Ventilation phenomena of a cavitation bubble induced by the Rayleigh-Taylor instability near a water surface

Jingzhu Wang (presenter)a,b, Guanghang Wang a,c, YiweWang a,b,c

a Key Laboratory for Mechanics in Fluid Solid Coupling Systems, Institute of Mechanics, Chinese Academy of Sciences, Beijing 100190, PR China; b School of Engineering Science, University of the Chinese Academy of Sciences, Beijing 100049, PR 9 China; c School of Future Technology, University of the Chinese Academy of Sciences, Beijing 100049, PR China

The behaviour of an oscillating bubble under the constraint of a water surface can be classified as an open bubble completely exposed to the atmosphere and toroidal collapse resulting from the re-entering jet. In the present study, we observe a new phenomenon of partial ventilation. As the bubble expands, the perturbed water surface develops and penetrates the bubble wall such that ambient air rapidly rushes into its interior. The bubble becomes nontransparent since the air flow disturbs the bubble wall. Three distinct types of bubble behaviour with decreasing dimensionless stand-off distance 𝛾 are summarized: (i) non-ventilation, (ii) partial ventilation, and (iii) complete ventilation, depending on whether ambient air enters the bubble interior. We investigate the partial ventilation phenomena through a combination of laboratory experiments, numerical simulations, and analytical modelling. An analytical model considering the Rayleigh-Taylor instability and bubble oscillation is developed based on the assumption that the fluid is inviscid, irrotational and incompressible. The analytical model is solved to obtain the criteria of the partial ventilation regime. These criteria include upper and lower bounds for the dimensionless time to start ventilating 𝑡𝑐 and the dimensionless stand-off distance 𝛾𝑐. The analytical estimates show good agreement with the experimental observations.

Acknowledgments: This work was supported by the National Natural Science Foundation of China (12202291, and 12272382, 12293000, 12293003, 12293004) and the Youth Innovation Promotion Association CAS (2022019).