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Key Accomplishments

➢ Tested the viability of µCT to identify defects as small as a few microns.
➢ Code for distinguishing low and high density defects, and measuring the morphology of individual defects.
➢ Tested the viability of X-ray phase contrast imaging to visualize crack initiation and growth at high strain rates.
➢ Preliminary visual evidence of crack initiating from pre-existing defect.
➢ Key fracture-related events in X-ray phase contrast images correspond to changes in gradients in stress-time curve.

Transitions to ARL, within CMRGs and to other CMRGs

➢ Assistance of Casem, Meredith and Schuster from ARL with imaging experiments and image interpretation.
➢ Sharing of equipment for synchrotron experiments.
➢ Our experiments provide direct inputs on defect distributions to the models of Tonge et al.
➢ Our experiments provide key parameters for fracture modeling and examination of coalescence, with Sikhande Satapathy (ARL) and Graham-Brady (JHU).
➢ Our experiments identify key subscale mechanisms for the integrative models of Qinglei Zeng (JHU).

Impact

Insight into the interactions between defect size distribution and crack behavior can:
➢ Guide the development and validation of physics-based constitutive models for dynamic failure of brittle materials.
➢ Standardize fabrication of boron carbide-based materials to optimize its performance under extreme conditions.

How We Fit

Materials-by-Design Process

Mechanism-based Approach

Key Goals

➢ The high hardness and low density of boron carbide (BC) makes it an ideal armor material.
➢ However, manifestation of micron size defects in BC during its fabrication influence crack behavior during dynamic loading and detrimentally affects its performance.
➢ X-rays possess the penetrative power and resolution to non-destructively study the defects in boron carbide and the intensity to study crack behavior in situ.

Effort is currently focused on using:
➢ µCT to characterize the defect distribution of BC.
➢ X-ray phase contrast imaging to visualize crack behavior in real-time.
➢ We are aiming to register the images recorded from the two modalities to understanding the interactions between the defects and behavior of cracks during high rate loading.

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3D characterization of defects

➢ Commercial grade boron carbide cut into 1.5 mm cuboids with a 1 µm surface finish.
➢ µCT performed at beamline 2-BM (APS-ANL).
➢ Single slice reconstructions stacked to form a volumetric reconstruction of BC.

In situ visualization of fracture

Crack behavior captured in real-time using X-ray phase contrast imaging at beamline 32-ID-C (APS-ANL) that are synchronized with a stress-time plot using a Kolsky bar apparatus.

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