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Droplets at Liquid-Fluid Interfaces: Pressure Field and Coalescence

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When a water droplet falls through oil to reach the interface above a water layer, it can remain at the interface for a prolonged time until coalescence takes place. A similar situation takes place when an oil droplet ascends through a water column and reaches the interface beneath an overlying oil layer. Several parameters affect the characteristic time to coalescence, including temperature, viscosity, relative densities and solubility. The purpose of this study is to gain further insight into the underlying mechanisms leading to coalescence.
We photograph droplets as they approach the liquid-liquid interface to assess the droplet and interface deformations; in particular, we obtain undistorted images of the droplet at the interface by matching the refractive index of silicone oil and a water-glycerol mixture, and determine the differential fluid pressure from continuous curvature measurements around the droplet (Young-Laplace). Results show that the droplet and the interface interact through the fluid pressure within the thin film that separates them; consequently, the droplet and the interface deform each other. Away from the interface, the droplet curvature responds to the interfacial tension □ between the two fluids; at the interface, the droplet curvature is proportional to ~2□ because of the double-surface structure of the thin film. More precisely, curvature measurements reflect the pressure gradient that drives fluid drainage within the liquid film and eventually leads to coalescence. Complementary observations show that an initially curved oil-water interface extends the time to coalescence (longer drainage path), confirm "dimple"formation at the interface (depends on viscosity), show droplets bouncing at interfaces (when they approach it with high terminal velocity), and indicate complex mutual interactions when multiple droplets reach the interface quasi-concurrently.
These results are relevant to a wide range of liquid-liquid and liquid-gas systems, such as emulsions, drug delivery, food preparation, cosmetics, painting, oil recovery, oil-water separation, offshore contamination, LNPL and DNPL migration, and augmented sealing capacity for geological CO2 storage.

Participation

In-Person

References

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