Bubble clouds generated by single and multi-plunging jets

Narendra Dev[1], J.John Soundar Jerome[1], Hélène Scolan[1] , Jean-Philippe Matas[1]

Univ Claude Bernard Lyon 1, CNRS, Ecole Centrale de Lyon, INSA Lyon, LMFA, UMR5509, 69622 Villeurbanne, France
narendra.dev@univ-lyon1.fr

The impact of a plunging jet with a liquid surface induces air entrainment beneath the surface, resulting in the formation of a bubble cloud (Fig. 1). This phenomenon is widely encountered in nature, such as breaking waves in water bodies, and in industrial techniques aimed at reducing foam formation in chemical processes. The depth (H) of this bubble cloud is an important parameter for modeling in such applications [1] . By employing laboratory-scale experiments and optical probes to carefully measure the local bubble void fraction (ϕ), we demonstrate that a simple momentum balance, including only liquid inertia and the buoyancy force due to the bubble cloud volume, provides a very good estimate for H when ϕ is known. Furthermore, we show that bubble clouds can be classified as inertial or buoyancy-dominated [2] based on a Froude number given by a characteristic bubble terminal speed, cloud depth and the net void fraction of the cloud [3]. Thereby, our findings help unify a large body of data in the literature corresponding to a wide range of injector diameters (250 μ m - 20 cm) and cloud depths from a few centimetres to a few metres. Finally, we use a simple set-up of closely packed multi-injectors as a model to investigate air entrainment by large scale plunging jets. Our preliminary results confirm that inertia imparted by the plunging liquid jet and the bubble cloud volume are sufficient to determine the cloud depth even in such complex cases, provided the bubble void fraction is given.

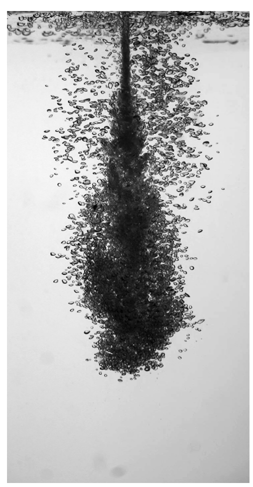

Figure 1. Instantaneous image of conical bubble cloud formed by plunging jet.

Références

1. C. Clanet & J.C. Lasheras, Depth of penetration of bubbles entrained by a plunging water jet, *Phys. Fluids*, **9**, 1864–1866 (1997).
2. G. Guyot , A. Cartellier & J.P Matas, Penetration depth of a plunging jet : from microjets to cascades, *Physical Review Letters*, **124 (19)**, 194503-1–194503-5 (2020).
3. N. Dev , J. John Soundar Jerome, H. Scolan & J.P Matas, Liquid inertia versus bubble cloud buoyancy in circular plunging jet experiments, *Journal of Fluid Mechanics*, **978**, A23-1 –A23-18 (2024).