DNS of Flash Atomization in Cryogenic Rocket Propellants

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Abstract

Flash boiling can occur in rocket thrusters operating in the vacuum of space when cryogenic propellants are injected into the reaction chamber that is initially at low pressure. This process determines the spray atomization that will then drastically affect the mixing of fuel and oxidizer, the reliability of the ignition and the subsequent combustion process. However, the mechanics of the primary breakup occurring in flash boiling conditions is not well understood and very difficult to observe. A multi-phase solver with interface capturing using the Volume of Fluid (VOF) method and PLIC reconstruction is used to perform direct numerical simulations (DNS) of the primary breakup of the liquid oxygen jet at the microscopic level. The breakup is driven by homogeneous nucleation of bubbles in the superheated liquid, followed by their growth, coalescence and bursting, generating a spray of small droplets. Simulations with regular arrays of bubbles demonstrate how the initial bubble spacing and thermodynamic conditions can be correlated to a range of Weber and Ohnesorge numbers, resulting in very distinct breakup mechanisms and liquid structures. Clusters of randomly distributed bubbles, are simulated and used to obtain statistical data on droplet size distribution, ligament surface area, velocities and other spray characteristics. This is demonstrated in a case with high Weber number. These results can be used to calibrate sub-grid-scale models for large-scale simulations of the injector and spray.

Keywords: Multiphase DNS, Flash boiling, cryogenic rocket propellants

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