SEDIMENTATION AND RHEOLOGY OF CONCENTRATED EMULSIONS OF SPHERICAL DROPS BY DYNAMICAL SIMULATION

ALEXANDER Z. ZINCHENKO* AND ROBERT H. DAVIS †

* Department of Chemical
and Biological Engineering
University of Colorado
Boulder, Colorado 80309, USA
alexander.zinchenko@colorado.edu

† Department of Chemical
and Biological Engineering
University of Colorado
Boulder, Colorado 80309, USA

Large-scale dynamical simulations have been previously made [1] to study sedimentation and shear-flow rheology of concentrated emulsions of deformable drops at finite capilllary numbers, *Ca*. In many practical situations, though, deformability is small and prior simulation methods [1] meet prohibitive difficulties in this case due to localization of stress between nearly-touching, almost spherical drops and very tight stability limitations on the time step, etc. As the limiting case, we study here sedimentation and shear-flow rheology of emulsions of spherical drops, $Ca=0$.

In the absence of deformation, drops make 'contacts' in a finite time (despite singular lubrication), even in the absence of van der Waals forces. The algorithm dynamically traces these 'contacts' and incorporates 'contact' forces (representative of lubrication forces between slightly non-touching slightly-deformed drops); drops separate when the contacts become unloaded. A special iterative scheme is developed for the coupled contact mechanics-fluid mechanics problem, which allows calculation of these forces subject to the requirement of no-flux between contacting drops. The hydrodynamical part is handled by economical multipole techniques [1,2], with some new features for faster performance. The method is not based on pairwise additivity approximations and gives, instead, a practically exact solution of the multibody problem at each time step. Singular hydrodynamic resistance between nearly-touching drops is rigorously incorporated by the 'geometry perturbation' method [2], which reduces the multibody problem to a new one in the geometry with slightly shrunken drop radii and modified force balances.

Long-time simulations are made for drop volume fraction up to 50%, drop-to-medium viscosity ratios up to 3, and 200-400 monodisperse drops in a periodic box. In sedimentation, we study the effect of contact forces and dynamical microstructure on the sedimentation rate. For shear flow, the emulsion viscosity and normal stress differences are compared to those [1] for deformable drops at small but finite Ca. Compared to the idealized case of "well-mixed" emulsions, an emulsion in dynamical simulation with contact forces exhibits appreciably higher viscosity and appreciably smaller sedimentation rate. The first and second normal stress differences are both negative. In dilute limit, the first difference is dominant, but they are both negligible compared to the shear stress. At high concentrations, in contrast, both the first and second normal stress differences can be comparable to each other and only several times smaller than the shear stress.

References

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