A robust multislope MUSCL method formulation for two-phase flow simulations inside solid rocket motors

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Various models have been designed to describe two-phase disperse flow. Among them, approaches based on the Williams-Bolztmann transport equation, approximated through a moment method, provides realistic and efficient solutions for particle flows of low and moderate inertia. Relying on the mathematical tools historically developed in kinetic theory of gases, it is possible to use closures guarantying the second fundamental principle of thermodynamics and the, eventually weak, hyperbolicity of the governing equations. Such well-posed systems of equations generate non-linear behaviors eventually leading to sever singularities. Both the classical monokinetic closure and the Anisotropic Gaussian closure, recently proposed for particle-laden flows [1] potentially can lead to vacuum areas, shocks and even δ-shock (discontinuity in velocity coupled to a Dirac delta function in density) for the monokinetic closure. Therefore, the resolution of these equations has to rely on dedicated numerical methods able to cope with singular solutions, leading to robustness, while proposing an accurate resolution of regular zones of the flow.
Part of the Godunov class of scheme, finite volume second order accurate MUSCL methods are known to be able to resolve discontinuity and avoid spurious oscillations. For multi-dimensionnal problems and general unstructured mesh, the multislope variant [2] provides an efficient formulation able to cope with sharp gradient, while preserving an accurate solution. Such formalism, depending on the limiter and the Riemann solver used, can provide LED properties and preserve the realizability of the moments.
We propose in this communication to present new features within this framework for disperse phase simulations resulting from a long-term collaboration between ONERA and EM2C Laboratory. We focus on the reconstructed variables providing realizable reconstructed states, procedures avoiding 'saw-tooth' reconstructions, Riemann problems providing positivity and procedures ensuring asymptotic behaviors near vacuum and pressureless areas. Through these developments, the key relationship between the governing equations and the numerical strategy is pointed out. The provided improvements are illustrated by simulations of solid rocket motor flows for which both the modeling of the aluminum oxide spray of particles and its accurate and robust numerical resolution are critical issues [3]. In these conditions, preserving the mathematical properties cited above is crucial to ensure the success of such simulations.

Références

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