Local behavior of dense suspensions of noncolloidal particles

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Dense suspensions of noncolloidal particles display a rich non-Newtonian behavior (yield stress, shear thickening, normal stress differences...), which is not yet fully understood. In particular, its link with the possible existence of direct contacts between the particles remains unclear.

We investigate the behavior of dense suspensions of monodisperse spherical particles [13] in a wide gap Couette geometry. We measure the torque/rotational velocity relationship for various shear histories. We also measure the velocity and particle volume fraction profiles thanks to MRI techniques. At the macroscopic scale, the systems display a torque plateau at low imposed shear rate, which is interpreted as a yield stress. They also show an irreversible discontinuous shear thickening behavior at moderate macroscopic shear rate. However, thanks to the local observations, we show that the intrinsic behavior is characterized by viscous and inertial behaviors only.

The macroscopic yield stress is associated with flow heterogeneity (shear banding): the material splits between a non flowing region and a region flowing at a shear rate higher than a critical value. In this last region, the local shear stress/shear rate relationship is shown to be linear: the material has a purely viscous behavior. We show that the flow instability is due to competition between slight sedimentation, which tends to create a contact network, and shear-induced resuspension.

The discontinuous macroscopic shear thickening is associated with very rapid shear-induced migration. At steady state, the material is heterogeneous. However, the combination of macroscopic and local measurements allows us to derive the local behavior of a homogeneous material; we then evidence a transition from a viscous ($\tau\alpha\dot{\gamma}$) to inertial ($\tau\alpha\dot{\gamma}^2$) local behavior. Migration is shown to be slow in the viscous regime, and rapid in the inertial regime. The macroscopic discontinuous shear thickening thus appears as a direct consequence of the existence of the intrinsic continuous shear thickening behavior. We finally discuss the volume fraction dependence of the locally observed behavior, and point out the role of direct contact forces in the observed behavior.

References

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