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Small-Scale Performance Testing for Studying New Explosives

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***Abstract*—The development of new high-explosive (HE) formulations involves characterizing their safety and performance. Small-scale experiments requiring only a small amount of explosives are of interest because they can facilitate development while minimizing hazards and reducing cost. A detonation-spreading, dent test, called the Floret test, was designed to obtain performance data for new explosives. It utilizes the detonation of about a 1.0 g sample of HE, initiated by an accelerated aluminum flyer. Upon impact, the HE sample detonates and a copper witness plate absorbs the ensuing shock wave. The dent of the plate is then measured and correlated to the energetic output of the HE. Additionally, the dent measurement can be used to compare the performance of different explosives. The Floret test is beneficial because it quickly returns important performance information, while requiring only a small explosive sample. This work will explain the Floret test and discuss some exemplary results.**

***Index Terms*—detonation-spreading, explosive performance, peak pressure, small-scale testing**

I. Introduction

High-Explosive (HE) materials are used in a variety of applications ranging from mining operations to complex military weapons systems. Though each application looks to the energetic aspect of a material for different reasons, most uses benefit from the achievement of high performance. HE performance is characterized by the peak pressure output, the duration of the pressure pulse, and the total energetic output of a material.

The formulation of an HE often involves the coupling of a powder explosive with a binder resulting in a material referred to as a plastic bonded explosive (PBX). There are many variables within this combination that affect the formulations performance. The particle size and morphology of the HE and the type of binder and its concentration all play a role in the potential energy output of the PBX. The optimization of performance requires the capability to dynamically alter the variables of the composition. During the developmental process, multiple formulations are prepared with variations in particle size, morphology, and amount of binder. Each new combination has to be tested in order to determine which one best meets the needs of an intended application. Small-scale tests allow the developers to rate the new formulations and isolate the features that are most beneficial.

For all applications utilizing newly developed energetic materials, experimenters must consider the availability, safety, and applicability of their samples. Small-scale tests are initially used to obtain a useful amount of data from a small amount of explosives. Developing and handling explosives is an expensive and potentially dangerous task, therefore the smaller the amount of material being used for any experiment the better. Considering safety, cost, and speed of production, small-scale testing is very useful.

One experiment developed to study the performance characteristics of an HE is the Floret test [1]. Using less than 1.0 g of HE, this test facilitates the performance study of a new material through the examination of its peak pressure and detonation-spreading characteristics. Such an approach allows for a semi-quantitative comparison of new formulations to other materials. This paper explains the test and provides some results showing the efficacy of this method.

II. The Floret Test

The Floret test measures the dent produced on a copper witness plate as a result of a detonating explosive sample. The cavity depth and its shape are useful semi-quantitative measures of the pellet energy and its detonation-spreading (divergence) characteristics, respectively.

The test specimen is detonated by an accelerated aluminum flyer. The flyer, which is driven by an LX-16 pellet (density = 1.70 ± 0.01 g/cm^3), detonated with an exploding foil initiator, travels over a 1.83 mm gap before impacting the sample. A copper witness plate (50.8 mm x 50.8 mm square x 25.4 mm thick) placed on the opposite surface of the test specimen, records the output of the detonating sample. The various components are stacked together with 50.8 mm steel discs as spacer or housing components. The stacks are held together with five 10 mm-diameter nuts and bolts. Testing procedures facilitate temperature controls as low as -54˚C, though the results shown in this paper are for experiments conducted at ambient temperature. Additional data are shown elsewhere [2].

A schematic of the Floret Test assembly is shown in Fig. 1. For each experimental run, the witness plate is catalogued as to which material caused the cavity and then set aside for relative performance analysis.

The dent shape profile across the center is read using a profilometer (Cordax 1808-MZ DCC MEA, Sheffield Measurement) that is programmed to take a reading every 25.4 μm along the horizontal scan through the center of the dent. Minor corrections are made to account for the small tilt and slight offset in the cavity profile record associated with each test.

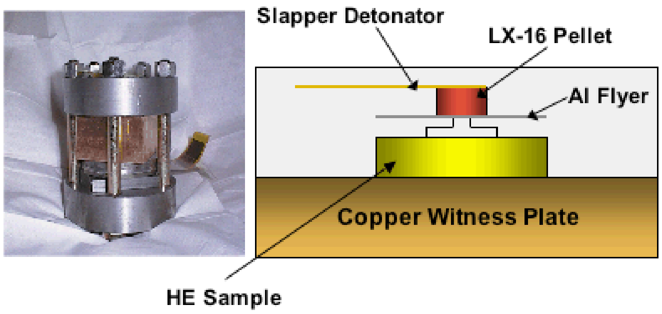

Figure 1. A schematic of the Floret Test assembly [2].

Fig. 2 shows a representative 3-dimensional scan of a witness plate. The resultant dent should exhibit symmetry because of the nature of shock wave propagation and the presumed homogeneity of the copper plates. Through the result processing procedure, profile scans have shown that the dents are indeed symmetric. The symmetry of the dent makes the 2-dimensional image, indicated in Fig. 3, as informative as a 3-D plot. The 3-D images can provide additional insight into the 3-dimensional behavior of the detonating pellet.

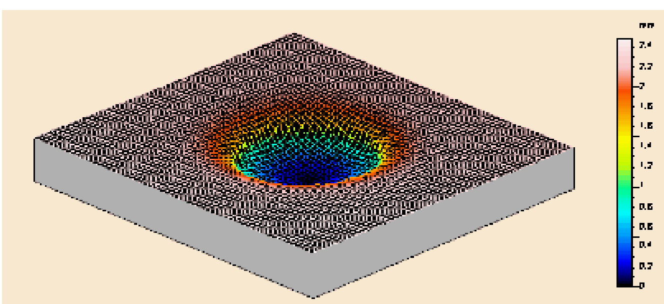

Figure 2. Cu witness plate's 3-D dent profile taken with the profilometer.

From the graphical representation of the dent, the depth and width for each sample are documented. Fig. 3 shows an example of how the results were extracted from a 2-D raw data. This scan, taken through the deepest point of the copper plate, is used to represent the energy output of the HE.

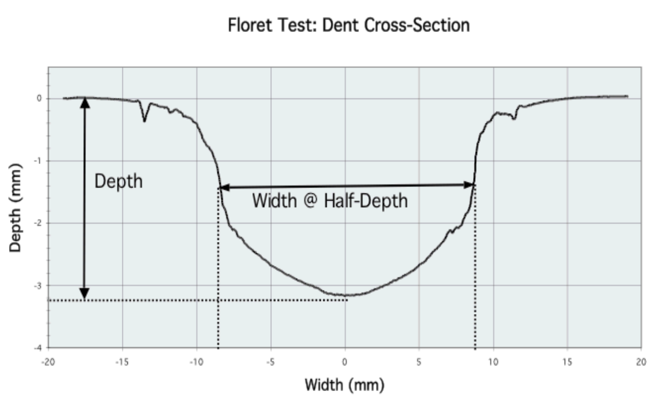

Figure 3. A cross-section of the dent in the copper witness plate.

The depth resulting from the shock wave can be related to the peak pressure of the detonation and is thus a function of energy. The width of the cavity at half-depth can be interpreted as a function of the detonation wave's spreading. These parameters can help define the performance of each explosive. Without modeling to understand the transfer of explosive energy into the copper plate, this technique cannot directly quantify the explosive performance. However, the depth and width can be correlated to the HE's energetic output.

III. Results and Discussion

To demonstrate the effectiveness of the Floret test, a series of experiments has been compiled in two examples. The first example shows the effects of density and flyer size on the explosive material ultra-fine Triamino trinitrobenzene (UF-TATB). The second example shows a comparison between the research explosive RX-55-AA3 and UF-TATB. RX-55-AA3 is composed of 95% of the HE LLM-105 and 5% of the binder Viton A. LLM-105 is a new explosive and the combination of it with 5% Viton A is one of the formulations under investigation as an alternative to UF-TATB.

A. *Example: Effects of Density and Pellet Size on UF-TATB*

The first group consisted of 8 samples of UF-TATB, with densities ranging from 1.690-1.840 g/cc. The dent depth and width at half-depth for each sample were extracted from the profilometer scans and plotted against density. Fig. 4 shows the correlation for density versus depth and Fig. 5 shows the results for density versus width. Two different specimen sizes (~0.5 g and ~1.0 g) were used to evaluate the test sensitivity to sample size. These are included in the same figures for comparison.

To show the reproducibility achieved with the Floret test, three ~1.0 g samples of UF-TATB, all with density of 1.803 ± 0.003 g/cc, were plotted. These samples, depicted in the first two plots enclosed within a circle, show that the variance is less than 6% difference in depth and 4% difference in width. Such slight changes in dent characteristics show that the test is reproducible when it is based on the independent variables: material, density, flyer size, and pellet size.

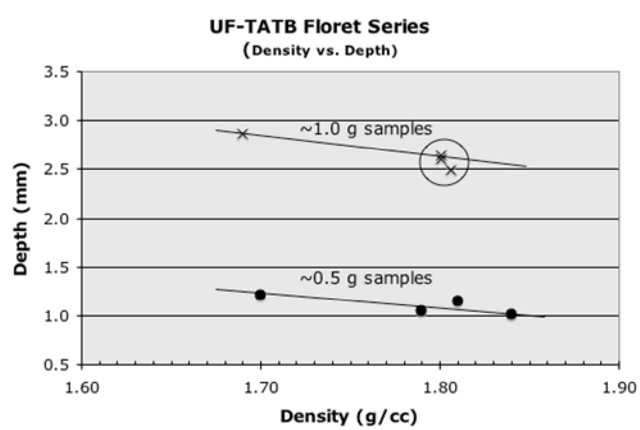

Figure 4. Results for UF-TATB series showing the effects of density and pellet size on depth. All experiments used 5.08 mm diameter aluminum flyers. A straight line is drawn through the data for visual aid only.

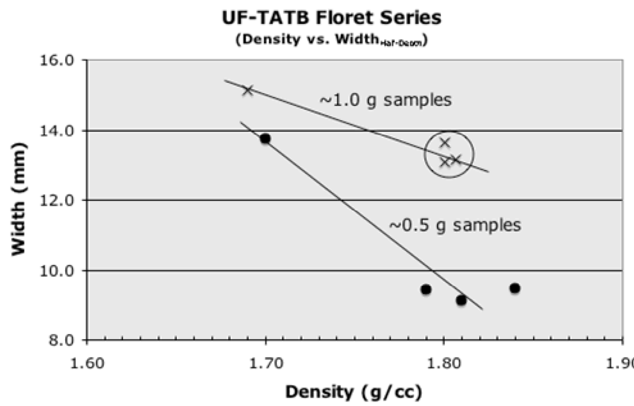

Figure 5. Results for UF-TATB series showing the effects of density and pellet size on width at half-depth. All experiments used 5.08 mm diameter aluminum flyers. A straight line is drawn through the data for visual aid only.

The next characteristic that is observed involves the different sizes of the HE sample pellets. The resultant depths for the larger samples at various densities are approximately twice as deep as those for the smaller samples, as seen in Fig. 4. The depth distribution amongst each sample size in nearly flat; the lines show a slight decrease from lower densities to higher. There is a parallel relationship between the two lines showing that the density does not affect one sample size more than the other.

The slope of the density effects on width for the two sizes is quite different. The widths for the smaller samples (i.e. 0.5 g) vary much more than anticipated, which is indicative of additional complicated effects from density and weight. Additional studies are needed to separate these competing effects.

From this example, one can see that the Floret test provides a reproducible means for determining the effects of size and densities. This feature presents the opportunity to compare one material to another in order to determine relative performance as discussed in the next example.

B. Example: Comparison Between RX-55-AA3 & UF-TATB

The following figures compare the dent characteristics from the material RX-55-AA3 to the results of UF-TATB samples. RX-55-AA3 was developed with the intention that it would outperform UF-TATB. The research explosives were pressed to similar densities as the UF-TATB samples and run using the same procedure. The following figures depict samples of nearly constant density (1.791 ± 0.003 g/cc) with the flyer size as the independent variable.

The performance of RX-55-AA3 is compared directly to UF-TATB in Fig. 6. When both materials are initiated by 5.08 mm flyers, the RX material results in a depth nearly 2.5 times the depth of that UF-TATB. Other experiments (not shown here) show the same superior energy increase.

Since RX-55-AA3 performed better in the tests, it was run with addition parameters, such as varied flyer sizes. The three RX samples were initiated by flyers with diameters of 2.50 mm, 2.80 mm, and 5.08 mm. The size of the dent produced was directly related to the flyer size, with the smallest flyer creating the smallest dent and the largest flyer creating the largest dent, as expected when considering the higher kinetic energy associated with the larger flyers.

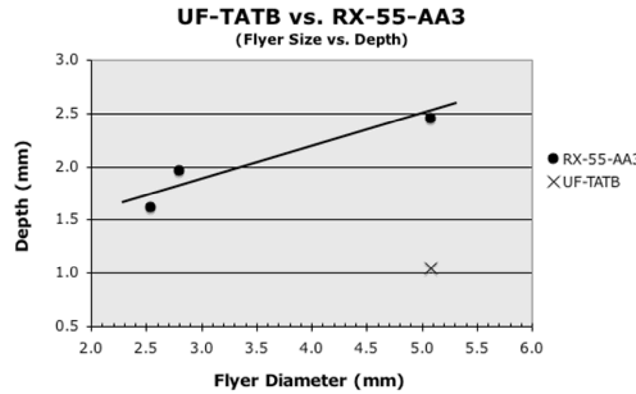

Figure 6. Floret test results for UF-TATB vs. RX-55-AA3 series, showing the effects of flyer size on dent depth of samples with density 1.791 ± 0.003 g/cc. A straight line is drawn through the data for visual aid only.

For depth measurements, the RX material, regardless of flyer size, surpassed the results for the 5.08 mm diameter sample of UF-TATB, shown in Fig. 6. These results show that RX-55-AA3 clearly outperforms UF-TATB when considering the correlation of dent depth (peak pressure).

Fig. 7 shows the width comparison between RX-55-AA3 and UF-TATB. The research material is shown to result with a width around 1.5 times the size as the UF-TATB when they are both initiated with 5.08 mm diameter flyers.

Similar to the depths, the widths were also compared considering the different flyer sizes. An increasing trend was noticed as well, with the larger flyers creating wider dents.

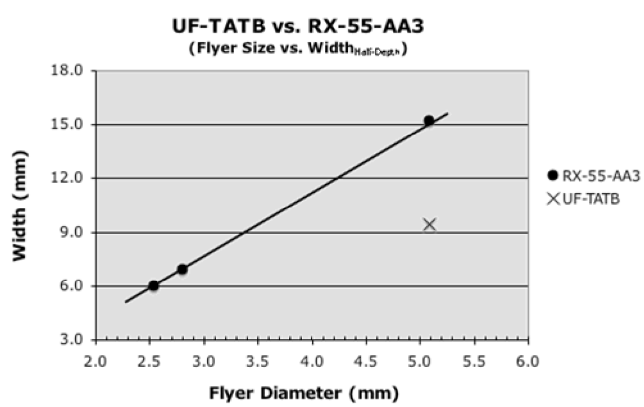

Figure 7. Floret test results for UF-TATB vs. RX-55-AA3 series, showing effects of flyer size on width for samples with density of 1.791 ± 0.003 g/cc. A straight line is drawn through the data for visual aid only.

IV. Summary

This paper demonstrates how a small-scale test (the Floret test), using less than 1 gram of explosive, can provide important performance information. Determining the energetic output of a material is essential in the developmental process of an explosive and the Floret test does it effectively using only a small sample and a relatively simple analysis process.

This test can be used to determine that a new explosive is more effective than an old one. As an example of this capability, RX-55-AA3 was shown to outperform UF-TATB when tested using the same independent variables (i.e. density, flyer size, and flyer material).

ACKNOWLEDGMENT

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