Desensitized Heterogeneous Explosives and Compliant Confinement

J. W. Banks, * D. W. Schwendeman, † A. K. Kapila †

The macroscopic behavior of high explosives (HE) is known to be driven largely by phenomenon occurring at temporal and physical scales which are much smaller than the scales of laboratory devices. Typically it is the interaction of shock waves with heterogeneous explosive material that eventually leads to laboratory scale phenomena such as the formation of dead zones, regions of unreacted material, during detonation diffraction. These explosives are made up of grains of crystalline HE, plastic binder and void regions which are described on the scale of tens of micrometers but the devices of interest are tens of centimeters. Given current simulation capabilities and trends there is no realistic prospect to perform simulations which resolve all scales from the microstructure up to laboratory scale devices and so we must rely upon macroscopic models of microscopic phenomena when simulating laboratory scale devices.

One such model which has seen much success is the ignition-and-growth (I&G) model. Here the JWL equation of state is used so that solid phases can be accurately described, and a multi-term reaction rate law is used to mimic the microscopic formation of hot spots. These hot spots occur as a result of void collapse and lead to localized high reaction rates that can strengthen and merge with other hot spots to form a larger detonation structure. The resulting method has been successful at capturing many of the features of detonation dynamics in practical high explosives, but the conspicuous inability of the model to reproduce experimentally realized dead zones points toward possible shortcomings. In an effort to mitigate these shortcomings the I&G model was extended by us and collaborators to include multi-material effects. This extension enables simulations of compliantly confined explosives which show qualitative prediction of detonation failure in conical charges of explosives, a phenomena demonstrated experimentally by Salyer and Hill. However, dead zone formation during detonation diffraction is not predicted. In a separate effort, a model for weak shock desensitization was developed which attempts to describe what happens when local hot spots are not sufficiently strong to grow and instead extinguish. For such cases the void is partially or wholly close off before significant chemical reaction can take place and the micro-scale structure is changed. Subsequent loading of the material will then produce different results than had pristine material undergone the same stimulus. With this desensitization model dead zones are predicted during detonation diffraction, but compliant confinement effects detonation failure in conical charges is not seen.

The current work investigates a combination of the desensitization and multi-material models and discusses the resulting capabilities. The combined model shows no changed in predictions of detonation failure for compliantly confined conical explosives as it relates to the multi-material model alone. Conversely, the combined model predicts dead zone formation during diffraction around compliant corners. During the discussion we also take time to delve into issues of shock capturing with non-ideal equations of state as well as artificial compression methods designed to help maintain sharp material interfaces.

---

*Center for Applied Scientific Computing, Lawrence Livermore National Laboratory, Livermore, CA 94550. This work was partially funded by the Department of Energy's Applied Mathematics Research program in the Office of Advanced Scientific Computing Research (ASCR) and was carried out at Lawrence Livermore National Laboratory operated for the U.S. Department of Energy under contract no. DE-AC52-07NA27344.

†Department of Mathematical Sciences, Rensselaer Polytechnic Institute, Troy, NY 12180.