A new tensorial model for non-colloidal suspensions: from microstructure anisotropy to normal stress differences and jamming

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Non-colloidal suspensions in Newtonian fluids exhibit non-trivial behavior in several flowing conditions, such as normal stress differences and an anisotropic micro-structure during shear flow or a drop of the apparent viscosity just after a shear reversal. As pointed out in \cite{Ozenda2018}, these features are linked to contact interactions between neighbouring particles. The anisotropy of microstructure can be modelled by a texture tensor following a rate-independent advection equation which is coupled to the bulk velocity. Hence suspensions are modelled like visco-elastic fluids.

As seen on the left plot, the apparent viscosity \( \eta_{\text{app}} \) versus the deformation \( \gamma \) during a shear reversal suddenly decreases at time \( t = 0 \) then reaches smoothly a minimum and finally increases and goes back to its stationary value. Remark the excellent quantitative agreement between the observation from (in red) and the model prediction (in black). The plot in the middle represents, in polar coordinates, the probability \( g(\theta) \) for a particle to have a neighboring particle in the \( \theta \in [0, 2\pi] \) direction, which is called pair distribution function. The model is able to predict the depletion angle \( \theta_e \), indicated by an arrow, where this probability is minimum. Observe also the global qualitative agreement between the observation (in red) and the model prediction (in black). The right plot shows the reduced second normal stress difference \( \alpha_2 \) versus the reduced volumic fraction \( \psi \). Our prediction (in black) agrees with the two experimental data sets, from \cite{Dbouk2013} and \cite{Couturier2011} (in red and in green). This third comparison presented in \cite{Ozenda2019} constitutes a great leap in suspensions modelling as normal stress differences are responsible for shear induced migration.

Finally, we integrate our new rheological model into a two velocities system in order to reproduce migration phenomenon and predict jammed zones. When \( \phi \) tends towards its maximal value, internal stresses diverge because of contact interactions and the flow is congested.

References


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