A SHARP DIFFUSE-INTERFACE APPROACH TO COMPRESSIBLE MULTI-FLUID FLOWS

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ABSTRACT

We propose a numerical model for simulating the flow of N ($N \geq 3$) different compressible materials separated with interfaces. Our model is based on the diffuse-interface method and generalizes the five-equation model of Allaire [1].

The model is constructed in a quasi-conservative form. The conservative part of the model consists of the conservation equations for mass of each component, total momentum and total energy. The non-conservative equations represent advection of $N-1$ characteristic functions that depend on volume fractions of the components. The model is closed by the isobaric assumption.

We study the following mathematical properties of the model: consistency and preservation of constant-pressure equilibrium. To ensure the latter property, we prove that the characteristic advection functions must be linear with respect to volume fractions.

We discuss also two numerical methods for the model proposed, which are based on the Roe-type scheme and the HLLC scheme, respectively. Direct high order extension of these schemes may lead to spurious oscillations and unphysical solutions (e.g., the sum of volume fractions can exceed 1). This is different from the case of two component. We propose special reconstruction variables for which the nonlinear cell face interpolation with sharpening techniques THINC [2] or CRP [3] will result in non-oscillatory and physically admissible solutions.

Finally, we test the proposed model and numerical methods with several benchmark problems. The results obtained demonstrate robustness and effectiveness of our methodology in modeling discontinuities in properties across the material interface.
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