MECHANICAL ENGINEERING SEMINAR

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Mechanics of bubble bursting in dilute oil-in-water emulsions

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Bubbles bursting at contaminated water surfaces aerosolize oil, microplastics and bacteria, with consequences for public health and climate. The classical description, in which a draining cap ruptures at a single hole and the retracting rim fragments into film droplets, was established for clean or surfactant-laden liquids. How dispersed oil droplets, which may occur in dispersant-treated spills and industrial wastewater, reshape rupture topology and droplet yield has remained unclear.

In this seminar, after briefly outlining my laboratory and field multiphase-flow thrusts at GTIIT, I present our experiments on centimetric bubbles that (i) reveal multi-hole rupture, previously unreported on a bubble cap, in which oil droplets with a positive spreading coefficient, comparable in size to the cap thickness, excavate thin spots and up to 47 holes open in a single burst, (ii) show that bubble lifetime still sets the film thickness through capillary-viscous drainage, which oil accumulated at the bubble foot retards through Marangoni stress, and (iii) establish a drop-yield law, growing as the square root of the hole number through the active rim length, that collapses the multi-hole data onto one master curve. The first hole forms preferentially near the foot, a second about 2 ms later, and the rest cascade at intervals of order 0.1 ms, after which colliding rims form a convoluted ligament network that can generate an order of magnitude more droplets than the classical scaling predicts. I also discuss the surprising finding that a tenfold increase in oil fraction leaves the film thickness at a given lifetime unchanged yet raises the probability of multi-hole bursting from 2.3% to 40.1%, with this probability and the droplet yield both peaking within a lifetime window of 4 to 9 s, in which the film is thin enough to rupture yet persists long enough for further holes to form. I close with the open question of what triggers the sub-millisecond cascade.

Dr. Cheng Li received a B.E. in Engineering Mechanics and a B.S. in Mathematics from Beijing University of Aeronautics and Astronautics in 2010, and a Ph.D. in Mechanical Engineering from Johns Hopkins University in 2017. From 2017 to 2021 he was a postdoctoral researcher at the National Energy Technology Laboratory of the US Department of Energy and at the University of Minnesota. He joined the Guangdong Technion-Israel Institute of Technology in 2021, where he is an Associate Professor in the Department of Mechanical Engineering and Robotics. His research covers experimental multiphase flow, bubble bursting and spray dynamics, optical flow diagnostics, and UAV-based environmental multiphase flow sensing.