Schwarz (D3162)

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SHOCK-INITIATION SENSITIVITY OF HEXANITROSTILBENE (HNS)*

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Experiments were conducted to study the influence of powder morphology, sample density, diameter of the impacting flyer and duration of the stimulus on the shock initiation sensitivity of the high explosive, hexanitrostilbene. The shock stimulus was provided by a polyimide flyer accelerated by an electrically-exploded, metallic foil. Impact pressure (P) was controlled between 3.8 and 9.8 GPa and pulse duration (τ) was nominally 0.035 μs except for the last experiment where pulse duration varied. Powder morphology significantly influenced the shock amplitude required for initiation with the finest-particle HNS requiring the least pressure, 6.3 GPa, and exhibiting the sharpest threshold. Both a reduction in density of HNS, from 1.60 to 1.30 Mg/m^3, and an increase in flyer diameter affected a reduction in impact velocity (or pressure) needed to induce detonation. The line which separates detonation from non-detonation is expressed by $P^{2.4}\tau$ = constant for τ between 0.01 and 0.10 μs; for longer pulses the initiation criterion becomes one of constant pressure.

INTRODUCTION

The usefulness of hexanitrostilbene in explosive components has been demonstrated (1,2) and many current applications exist. During the past several years, initiation studies have been performed to identify some of the factors which influence shock initiation sensitivity and to quantify those effects. The parameters evaluated were powder morphology, sample density, diameter of the impacting flyer and duration of the shock stimulus. In all experiments, a polyimide flyer provided the shock stimulus.

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EXPERIMENTAL TECHNIQUES

Test Device

The impact of a thin flying plate on an explosive provides a reproducible means for applying a pressure whose amplitude (P) and duration (τ) can be independently controlled. A device which provides this stimulus is shown in Fig. 1. The firing set is a capacitor discharge unit which provides a current pulse which explodes the metallic foil and propels the polyimide flyer to the desired impact velocity. The impact velocity is determined precisely from a pre-calibration curve, Fig. 2, which is derived from measured burst current densities and VISAR*-measured flyer velocities. (Burst current density is the burst current divided by the cross-sectional area of the foil.)

*Velocity Interferometer System for Any Reflector (3)

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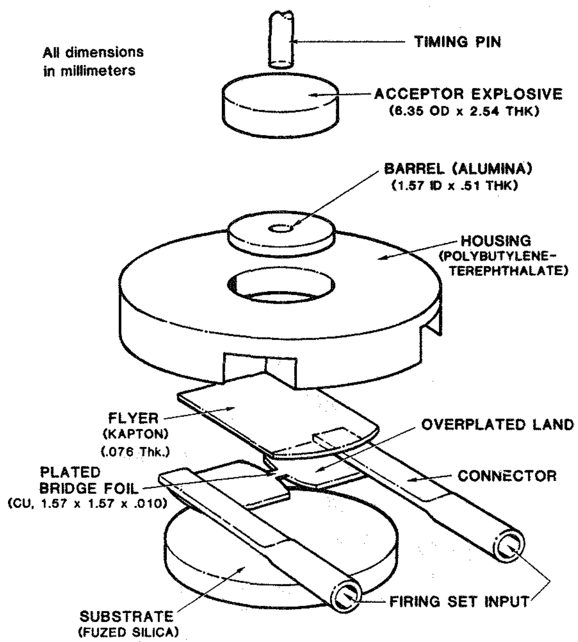


Fig. 1 Exploded view of flying plate test device.

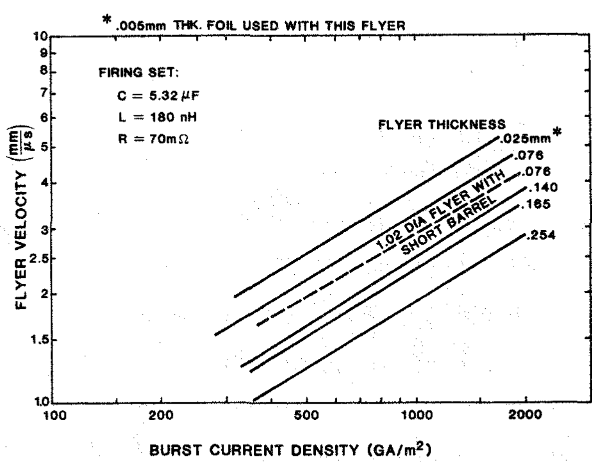


Fig. 2 Flyer velocity versus burst current density for several flyer thicknesses.

The impact pressure was controlled between 3.8 and 9.8 GPa and the pulse duration, which was determined by a double transit time through the flyer, was controlled between 0.011 and 0.137 μs. In all experiments (except for HNS density of 1.30 Mg/m^3) the shock impedance of the flyer was less than that of the explosive, assuring a constant-pressure, fixed-duration pulse in the test specimen.

Test Procedure

Each detonation threshold experiment consisted of 24 individual test firings using an "up-down" method, per Fig. 3, in which the charging voltage on the firing set was adjusted upward after a non-detonation and downward after a detonation. Shock arrival time measurements confirmed detonation. There are documented techniques (4) which allow probability distributions to be computed.

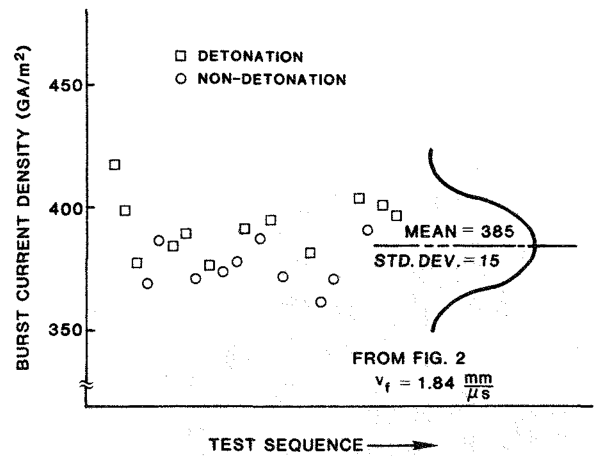


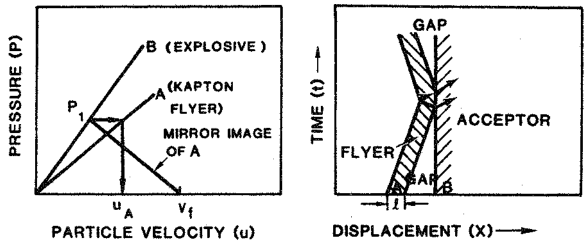
Fig. 3 Burst current density data from "up-down" experimental method.

Threshold is defined as that value of input stimulus for which the probability of detonation is 50 percent. The threshold current density, as determined using the methods of Ref. 4, is used with the appropriate line for the flyer thickness in Fig. 2 to establish the flyer velocity. The Hugoniot relationships, as illustrated in Fig. 4, are then used to determine impact pressure and pulse duration. Hugoniot data on HNS and on polyimide were taken from References 5 and 6 respectively.

TEST RESULTS

Effect of Powder Morphology

Three types of HNS were evaluated in this series of tests--each type of explosive being made by a different process which resulted in materials of divergent particle size (or specific surface area). These materials are identified as HNS-hyperfine (HF), HNS



P_1 = PRESSURE IMPARTED TO ACCEPTOR WHEN KAPTON IMPACTS AT VELOCITY, V_f

$$\tau \cong \frac{2 \ell u_A \rho_A}{P_1}$$

WHERE

τ = PULSE DURATION OF P_1

ℓ = THICKNESS OF FLYER

u_A = PARTICLE VELOCITY IN FLYER

ρ_A = ORIGINAL DENSITY OF FLYER

Fig. 4 Graphical solution to determine P_1 and τ from P - u and x - t diagrams.

superfine (SF), and HNS-1 and have measured specific surface areas of 10.00, 2.56, and 1.59 m^2/g, respectively, as determined by the gas adsorption method. Photomicrographs of the three types of materials are shown in Fig. 5 along with test results which show probability of detonation versus impact pressure. The role of powder morphology is clearly illustrated by the fact that the threshold pressure (taken as the point of 0.5 probability) varied with particle size, being lowest for the finest particle-size material (HNS-HF). In addition, the HNS-HF showed the narrowest band of pressure separating no-fire (0.001 probability and all-fire (0.999 probability).

As a cautionary note, the relationships among these three materials should not be extrapolated to applications where the pulse durations are significantly different from the 0.034 µs of these experiments (7).

Effect of Explosive Density

The effect of density on the shock initiation sensitivity of HNS-SF is illustrated is Fig. 6. The threshold pressure required to initiate the lower density (1.30 Mg/m^3) specimen was 3.8 GPa compared to 5.3 GPa for the higher density (1.60 Mg/m^3) specimen. This agrees with results of modeling explosives as porous materials (8) where less dense materials receive larger shock heating.

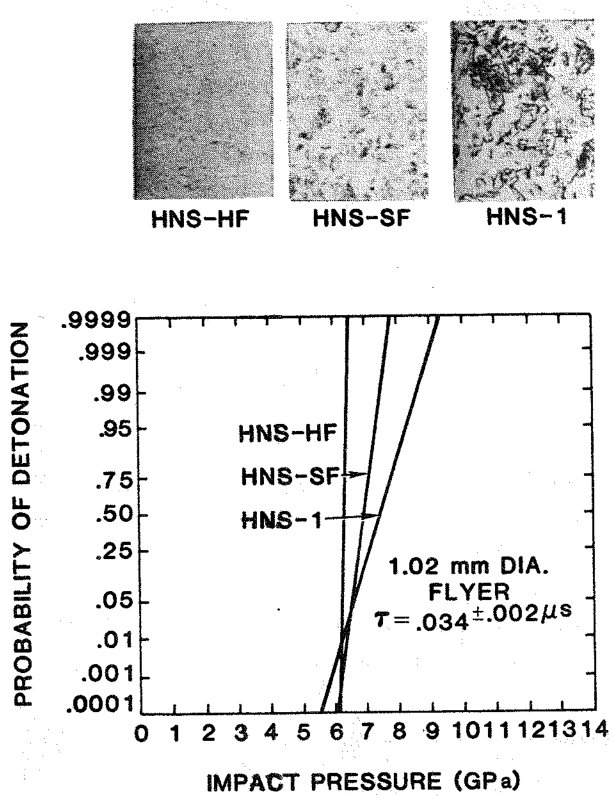


Fig. 5 Effect of morphology on sensitivity.

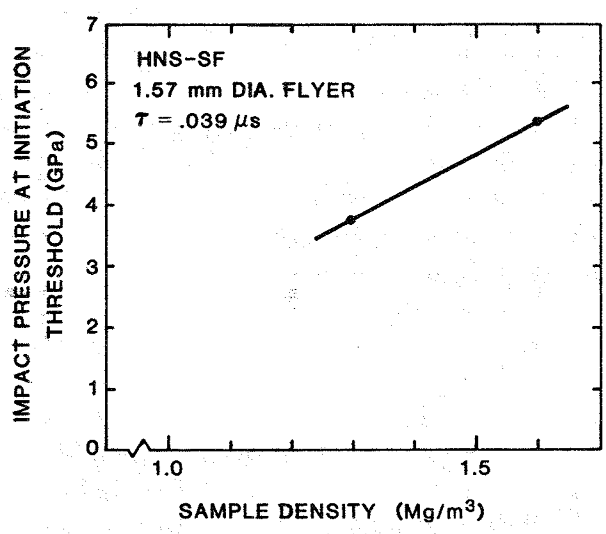


Fig. 6 Effect of sample density on sensitivity.

Effect of Flyer Diameter

Experiments were also performed using two different flyer diameters, 1.02 mm and 1.57 mm, for impacting HNS-SF at a density of 1.60 Mg/m^3. The results given in Fig. 7 show flyer velocity at initiation threshold versus the reciprocal of flyer diameter. A single datum from the Lawrence Livermore National Laboratory (9) confirms the observed trend of larger flyers requiring a smaller impact pressure. There should be some flattening of the curve for large diameter flyers (10) since, at very large diameters, edge effects can't perturb threshold.

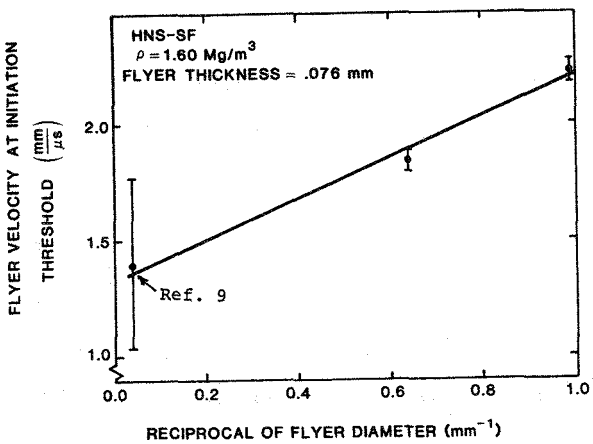


Fig. 7 Reciprocal of flyer diameter versus flyer velocity at initiation threshold.

Effect of Pulse Duration

Finally, experiments were performed to determine the effect of pulse duration on the shock initiation sensitivity of HNS-SF at 1.60 Mg/m^3 using a 1.57 mm diameter flyer. Pulse duration was controlled by the flyer thickness which varied between 0.025 and 0.254 mm, providing pulses that varied from 0.011 to 0.137 μs. The test results are shown in Fig. 8. The line of demarcation which separates detonation from non-detonation is not a straight line. However, for a pulse duration between 0.01 and 0.10 μs the relationship $P^{2.4}\tau$ = constant applies. As τ increases to about 0.15 μs, the initiation criterion is more nearly one of constant pressure ($\geq$ 3.6 GPa).

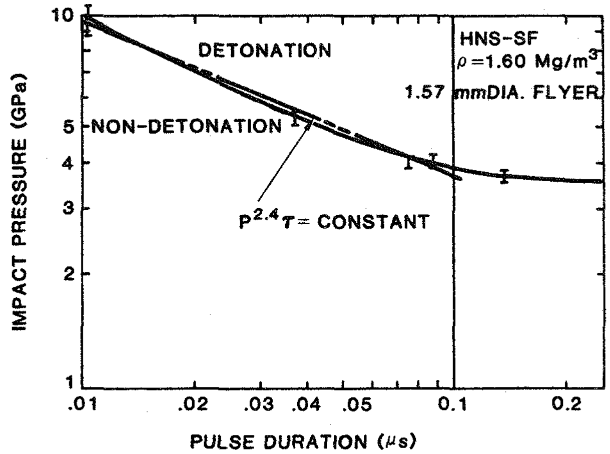


Fig. 8 Effect of pulse duration on initiation sensitivity.

SUMMARY AND CONCLUSIONS

Based on the test results presented herein, it is concluded that:

1. Powder morphology plays a significant role in the shock initiation sensitivity of HNS. For 0.035 μs pulses, the pressure required to cause initiation at threshold varied from a low of 6.3 to a high of 7.6 GPa, being lower for the smaller particle-sized HNS-HF. Not only was the HNS-HF more sensitive, but it also was less variable in that it displayed the narrowest band of pressure separating no-fire (0.001 probability) from all-fire (0.999 probability).

   These data suggest that HNS-HF would be an excellent acceptor explosive for thin fragment initiation in detonation transfer systems.

2. Lower density specimens and specimens impacted by larger diameter flyers required lower impact velocities (or pressures) than their counterparts to induce initiation. These facts are useful design aids.

3. For pulse durations between 0.01 and 0.10 μs, the line which separates detonation from non-detonation can be approximated by $P^{2.4}\tau$ = constant. This is the type of equation that has been used in explosive component design optimization studies (11, 12). It is also significant that, as the pulse duration approached 0.15 μs, the pressure

for initiation became essentially constant (3.6 GPa).

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