Two-phase separated and disperse flow : towards a two-scale diffuse interface models with geometrical variables

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Multi-fluid two-phase combressible flows play a critical role in numerous industrial processes and some of them highly depend on the interface dynamic such as in combustion chambers or potential leak scenario in pressurized-water nuclear power plants. Indeed, separated and dispersed phases *i.e. spray of small droplets* coexist in such flows and therefore, a large number of droplets and a broad spectrum of sizes are involved. Direct Numerical Simulations (DNS) using a Lagrangian approach or an interface-tracking Eulerian one are often not tractable for industrial applications because of this multi-scale behaviour.

Two-scale Eulerian models with diffuse interface then propose an economical alternative thanks to the modeling of a sub-scale flow below the mesh resolution. Aiming such models, the Stationary Action Principle (SAP) and the second principle of thermodynamics [4] greatly help to construct a coherent two-phase flow model from given potential and kinetic energies. Several works [3, 1] indicate that additional geometrical variables (interfacial area density, surface average of mean and Gauss curvatures) is a path to describe these sub-scale phenomena and establish two-scale models but the possibilities of enrichment are numerous and need to be more carefully studied.

Pursuing the efforts of sub-scale flow modeling led in [2], our research work focus on the two-fold potential of these geometrical quantities for both modeling the sub-scale flow and its interaction with the large scale flow. In this work [6], we are using differential geometry to assess the right modeling usage of these geometrical quantities through the comparison of theoretical perturbation of droplets and DNS post-processing. These results will then be used to construct energies and constraints for our SAP-derived two-phase two-scale models which are tested using `Josiepy` a finite-volume solver [5].

[1] P. Cordesse. *Contribution to the study of combustion instabilities in cryotechnic rocket engines : coupling diffuse interface models with kinetic-based moment methods for primary atomization simulations.* PhD Thesis, Université de Paris-Saclay, 2020.

[2] P. Cordesse, R. Di Battista, Q. Chevalier, L. Matuszewski, T. Ménard, S. Kokh, M. Massot. *A diffuse interface approach for disperse two-phase flows involving dual-scale kinematics of droplet deformation based on geometrical variables.* In *ESAIM : Proceedings*, p. 22, 2020.

[3] D. A. Drew. *Evolution of geometric statistics.* SIAM Journal on Applied Mathematics, **50(3)**, 649–666, 1990.

[4] S. Gavrilyuk, H. Gouin. *A new form of governing equations of fluids arising from Hamilton's principle.* International Journal of Engineering Science, **37(12)**, 1495–1520, 1999.

[5] A. Loison, R. Di Battista, S. Kokh, M. Massot, T. Pichard. *Diffuse interface model for two-phase two-scale flow using stationary action principle, geometrical variables and a finite-volume method.* In preparation, 2021.

[6] A. Loison, S. Kokh, M. Massot, T. Pichard. *Sub-scale modeling for eulerian two-phase flows : analysis of a perturbed droplet using differential geometry.* In preparation, 2021.

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