Fluid Instabilities and Mixing in Variable Density Flows at Extreme Conditions

ABSTRACT

Mixing is central to several important phenomena in nature and engineering. Rayleigh-Taylor (RT) and Richtmyer-Meshkov (RM) driven wrinkles at the interface of materials lie at the heart of an overarching science for material mixing that stretches from oil trapping salt domes, that develop over tens of millions of years, to degradation of Inertial Confinement Fusion (ICF) capsule performance in 10-12 ns. Everyday phenomena include mixing of milk into coffee, and emptying of water from a glass. Technological and environmental applications include: drop disintegration in engine fuel sprays, enhanced heat transfer in tubes, plasma instabilities, material component mixing in the pharmaceutical industry, and buoyancy driven flows in the oceans and atmosphere. RT and RM are insidious instabilities that start with exponential growth of small scale perturbations, and end in a fully turbulent mixing process. It is this scale range and chaotic nature that challenges our experimental capabilities and physical understanding. But, the timely need to understand, predict, control, and utilize is because RT/RM mixing lies at the heart of national security priorities such as energy, threat reduction, and NNSA interests. Should the relationship between initial conditions and mixing be determined, then, in principle, the level of mixing could be controlled through the setting of specific conditions. In this talk, I will describe the results of laboratory experiments for the study of shock-accelerated spherical interfaces (soap bubbles filled with a gas different than its surroundings) with and without combustion. This particularly simple geometry falls within the broader category of “shock-accelerated inhomogeneous flows” (Ranjan et al., Ann. Rev. Fluid Mech., 43, 117-140, 2011), viz. the propagation of a shock wave (not necessarily planar) through a medium of variable thermophysical properties. In these experiments, flow visualizations are obtained using planar laser diagnostics (Mie-scattering and Planar laser-induced fluorescence). Quantitative analysis of the experimental data includes the vortex core velocity, and subsequent circulation calculations, along with a new set of relevant geometrical length scale measurements to highlight the effects of shock focusing in this environment.

BIO

Dr. Devesh Ranjan is an assistant professor in the Department of Mechanical Engineering, having joined the Texas A&M faculty in 2009. He was previously a postdoctoral research associate and a director's research fellow at Los Alamos National Laboratory. He earned a bachelor's degree from the National Institute of Technology, Trichy (India) in 2003, and master's and Ph.D. degrees from the University of Wisconsin in 2005 and 2007 respectively, all in mechanical engineering. His research interests are in the area of turbulence and mixing at extreme conditions, analysis of shock-driven flows, and design of thermal systems. In 2013 he was named a recipient of the Young Investigator's Research Program Award (YIP) by the Air Force Office of Scientific Research and the National Science Foundation CAREER Award.