LEGIBILITY NOTICE

A major purpose of the Technical Information Center is to provide the broadest dissemination possible of information contained in DOE's Research and Development Reports to business, industry, the academic community, and federal, state and local governments.

Although a small portion of this report is not reproducible, it is being made available to expedite the availability of information on the research discussed herein.

LA-UR -87-322

CONF-871040--1

LA-UR--87-322

DE87 006070

TITLE A STUDY OF DIVERGING DETONATION IN HIGH-EXPLOSIVE SYSTEMS

AUTHOR(S) Pier K. Tang, X-4

SUBMITTED TO International Symposium on Pyrotechnics and Explosives,

12-15 October, 1987, Beijing, China

A STUDY OF DIVERGING DETONATION IN HIGH-EXPLOSIVE SYSTEMS

Pier K. Tang
(Los Alamos National Laboratory, University of California, Los Alamos, NM 87545, USA)

ABSTRACT

Initiation of an insensitive high-explosive main charge can be achieved by using a booster. The requirement for the booster high explosive should be high sensitivity rather than high energy. Using a reactive model, this study presents the evolution of detonation in PBX-9502 main charge with two different booster materials: low-density ultrafine TATB and X-0407 in a diverging configuration.

INTRODUCTION

In many high-explosive (HE) systems, only a small detonator is needed to initiate the main charge if sensitive explosive is used. However, with insensitive high explosive (IHE), that same detonator cannot support a strong shock with enough duration to initiate the main charge because of the longer distance needed for shock-to-detonation transition. The diverging configuration of wave weakens the shock strength further and makes the situation even worse; the detonation wave may eventually vanish. With a staging approach, for example, using a booster, we can initiate the IHE main charge without difficulty. Of course, the explosive in the booster should be more sensitive and usually more energetic. The booster is typically hemispherical and should be large enough to support a detonation with sufficient intensity and duration as the wave propagates into the main charge. On the other hand, for safety, we do not want to use too large a booster; that would defeat the purpose of using IHE as the main charge. Therefore, determination of booster size is crucial.

BOOSTERS

The selection of booster size and material is usually carried out experimentally;[1] a class of experiments, commonly known as onionskins, has been conducted to examine the detonation pattern in the main charge as the wave emerging from a hemispherical surface recorded by a streak camera. If the breakout pattern is nearly even, then the detonation wave must be close to hemispherical inside the main charge and should be considered a good initiation. Because of the location of the detonator and the weakening of the detonation in divergence, particularly on the side, the wave is not exactly hemispherical. If the booster is small, the detonation may not develop at all on the side, leaving a region of no identifiable reaction in the experiments. Also, weak and less sensitive booster HEs can produce erratic breakout patterns. Using onionskin experiments, we can choose the proper material and size for the booster. However, the objective of this study is not experimentation; rather, we want to reach the same goal through modeling and numerical simulation. With better modeling of HE behavior, particularly an explicit hot-spot model,[2,3] which treats the explosive reaction with a multistep process, we have reported the booster behavior with regard to grain size effects.[4]

As stated earlier, the booster HE is typically more energetic and more sensitive than the main charge, but the energetic aspect sometimes overdrives the main charge, resulting in some undesirable effects. Fortunately, we find ways of enhancing the initiability of a mainly insensitive component by lowering the density and reducing the grain size or by adding a small amount of sensitive material to the basically insensitive main component. Low-density ultrafine TATB (1.8 g/cm^3) is representative of the former and X-0407 (70% TATB, 25% PETN, 5% Kel-F) the latter; both are used as booster materials in this investigation. Their experimental Pop plots are shown in Fig. 1. In general, X-0407 is less sensitive than low-density TATB except in the low shock pressure range, but X-0407 is more energetic because of its higher density (1.87 g/cm^3) and PETN content as compared with low-density TATB. The Chapman-Jouguet (CJ) pressure of X-0407 is 290 kbar versus 270 kbar for low-density TATB.

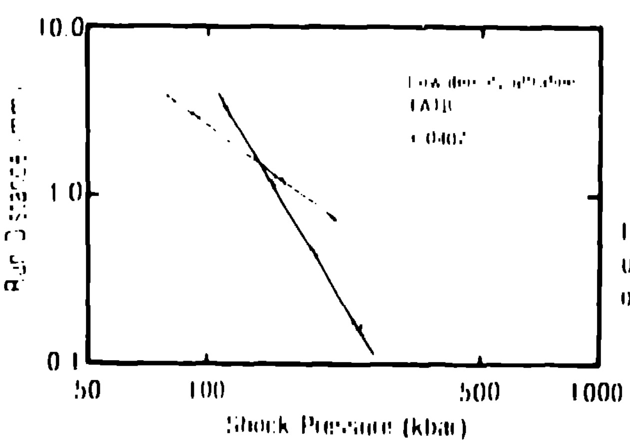

Figure 1. Low density TATB and X 0407 Pop plots.

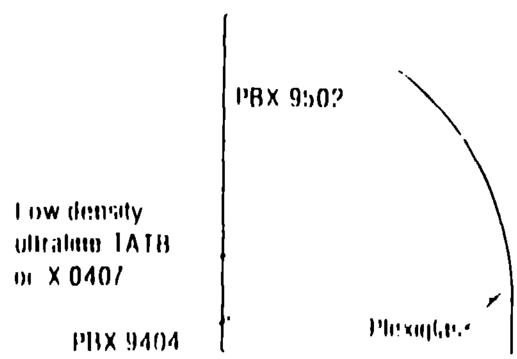

Figure 2. Simulation configuration.

DIVERGING DETONATION

The configuration for numerical simulation is shown in Fig. 2, one half of the region commonly found in onionskin experiments. The booster size is 30 mm in diameter, and a layer of PBX-9502 (95% TATB, 5% Kel-F) with 10-mm thickness envelops the booster. The explicit hot-spot model and HOM equation of state[5] are used for those two booster HEs and the acceptor. The initiation of the booster is accomplished by a small detonator of 8-mm diameter and 4-mm thickness. The reaction model is called programmed burn based on constant detonation velocity with a fraction of surface used for initiation on the bottom of the detonator. The detonator explosive is PBX-9404 (94% HMX, 3% NC, 3% CEF) with JWL equation of state used.[6] The HE system is bound by layers of Plexiglas to provide some pressure boundary and to prevent excessive mesh distortion for computational convenience. Computation is performed using DYNA2D code.[7]

Figures 3-a through 3-d show a sequence of burned mass fraction contours at different times with X-0407 on the right and low-density ultrafine TATB on the left. At 1 μs, Fig. 3-a, the detonation front is well developed except for the slight sideways rarefaction in the low-density ultrafine TATB booster. For the X-0407 booster, the detonation propagates mainly in a conical fashion; on the side the reaction spreads over some distance but without detonation. The difference is due to the much higher sensitivity of low-density ultrafine TATB over X-0407 in the high shock pressure level. However, the situation improves a great deal as time goes by since X-0407 is more energetic than low-density TATB, and can provide a higher shock pressure to drive itself to fully developed detonation even on the side as seen at 2 μs, Fig. 3-b. At 3 μs, Fig. 3-c, the detonation is already well established in the main charge region for both cases. The pullback of the wave at the HE and Plexiglas interface is caused by the dead or partial reaction region and by the local rarefaction. The wave front is quite close to a hemispherical configuration and we consider that a good initiation in a diverging situation. Figure 3-d shows that the reaction is essentially completed at 4 μs. Although the X-0407 booster leaves a large partially reacted zone whereas the low-density ultrafine TATB booster yields a definite, even though small, dead region, they do not have any significantly ill effect on the development of detonation in PBX-9502.

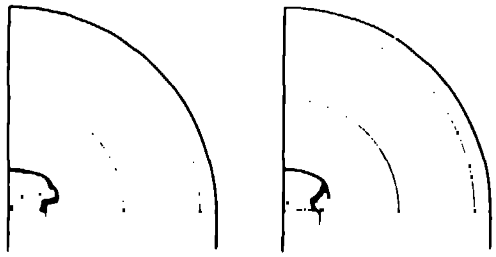

Figure 3-a. Burned mass fraction contours at 1 μs.

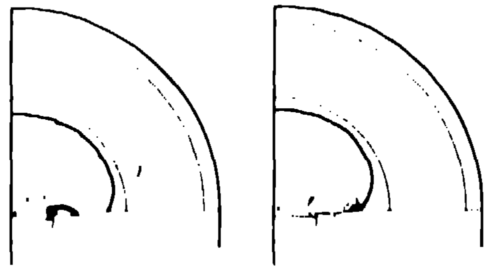

Figure 3-b. Burned mass fraction contours at 2 μs.

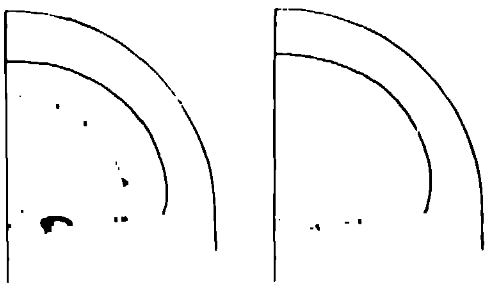

Figure 3-c. Burned mass fraction contours at 3 μs.

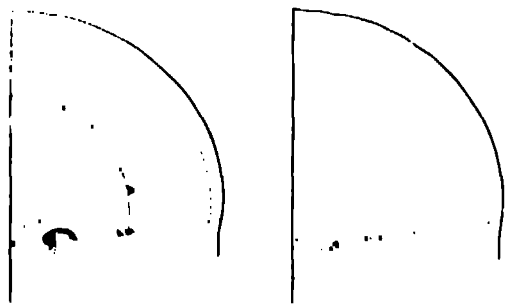

Figure 3-d. Burned mass fraction contours at 4 μs.

CONCLUSIONS

At the writing of this paper, experimental evidence is not yet available to support this numerical study. However, this investigation demonstrates the feasibility of using modeling and numerical computation to evaluate the diverging detonation in an HE system, in particular the enhancement of initiability by using low-density and small grain HE or by adding a sensitive ingredient to the insensitive main body for booster use. Both X 0407 and low density ultrafine TATB are acceptable for that purpose.

REFERENCES

1. Bahl K, Bloom G, Erickson L, Lee R, Tarver C, Von Holle W, and Weingart R, Initiation Studies on LX-17 Explosive, Proceedings of the Eighth Symposium (International) on Detonation, preprint (1985), 729.
2. Johnson J, Tang P, and Forest C, Shock-Wave Initiation of Heterogeneous Reactive Solids, J. Appl. Physics 57:4323 (1985).
3. Tang P, Johnson J, and Forest C, Modeling Heterogeneous High Explosive Burn with an Explicit Hot-Spot Process, Proceedings of the Eighth Symposium (International) on Detonation, preprint (1985), 375.
4. Tang P, A Numerical Investigation of High-Explosive Grain Size Effects on the Performance of Boosters, Combustion and Flame, to appear.
5. Mader C, Numerical Modeling of Detonations, University of California Press, Berkeley, (1979).
6. Lee E, Hornig H, and Kury J, Adiabatic Expansion of High Explosive Detonation Products, Lawrence Livermore National Laboratory report UCRL-50422 (1968).
7. Hallquist J, User's Manual for DYNA2D--An Explicit Two-Dimensional Hydrodynamic Finite Element Code with Interactive Rezoning, Lawrence Livermore National Laboratory report UCID-18756 (1982).