A HIGH RESOLUTION GODUNOV METHOD FOR HIGH SPEED MULTI-MATERIAL FLOWS

By

Jeffrey Banks

An Abstract of a Thesis Submitted to the Graduate

Faculty of Rensselaer Polytechnic Institute

in Partial Fulfillment of the

Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: Mathematics

The original of the complete thesis is on file
in the Rensselaer Polytechnic Institute Library

Examining Committee:

Donald Schwendeman, Thesis Adviser
Ashwani Kapila, Thesis Adviser
Mark Holmes, Member
Kenneth Jansen, Member

Rensselaer Polytechnic Institute
Troy, New York

April 2006
(For Graduation May 2006)

ABSTRACT

This thesis is concerned with the study of inviscid, compressible, multi-material flows in two space dimensions. These flows can be either inert or reactive and are governed by the multi-material Euler equations. The Jones-Wilkins-Lee (JWL) equation of state (EOS), which is a Mie-Grüneisen type EOS, is used to close the system. This choice is motivated by the goal of simulation of condensed phase explosives for which the JWL EOS is a classic choice. However, the method is equally applicable to more general EOS. Complex geometry is described through the use of composite overlapping grids. In this methodology, geometry is described with the use of thin boundary-fitted grids with the bulk of the domain covered by Cartesian grids. The solution is then interpolated between grids in regions where they overlap. This allows simulation on complex geometries while maintaining the essential efficiencies in both computational time and memory inherent to logically rectangular structured grids. Adaptive mesh refinement (AMR) is used to capture sharp features of the flow by locally increasing grid resolution near these features. The discretization of the governing equations is based on a high-resolution Godunov method, but includes an energy correction designed to suppress numerical errors that develop near a material interface for standard, conservative shock-capturing schemes. The energy correction is constructed based on a uniform pressure-velocity flow and is significant only near the captured interface. A variety of two-material flows are presented to verify the accuracy of the numerical approach and to illustrate its use. Problems considered include both inert and reactive flows. For the inert problems an initial emphasis is placed on algorithmic verification and then a number of more realistic problems are investigated. The reactive problems investigate flows of interest to the explosive science community and includes problems of compliantly confined explosive rate sticks, and detonation diffraction around compliant corners.