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Unraveling the mechanics of liquid-liquid impacts: a computational window into micro-bubble entrapment in oceans

By

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2:30- 4:00 PM

Abstract:

Micro-bubbles have a long residence time under the free surface, influencing heat and mass transfer and the traceability of ship vessels in oceans. Hence, the formation mechanism of such bubbles is of great interest. Based on evidence from drop-pool impact experiments, the leading hypothesis for micro-bubble formation is Mesler entrainment. In this process, liquid interfaces collide, entrapping a thin gas film that sheds hundreds of micro-bubbles after its rupture. Before the work presented here, there was a limited understanding of Mesler entrainment due to the microscopic scales involved and a lack of quantitative data related to the film and micro-bubbles. Understanding Mesler entrainment has practical value in modeling micro-bubble generation in large-scale multiphase flow simulations. This talk briefly introduces a novel diffuse interface method for the simulation of complex multiphase flows. Afterward, the drop-pool impact is examined as a model problem to reveal how collisions between two arbitrarily curved interfaces can lead to microbubble generation. A capillary transition that prevents early contact is discovered using boundary integral method (BIM) simulations and theoretical analysis. This transition allows the drop to penetrate further into the pool, providing a pathway for the formation of elongated films required for Mesler entrainment. The spreading kinematics of the drop after transition and asymptotic scaling laws governing the film thickness are described. Using a linear stability analysis, intermolecular Van der Waals forces are shown to trigger the rupture of the thin film. Employing the novel diffuse interface method implemented in high-performance in-house software, post-rupture dynamics of the film are numerically simulated to reveal a new scaling law for gas film retraction velocity. Additionally, using high-fidelity 3D simulations, a transverse instability on the edge of the film is shown to be responsible for micro-bubble generation. Similarities between this multi-stage, multi-scale multiphase flow problem and the additive manufacturing process of liquid metal jetting, are outlined in the conclusion.

Speaker Biography:

Dr. Shahab Mirjalili is currently employed as a research associate in the Department of Mechanical Engineering at Stanford University. He earned his Ph.D. in Mechanical Engineering from Stanford University in 2019, where he was supervised by Professor Ali Mani. His doctoral work focused on developing numerical methods for simulating multiphase flows with application to studying micro-bubble generation in oceanic environments. Prior to his Ph.D., Shahab received an MS from Stanford University and a BS from Sharif University of Technology, both in Mechanical Engineering. In 2018, he was awarded the Gallery of Fluid Motion Award by the American Physical Society Division of Fluid Dynamics. Broadly, Shahab's research lies in the intersection of fluid mechanics, scientific computing, and machine learning. He aims to develop and use computational methods to improve our predictive understanding of complex multiphase flow problems involving multi-physics interactions across a broad range of scales and Reynolds numbers. He is particularly interested in applying his research to additive manufacturing processes, biophysical systems, energy conversion/storage, and environmental flows.

Hosted by: Prof. Reza Alam, (reza.alam@berkeley.edu)