused on the modeling of particle Quincke electrorotation induced negative ER liquid flows in both Couette and Poiseuille flow geometries. Previous modeling approaches of such phenomenon have been based on single particle dynamics analysis and subsequently obtaining the macroscopic effective viscosity as a function of the electric field dependent particle rotation speed. While the single particle dynamics modeling has been reasonably successful describing the negative ER responses in the high shear rate regime, the single particle dynamics theoretical predictions made in the low shear rate regime agree poorly with the experimental Couette effective viscosity and Poiseuille flow rate measurements reported in the literature. Here, by introducing the theories of continuum angular momentum balances and couple stresses, we take on a continuum mechanical modeling approach to describe and analyze the negative ER flow behavior and responses induced by internal micro-particle Quincke electrorotation of Couette and Poiseuille suspension liquid flows. Assuming finite couple stresses and small fluid spin velocities, analytical solutions to the effective viscosity, volume flow rate as well as the flow velocity distribution are obtained and compared to the experimentally measured values reported. Very good agreement is found between the continuum theory predictions and the experimental measurements in the low shear rate regime.