Modeling of non-colloidal suspensions using effective medium theories

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We present a model for the shear and elongational viscosities of non-colloidal suspensions with Newtonian matrix fluids. The model is based on the original idea first presented by Brinkman (1947) for the viscous force exerted by a flowing fluid on a dense swarm of spherical particles. In particular, we consider an inertialess suspension in which the mean flow is driven by (a) a pressure difference and simultaneously the suspension is subject to simple shear or (b) to uniform uniaxial elongation. Assuming steady state, incompressibility and taking into account a resistance force which is generated due to the presence of the particles in the flow, the three-dimensional governing equations for the mean flow around a single spherical particle are solved analytically in both cases. In the first case, self-consistency of the model provides a relationship between the resistance parameter and the volume fraction of the solid phase. A volume averaging of the total stress gives expressions for the bulk (shear and elongational) viscosities of the suspension. These expressions reduce to the Einstein limit for dilute suspensions and agree well with empirical formulas from the literature in the semi-dilute and concentrated regimes.