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Capillary-hydraulic jump in liquid foams

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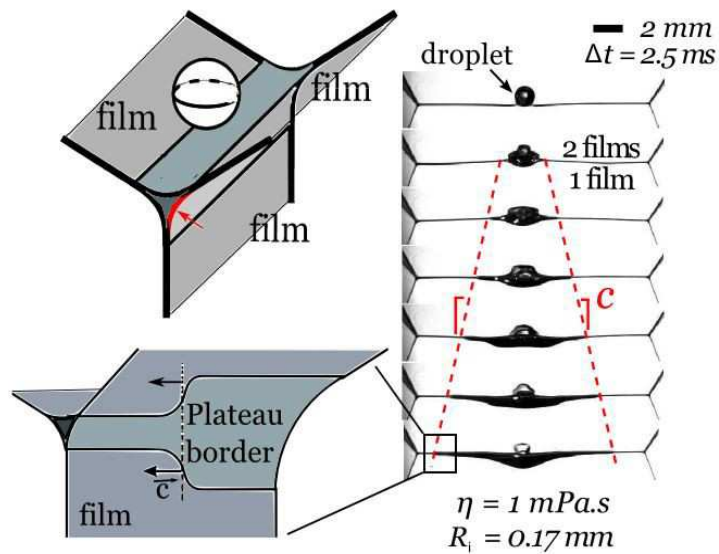
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Liquid foams are dispersion of gas bubbles in a continuous liquid phase. The organization of the liquid-gas interfaces is of paramount importance to understand the mechanical stability of such media. While soap films result from the contact between two bubbles, the contacts between three bubbles form a network of micrometer-thick liquid channels called “Plateau borders”. Due to their distinctive geometry, these unbounded channels (i.e. without rigid boundary conditions) are not prone to the Rayleigh-Plateau instability; this ensures the stability of the bubbles assembly.

The dynamics and stability of Plateau borders regarding a local perturbation are not well understood. Only few experiments were devoted to the Plateau border scale [1-4] and none of them dealt with transient regimes. We study a single, centimeter-long, horizontal, Plateau border (PB). We perturb it locally by dropping a droplet of liquid, which coalesces with the PB, and we follow the dynamics of the subsequent liquid imbibition. Because the PB is horizontal, gravity effects are negligible and the liquid flow is driven by capillarity only.

The transient flow is analyzed for several Plateau border radii and several bulk viscosities of the surfactant solution (in the high surface mobility regime). We find that an inertial regime precedes a viscous one, on a critical length that decreases as the bulk viscosity increases. The critical length can be as large as several centimeters for very thin Plateau borders and low bulk viscosities. This inertial regime is reported for the first time; it is characterized by the formation of a hydraulic jump, and by a fast (0.1-1 m/s) and constant imbibition velocity. The resulting Reynolds number is thus larger than one, even for micrometer-thick channels. We show that the liquid redistribution is triggered by an effective negative surface tension [5] and we propose a model based on the hydraulic jump geometry [6].

This study should have applications for liquid foam drainage [7], in particular to account for the exact shape of the front zone in forced drainage experiments [8]. The inertial regime might also be relevant to understand the liquid reorganization following bubbles rearrangements [9].



Figures: As sketched (top left), the experiment consists in dropping a droplet of the same surfactant solution on a single horizontal PB. The set of snapshots on the right shows the relaxation of the local perturbation after coalescence of the droplet with the PB, in the capillary-inertial regime. An outline of the capillary hydraulic jump geometry is given on the bottom left.

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