High-Resolution Numerical Simulation of Detonation Propagation and Dead Zones in Condensed Explosives

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Abstract

In this paper, the detonation propagation and corner turning process of LX-17 is calculated with a parallel two-dimensional Eulerian hydrodynamic code. The fifth-order WENO method is used for spatial discretization, and the third-order Runge-Kutta method is used for temporal discretization. The reactants and products of explosive are treated together in the governing equations, using JWL equations of state and Ignition & Growth reaction rate model. Various confinement materials are simulated and compared, including the rigid and weak confinement. Level set method is employed to track the interface between explosive and air. The real ghost-fluid method (RGFM) is employed for treatment of interface with high-pressure ratio and high-density ratio. We calculate the LX-17 double-cylinder with axisymmetric governing equations, and the results show that dead zone in LX-17 could be calculated well in both size and position before 4.20μs after reaching the corner, although it is not persistent enough compared to experimental results.

Keywords: Corner turning, detonation propagation, dead zone, WENO, level set, RGFM

Introduction

Insensitive High Explosive (IHE) is the most influential energetic material, which have good thermal stability and other insensitivity in many other aspects, such as shockwave or electricity. For IHE, dead zones in the corner-turning is a significant phenomenon, and many researches have been conducted to it.

Ferm et al. examined the uninitiated region of the corner turning experiment using Proton Radiography, and observed a high-density unreacted region for more than 5 μs [1]. Souers et al. developed a "hockey puck" experiment to measure the divergence of LX-17 detonation wave and the position of dead zone in the experiment [2]. Tarver compared calculation results with those of experiment, and presented a three pressure-dependent reaction rate laws [3]. Oliveira et al. presented an augmented model including explosive desensitization by weak shock, and simulated LX-17 corner-turning in the hockey puck experiment configuration at a rigid corner boundary [4]. Kapila et al. calculated the detonation diffraction of PBX-9502 with different corners, while the dead zone is temporary [5,6]. Hill presented a modified CYLEX test to quantitatively infer the level and timescale of dead zone reactivity [7].

In this paper, LX-17 corner-turning is calculated with a fifth order finite difference WENO scheme [8]. Jones-Wilkins-Lee (JWL) equation of state and Ignition & Growth reaction rate are employed for calculation of HE detonation. Level set method and Real Ghost Fluid Method (RGFM) [9] are employed for interface tracking and treatment between reaction products and the corner confinement. We calculated the LX-17 double-cylinder with axisymmetric governing equations, which geometry is motivated by experiments discussed by Souers et al. in [10]. The results show that dead zone could be calculated well in both size and position before 4.20μs after reaching the corner, but it could not persist long enough compared to experimental results.

LX-17 double-cylinder calculation

The geometry of LX-17 double-cylinder calculation is shown schematically in Fig. 4, which is cylindrically symmetric around the heavy line. The calculation geometry is the repeat of experiments in [1] and [10]. The shock wave reaches the corner at 4.96μs after ignition, and the zoomed density contour is shown in Fig. 1.

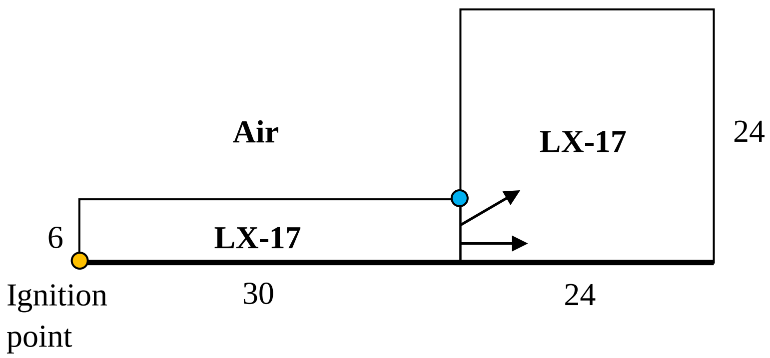

Figure 1. Geometry of LX-17 double-cylinder calculation

The results show that detonation propagates across the corner, and forms an unreacted zone with higher density than the surroundings at 2.48μs after reaching the corner, shown in Fig. 2. This “dead zone” has both similar size and similar position with the X-ray (2.48μs), which is consistent with the X-ray (2.48μs) shown in Fig. 4 of Souers et al. [6].

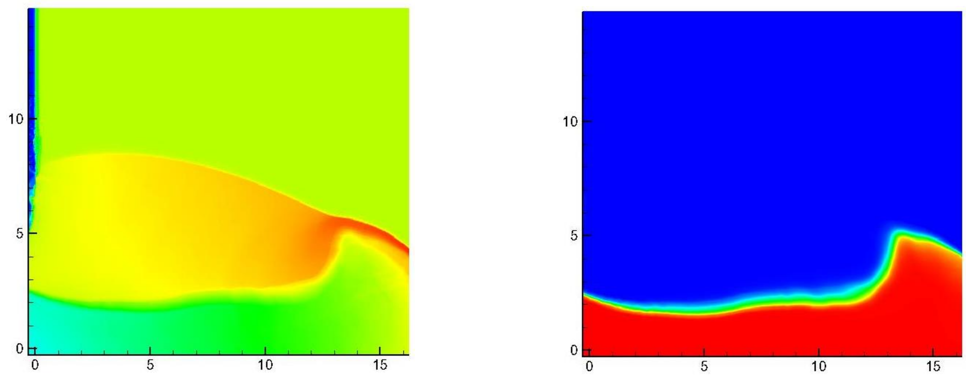

Figure 2. Density (Left) and reaction rate (Right) contours at 2.48μs

The dead zone still exists at 4.20μs (shown in Fig. 3), but could not persist after 4.80μs (shown in Fig. 4).

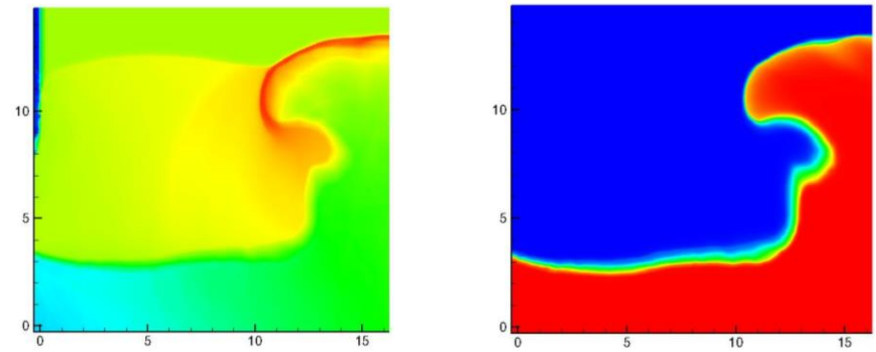

Figure 3. Density (Left) and reaction rate (Right) contours at 4.20μs

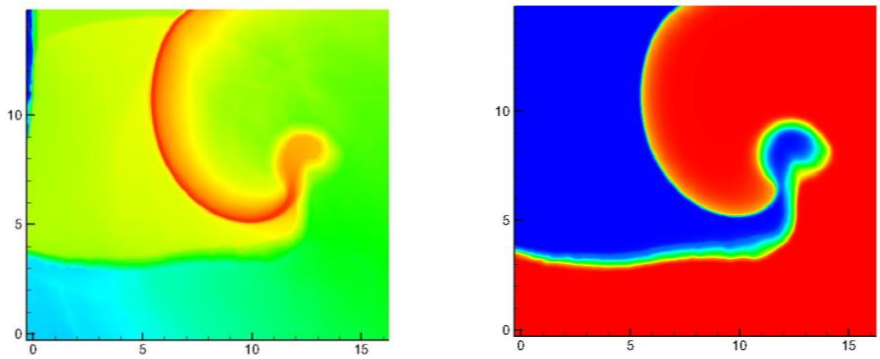

Figure 4. Density (Left) and reaction rate (Right) contours at 4.80μs

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