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Numerical simulations of microcrack-related damage and ignition behavior of mild-impacted polymer bonded explosives

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Highlights

A damage and ignition model is developed for predicting failure and sensitivity of PBXs under mild-impact.

Investigating the features of damage and plasticity for PBXs under dynamic uniaxial and triaxial compression.

Burning violence following ignition within the microcrack is characterized by gas products pressure and crack size.

Abstract: A physical model is developed to describe the viscoelastic-plastic deformation, cracking damage, and ignition behavior of polymer-bonded explosives (PBXs) under mild impact. This model improves on the viscoelastic-statistical crack mechanical model (Visco-SCRAM) in several respects. (i) The proposed model introduces rate-dependent plasticity into the framework which is more suitable for explosives with relatively high binder content. (ii) Damage evolution is calculated by the generalized Griffith instability criterion with the dominant (most unstable) crack size rather than the averaged crack size over all crack orientations. (iii) The fast burning of cracks following ignition and the effects of gaseous products on crack opening are considered. The predicted uniaxial and triaxial stress-strain responses of PBX9501 sample under dynamic compression loading are presented to illustrate the main features of the materials. For an uncovered cylindrical PBX charge impacted by a flat-nosed rod, the simulated results show that a triangular-shaped dead zone is formed beneath the front of the rod. The cracks in the dead zone are stable due to friction-locked stress state, whereas the cracks near the front edges of dead zone become unstable and turn into hotspots due to high-shear effects.

Keywords: Numerical simulation; PBX explosives; Damage and ignition; Mild impact; Statistical microcracks

1. Introduction

High explosive (HE) materials could be exposed to abnormal impact insults (e.g., dropping, crushing, punching, and needling) during their life cycle, including manufacture, transportation, and storage periods [1-3]. Such relatively mild impacts may induce complicated thermal-mechanical-chemical responses of HEs, such as deformation, damage, and even inadvertent ignition or initiation [4]. Thus, understanding the combined damage and ignition behavior of HEs under mild-impact loading is vital for safe use of HEs.

In 1992, Field et al. [5] proposed several hot spot mechanisms for ignition of HEs, including void collapse, adiabatic shear bands, and heating at crack tips. Although many scholars have evaluated the hotspot mechanisms of HEs [6-9], the dominant hot spot mechanism for HEs under mild-impact has not yet been definitively identified [10]. Several scholars [11-14] proposed that the heterogeneous damage of HEs at the mesoscale level (such as microcracks and microvoids) exacerbates energy localization during material deformation and failure and probably affects the formation of hot spots. Dienes [13] treated the