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Interface Dynamics during Droplet Impact on a Two-Fluid System

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Abstract

The liquid-liquid encapsulation process involves the impact of a core liquid drop into a two-fluid system, which involves a thin layer of compatible interfacial shell liquid floating on a host liquid bath and consequently obtaining stable, ultrafast encapsulated cargo of core liquid droplets wrapped with the interfacial shell liquid. The technology finds potential applications in the pharmaceutical and nutraceutical industries. Hence it is necessary to investigate the interfacial dynamics involved at the four-fluid interface during the impact process to identify the key process parameters for the desired core-shell morphology and the stability of the encapsulated cargo which is necessary for the commercialization of the process. The dynamics have been studied by varying three process parameters: impact Weber number, the volume of the interfacial liquid dispensed, and the thermophysical properties of the interfacial liquid. The impacting core drop dragged the interfacial liquid into the host liquid, forming an interfacial liquid column with an air cavity inside the host liquid bath. The dynamics was resolved into cavity expansion and rapid contraction, followed by thinning of the interfacial liquid. The air cavity underwent cavity closure dynamics and a necking process due to the interplay of hydrodynamic pressure, interfacial pull, viscous dissipation, and core drop inertia. The necking kinematics depended on the kinetic energy of the core droplet post-impact which is essentially higher with higher impact Weber number and lower with increased viscous dissipation. The viscous dissipation rises with the thickness of the interfacial layer, which depends on the volume dispensed and its radial spread over the water surface. The necking dynamics transitioned from inertia-dominated deep seal closure at higher Weber numbers and lower interfacial film thickness (lower volume and higher spread) into inertia-capillary-dominated deep seal closure with decreasing Weber number or increasing film thickness (increasing volumes and lower spread) and finally into a no-seal closure at low Weber numbers and high film thickness (high volumes and low spread). Post cavity closure, a thin cylindrical column of interfacial liquid remained which underwent a slow thinning process due to the interfacial pull from the bulk layer floating above and the descending encapsulated cargo below.