Journal of Energetic Materials
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713770432

Shock ignitability test for azide polymer propellants

E. Kimura[a]; Y. Oyumi[a]
[a] Third Research Center, Technical Research and Development Institute, Japan Defense Agency, Tokyo, Japan

To cite this Article Kimura, E. and Oyumi, Y.(1998) 'Shock ignitability test for azide polymer propellants', Journal of Energetic Materials, 16: 2, 173 — 185
To link to this Article: DOI: 10.1080/07370659808217511
URL: http://dx.doi.org/10.1080/07370659808217511

SHOCK IGNITABILITY TEST FOR AZIDE POLYMER PROPELLANTS

Eishu Kimura and Yoshio Oyumi

Third Research Center, Technical Research and Development Institute,

Japan Defense Agency, 1-2-10 Sakae, Tachikawa, Tokyo 190, Japan

ABSTRACT

The shock ignitability test, which is relatively simple method yet rarely applied to solid rocket propellants, was used to evaluate the sensitivities of azide polymer propellants. Variations in sensitivities were observed when compared with results from the card gap test. Although AP-based propellants were insensitive in the card gap test, they demonstrated high ignitability in this test. These differences are ascribed to differences in sample weight, the manner in which samples are held, and the input energy from the donor explosive. It was found that the results of the shock ignitability test were closer to those of the fragment impact test than to those of the card gap test.

INTRODUCTION

For the design of low sensitivity solid rocket propellant, it is valuable to have some understanding of the effects of individual component (oxidizer, binder, catalyst, etc.) and mechanical properties on the sensitivities. There are various methods for assessing a sensitivity according to the kind of the energy put into a sample. Even with the use of appropriate standard sample,

Journal of Energetic Materials Vol. 16, 173-185 (1998)
Published in 1998 by Dowden, Brodman & Devine, Inc.

it is often difficult to absolutely compare results obtained with different instruments and criteria by different operators[1]. In 1993 it was reported that the shock ignitability test was suitable for assessment of explosives' sensitivities[2,3]. The merit of the test was relatively simple and easy to judge. In the current work, the assessment was applied to sensitivity of solid rocket propellants and the results were compared with results obtained with another test.

MATERIALS

Tables 1 and 2 show propellant compositions of GAP-based and NMMO-based samples tested here, respectively. The oxidizers used were ammonium nitrate (AN), ammonium perchlorate (AP) ,HMX and AN mixed with approximately 14% HMX. Samples 1 and 2 differ in mechanical properties, and were prepared to evaluate the relationship between mechanical

TABLE 1

Compositions of the GAP-based Samples

No.	GAP	TTN	HMX	AP	AN	NC	PbCi	FeO	CuC	CB	B	Al
1s	29.5	-	14.8	-	54.1	-	-	-	-	0.6	1.0	-
1h	29.5	-	14.8	-	54.1	-	-	-	-	0.6	1.0	-
2s	14.5	14.5	-	-	48.2	19.3	1.9	-	1.0	0.6	-	-
2h	14.5	14.5	-	-	48.2	19.3	1.9	-	1.0	0.6	-	-
3	17.8	-	-	79.2	-	-	-	1.0	-	-	-	2.0

GAP: Glycidyl azide polymer, TTN: Trimethylolethene trinitrate (TMETN),
AP: Ammonium perchlorate, NC: Nitrocellulose, PbCi: Lead citrate, FeO: Iron oxide(III),
CuC: Copper chromite, CB: Carbon black, B: Boron, Al: Aluminum
s = It symbolized the softer mechanical property.
h = It symbolized the hard mechanical property.

TABLE 2

Compositions of the NMMO-based Samples

No.	B/N	HMX	AP	AN	PbCi	FeO	FeB	CuC	ZrC	CB
4	23.8	14.3	-	57.1	-	-	1.9	2.9	-	-
5	24.1	72.5	-	-	2.9	-	-	-	-	0.5
6	21.9	-	73.3	-	-	2.9	-	-	1.9	-
7a	22.4	-	75.1	-	-	0.5	-	-	2.0	-
7b	22.4	-	75.1	-	-	0.5	-	-	2.0	-
8a	23.0	-	77.0	-	-	-	-	-	-	-
8b	23.0	-	77.0	-	-	-	-	-	-	-

B/N: BAMO/NMMO binder, FeB: Butacene

a = It has a smaller average size of AP particle.

b = It has a larger average size of AP particle.

properties and sensitivities. Differences in mechanical properties were achieved by varying the level of curing agent in the binder. The symbols "h" and "s" indicate hard and soft samples, respectively. Samples 7 and 8 vary with respect to the distributions of AP particle size, and were prepared to evaluate the relationship between oxidizers particle size and sensitivities. The formulation with the "a" notation has a smaller average of AP particle size than does that with the "b" notation.

METHODS

The test procedure was based on a previously reported method[2] except for a modification made in order to evaluate solid propellant sensitivity. The test set-up shown in Figure 1 was composed of a steel tube with a base. The tube had a 30mm inner diameter and a height of 50mm. The gap plate(s) were 29mm in diameter and were made of aluminum. A no.6 detonator was

used. The sample weighed 20g and had a 29mm outer diameter. The gap material used was aluminum (JIS H 4000, 6061) and had a density of 2.703g/cm^3. This material was chosen to facilitate comparison with card gap tests we have carried out previously[9]. The thickness of the plates were 1, 2, 4, 8 and 16mm; each of them or their combination were applied to the test. The test procedure is shown as follows.

1. A sample having an outer diameter of 29mm and a weight of 20g is molded and placed into the steel tube.
2. A plate with given thickness was placed directly on the top of sample. If the gap material protruded over the steel case wall, a tubular steel pipe of the same diameter as the case was attached to the top end of the case.
3. A no.6 detonator was inserted through a piece of cardboard with a 29mm diameter and a 6mm hole in the center of it. The detonator was held in place by means of a piece of tape.
4. The sample was buried under sand 30cm in depth.
5. The detonator was ignited. Reaction behavior was evaluated based on the damage condition of the case.

The behavior was judged to be either "detonation", "burning" or "no reaction". In the case of the detonation, the steel case bursts and breaks into fragments or cleaves at the bottom like a tulip flower. All of the sample is consumed and unrecoverable after the test. It is difficult to distinguish "deflagration" from "burning". In both cases, part or all of the case bottom separates from the case body and some expansion is observed around the case body. Samples are also not recoverable. Some fumes are observed and the case temperature is high immediately after the test. In the case of "no

reaction", the sample remains nearly intact in the case. The method for judging a sensitivity is described below.

1. At first, use a given gap length, Use a gap length twice as thick as the original gap length if any reaction occurs. Use a gap length half the thickness of the original length if the sample doesn't react.
2. Attempt on a gap length three-fourths as thick as the original length if "no reaction" is observed at twice the gap length. Use a gap length 1.5 times as thick as the original length if the sample doesn't react on the half gap length.
3. Stop testing when the difference of the gap thickness between "reaction" and "no reaction" becomes 1mm.

The minimum gap length (symbolized G/L) of "no reaction" is defined as the critical gap length (symbolized Critical G/L), when reaction is defined as "detonation" and "burning", which are noted in the remarks of the tables. It is impossible for the metal-jet generated from no.6 detonator to penetrate the gap plate over 7mm in thickness.

RESULTS

The test results of the GAP-based samples are shown in Table 3. Judgments, which indicate reaction or not, are represented respectively by circle or cross symbols in the order of trials from left to right. Comparison of sample 1 with sample 2 indicates that the nitrate esters, TMETN and NC, sensitized the sample because they are sensitive to the shock stimuli. When HMX is present at a level of 15% or less, it has no effect on the sensitivity even though HMX has a detonation characteristic. Sample 3, whose oxidizer

is AP, was sensitive based on its high flammability and the reaction was judged to be "burning".

More effects of mechanical properties on sensitivity were observed between samples 2s and 2h than between those of samples 1s and 1h in spite of the lower binder content. It is suspected that the shock wave of the detonator through the gap plate is better absorbed by the softer sample.

The results of NMMO-based samples are shown in Table 4. Detonation occurred only for sample 5, which contained 73% HMX, and is used as a high explosive. The sensitivities of the AP and AN/HMX samples in the NMMO binder were observed to be approximately equal while the sensitivities of the AP and AN/HMX samples in the GAP binder had quite different sensitivities. As regards the diameter of the AP particles, samples with a larger average of AP particle size were more sensitive than those with smaller ones as evidenced by comparison of samples 7a and 8a with samples 7b and 8b. Based on a comparison of samples 7 and 8, the catalysts appeared to sensitize the sample.

It was possible for the shock ignitability test to better distinguish sensitivities between one sample and another than would the card gap test. The main reasons for this is that the plate thickness for the gap plate is 5mm (versus 1, 2, 4, 8 or 16 for the shock ignitability test) and the witness plate under the sample are used for judgment in the card gap test (versus examination of actual propellant in the shock ignitability test). The gap material of the shock ignitability test was identical to that of the card gap test in order to compare each test characteristics. Table 5 shows the critical gap length of the shock ignitability test as well as the card gap test for reference[4].

The results indicate quite different results for some of the samples examined by the two test methods. The sensitivity characteristics evaluated by each method were also different.

First of all, it was remarkable that the sensitivity of the AP oxidized GAP-based sample was significantly lower in the card gap test than it was in the shock ignitability test. Reactions in the card gap test may be judged "no reaction" if no crack or hole is observed on the witness plate even if the sample completely burns. In practice, the AP-oxidized sample was entirely consumed after the test. Also, AP is known to be highly flammable.

An HMX-based sample (B/N; 23.7, HMX; 71.2, lead stearate; 4.6, CB; 0.5) with the same composition as sample 5 except the catalysts were different, had a critical gap length of 25mm in the card gap test[9]. On the other hand, sample 5 was low sensitivity in the shock ignitability test. The reaction behavior to the shock ignitability, however, was "detonation". It is impossible to directly compare with another burnt sample results just based solely on the thickness of the gap plate.

In this series of shock ignitability tests, only one detonation was observed presumably because of the smaller energy put into the sample and because only a forth to a third of the sample weight normally used in the card gap test was used. Samples were held relatively tightly because the case is made of a steel and has a bottom. It is possible to judge directly between "no reaction" and "burning" since samples remain intact in the case at "no reaction". The shock ignitability test may have two characteristics: one is of the card gap test, whose energy is a shock wave generated by a explosive. The other is of the fragment impact test, whose energy is a heat made by a friction

between the fragment and the sample.

CONCLUSIONS

The effect of the main oxidizer on sensitivity to the shock ignition was different for propellants with different binders. The sensitivity of the AN/HMX sample in the GAP-based sample showed much lower sensitivity than that of the AP sample though the sensitivity of the AN/HMX sample in the NMMO-based indicated almost the same level of the sensitivity.

The effect of the mechanical properties on sensitivity to the shock ignition was observed for a series of GAP-based samples. It was found that harder samples were slightly more sensitive than the softer ones.

The effect of the AP particle size distribution was observed for a series of NMMO-based samples. It was found that samples with a larger AP particle size distribution were more sensitive than those with a smaller particle size. The addition of catalysts caused the sample to become more sensitive to shock ignitability.

REFERENCES

(1) Standard of the Japan Explosive Society (III), (1988).

(2) T. Kazumi, Y. Suzuki, T. Okada, K. Hara, K. Aoki and T. Yoshida, "Shock ignitability test of mixtures of detonatable compounds and oxidizers", J. Indust. Explos. Sci., Japan, 54, 76-86 (1993).

(3) H. Hatano, K. Hara, K. Aoki, J. Peng, F. Hosoya and T. Yoshida, "Shock ignitability test of explosive compounds", J. Indust. Explos. Sci., Japan, 54, 94-102 (1993).

(4) E. Kimura and Y. Oyumi, "Screening test of azide polymer propellants ", Technical Report of Technical R & D Institute, Japan Defense Agency, T-265 (1995).

(5) E. Kimura and Y. Oyumi, "Insensitive munitions and combustion characteristics of BAMO/NMMO propellants", J. Energetic Materials, 14, 201-215 (1996).

TABLE 1

Test Results of the GAP-based Samples

Sample 1s		Sample 1h	
G/L [mm]	Judgment	G/L [mm]	Judgment
2	×	2	×
1	×	1	×
0	×	0	×
Critical G/L: 0mm, Reaction: None		Critical G/L: 0mm, Reaction: None	
Sample 2s		**Sample 2h**	
G/L [mm]	Judgment	G/L [mm]	Judgment
4		4	×
3		3	×
2	× ×	2	× ○ ○
1	× ○ ×	1	○
0	○	0	
Critical G/L: 1mm, Reaction: Burning		Critical G/L: 3mm, Reaction: Burning	
Sample 3			
G/L [mm]	Judgment		
32	×		
24	×		
20	×		
18	×		
17	○		
16	○		
8	○		
4	○		
Critical G/L: 18mm, Reaction: Burning			

○: Detonation or burning, ×: No reaction

TABLE 2

Test Results of the NMMO-based Samples

Sample 4		Sample 5	
G/L [mm]	Judgment	G/L [mm]	Judgment
8	×	4	×
6	×	2	×
5	○	1	×
4	○	0	○
2	○		
Critical G/L: 6mm, Reaction: Burning		Critical G/L: 1mm, Reaction: Detonation	

Sample 6	
G/L [mm]	Judgment
6	×
4	○
2	○
1	○
Critical G/L: 6mm, Reaction: Burning	

Sample 7a		Sample 7b	
G/L [mm]	Judgment	G/L [mm]	Judgment
8	×	16	×
6	×	12	×
5	○	10	×
4	○	9	×
		8	○
Critical G/L: 7mm, Reaction: Burning		Critical G/L: 9mm, Reaction: Burning	

Sample 8a		Sample 8b	
G/L [mm]	Judgment	G/L [mm]	Judgment
8	×	8	×
6	×	7	×
5	○	6	○
4	○	4	○
Critical G/L: 6mm, Reaction: Burning		Critical G/L: 7mm, Reaction: Burning	

TABLE 3

Comparison of the Critical Gap Length between the Card Gap Test and the Shock Ignitability

No.	Card gap	Shock ignitability
1s	0	0
1h	0	0
2s	25	1
2h	25	3
3	0	18
4	5	6
5	-	1
6	5	6

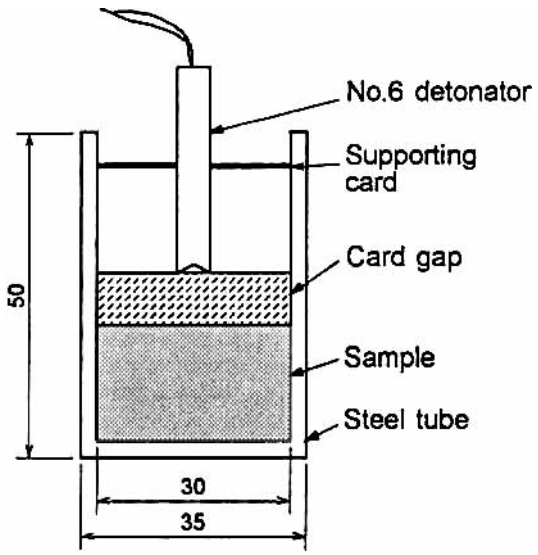

FIGURE 1
Schematic Diagram of the Test Set-up of the Shock Ignaitability