Multi-phase flow modeling using entropy symmetrization and variational calculus for jet atomization simulations

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Mots-clés : Multiphase flow, thermodynamics, entropy symmetrization, variational calculus, numerical simulation

Jet atomization plays a crucial role in many applications such as in cryogenic combustion chambers, thus must be thoroughly studied to understand its impact on high-frequency instabilities. Since direct numerical simulations of these two-phase flows in a real engine are still out of reach, predictive numerical tools must be developed using reduced-order models. However great care must be taken on the choices of these models in order to reach sound mathematical properties and predictive simulations after a validation process. The contribution of this talk is three-fold. First, we present two original Eulerian diffuse interface models describing various disequilibrium level of the mixture. Both are based on the extension of the usual multi-phase flow thermodynamic to include a mixture entropy contribution [1, 4]. Doing so, a strictly convex entropy is obtained permitting first to symmetrize in the sense of Mock and Godunov [5] the existing Baer-Nunziato seven equations model [7]. Then, the extended thermodynamics also helps in defining an extended Lagrangian energy $\mathcal{L}$. The Least Action Principle combined to the entropy inequality returns new governing equations for the system under consideration [3]. This method hence depicts a coherent mathematical system of equations and is compared to the symmetrized Baer-Nunziato seven equations model. Second, to cope with the strong discontinuities encountered in jet atomization, a robust and accurate numerical method using multi-slope MUSCL technique will be applied [6]. The extension of the proposed strategy to the various levels of the diffuse interface models will be discussed. Third, relying on the previous two points, large eddy simulations of a jet atomization in a cryogenic combustion chamber in subcritical conditions are presented using a hierarchy of diffuse interface models coupled with an Eulerian kinetic-based moment method (KBMM) [8]. Numerical results of jet atomization on the test bench MASCOTTE (ONERA) should eventually be obtained.

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