ME Seminar

From unstable jets to levitating droplets: Exploring instability, forcing, and interfacial dynamics in fluid flows

Dr. Abhijit Kushwaha, Postdoctoral Fellow, KAUST, Saudi Arabia

ABSTRACT

Fluid systems, ranging from free shear flows to levitating droplets, are ubiquitous in numerous technological processes such as thermal plasma spraying, electronic cooling, and fuel injection. These flows exhibit rich dynamics driven by instability, symmetry breaking, and nonlinear coupling across scales. Controlling such dynamics is crucial for applications in heat transfer, energy systems, and flow manipulation. This talk will highlight two distinct studies that explore how external forcing and interfacial physics govern flow dynamics across regimes.

The first part focuses on globally unstable, self-excited axisymmetric jets, showing how different forcing symmetries influence the spatiotemporal dynamics of globally unstable jets through their distinct modal interactions. Specifically, the transverse forcing breaks the intrinsic axisymmetry of the global mode by exciting helical modes, while the axial forcing preserves it, demonstrating that forcing symmetry can either amplify or suppress global oscillations. The nonlinear dynamics of these forced jets can be captured through low-dimensional models based on a pair of coupled VDP oscillators or complex Ginzburg-Landau equations. The second part explores droplet dynamics on non-wetting surfaces, where a transition from partial wetting to aerodynamic levitation occurs as a lubricating air-film forms beneath the droplet. The air-film thickness is characterized by reflective interference contrast microscopy (RICM) and spectroscopic reflectometry. In this talk, I will uncover distinct friction regimes governed by contact-line pinning, viscous dissipation, and aerodynamic drag over a broad range of velocities and viscosities, and present force-based scaling laws that capture the transition between these regimes as a function of the capillary number. I will demonstrate that droplets up to 450 times more viscous than water can levitate due to the spontaneous air-film formation beneath the droplets, enabling them to glide or even fly on ordinary surfaces where they would otherwise move thousands of times slower. These findings reveal that thick liquids as honey, can move at speeds comparable to water when aerodynamically levitated. This talk will conclude with prospects for interfacial flow control and the design of adaptive non-wetting surfaces for liquid transport, condensation, and bioinspired applications.

ABOUT THE SPEAKER

Dr. Abhijit Kushwaha is an experimental fluid dynamicist specializing in advanced optical diagnostics, droplet dynamics, and flow control. He is currently a Postdoctoral Fellow in the Splash Lab at KAUST. His research integrates precision experiments-such as stereoscopic PIV, high-speed imaging, interferometry, and microfabrication- with theoretical modeling to uncover the fundamental physics of complex flows and liquid-surface interactions. He is a recipient of the prestigious Ramanujan Fellowship awarded by the ANRF, Government of India. Dr. Kushwaha earned his Ph.D. from the Hong Kong University of Science and Technology (2021) and M.Tech in Aerospace Engineering from the Indian Institute of Technology Kanpur (2016). During his doctoral studies, he also spent a year as a visiting scholar at NTNU, Norway. His work spans from the control of combustion-driven instabilities and open-loop manipulation of globally unstable flows to micro-Newton-scale friction measurements and droplet dynamics on non-wetting surfaces. His research aims to advance both fundamental understanding and practical design strategies in microfluidics, aerospace, biomedical systems, and industrial fluid transport processes.

7th November 2025, 4:00 PM, Online (MS Teams)