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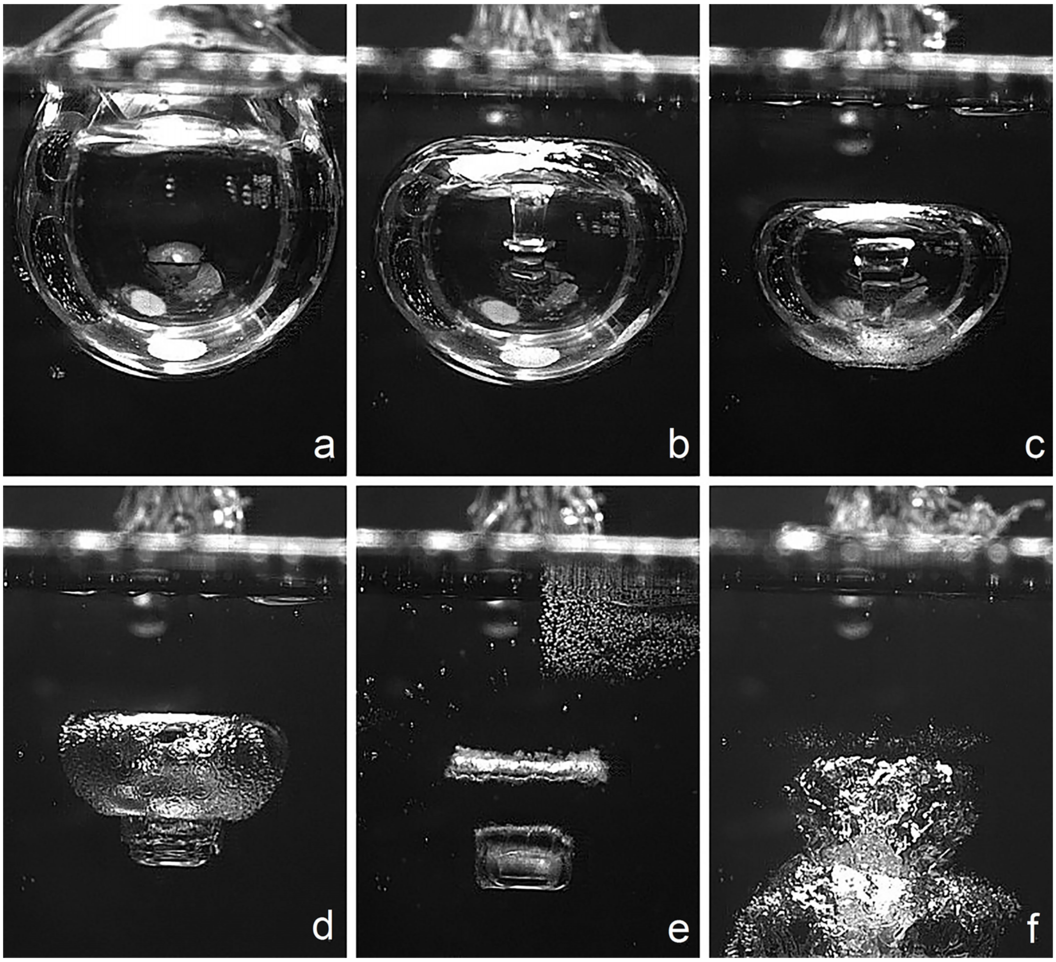

FIG. 1. A centimetric cavitation bubble collapsing in the vicinity of a free surface is pierced by a liquid microjet. The snapshots are shown from instants (a) $t = 0$, (b) $t = 0.3t_c$, (c) $t = 0.5t_c$, (d) $t = 0.7t_c$, (e) $t = 0.8t_c$, and (f) $t = 1.3t_c$, where the Rayleigh collapse time for a spherical bubble ($t_c = 0.915R_{\max}\sqrt{\rho/\Delta p}$[1]) is used as a reference. Source: APS-DFD (http://dx.doi.org/10.1103/APS.DFD.2014.GFM.V0084).

The inner world of a collapsing bubble

Outi Supponen,[1] Philippe Kobel,[1] Danail Obreschkow,[2] and Mohamed Farhat[1]
[1]*Laboratory for Hydaulic Machines, Ecole Polytechnique Fédérale de Lausanne, Avenue de Cour 33bis, 1007 Lausanne, Switzerland*
[2]*University of Western Australia, 35 Stirling Hwy, Crawley, WA 6009, Australia*

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When the sphericity of an unstable, spherical cavitation bubble is broken by pressure field anisotropies induced by nearby surfaces[2] or inertial forces such as gravity,[3] the bubble folds on itself and is pierced by a liquid microjet during its collapse. The jet leaves a protrusion when pushing along a part of the bubble's gaseous contents and is visible either with the rebound bubble or, in case of extreme deformations, even well before the collapse, as seen in Figure 1. Here, it is the vicinity

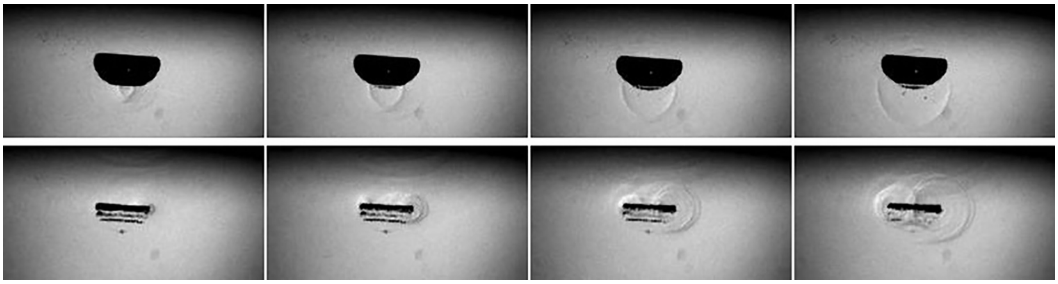

FIG. 2. Shadowgraphy visualizing the shock waves emitted as a result of the jet impact (upper row) and the toroidal collapse (lower row). Interframe time 300 ns and exposure 50 ns.

of a free surface that induces the broad jet by increasing the collapse speed of the upper part of a laser-generated bubble.

Peculiar dynamics within the bubble are revealed during the collapse of this violently deformed bubble. When advancing inside the bubble in a direction away from the free surface, the tip of the liquid jet has an interesting "mushroom cap" shape (Figure 1(b)), which is likely due to interface instabilities. The jet then impacts onto the opposite bubble wall, causing a set of shock waves to be emitted (Figure 2, upper row). In fact, the jet is so broad that its contact onto the interface is not a single point but a ring, for which the shock wave emission mechanism is more complex.[4] Part of the liquid jet forms a thin liquid sheet appearing to be a crown-splash within the bubble while the rest continues to pierce the wall, entraining a pocket of vapor. The crown splash arising from the impact at spectacular Reynolds and Weber numbers ($Re \approx 10^4$ and $We \approx 10^3$) shoots microdroplets onto the inner bubble wall, resulting in a capillary wave formation on the interface (Figure 1(d)). This phenomenon exhibits a striking resemblance to a droplet impact on a flat free surface where the formation of an "ejecta"-sheet has been reported at similar parameters.[5]

Following the impact, the bubble breaks into two parts as the vapor pocket entrained by the jet is separated from the main toroidal bubble.[6] At the moment of collapse of the "main" torus, a stronger set of shock waves is emitted (Figure 2, lower row), and when reflected from the free surface as a rarefaction wave, it results in tension in the liquid and hence excites nearby small bubbles (Figure 1(e)).[7] After the individual collapses of the two separate vapor cavities, an elastic rebound bounces off the violently compressed bubble contents forming a shape reminiscent of an upside-down mushroom cloud.

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