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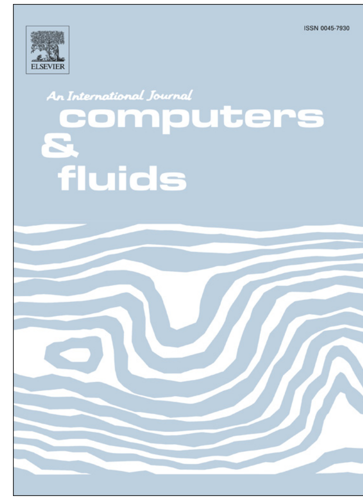

A multi-material flow solver for high speed compressible flows

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Abstract

This paper describes a three-dimensional Eulerian-Lagrangian method for the modeling and simulation of high-speed multi-material dynamics. The equations for conservation of mass, momentum, and energy are solved on a fixed Cartesian grid using a fully conservative higher order MUSCL scheme. The dilatational response of each material is handled using a suitable equation of state. The embedded interfaces are handled using a mixed-cell approach. This approach uses an Eulerian treatment for the computational cells away from the interface and a Lagrangian treatment for the cells including interface elements, resulting in a fully conservative method for multi-material interactions. The method has shown capability to resolve and capture non-linear waves such as shock waves, rarefaction waves, and contact discontinuities in complex geometries. This work mainly emphasizes the handling of shock-wave interaction with bubbles, bubbly media, and multi-fluid interfaces in a compressible flow framework. Several numerical examples are shown to demonstrate the validity and robustness of the method.

Keywords: Compressible Flows, Mixed Cell, Conservation, MUSCL scheme, Shock waves, interfaces

2 Introduction

The understanding of high speed flow phenomena is critical to many applications such as blast wave interactions with structures [2], underwater explosions [3], munitions-target interactions [4], detonation shock dynamics [5], dynamics of shaped charges[6], … etc. These interactions involve the presence of non-linear waves such as shock waves, rarefaction waves, and detonation waves resulting in localized high intensity phenomena such as large deformation of the interface, fragmentation, and shattering.

The methods of choice for solving these problems can be mainly categorized into Eulerian and Lagrangian methods [4]. Both Lagrangian and Eulerian frameworks have been identified with certain advantages and limitations and take different paths in formulating large deformation problems [4,7,8]. Flow solvers based on a Lagrangian formulation, such as in EPIC [9] and LS-DYNA [10], have the material interface attached to the mesh, which is used to follow the deformation. Those based on an Eulerian formulation, such as HULL [11] and