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Experimental Investigation of the shock response of energetic materials simulants

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Energetic materials are substances that undergo rapid chemical reactions when subjected to an appropriate stimulus, releasing substantial amounts of energy, heat, and gas. This class of materials finds various applications, including pyrotechnics, explosives, and rocket propellants. Energetics are intrinsically linked to shock wave propagation phenomena: while their chemical reaction often induces the formation and propagation of a shock front within the medium, a shock-loading stimulus can, conversely, trigger the reaction of an initially undisturbed material. Consequently, this work aims to investigate the shock response of these materials, with a particular focus on mesostructural evolution under dynamic loading conditions.

Because experimental investigations involving energetic materials pose inherent safety risks to personnel, inert surrogate materials are frequently employed as a mitigation strategy. Additionally, the adoption of energetic simulants permits the decoupling of the mechanical response from the chemical reaction of the energetic crystals. In this study, plate impact experiments were performed on specimens composed of sucrose crystals embedded within a polymer binder. This inert simulant was designed to mimic the structure and behavior of a polymer-bonded explosive (PBX); specifically, the energetic crystals were replaced by granular sucrose dispersed in a polydimethylsiloxane (PDMS) binder at an 80:20 sucrose-to-binder mass ratio.

Various impact velocities and crystal particle sizes were investigated. Photonic Doppler Velocimetry (PDV) measurements were conducted to record the rear-surface velocity of the specimens, thereby extracting quantitative data regarding the material's shock response. Furthermore, a subset of tests was performed at the ID19 beamline of the European Synchrotron Radiation Facility (ESRF), where high-rate X-ray phase contrast imaging enabled the in-situ observation of structural evolution, tracking microstructural features across the propagating shock front. This approach proved particularly valuable, as complex mesostructures and heterogeneities at relevant volumetric scales often dominate the dynamic material response. The coupling of in-situ imaging and velocimetry applied to energetic simulants constitutes a novel contribution to the field, providing both qualitative and quantitative insights into mesostructural evolution and the distinct influences of impact velocity, particle size, and porosity on shock wave propagation.

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