DETONATION ELECTRIC EFFECT STUDIES

C. E. Canada
L. D. Hanes

DEVELOPMENT DIVISION

APRIL - JUNE 1975
FINAL REPORT

Normal Process Development
Endeavor No. 231

MASTER

Mason & Hanger-Silas Mason Co., Inc.
Parlex Plant
P. O. BOX 647
AMARILLO, TEXAS 79177
806-335-1581

operated for the
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
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U. S. GOVERNMENT Contract DA-11-173-AMC-487(A)

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ABSTRACT

A technique has been devised to determine the configuration dependent induction time for transfer of detonation from a small diameter confined donor to a large diameter unconfined acceptor via the detonation electric effect. This report explains some of the attributes and limitations of the technique and includes test data for PETN, RDX/Sylgard, and HNS explosive assemblies.

DISCUSSION

Explosive trains are frequently used in ERDA components for time sequencing or information transmittal requirements. A typical explosive train may consist of a desired length of small diameter MDF, which is terminated with a much larger diameter booster section for activation of downstream components. Propagation characteristics are determined by interactions between geometry and material dependent waves generated at the interface between the MDF and booster.

The purpose of work reported here is to establish a technique suitable for prediction of these geometry and material induced effects thereby aiding component design. Transit time variation as a function of the interface configuration was selected as that propagation characteristic to be measured. This variable provides insight into the effects of wave interactions and is certainly the most convenient and least expensive of the dynamic characteristics that could be measured.

EXPERIMENTAL TECHNIQUE AND RESULTS

The experimental technique is illustrated in Fig. 1. The small diameter confined donor is segmented into known lengths, which are in turn separated by air gaps of known thicknesses. The air gaps provide heterogeneous interfaces which, when shocked, generate electromagnetic disturbances detectable by the antenna(1). Of those materials tested (water, Plexiglas, Krylon,^a and air) the air gap produced both the fastest rise and highest amplitude signals.

The pieces of the explosive train are supported by a hardwood block which has been precisely machined to confine each piece halfway around its circumference. The donor segments were held in a specially made fixture while being cut to length with a razor blade. Of the various methods tried, this produced the most perpendicular cut with the least gouging of the explosive core material. The air gap thicknesses were controlled by punching circular holes in plastic shim stock and inserting these shims between the segments of the donor with proper alignment of the holes.

^aNo. 1303, an acrylic spray manufactured by Borden, Inc.

Since a finite time is required for a shock wave to traverse an air gap and reinstitute detonation, it was at first thought necessary to determine this time for each type of donor. One method used was to vary the lengths of the donor segments, while holding the air gap thicknesses constant. The excess transit time due to gap effects equals the time axis intercept of a linear fit to the distance-time data. Another method used to define air gap excess transit times was to hold the donor lengths constant while varying the air gap thicknesses. An analysis similar to that of the first method is then used to find the excess transit times. Fig. 2 shows results from such an evaluation. Here the donor, either 0.21 g/m or 2.1 g/m commercially available PETN MDF, was segmented into 6.35 mm lengths. A sequence of air gaps with thicknesses of 25, 51, 127, 51, and 25 μm , respectively, were introduced between segments of the donor. The resultant interfacial signals were thus separated by the time required for detonation of a 6.35 mm segment plus the time to traverse an air gap. Average interfacial times corresponding to the sequence noted above were 917, 925, 938, 925 and 917 ns for the 0.21 g/m MDF and 900, 908, 921, 908 and 900 ns for the 2.1 g/m MDF. Since that time interval which includes the transit time of the 127 μm gap should be maximum, these data indicate that the start of an interfacial signal is generated when the shock wave exits rather than enters a donor segment. As may be seen from the curves of Fig. 2, the time required for a shock to traverse an air gap is not a linear function of thickness. In fact the effective velocity at which the detonation process propagates across an air gap, apparently increases with increasing gap thickness. This anomaly, although interesting, was not pursued here since a knowledge of the transit time for an air gap is in fact not necessary to determine excess transit times in acceptors as will be explained below.

Preliminary verification tests were conducted using PETN as both donor and acceptor. Fig. 3 shows a typical record for this work, and Fig. 4 illustrates the method used to determine excess transit times. Fig. 3 is derived from the assembly of an EX-12B detonator, a 5.1 mm diameter by 2.0 mm PBX 9407 pellet, 6.35 mm long donor segments, and a 12.7 mm diameter by 6.35 mm acceptor pellet. The donor was 2.1 g/m PETN MDF, and the acceptor was PETN at a density of 1.53 Mg/m^3 . Each donor segment and the interface between acceptor and antenna were separated with 25 μm air gaps. However, the last donor segment was in direct contact with the acceptor since a gap at this interface would perturb propagation characteristics. Eleven signals are visible in Fig. 3. The first two signals arise from the detonator while the third one is generated by a 25 μm air gap between the PBX 9407 pellet and the first donor segment. Time intervals between signals 3 through 10 result from donor segment-air gap combinations, but the time interval between the last two signals results from a donor segment-air gap combination plus the 6.35 mm length PETN pellet, since interfacial signals originate when shocks exit rather than enter a donor segment. Transit time through the acceptor pellet is thus determined by simply subtracting the average time for a donor segment-air gap combination from the time interval

between the last two signals. If signals were generated as the shock entered a donor segment this subtraction would not be valid and a knowledge of air gap transit times would be necessary for data reduction.

The expected velocity for PETN at a density of 1.53 Mg/m^3 is 7.482 km/sec (2). The curves of Fig. 4 are least-squares fits assuming a slope of 7.482 . These limited data thus indicate excess transit times (equal to the time axis intercepts) of 40 ns and 130 ns , respectively, for the 2.1 g/m and 0.21 g/m donor systems.

Tests using an RDX/Sylgard explosive as donor and acceptor were also conducted. Fig. 5 shows a typical record. Here the donor consisted of four each 19.05 mm long segments which were extrusion loaded stainless steel tubes with wall thickness of 0.25 mm . The acceptor was an unconfined 12.7 mm diameter by 6.35 mm extrusion formed pellet. As above the donor segments and the interface between acceptor and antenna were separated with $25 \text{ }\mu\text{m}$ air gaps, and the last donor segment was in direct contact with the acceptor. These tests, however, proved unsatisfactory because of electrical polarization within the acceptor. As may be seen immediately before the seventh signal in Fig. 5, the signals due to shock induced polarization and the air gap ionization signal are superimposed. An accurate knowledge of shock wave arrival at the acceptor pellet output surface is thus not obtainable for the configuration used. Fig. 3 also shows the effect of polarization. However, for PETN systems the relative signal amplitudes for polarization and air gap were such that timing information was obtainable.

This problem from polarization within the acceptor was alleviated by simply increasing the air gap thickness at the acceptor antenna interface. Gaps of 6.35 mm and 12.7 mm were investigated for PETN systems. Both gap thicknesses gave unambiguous signals, and either would be acceptable. However, a gap thickness of 6.35 mm is preferred and was used for all subsequent testing, since measured signal amplitudes vary inversely with distance between source and detector.

The next objectives were to apply the method to HNS and to refine the technique. Two types of compacted HNS II MDF were prepared. Pertinent properties are given in Table I. Acceptor pellets were pressed to 2.54 mm thickness x 12.7 mm diameter. Up to three pellets were stacked on each shot. The HNS II pellets were made from the same two lots used for manufacturing the MDF; the HNS I pellets were made from Ensign-Bickford Lot 5737 and Chemtronics Lot 66-48.

Initial interest was in determining whether detonation would transfer from the MDF to a pellet pressed from the same material at approximately the same density as in the MDF. The pellets were pressed from HNS II to 1.65 Mg/m^3 . Detonation did not transfer for either the E-B or the Chemtronics explosive trains. The E-B train was slightly modified in three different ways, but none enabled transfer of detonation. The first modification was the placement of a $25 \text{ }\mu\text{m}$ air gap between the MDF and pellet. The second was the addition of aluminum disk of 2.5 mm

thickness x 12.7 mm diameter in front of the pellet with the MDF inserted through a hole in the center of the disk and contacting the pellet. The third was the placement of a PBX 9407 booster pellet 2.0 mm thick x 5.1 mm diameter at 1.62 Mg/m³ between the MDF and pellet. With this modification reaction occurred in one of three shots.

The effort was then directed toward more closely simulating the conditions existing in the end tips for the C-4 energy transfer system. Partial results of a pressing study which was being done at Pantex indicated that HNS I when pressed at 220 MPa (the pressure at which the end tips are filled) yields a density of approximately 1.55 Mg/m³(3). Therefore, pellets were pressed from both Ensign-Bickford and Chemtronics HNS I at 1.55 Mg/m³. Shots were built to ascertain whether transfer would occur from E-B MDF to an E-B pellet, from E-B MDF to a Chemtronics pellet, from Chemtronics MDF to a Chemtronics pellet, and from Chemtronics MDF to an E-B pellet. A typical record is shown in Fig. 6. Results are given in Table II. Both transfer and nontransfer of detonation to the acceptor pellet was observed. The calculated excess transit times for the acceptor pellets are based upon a detonation velocity of 6.75 km/s for HNS I at 1.55 Mg/m³, which is an interpolation from measurements on Chemtronics Lot 66-48 at densities of 1.50 and 1.60 Mg/m³(4). Evidently the donor size was near the threshold for initiation of the HNS I at 1.55 Mg/m³. Also evidence from the shot remains, e.g. pieces of the pellet still intact and less destruction than expected, indicated that the entire pellet did not detonate in many of the shots.

For comparison with air gap excess transit times in PETN systems, those for HNS were determined. HNS MDF segment lengths were 6.35 mm and 12.7 mm and all air gaps were 25 μm. Excess transit times due to air gap effects were calculated by two methods:

$$\text{Excess } T_t = 2 T_t (6.35 \text{ mm length segment}) - T_t (12.7 \text{ mm length segment})$$

and

$$\text{Excess } T_t = T_t (\text{for a segment length}) - \frac{\text{Length of Segment}}{\text{Detonation Velocity}}$$

The detonation velocity used in the second formula is that given in Table I. Average excess transit times calculated by each formula for E-B MDF were 12 and 11 ns, respectively; for Chemtronics MDF they were 13 and 12 ns. After subtracting these excess transit times from the total segment transit times, the calculated average velocity of each MDF agreed with that in Table I within 0.1%. For PETN MDF excess times for a 2.5 μm air gap was 9 to 10 ns. This decreased time interval relative to HNS systems is probably indicative of material sensitivity.

During testing of HNS systems a ten fold increase in CDU induced noise was encountered. A search for the reason revealed that the placement of the shot on the test firing pad was critical(5). Originally the shots

had all been laid directly upon the steel pad and the signal-to-noise ratio was very good. However, when the shots were placed upon a wooden stand about 0.6 m above the pad, an order of magnitude increase in electrical noise resulted. Records are shown in Fig. 7 for a comparison of noise pickup under identical circumstances except for shot placement.

CONCLUSIONS

An experimental technique suitable for determining excess transit times as a function of donor-acceptor configurations has been established. Assemblies described herein all had coaxial geometries with small diameter confined donors in direct contact with larger diameter, unconfined acceptors. However, the technique is compatible with investigations of other interface geometries more closely simulating those found in actual explosive components.

FUTURE WORK

HNS systems which have both optical as well as electrical coverage will be tested in order to better correlate acceptor detonation with electrical signals produced.

The CDU induced noise as a function of shot placement is not quantitatively understood and is to be investigated further.

Fig. 1. Typical Shot Make-up

Fig. 2. Average Velocity and Transit Time for 25.4, 50.8 and 127 μm Air Gaps

Signal No.	Comment
1	Start of current flow in bridgewire
2	Bridgewire burst
3	Air gap between PBX 9407 pellet and first donor segment
4	Air gap between first and second donor segments
5	Air gap between second and third donor segments
6	Air gap between third and fourth donor segments
7	Air gap between fourth and fifth donor segments
8	Air gap between fifth and sixth donor segments
9	Air gap between sixth and seventh donor segments
10	Air gap between seventh and eighth donor segments
11	Air gap between acceptor and antenna

Fig. 3. Typical Record for a PETN Explosive System
(Trace length is 20 μ sec)

Fig. 4. Transit Times for 6.35, 12.7 and 19.05 mm Thick PETN Pellets

Signal No.	Comment
1	Start of current flow in bridgewire
2	Bridgewire burst
3	Air gap between detonator and first donor segment
4	Air gap between first and second donor segments
5	Air gap between second and third donor segments
6	Air gap between third and fourth donor segments
7	Air gap between acceptor and antenna

Fig. 5. Typical Record for an RDX/Sylgard Explosive System
(Trace length is 20 μ sec)

B Sweep is First Part of A
Sweep Expanded

Fig. 6. HNS Detonation Electric Effect Record

Shot Above Pad

Shot On Pad

Fig. 7. Comparison of CDU Induced Noise as a Function of Shot Position with Respect to Ground Plane

Table I. Pertinent Properties of HNS MDF

<u>Property</u>	<u>Ensign-Bickford HNS-IIB, Lot 5737</u>	<u>Chemtronics HNS-IIA, Lot 66-47</u>
MDF Inner Diameter (mm)	0.483	0.521
MDF Outer Diameter (mm)	1.117	1.117
MDF Load Size (g/m)	0.364	0.386
HNS Final Density (Mg/m ³)	1.69	1.67
MDF Velocity (m/s)	7000	7010

Table II. Results of HNS Work for an Acceptor
Pellet Density of 1.55 Mg/m³

<u>MDF</u>	<u>Acceptor Pellet</u>	<u>Acceptor Excess Transit Time (ns)</u>
Ensign-Bickford ^a	Ensign-Bickford ^c	NO GO ^e
Ensign-Bickford	Ensign-Bickford	NO GO
Ensign-Bickford	Chemtronics ^d	42
Ensign-Bickford	Chemtronics	41
Chemtronics ^b	Ensign-Bickford	43
Chemtronics	Ensign-Bickford	34
Chemtronics	Chemtronics	NO GO
Chemtronics	Chemtronics	41

^aProperties given in Table I.

^bProperties given in Table I.

^c12.7 mm diameter pellet pressed from HNS-IB, Lot No. 5737.

^d12.7 mm diameter pellet pressed from HNS-IA, Lot No. 66-48.

^eNO GO - Means that detonation did not propagate from the donor to the acceptor pellet.

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