Center for Environmental & Applied Fluid Mechanics

“Liquid Breakup at Supercritical Conditions: Toward Understanding Mixing and Combustion at Extreme Conditions”

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The design of liquid-fueled propulsion systems has shifted toward high pressures and temperatures exceeding the critical point of the fuel-air mixture, known as supercritical conditions to enable performance gain, lighter and more reliable systems for aviation, power generation, ground and space transportation. Shock interaction with fuel sprays or a dense droplet medium is a multiscale phenomenon governing shock-enhanced mixing in liquid-fueled scramjets and rotating/pulsed detonation engines that can revolutionize the design of future commercial hypersonic flights. However, our understanding of the interaction of shock-laden flows with liquid droplets is significantly less developed than its gas-phase counterpart. Meanwhile, the complex behavior of multiphase flows at supercritical conditions is less understood due to the dearth of detailed experimental data at such extreme conditions. I will introduce a new computational framework comprised of Molecular Dynamics and Direct Numerical Simulations and elucidate the mechanisms underlying shock-driven droplet breakup at supercritical conditions from molecular-level interactions to higher scales. The results indicate that supercritical droplet-shock interaction poses unique shock dynamics departing from its subcritical counterpart causing droplet transition from classical two-phase breakup to gas-like diffusion mixing. The generated knowledge establishes the secondary droplet breakup morphologies at supercritical conditions for the first time which will pave the way toward a better understanding of supercritical fuel/air mixing and achieving more stable combustion processes in the next generation of high-speed propulsion systems.

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