Propellants, Explosives, Pyrotechnics *12*, 130–132 (1987)

The Initiation Threshold Sensitivity of HNS Explosive as a Function of its Grain Size

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Die Zündschwellenempfindlichkeit des Sprengstoffs HNS in Abhängigkeit von seiner Korngröße

Die Zündschwellenempfindlichkeit von HNS wurde in Abhängigkeit von der Korngröße gemessen unter Verwendung einer elektrischen Kanone bei zwei Plattendicken. Die Zündschwelle (kinetische Energie der Flugplatte) in Abhängigkeit von der Korngröße zeigt, daß die Grenzwertkurve dramatisch ansteigt bei einer Korngröße größer als 5,4 µm (bei einer Plattendicke von 76,2 µm und Sprengstoffdichte von 1,6 g/cm³). Die Mindestwerte für die kritische Energie wurden berechnet zu 12,15 ± 0,5 J/cm² bei einer Plattendicke von 76,2 µm bzw. zu weniger als 7,0 J/cm² bei einer Plattendicke von 20,0 µm.

Variation du seuil de sensibilité à l'amorçage de l'hexanitrostilbène en fonction de sa granulométrie

On a analysé l'influence de la granulométrie de l'hexanitrostilbène sur son seuil de sensibilité à l'amorçage à l'aide d'un canon électrique en utilisant deux différentes épaisseurs de clinquant. L'évolution du seuil d'amorçage (énergie cinétique de la plaque projetée) en fonction de la granulométrie montre que la sensibilité croît considérablement, dès que la taille des grains dépasse 5,4 µm (pour un clinquant de 76,2 µm d'épaisseur et une masse volumique de l'explosif de 1,6 g/cm³). Les valeurs minimales pour l'énergie critique, fournies par le calcul, sont de 12,15 ± 0,5 J/cm² pour une épaisseur de clinquant de 76,2 µm et de moins de 7,0 J/cm² pour une épaisseur de clinquant de 20,0 µm.

Summary

The initiation threshold sensitivity of HNS versus explosive grain size has been measured, using an electric gun, with two flyer thicknesses. The initiation threshold, (kinetic energy of flyer plate), versus explosive grain size shows that the threshold curve increases dramatically at grain size over 5.4 µm (for flyer thickness 76.2 µm at explosive density 1.6 g/cm³). Minimum critical energies were calculated to be 12.15 ± 0.5 J/cm² and less than 7.0 J/cm², for flyer thicknesses 76.2 µm and 20.0 µm, respectively.

1. Introduction

The usefulness of HNS in explosive components has been demonstrated by Kilmer[1] and Schwarz[2]. The initiation threshold of HNS by electrically-driven flyer plate (slapper) had been investigated by Schwartz[3]. He measured the initiation threshold sensitivity of three types of explosive, which differ in their grain sizes: (1) HNS-Hyperfine (HF), (2) HNS-Superfine (SF) and (3) HNS-1 Schwarz[3] showed that the probability of detonation of HNS (HF) by impacting flyer, is very high, in comparison to the other types of explosive grain size.

It was shown earlier on HNAB[4,5] that the powder morphology plays also a significant role in the shock initiation sensitivity of the explosive.

At this note we measured, for the first time, by electric gun, the exact value of HNS grain size, where the initiation threshold energy changes dramatically.

2. Experimental and Material Properties

Experiments were conducted for studying the effect of explosive grain size on the shock initiation threshold of HNS, using the electric gun previously described in detail in Refs. 4 and 5. The electric gun was usually composed of copper foil (thickness 8 µm, area 1 mm × 1 mm), and polyamide or polyester flyer, thickness 76.2 µm or 20 µm.

The explosive HNS was prepared by method described in Refs. 6 and 7. We developed a recrystallization method of controlling the distribution of particle sizes around the mean value required grain size. Two batches were prepared at different times in order to prove the constitency of the recrystallization method. The values of each particle size were measured by Hiac Particle Size Analyzer – PA-770, and summarized in Table 1. In Figs. 1a, 1b, we show typical examples of HNS with different grain sizes as were detected by SEM (Scanning Electronic Microscope).

3. Results and Discussions

Many experiments were performed in order to ensure good statistics for the initiation threshold data. (The experimental points represent 50% probability of the explosive's detona-

Table 1. The Distribution of Particle Sizes around the Mean Value of HNS Grain Size

Mean Values of HNS Grain Sizes											
3.3 µm Distribution				5.4 µm Distribution				16.3 µm Distribution			
[µm]	[%]	[µm]	[%]	[µm]	[%]	[µm]	[%]	[µm]	[%]	[µm]	[%]
1.1	3.85	11.1	1.32	1.1	6.01	11.1	5.14	1.1	0.13	11.1	8.27
1.3	7.67	13.0	0.78	1.3	9.14	13.0	3.81	1.3	0.35	13.0	10.06
1.5	4.47	15.4	0.42	1.5	4.29	15.4	2.30	1.5	0.17	15.4	10.23
1.8	7.86	18.2	0.41	1.8	6.56	18.2	1.52	1.8	0.42	18.2	11.46
2.1	7.92	21.4	0.29	2.1	5.58	21.4	0.76	2.1	0.60	21.4	9.37
2.5	9.30	25.3	0.12	2.5	6.13	25.3	0.27	2.5	0.78	25.3	8.06
2.9	7.63	29.9	0.04	2.9	5.02	29.9	0.07	2.9	0.90	29.9	6.52
3.5	9.53	35.2	0.00	3.5	5.98	35.2	0.04	3.5	1.35	35.2	4.41
4.1	9.00	41.6	0.00	4.1	5.61	41.6	0.00	4.1	1.80	41.6	2.35
4.8	8.96			4.8	6.08			4.8	2.45		
5.7	7.87			5.7	6.39			5.7	3.41		
6.7	5.80			6.7	6.59			6.7	4.29		
7.9	4.21			7.9	6.64			7.9	5.40		
9.4	2.51			9.4	5.87			9.4	7.27		

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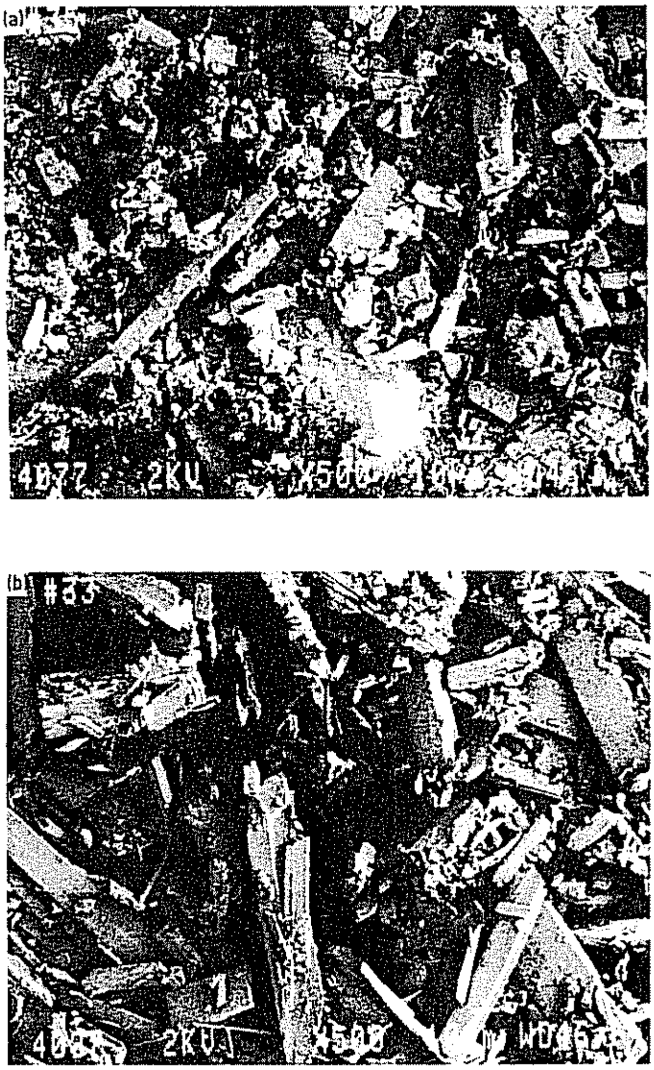

Figure 1. Morphology picture of HNS by SEM, magnification × 500. (a) Mean value grain size 5.4 μm; (b) Mean value grain size 16.3 μm.

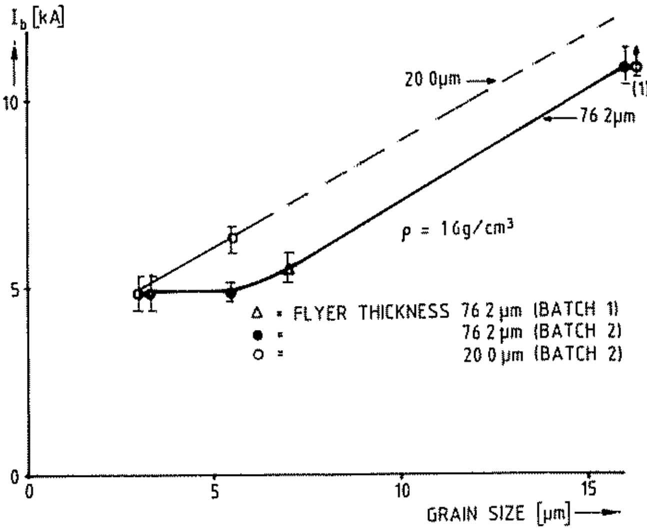

Figure 2. Burst current, I_b, at initiation threshold versus explosive grain size, where explosive density 1.6 g/cm³. (Point 1, is under estimate for the threshold of I_b at flyer thickness 20.0 μm)

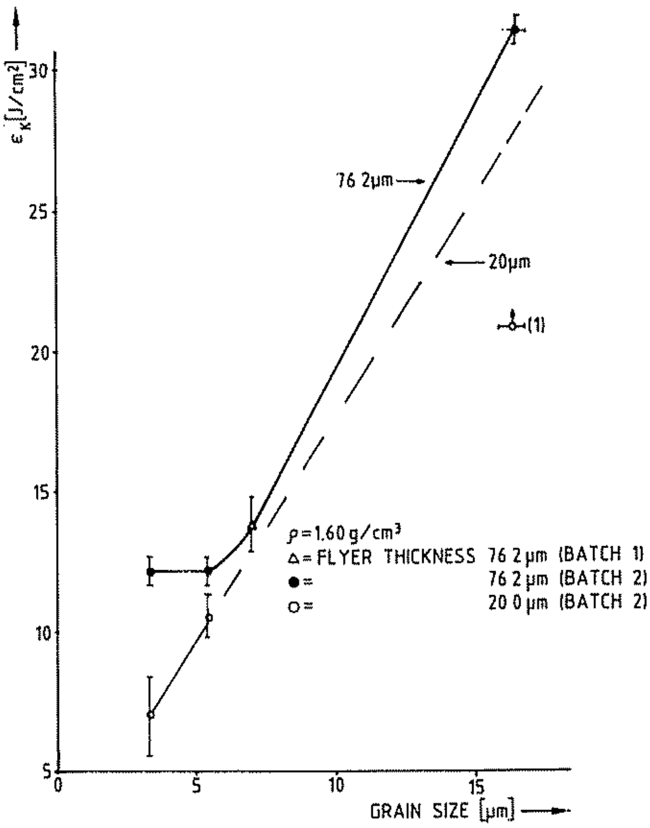

Figure 3. Kinetic energy, E_k, of flyer plate at initiation threshold versus explosive grain size (μm), where explosive density 1.6 g/cm³. (Point 1, is under estimate for the threshold of E_k at flyer thickness 20.0 μm)

tion). In each experiment we measured the foil's current and voltage waveforms. The flyer velocity can be controlled between 0.7 mm/μs to 2.5 mm/μs by adjusting the burst current density, as described earlier in Ref. 5.

The effect of the explosive grain size between 3.3 μm and 16.3 μm on threshold current is shown in Fig. 2. We used in the experiments two flyer thicknesses, 20 μm and 76.2 μm.

In Fig. 3 we plotted the kinetic energy, E_k, of the flyer, as a function of grain size for the two flyer thicknesses.

There are two main results:

(a) The kinetic energy, E_k, required for initiation threshold of HNS is lower as the shock pulse duration is shorter (flyer thicknesses 76.2 μm and 20.0 μm corresponding to pulses duration 42 ns and 11 ns, respectively[5]).

(b) There is a plateau range in the burst current (Fig. 2) and in the kinetic energy (Fig. 3) which is dependent on the grain size and the flyer thickness.

The results clearly indicate (Fig. 3) that as the pulse duration of initiating gets longer, the threshold curve swings away from the curve $P^2\tau$ = const as previously described[5] for HNAB (P is the impact pressure).

The initiation threshold (kinetic energy at Fig. 3) versus grain size shows that the threshold curve increases dramatically at grain size over 5.4 μm (for flyer thickness 76.2 μm). Moreover, at smaller flyer thickness (20.0 μm) the critical grain size is equal or less than 3.3 μm (which was the smallest grain size of HNS that had been checked in our measurements).

The sharp changes in the threshold curves (see Figs. 2 and 3), can be expected from the hot spot model[8] as we explain below.

The plateau in the kinetic energy E_k (Fig. 3), shows that there is a minimum value for critical energies[9]. These critical energies are the minimum energy required to initiate the explosive with constant flyer thickness and explosive density.

The minimum critical energies were calculated to be 12.15 ± 0.50 J/cm² and less than 7.0 J/cm² for flyer thicknesses 76.2 µm and 20 µm, respectively. (The critical energy, E_c, was calculated[10] from impedance matching between the impact flyer (mylar) and the explosive target (HNS). The result is, that $E_c = E_k$ for explosive density 1.6 g/cm³.)

We can summarize that the sensitivity of HNS, in terms of reaching detonation from a given shock pulse input, would simply increase with decreasing grain size.

The result above is compatible with the argument[11] that the rate of chemical energy release is governed by the number of reaction sites which are larger for an explosive with fine grain size.

We intend to continue our work and try to find the initiation threshold sensitivity of PBX (plastic bonded explosives) based on HNS, as a function of explosive grain size.

4. References

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Acknowledgement

We are grateful to Ms. D. Ayalon for preparation of HNS and development of recrystallization method

(Received February 6, 1987; Ms 2/87)