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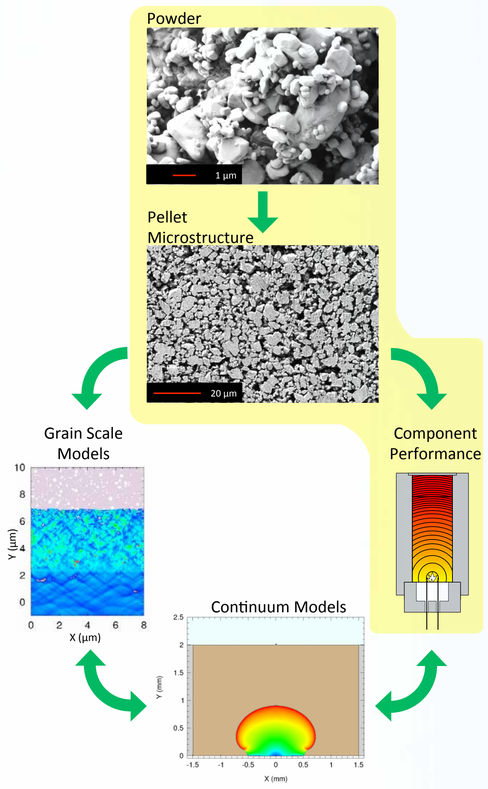
Exploring the Influence of Microstructural Properties of Heterogeneous Explosives on Performance

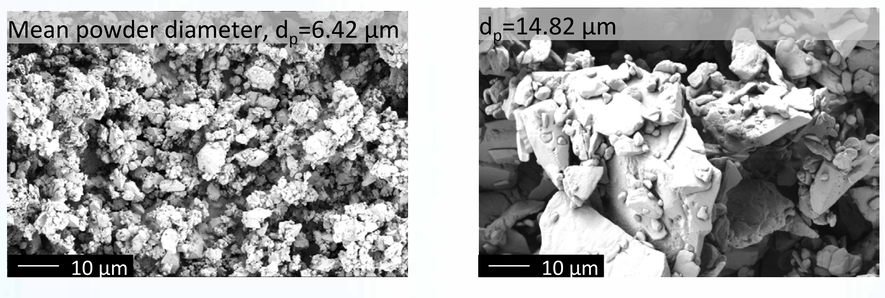
Todd Reedy and Ryan Wixom, Explosives Technologies Group

Project Overview

- Conventional detonators rely on the bursting of an electrically conductive bridge to deliver an impulse to the explosive which initiates detonation. The transfer of energy and the processes which govern the initiation of chemical reactions and build-up to steady detonation are not fully understood.
- This project will further the basic understanding and document the influence of the microstructural properties of heterogeneous explosives on performance.
- Project Objectives
  - Characterize explosive powder
  - Characterize pellet microstructure
  - Characterize flyer performance
  - Characterize explosive performance
  - Deliver data to enhance predictive modeling capabilities

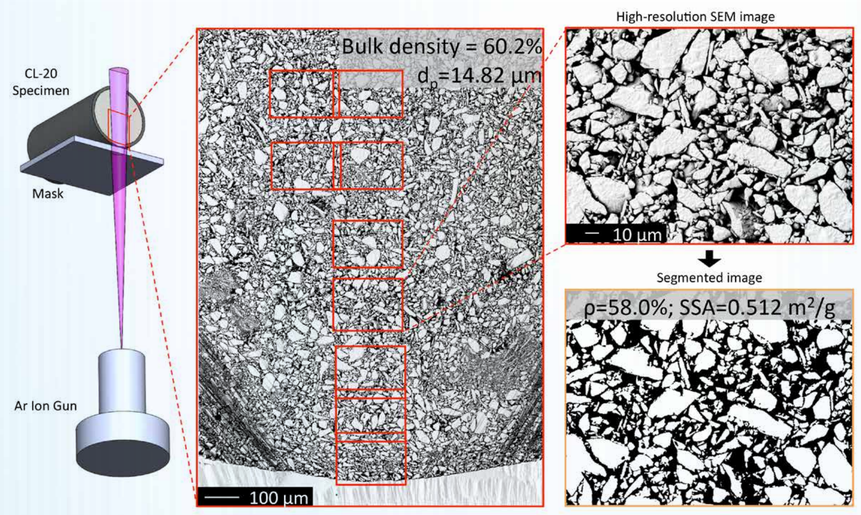


Powder Characterization



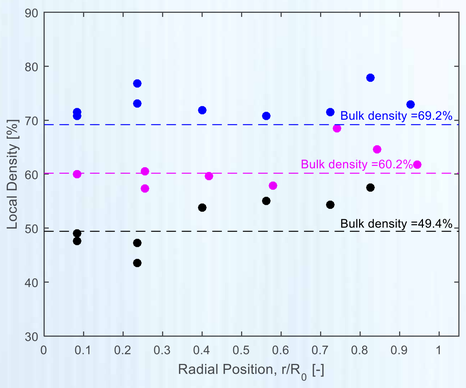
- Chosen for its high-performance, CL-20 (2,4,6,8,10,12-hexanitro-2,4,6,8,10,12-hexaazaisowurtzitane) is the specific explosive under investigation.
- Particle size distribution and specific surface area (SSA) for two specific CL-20 powders have been characterized.

Pellet Microstructure



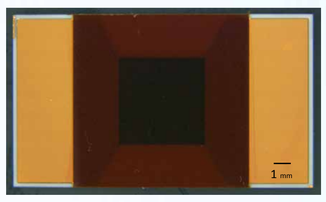
(left) Mechanically consolidated explosive pellets are cross-sectioned with an Argon ion-beam, exposing internal microstructure.

(center and right) Scanning electron microscope (SEM) images are filtered and segmented to extract local density and specific surface area.



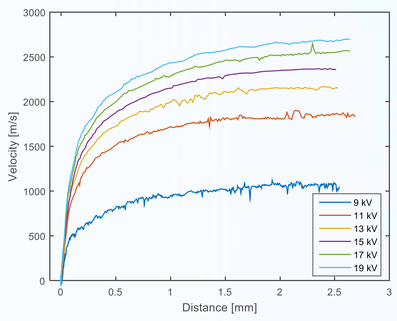
- Local density as a function of radial position for pellets of different bulk densities (d_p = 14.82 µm, depth of 75 µm from top surface).
  - Data indicates local density varies significantly from bulk density, as much as 15%.

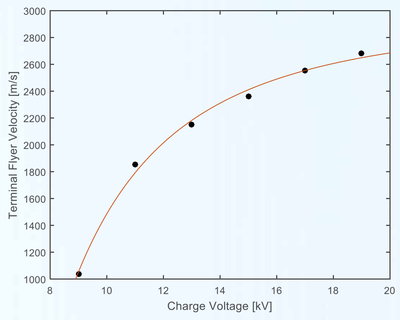
Flyer Characterization



Chip slappers are used to shock initiate CL-20 explosive pellets. The bridge is a 8 µm thick, 5.08 mm aluminum square on a thick silicon substrate exploded to propel a 0.127 µm thick polyimide flyer.

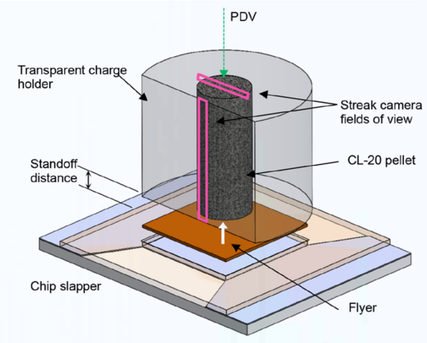
Chip slappers are driven by a 20 kV, 1 µF capacitive discharge unit (CDU).

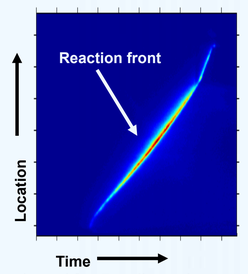




Flyer characterization provides quantifiable shock impulse to the explosive. (left) Flyer velocity versus distance measured with photonic Doppler velocimetry (PDV). (right) Terminal flyer velocity as a function of CDU charge voltage.

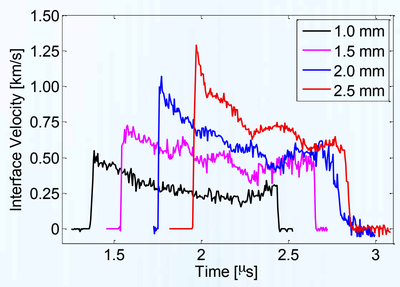
Explosive Performance

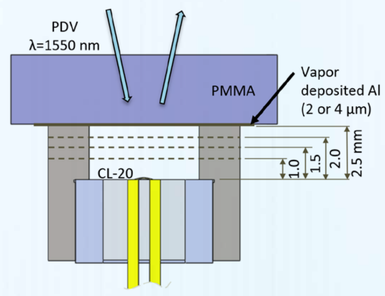




Adapted from Welle et al., SAND2008-1017, 2008

- Upcoming experiments are designed to capture explosive performance for pellets of different particle size and nominal density.
  - Side-view steak imaging: reaction front including the build-up to detonation
  - Top-view streak imaging: reaction front curvature for different explosive pellet heights.
  - Early experiments to develop a diagnostic for simultaneous streak imaging and PDV have successfully be completed.
- Preliminary proof-of-concept experiments to characterize CL-20 output.





  - Pellets of different column heights, pressed to nominally 50% TMD.
  - Never having been captured before for CL-20, these data are helping SNL modelers to calibrate grain-scale hydrocode.

Summary/Impact

- To better understand the initiation mechanisms of heterogeneous explosives, microstructural properties of CL-20 explosive (powder and pellets) have been characterized.
- Flyer velocities have been measured at different firing voltages to quantify the shock pulse into the explosive.
- Future experiments are planned to further characterize the initiation process for each of the CL-20 powders and nominal pressing densities.
- Microstructure data will help guide component design decisions.
- Validation-quality data will enhance modeling capabilities to quantify component margin and reliability.
- Presentations:
  - Reedy, Todd and Wixom, Ryan, “Characteristization of CL-20 Microstructure and Performance,” 39th JOWOG 9 Plenary Meeting, AWE Aldermaston, 18-22 May 2015.
  - Reedy, Todd and Wixom, Ryan, “Characteristization of CL-20 Microstructure and Performance,” JOWOG 9 Initiation Train SubWOG, 11 March 2015.

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