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Author(s): J.E. Kennedy
K.-Y. Lee
T. Spontarelli
J. R. Stine

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Detonation Spreading in Fine TATBs

J. E. Kennedy, K.-Y. Lee, T. Spontarelli and J. R. Stine
Los Alamos National Laboratory
Los Alamos, NM 87545, USA

Abstract

A test has been devised that permits rapid evaluation of the detonation-spreading (or corner-turning) properties of detonations in insensitive high explosives. The test utilizes a copper witness plate as the medium to capture performance data. Dent depth and shape in the copper are used as quantitative measures of the detonation output and spreading behavior. The merits of the test are that it is easy to perform with no dynamic instrumentation, and the test requires only a few grams of experimental explosive materials.

1. Introduction

Metal witness plates have been used for many years as an inexpensive diagnostic of the performance of an explosive system. Typically an explosive acceptor pellet is subjected to a shock input in a gap test or some other type of sensitivity test, and the expected result is that a deep dent or essentially no dent is observed in the recovered witness plate. This is called a go/no-go test because conventional high explosives usually react very little, or they detonate completely, depending upon the magnitude of the stimulus.

Insensitive high explosives (IHEs), however, behave differently. They have long reaction zones and they can have a protracted volume over which the reaction of the explosive is directional. This means that detonation turns corner slowly in IHEs.

Los Alamos has been interested in developing an IHE that can exhibit improved detonation spreading behavior while retaining its status as a certifiable IHE. We approached this study by considering ultrafine triaminotrinitrobenzene (UF-TATB), supplied to LLNL by Pantex,[1] to be a baseline material, and compared its performance in detonation spreading with that of fine TATB materials made at LANL by other methods.

This paper describes some experimental TATB materials that we have produced in small quantities, and a test that we have devised to allow us to compare the detonation spreading behavior of these IHE materials.

2. Spot Size Test for Detonation Spreading Behavior

The test we developed to screen potential IHE booster materials is called the ***detonation-spreading spot-size test.*** The original idea for screening in this way is attributed to W. F. Hemsing[2] of Los Alamos, and previous work by these authors at Los Alamos was reported in Ref. 3. The test configuration used in the current work is sketched in Fig. 1. Dimensions of test IHE samples are 12.7 mm in diameter by 4 mm high. Initiation of the test sample is done by an HE-driven small-diameter flyer plate. The choices of a relatively short sample pellet and a small initiation source were made to limit the opportunity for detonation to spread in the explosive sample. Use of a small-diameter flyer plate as the initiation source also makes it difficult for detonation to spread in an IHE. The response that is measured is the depth and shape of the dent driven by the partial detonation of the test sample into a 3/4-in.-thick copper witness plate upon which the explosive test sample rests.

The initial density considered was 1.80 g/cm^3, the value used by LLNL in their applications of UF-TATB. We found in our initial testing of fine TATB samples at 1.80 g/cm^3 that suitable flyer diameters ("spot sizes") were 3 and 4 mm, with detonation spreading better, of course, when the initiation spot size was larger. These spot sizes produced a dent pattern in the witness plate that indicated the detonation had spread slightly beyond the diameter of the flyer, but had not spread sufficiently to detonate the entire

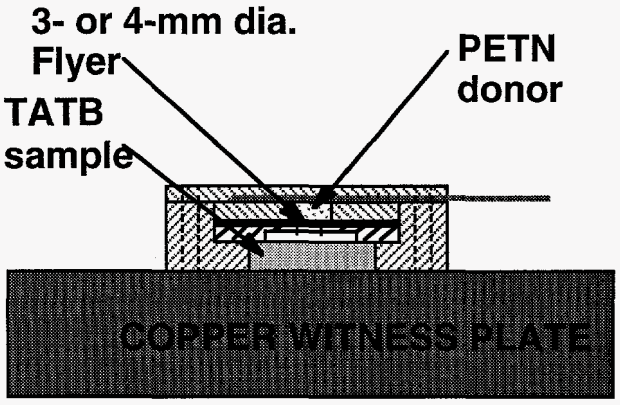

Fig. 1 Detonation-Spreading Spot-Size Test Configuration

diameter of the test sample pellet. Comparison of the dent profiles then indicated the relative detonation-spreading performance of several explosive material samples. Testing of an explosive sample (2-4 shots) can be conducted at a single density with 2-4 g of material, with the time required to press, fire, measure and plot the test results totaling less than one day of effort. We have noticed that the test results are quite sensitive to the density of the explosive pressing; variations in density of 0.01 g/cm^3 produce significantly different dents. All testing to date has been done at room temperature. There are plans to conduct cold tests in the future as a second step in the materials screening process.

3. Preparation of Candidate TATB Materials

Fine and coarse TATB powders were obtained or prepared for evaluation in the detonation-spreading spot-size test. In addition to the UF-TATB standard, samples were prepared by sonochemical amination, and by recrystallization from a mixture of DMSO and sodium hydroxide.

3.1. Preparation of sonochemically-aminated TATB (SA-TATB)

We synthesized TATB from 1,3,5-trichloro-2,4,6-trinitrobenzene by amination with ammonium hydroxide under the influence of ultrasonic irradiation, seeking an easier synthesis route and finer grained material directly from the synthesis. Results from powder charaterization showed that the sonochemically-aminated TATB (SA-TATB) had a particle size comparable to the UF-TATB (~6 μm median size). Scanning electron micrographs showed that the surface is extremely porous.[4]

3.2 Preparation of TATB from recrystallization (TS-TATB)

For the other materials reported in this paper (TS-94 and TS-102), a weak organic acid was added to the solution and slower crystallization occurred at room temperature. To make recrystallized TATB, we started by mixing production grade TATB with solid sodium hydroxide in DMSO and stirred until all solids were dissolved (20 wt. %). This formed a TATB salt solution. The TATB salt solution was added to an acid-containing solvent (or vice versa). The material described below as crash precipitated (TS-CP) was

made by injecting the TATB salt solution into a dilute water solution of hydrochloric acid. The neutralization of the TATB salt caused rapid precipitation to occur, resulting in very fine particle size. It is noted that sodium citrate and sodium acetate are not very soluble in DMSO, and those salts precipitated out with the TATB; such salts were then removed by washing with water.

The particle sizes of the set of TATB materials produced in these ways are compared in Table I.

Table I. Types of Fine TATB Tested for Detonation Spreading

TATB Type	Preparation	Median Particle Size
Production Grade	Hercules	50 μm
UF-TATB[3]	Milled	6 μm
TS-CP	Crash Precipitated	< 1 μm
SA-TATB	Sonochemically Aminated	4 μm
SA-TATB	Sonochemically Aminated	6 μm
TS-102	Recrystallized from DMSO w/ Acetic Acid	2.5 μm
TS-94	Recrystallized from DMSO w/ Citric Acid	1.2 μm

4. Detonation Spreading Test Results

Weights and dimensions of all sample pellets were measured so that density could be calculated, and tests were done with densities matched as closely as possible among the available sample pellets. At nominal densities of 1.80 and 1.78 g/cm^3, no TATB sample detonated completely at either flyer spot size. Thus all materials performed "within the range" of this test at these densities. No results were encouraging to the point of suggesting that a booster smaller than 50 mm in diameter would exhibit favorable detonation spreading.

R. S. Lee of LLNL[5] found that detonation spreads much better in fine TATB at a density of 1.70 rather than 1.80 g/cm^3. Initial results with 1.70-g/cm^3 fine TATB are encouraging in that some, but not all, of the TATB samples appear to detonate completely. The dents produced in the witness plate are then much deeper than those produced by 1.80-g/cm^3 UF-TATB, even though the explosive density is lower.

No TATB materials containing binder have yet been tested in the detonation-spreading spot-size test.

Representative dent shapes are plotted in Fig. 3, and Table II contains a listing of dent depths as a means of comparing various preparation methods, particle sizes, and pressed densities.

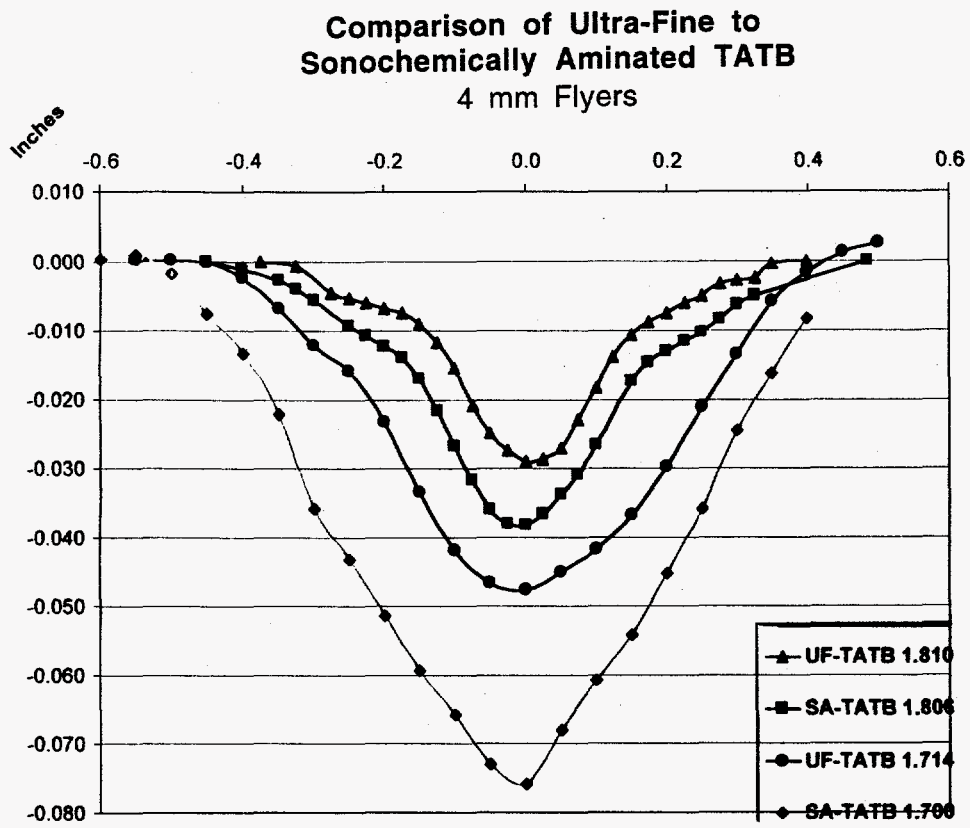

Fig. 3. Dent Profiles for Fine TATBs Impacted by 2.6-km/s, 4-mm-Dia. Stainless Steel Flyers. Legend indicates density of sample pellet.

Table II. Dent Depth in Detonation-Spreading Spot-Size Test with 4-mm-Diameter Flyers

TATB Type	Density	Particle Size	Max. Dent Depth	Comment
Prod. Grade	1.805 g/cc	50 μm	0.018 in.	
UF-TATB	1.810 g/cc	6 μm	0.029 in.	
SA-TATB	1.806 g/cc	6 μm	0.031 in.	
SA-TATB	1.806 g/cc	4 μm	0.037 in.	
TS-CP	1.78 g/cc	< 1 μm	failed	"Amorphous" structure
UF-TATB	1.700 g/cc	6 μm	0.065 in.	
SA-TATB	1.700 g/cc	6 μm	0.072 in.	Detonated completely
TS-102	1.700 g/cc	2.5 μm	0.076 in.	Detonated completely
TS-94	1.693 g/cc	1.2 μm	0.056 in.	

For most explosive materials, more finely divided powders are more sensitive than coarser powders of the same explosive, particularly when the initiation stimulus is a strong shock source, such as our high-velocity steel flyer plate. However, the observation that the crash-precipitated TATB, which is the finest material tested, produced the smallest dent of

all samples indicates that particle size is not the sole factor influencing sensitivity in TATB. The crystal structure appears to be important (the crash-precipitated TATB appeared to be amorphous). The particle morphology is also important, since materials with comparable particle sizes (UF-TATB and SA-TATB) behaved differently.

The fact that some of the fine 1.70-g/cm^3 TATB samples detonated completely means that the test ran out of range, and could not rank the detonation-spreading characteristics of the most sensitive materials. Test results might be brought back into range by (1) employing shorter pellets, or (2) conducting the test at cold temperature. Of course, if the test sample pellet shape is changed, the results should then only be compared with those from tests of other materials done with the same sample pellet size.

5. Conclusions

These results indicate that it is possible to obtain better detonation corner-turning performance from fine TATB materials made with simple manufacturing processes. Particle morphology and perhaps crystal structure appear to influence the sensitivity of TATB, in relation to detonation spreading. It remains to be seen whether these more sensitive TATB materials can be certified as IHEs, particularly if they are used at lower density such as 1.70 g/cm^3.

Acknowledgments

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