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Simulation of a Shockwave Impacting a Near-critical Fuel Droplet

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Shock-droplet interactions occur in a spectrum of high-speed propulsion systems involving liquid fuels. When the combustion chamber pressure nears the critical pressure of the fuel/air mixture, transcritical behavior involving the transition from liquid-like to gas-like states is observed. Our understanding of multiphase-shock interaction is significantly less developed than its gas-phase counterpart and is particularly limited at transcritical conditions. We consider the interaction of a shockwave with a liquid droplet at near-critical conditions. A fully-conservative diffuse-interface framework coupled with the Peng-Robinson equation of state and a vapor-liquid-equilibrium solver is developed to accurately determine the state of the fluid as the shock propagates through the droplet. The thermodynamic state of the droplet changes by the passage of the shock and rarefaction waves causing the droplet interface to transition from a diffusion-controlled mixing that prevails at supercritical conditions to two-phase disintegration as phase separation occurs. The influence of varying the initial temperature of the liquid and the shockwave strength on the droplet breakup and interface transition from supercritical to subcritical (and vice versa) is delineated.

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