Title: Sub-sonic thermal explosions investigated by radiography

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SUB-SONIC THERMAL EXPLOSIONS INVESTIGATED BY RADIOGRAPHY


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Over the past four years, we have developed the capability to perform dynamic radiography experiments on the evolution of ignition and subsequent sub-sonic burn propagation in thermal explosions. Radiography provides a measure of the evolution of density caused by material flow and decomposition leading up to ignition and then a measure of the rapid consumption of material during burn propagation subsequent to ignition. The ability to perform these experiments was predicated on several developments: the control of ignition location in a thermal explosion, the prediction of ignition time for a given boundary condition, in some cases the synchronization of the ignition event, and the triggering of external diagnostics synchronous with the breakout of ignition. In this talk, the developments enabling radiography of thermal explosions will be discussed, the radiographic images of thermal explosions in several different geometries and formulations presented, and an analysis of the images and their implications for our understanding of the mechanism of thermal explosions will be discussed.

Work leading up to the ability to perform radiographic imaging of thermal explosions involved designing a thermal explosion experiment to drive ignition to a predetermine location. For this, we use our radial thermal explosion design which uses a cylinder of explosive with an aluminum boundary that is held at the boundary temperature. This allows the explosive to be heated to the final boundary temperature from the outside, and then causes the aluminum case to act as a heat sink once the exothermic chemistry begins, thus driving the ignition location to the center of the cylinder. Once the ignition location was determined, high temporal and spatial resolution diagnostics such as thermocouples and fiber optics could be placed at this location. These diagnostics probe the state of the explosive during the time leading to ignition and can then be used as triggers for external diagnostics. Additionally, a fiber optic terminating at the ignition location can be used to synchronize the ignition event if needed. Having designed a thermal explosion experiment with controlled ignition location and ignition time, the final design constraint was to make the aluminum case thin enough for
compatibility with radiographic imaging. In this paper, we will describe in detail the internal diagnostics and triggering techniques developed.

We have fielded these radial thermal explosion experiments using two different types of radiography. We have collected multiple dynamic images of thermal explosion events using proton radiography at the Los Alamos National Laboratory Proton Radiography (pRad) facility\(^2\), and we have collected multiple dynamic x-ray images at the Livermore National Laboratory Hydra Facility\(^3\). These experiments have been performed using both the HMX based formulations PBX 9501 and PBXN-9. In addition, two different aspect ratios have been investigated and two different case confinements used.

We will present radiographic images for thermal explosions in all the configurations described above. We will compare burn propagation behavior between the two HMX based formulation as well as compare differences for a given formulation with different geometries and case confinement strengths. Analysis of the radiographic images obtained will be discussed. We will conclude by describing the understanding of ignition and subsequent sub-sonic burn propagation enabled by this data set.

References

