McCormick

Northwestern Engineering

Computational Simulations of Electrohydrodynamics of Suspensions of Liquid Drops

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Interaction of electric field with an uncharged liquid drop has been a problem of long standing interest and finds relevance in a host of natural and industrial processes. Examples include disintegration of rain drops in thunderstorm and enhancement of coalescence and demixing in emulsions. Here, the mismatch between the dielectric properties of the drop and the host fluid results in electrical stresses at the drop surface, which can be utilized to regulate the drop. Experimental and theoretical studies of the subject have been mostly limited to investigations on the behavior of a single drop, or interactions of a pair. In practical applications, however, the goal is to manipulate a large number of drops. As such, the key to successful operation lies in understanding the underlying mechanisms behind the collective behavior of the drops. Unfortunately, such an understanding is currently lacking because of the complexity of the problem and involvement of small spatial and temporal scales which make the detailed experimental studies extremely difficult.

The aim of this study is to explore the electrohydrodynamics of a large number of liquid drops under a DC uniform electric field. A front tracking/finite difference technique is used to solve for the governing equations of the fluids inside and outside of the drops and to account for the interfacial jump conditions. The drops are initially spherical and distributed randomly in the computational domain; however, under the application of the electric field they deform to prolate or oblate ellipsoids and form columnar microstructures or horizontal rafts. This leads to dramatic change in the effective viscosity of the suspensions and other rheological properties compared to the corresponding ones at zero field. The study suggests that the relative magnitude of the electric conductivity ratio and the permittivity ratio (of the drop to that of the host fluid) of the suspension is the key parameter that determines the type of the microstructure and the subsequent change in the rheological properties of the suspension upon electrification.

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