
# Contribution to the study of combustion instabilities in cryotechnic rocket engines: coupling diffuse interface models with kinetic-based moment methods for primary atomization simulations

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**Résumé**

Gatekeepers to the open space, launchers are subject to intense and competitive enhancements, through experimental and numerical test campaigns. Predictive numerical simulations have become mandatory to increase our understanding of the physics. Adjustable, they provide early-stage optimization processes, in particular of the combustion chamber, to guaranty safety and maximize efficiency. One of the major physical phenomenon involved in the combustion of the fuel and oxidizer is the jet atomization, which pilotes both the droplet distributions and the potential high-frequency instabilities in subcritical conditions. It encompasses a large sprectrum of two-phase flow topologies, from separated phases to disperse phase, with a mixed region where the small scale physics and topology of the flow are very complex. Reduced-order models are good candidates to perform predictive but low CPU demanding simulations on industrial configurations but have only been able so far to capture large scale dynamics and have to be coupled to disperse phase models through adjustable and weakly reliable parameters in order to predict spray formation. Improving the hierarchy of reduced order models in order to better describe both the mixed region and the disperse region requires a series of building blocks at the heart of the present work and give on to complex problems in the mathematical analysis and physical modelling of these systems of PDE as well as their numerical discretization and implementation in CFD codes for industrial uses. Thanks to the extension of the theory on supplementary conservative equations to system of non-conservation laws and the formalism of the multi-fluid thermodynamics accounting for non ideal effects,we give some newleads to define a strictly convex mixture entropy consistent with the system of equations and the pressure laws, which would allow to recover the entropic symmetrization of two-phase flow models, prove their hyperbolicity and obtain generalized source terms.

Furthermore, we have departed from a geometric approach of the interface and proposed a multi-scale rendering of the interface to describe multi-fluid flow with complex interface dynamics. The Stationary Action Principle has returned a single velocity two-phase flow model coupling large and small scales of the flow. We then have developed a splitting strategy based on a Finite Volume discretization and have implemented the new model in the industrial CFD software CEDRE of ONERA to proceed to a numerical verfication. Finally, we have constituted and investigated a first building block of a hierarchy of test-cases designed to be amenable to DNS while close enough to industrial configurations in order to assess the simulation results of the new model but also to any up-coming models.

**Mots clés**
Reduced-order two-phase-flow models, multi-fluid thermodynamics, dual-scale interface dynamics, variational calculus, approximate Riemann solvers, numerical simulations.