The shrinkage of surface bubbles

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ABSTRACT

The draining of a tank initially filled with a liquid is a common problem that impacts many processes in fields that include food and oil industries. Here, we investigate the case of deformable tanks by working with surface bubbles sitting on a thin solid plate with a circular orifice located under the apex of the bubble. We identify three different shrinking regimes, the occurrence of which depends on a combination of key parameters that include the ratio between initial bubble and orifice sizes and the physicochemical properties of the fluid system. For low-viscosity liquids and/or large ratios, a bubble remains quasi-hemispherical as shrinking proceeds (see Fig. 1). By contrast, for liquids with sufficiently large viscosities and/or small geometric ratios, a bubble seeks the shape of a spherical cap while the air inside it escapes through the orifice. In this case, shrinking proceeds with a bubble foot that either recedes over time or does not move for the largest viscosities and/or smallest ratios. A simple model based on Bernoulli's principle for the air flow, volume conservation and a friction law that accounts for viscous dissipation at the moving bubble foot allows us to rationalize the three regimes seen experimentally and to capture the shrinking dynamics.

Figure 1: The photographs illustrate one of the three scenarios of shrinking surface bubbles: in this case, a bubble remains hemispherical when it shrinks.