A Robust Lagrange-Projection Splitting Scheme for Compressible Multiphase Flows with Viscous and Heat Conduction Effects: Application to the Melting Process

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The present work takes place in the context of the atmospheric re-entry problem. This study can concern re-entry vehicles globally or partially made of metallic components, like space debris for instance. During the re-entry phase, a solid undergoes a heating due to the friction of atmospheric gases. Conversion of kinetic energy to thermal energy leads to a sudden increase of the temperature of the object. This rise drives to a physical-chemical degradation of the thermal protective system, and to a boundary recession. There are two main causes of the solid ablation during the re-entry phase: the fusion of the metallic part, which creates a liquid phase into the gas flow, and the sublimation process leading to an injection of gas into the atmosphere. In order to simulate these phenomena, a compressible multiphase flow model needs to be coupled with a heat equation inside the solid.

In the present work, our solvers are based on the Finite Volume Method to solve compressible Navier-Stokes and heat equations. A splitting strategy to compute compressible two-phase flows using the five-equation model with viscous and heat conduction effects is presented. The main idea of the splitting is to separate the acoustic and dissipative phenomena from the transport one. The acoustic and dissipative step is solved in a non-conservative form using a scheme based on an approximate Riemann solver. Since the acoustic time step induced by the fast sound velocity is very restrictive, an implicit treatment of this step is performed. For the transport step driven by the slow material waves, an explicit scheme is used. The overall scheme resulting from this splitting operator strategy is very robust, conservative, and preserves contact discontinuities.

The boundary interface condition between the solid and the multiphase flow is enforced by mass and energy balances at the wall. The melting front is tracked explicitly using an ALE formulation of the equations.

The robustness of the approach is demonstrated through numerical simulations involving large density ratios. The computation of the melting process with a two-phase flow is also presented.

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