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Understanding mudpots: Dynamics of bursting bubbles in viscoplastic medium

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We study the dynamics of bursting bubbles in a viscoplastic medium using full scaled detailed numerical simulations. Deike et al., 2018 has provided quantitative cross-validation of the numerical and experimental studies for Newtonian liquids. Nonetheless, the literature lacks comprehensive research on the influence of liquid pool properties on the bubble bursting process. Notably, the influence of rheological properties on the scaling laws can provide a close-up to the understanding of the phenomenon. In particular, we are interested in the dynamics of bubbles in mudpots where the mud behaves like as a viscoplastic liquid.

First, the air bubble, generated in the liquid bulk, being lighter than the surrounding medium, rises because of buoyancy and reaches the liquid-air interface. It stays there as the thin film between the bubble and the free surface drains. We find this initial shape of the bubble cavity by solving a set of non-linear and coupled Young's Laplace equations (similar to the method of Lhuissier and Villermaux, 2012). The thin liquid film then ruptures and results in an open cavity.

The cavity collapses leading to the interaction of the capillary waves. For Newtonian liquids, depending on the size of bubbles (Bond number) and viscous effects (Laplace number), this collapse may lead to the formation of a Worthington jet. Figure 1(a) illustrates one such example in which the collapse of the cavity leads to the formation of a thin high-velocity jet. Rayleigh-Plateau instability leads to the formation of droplets. Introduction of non-Newtonian fluids can significantly influence the process. At moderate values of yield stress, the collapse of the cavity can still lead to the formation of Worthington jet, but the high effective viscosity suppresses the droplet formation (Figure 1(b)). Furthermore, interactions of the capillary waves lead to a non-trivial "wavy "yield surface. At high values of yield stress, the unyielded region of the viscoplastic fluid can seize the collapse of this cavity which leads to distinct equilibrium shapes (Figure 1(c)). Finally, we categorize the final shapes of the craters using relevant non-dimensionalized numbers (Laplace, Bond and normalized yield stress).

References

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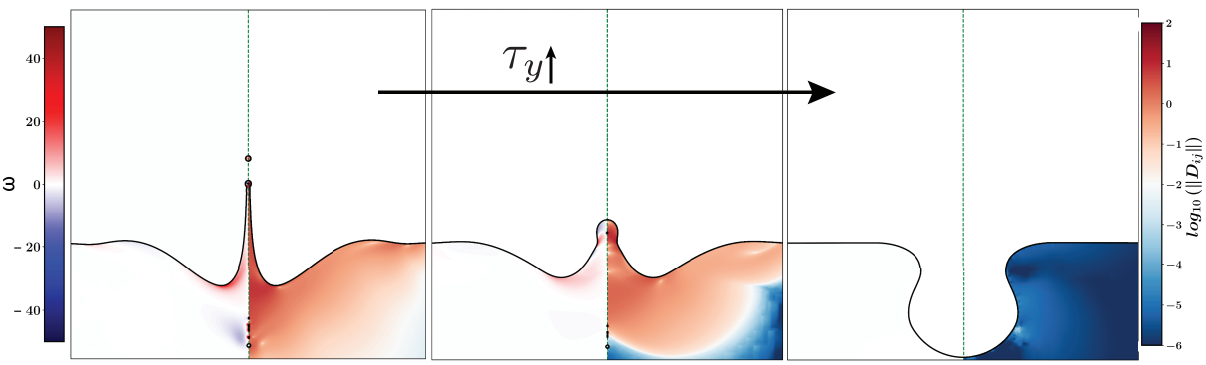

Figure 1: Influence of yield stress (τ_y) of the viscoplastic fluid on the process of bursting bubbles. In each figure, the left shows vorticity and right shows $log_{10}(\|D_{ij}\|)$ where $\|D_{ij}\|$ is the second norm of deformation tensor. Blue is the unyielded region.