Fragmentation and Dispersion of Reactive Metal Systems

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Introduction

Exploding cylinder type experiments have been extensively studied and have been useful for correlating dynamic fragment formation with fragment velocity and for being able to predict fracture processes. In the case of reactive metal cylinders, fragment size and its state determine their ability to undergo chemical reaction upon impact loading[i]. These experiments can be used to generate the fundamental understanding needed for design of systems for civilian and defense applications.

While much has been studied of large scale, exploding metal cylinder experiments, the need for smaller scale reactive metal ring exploding tests still exists. Therefore, the objective of this study is to design a setup to perform these small ring explosion tests, including an acceptable manner of determining the conditions of fragmentation and the fragment's velocity, along with an appropriate soft-catch method to characterize the state of the fragments.

Procedure

Four setups were explored during the course of this study. Each setup used Aluminum rings with dimensions of 30mm o.d by 22 mm i.d by 4 mm thickness as the test rings, SX2 explosive (88.2% RDX by mass, with the remainder being plasticizer), and for the most part, number 6 detonators were used.

The first setup had a test Al ring filled with explosive, placed on top of a detonator holder (6.5mm i.d by 18mm o.d by 35mm long with 1mm hole drilled 5mm to end for optical fiber and 5mm notch for the detonator wires at the other end) oriented upwards, in a gap testing stand within a bomb box with sand bags lining the walls as a soft catch method (fragments were sieved out), and high speed framing photography.

The second setup had the explosive-filled Al ring blue-tacked to the detonator oriented sideways, again with sand bags, but streak photography was implemented instead, and Photonic Doppler Velocimetry *(*PDV) was incorporated.

The third setup was the same as the second, but included a block to hold up the PDV fiber and a block to support the detonator holder at known heights, and a Perspex (PMMA) spacer between the Al ring and the explosive to limit explosive and shield the ring from the blast.

The forth setup returned to framing photography, and used an opaque acetal cap instead of a spacer, wax instead of sand for soft-catching of fragments, a less intense but longer duration flash, a capacitor to trigger the detonator, and was the only setup to use an Exploding Bridge Wire Type A detonator. It still used the Perspex support system from previous setups.

Results

The images from various setups are shown in the following figures.

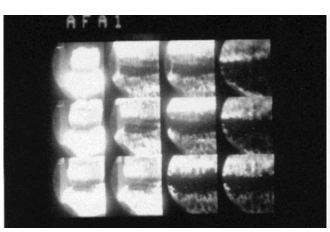

Figure 1. *Framing photography of a ring exploding (Setup 1)*

Figure 2. *Streak image of exploding ring (Setups 2&3)*

Figure 3. *Detonator exploding with new flash and timings (Setup 4)*

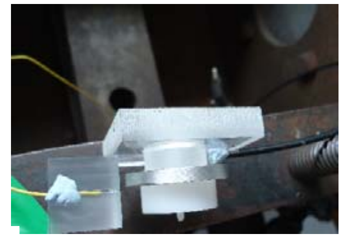

Figure 4. *Setup 4*

The first setup had too much self light and the cloud of fragments and detonator debris obscured any information about point of fragmentation gained from the image (Fig. 1). The sand soft-catch method was effective, however, as a collection rate of between 70-90% was achieved, which is standard with other literature, and it acted as a blast mitigant.

Due to the difficulties in the first setup, streak photography was investigated (Fig. 2), which provided information on fragment velocity that could be correlated with PDV data.

In the third setup, the PDV signal was improved by getting the fiber perpindicular to the ring by creating a known height of the location of the center of the ring and of the fiber through the support blocks. The Perpex spacer was included to produce differing strain rates induced upon the ring by varying the thickness of the spacer.

Upon further consideration of the images achieved from streak photography, it was decided that too much was left to interpretation of the images, and a clear fragmentation point was not discernable.

Therefore, framing photography was reinstated, but with improvements. First, the opaque acetal cap served as a spacer and to block out the self light. Next, the flash timings (time to warm up and duration of the flash) were investigated. The PDV record displayed that the flash was going too late, resulting in the camera missing the time of interest. To correct this issue, a different flash was used, and instead of intially triggering the detonator, the flash was make-triggered and then the detonator triggered through a capacitor connected to a delay generator for accurate timings. Unfortunately, the strong current from the capacitor also caused the number six detonator to punch straight through the SX2, thereby not initiating the explosive and not fragmenting the ring, which is why the EBW Type A detonator was used. Additionally, a wax mold surrounding the perspex supports and Al ring was used instead of sand because it was discovered under microscopic inspection that sand erosion was occurring.

Conclusion

Through the progression of the various test methods, the setup employing framing camera, PDV, and EBW detonator was designed for producing clear images of the fracturing ring, soft-catching the fragments, and measuring their velocity more accurately. Experimentation can now be on actual reactive material rings, as well as for other similar experiments that require small-scale testing.

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[i] Specht, P., Aydelotte, B., Stover, A., Weihs, J., & Thadhani, N. (2009). Impact response of aluminum-based intermetallic-forming powder mixtures. *JANNAF Conference*, (p. 1). La Jolla, CA.