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Title: Proton Radiography Examination of Unburned Regions in PBX 9502 Corner Turning Experiments

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Los Alamos
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PROTON RADIOGRAPHY EXAMINATION OF UNBURNED REGIONS IN PBX 9502 CORNER TURNING EXPERIMENTS

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Abstract. PBX 9502 Corner Turning Experiments have been used with various diagnostics techniques to study detonation wave propagation and the boosting of the insensitive explosive. In this work, the uninitiated region of the corner turning experiment is examined using Proton Radiography. Seven transmission radiographs obtained on the same experiment are used to map out the undetonated regions on each of three different experiments. The results show regions of high-density material, a few percent larger than initial explosive density. These regions persist at nearly this density while surrounding material, which has reacted, is released as expected. Calculations using Detonation Shock Dynamics are used to examine the situations that lead to the undetonated regions.

INTRODUCTION

The PBX 9502 corner turning experiments were one of many explosive assemblies used to study the initiation and boosting requirements of insensitive explosive. The experiment was able to identify differences in materials that had subtle particle size changes in the material. The experimental configurations shown in Fig. 1 show two of the charges used for this work. Although the charges from different experimental groups differ in details, they can be described as consisting of three sections, an initiation/booster charge, a smaller diameter donor charge, and a larger diameter acceptor charge. The most common diagnostic used on these assemblies was to place a flasher material along the edge of the acceptor charge and measure the axial distance from the face of the acceptor to the first breakout on the cylinder edge[1]. With an ideal explosive, first breakout occurs at the face of the acceptor. The further down the acceptor charge the breakout occurred, the more difficulty the donor had initiating the acceptor.

FIGURE 1. Corner turning charges used in PRad0067 and PRad0068 experiments.

Radiographs of planar corner turning experiments have been taken using the PHERMEX radiographic machine[2]. Radiographs showed regions of high-density material that did not appeared to have reacted or expanded significantly.

These have been described as “Dead Zones” or regions where the reaction rate seems to be significantly reduced.

The Proton Radiography Program at LANL has developed a radiographic facility at the Los Alamos Neutron Science Center. Multiple proton radiograph images of the same explosive experiment[3, 4] can be taken. This paper analyzes the three corner turning experiments that have been performed using this facility and allows examination of the situations that leads to the creation and persistence of the undetonated regions.

Experiment

The corner turning experiments were designed to develop a very steady detonation wave in the donor explosive. The description of the charges can be found in Table 1. The explosive was placed in a foam box which held the charge at the detonator and at the end of the acceptor charge, while the remainder of the charge was free to expand to 63.5 mm before reaching the foam wall. The charge is placed in a containment system design to allow for the magnetic imaging of the protons transmitted through the experiment at the object location to an image location where a scintillator allows cameras to photograph a signal proportional to the transmitted proton image[4]. The containment system is evacuated to minimize the blurring from atmospheric scattering of the protons in the long magnetic lens system.

The static image, the beam profile, and the camera dark current along with the dynamic images are used to obtain normalized transmission and pathlength images. The inverse Abel transforms may then be used to make density of the dynamic experiment.

Shown in Figure 2 is a ratio of the dynamic to static image of Prad0068. The image shows regions where the pathlength is thicker while surrounding areas have much thinner pathlengths.

In Figure 3 the inverse Abel transform of the image is shown. The transform raises the contrast of features like the shock front, however it also concentrates noise near the symmetry axis. The detonation front can be seen easily as well as the high-density region near the face of the acceptor charge.

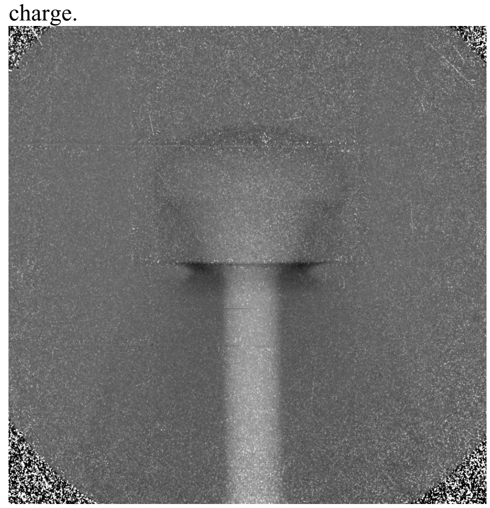

FIGURE 2. Ratio of dynamic image to static image for the 12-mm corner turner experiment at 25.3 µs after detonator breakout. The ratio shows changes in pathlength occurring since the static. Dark areas show that more material is present along the projection path than initially present.

TABLE 1. Charge description of the Proton Radiography Corner Turning Experiments

Shot	Initiation System	Donor	Acceptor
PRad 0043	SE-1 0.5”ø x 0.5” PBX 9407 17 mm ø x 50 mm PBX 9502	17 mm ø x 100 mm PBX 9502	2” ø x 2 3/16” PBX 9502
PRad 0067	SE-1 0.5”ø x 0.5” PBX 9407 18 mm ø x 50 mm PBX 9502	18 mm ø x 100 mm PBX 9502	50 mm ø x 50 mm PBX 9502
PRad 0068	SE-1 0.5”ø x 0.5” PBX 9407 18 mm ø x 50 mm PBX 9502	12 mm ø x 100 mm PBX 9502	50 mm ø x 50 mm PBX 9502

ANALYSIS

A high-density region is visible in Figure 3, which appears to emanate out of the detonation front and widen as it approaches the face of the acceptor charge. Analysis of the images indicates the average density is higher than the initial density of the explosive, which is confirmed by examining Figure 2.

The leading edge of the deadzone is radially expanding about 3.3 mm/µs while the trailing edge is expanding about 0.9 mm/µs. The attachment point to the detonation wave was estimated by extrapolating the surface leading the deadzone and the trailing edge back to where it appears to blend into the detonation front. The axial position of the attachment point is entering the charge at 3.mm/µs and then slows down to near zero. In the 12- and 18-mm donor charges, the attachment point enters acceptor as deep as 13- and 11-mm respectively. Radially growth is initially stalled, and then rapidly increases to more than 6 mm/µs. During this period it becomes clear that the detonation wave has turned the corner, i.e. the detonation wave has a point that is radially expanding to the wall, and will be the first breakout point.

MESA calculations using Detonation Shock Dynamics (DSD) [5] are compared with the experiment in Figure 4. DSD as implemented has no curvature failure criterion. Without a criterion, it can easily be seen that the deadzone is not modeled nor does the calculation reproduce the corner turning distance. Although the curvature slows the wave propagation along the face of the acceptor it is not sufficient to model the effect. The existence of the deadzone is required to model the corner turning effect.

A boundary of the dead zone can be chosen by connecting up the detonation wave attachment points found in the experiment. This region is about twice as big as the estimated mass of the dead zones from the radiographs. When this boundary is used in the calculation the corner turning distances is represented much better, although this is not surprising.

The significant overestimation of the deadzone mass indicates that there is reaction taking place in the vicinity of the attachment point. The size of dead zone region is influenced by several factors, including rarefactions coming from acceptor face, possible shock desensitization, and the length of time before rarefactions quench shocked explosive.

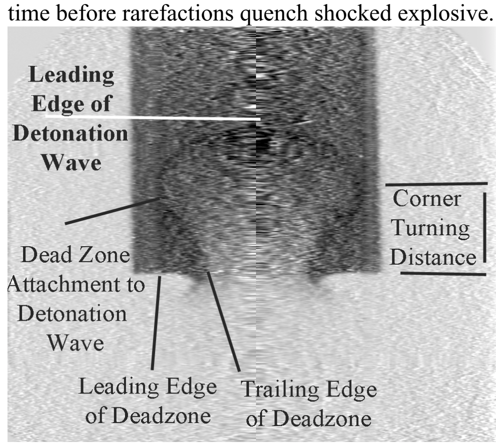

FIGURE 3. Volume density image of the 12 mm corner turner experiment 25.3 µs. The identified regions are used in describing the deadzone region.

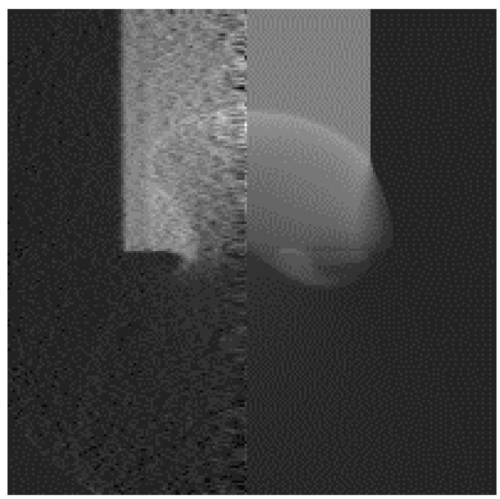

FIGURE 4. A MESA calculation of density is shown on the right half of the above image, while the left side is and average density from the two symmetric sides in figure 3.

CONCLUSIONS

The proton radiographs of "deadzones" are persistent features of corner turning experiments. The regions of material persist for more than 6 μs near initial density and typically slightly higher. The front radial edge of the deadzone appears to propagate slightly faster than sound speed in undetonated explosive. At late times this motion is stalled, either being too small of compression to measure or possibly rarefaction entering in from the side of the charge.

Regions of the deadzone are reacting near the detonation front attachment point. In the 12-mm charge it appears that the outside layer of the 50-mm charge is detonating, back from the corner turning point towards the face of the corner turning charge beyond the deadzoned.

Corner turning experiments do have regions of material that are not reacting over a time period of more than 5 μs. Other parts of the deadzone regions show indications of a slow reaction-taking place at this time scale. The deadzone region next to the attachment point is a reactive zone, which has been lengthened due to a high curvature and low amplitude shock wave, which was the stimulus for initiation. Ultimately this shock wave becomes too weak or rarefaction waves quench the reactions, leaving material behind to be observed at our latest images.

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