A NUMERICAL STUDY OF SHOCK INDUCED CAVITY COLLAPSE

By

Melih Ozlem

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: MATHEMATICAL SCIENCES

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

Examining Committee:

Donald Schwendeman, Thesis Adviser

Ashwani Kapila, Member

Fengyan Li, Member

Zvi Rusak, Member

Rensselaer Polytechnic Institute
Troy, New York

August 2010
(For Graduation August 2010)

ABSTRACT

Motivated by the need for an improved understanding of a prominent mechanism of the generation of hot spots, a model of shock-induced void collapse in a solid material is examined numerically. The problem arises in the context of a solid explosive, where hot spots are the discrete sites of preferential reaction, and play a crucial role in the ignition of a shocked heterogeneous explosive. Specifically, an axisymmetric configuration consisting of a single gas cavity in a solid matrix is considered. The mathematical model is a system of hyperbolic PDEs, the Euler equations of gas dynamics, supplemented by nonideal equation of state for the solid and ideal equation of state for the gas constituent. A mixture formulation is introduced, and the interface is treated as an artificial zone of finite thickness extending over a few computational cells. A finite-volume numerical strategy is employed; it incorporates adaptive mesh refinement and is based on a variant of the Godunov scheme modified to suppress nonphysical instabilities in the vicinity of shocks and interfaces. Complete histories of cavity collapse induced by an incident shock are presented for a variety of cavity shapes and configurations. Hydrodynamic features produced by the shock-cavity interaction are carefully followed, and special attention is paid to mechanisms leading to the evolution of regions of high temperature or pressure. In the case of a spherical shaped cavity the on-axis collapse mechanism is examined as the cause of hot spot formation, and in the case of a tall elliptical cavity and some multiple bubble configurations an off-axis collapse mechanism is discovered. Off-axis collapse mechanisms are found to yield higher temperature and pressure peaks during hot-spot generation.