PINCH-OFF IN LIQUIDS, BUBBLES, AND LENSES

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Breakup of droplets and bubbles is important for a variety of industrial processes, and is an important component of many complex fluid phenomena. Pinch-off is also a prototype system described by relatively simple dynamical equations which exhibits a spontaneous finite time singularity. One of the central issues in understanding fluid pinch-off is to classify the possible types of singular behavior, and in particular to understand the conditions for which the singularity is self-similar and universal.

We have experimentally studied pinch-off phenomena in a variety of different systems including liquid mercury, nitrogen bubbles in liquids with a wide range of viscosity, and hydrocarbon lenses on the surface of water. Our experiments with liquid mercury utilize a a high speed oscilloscope to monitor the electrical conductivity of a mercury contact during pinch-off[1]. Electrical measurements have several advantages over more conventional video imaging techniques. They have subnanosecond time resolution, and because they are not limited by diffraction, they are useful even in the nanometer regime. Inviscid pinch-off is expected to obey the scaling law $R \sim \tau^{\frac{2}{3}}$, where R is the minimum neck radius and τ is the time before the break. Our measurements using mercury have verified this relation down to spatial dimensions approaching atomic scales, which is orders of magnitude better than previous optical techniques. Our experiments on bubble pinch-off use high speed video, and have shown that bubble pinch-off is quite different from liquid droplet pinch-off[2]. The exponents governing the neck radius range from $R \sim \tau^{\frac{1}{2}}$ for low viscosity exterior fluids to $R \sim \tau$ for high viscosity exterior fluids. For a narrow range of intermediate viscosities, we observe long threads of gas a few microns in diameter.

Dimensionality is an important parameter in critical phenomena in thermodynamic phase transitions, so it is of some interest to explore the role of dimensionality in flow singularities. We report some exploratory investigations using pinch-off of thin hydrocarbon lenses on water as an approximation of a 2D drop. In some regimes we find sharply pointed conical pinch structures which are qualitatively similar (but quantitatively different) from invisid 3D pinch-off. In other regimes , we find a complex hierarchical sequence of pinches on many length scales which leads to many satellite droplets.

References

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[2] J.C. Burton, R. Waldrep, and P. Taborek “Scaling and Instabilities in Bubble Pinch-off” Phys. Rev. Lett. **94**, 184502, (2005).

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