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BARNIE: A UNITARY DEMOLITION WARHEAD

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The U.S. Army TACOM-ARDEC warheads group has recently developed and demonstrated a shaped charge based terminal chemical energy warhead named "Barnie". The Barnie warhead penetrates the desired target with a jet containing energetic material that releases chemical energy during the penetration process. High rate dynamic continuum modeling was instrumental to the design of appropriate warhead mechanics using terminal chemical energetic materials. The energetic properties of the candidate materials were predicted and tailored to allow the modeling and selection of a suitable candidate energetic material. The final concept 81 mm diameter warhead designs were fabricated using high precision parts and loaded with Octol 70/30 explosive cast into aluminum bodies. Subsequent testing of the Barnie warheads against semi-infinite concrete targets produced extremely large craters.

BACKGROUND

Modern penetration warheads, such as shaped charges and explosively formed penetrators produce deep target penetration. However, for demolition applications, much greater effectiveness could be achieved from a unitary warhead by releasing chemical energy within the target during or at the conclusion of the penetration process. This warhead concept, termed a "Terminal Chemical Energy Warhead", consists of a warhead that produces a penetrator that uses an energetic material during the projectile formation. The projectile penetrates the desired target and the energetic material releases chemical energy inside the target during or at the termination of the penetration process. Such a warhead would have excellent demolition capabilities with devastating effects against many targets including concrete, masonry and earth supports and barriers. The U.S. Army TACOM-ARDEC warheads group has recently developed and demonstrated a shaped charge based terminal chemical energy warhead named "Barnie".

MODELING

The energetic properties of the candidate materials were predicted and tailored to allow the modeling and selection of a suitable candidate energetic material. Several energetic materials were evaluated for energy output and mechanical properties characterization. The JAGUAR thermochemical equation of state program [Baker 1997] was used for energy output calculations. The modeling studies concluded that a class of solid energetic materials was suitable for more complete design studies. In order to address warhead mechanics issues, the terminal chemical energy warhead concepts were investigated through the use of the CALE [Tipton 1991] Arbitrary Lagrange-Eulerian high rate dynamic continuum modeling program. The Mie-Gruneisen equation of state was used for the downselected energetic liner materials. The equation of state parameters were predicted using simple mixture rules and existing Mie-Gruneisen equation of state data for constituent materials. A low value of perfect plasticity was used for the compressive strength properties and material failure at the onset of tensile behavior. Chemical reactivity was not used for the energetic liner material continunm modeling. The Octol 70/30 high explosive was modeled using the Jones-Wilkins-Lee-Baker detonation properties equation of state [Baker 1993]. Using optimization techniques, the exploratory finite difference calculations of shaped charge warheads identified promising terminal chemical energy warhead baseline designs. Based on this result, a family of shaped charge jetting terminal chemical energy warheads were investigated. The computational design process concentrated on producing reasonable jetting properties in order to produce practical penetration capability. In addition, the elimination of reactive material cavitation during jet formation was a primary interest, as well as maintaining relatively low jet formation pressures in the energetic liner material. A final 81 mm diameter “Barnie” warhead configuration was downselected based on a balance of these considerations. Figure 1 presents a series of design calculations comparing various jet formation properties. Figure 2 presents calculations of the final downselected “Barnie” warhead configuration.

EXPERIMENTATION

Shaped charges were fabricated using the final Barnie shaped charge design that was computationally developed. Four liner types were fabricated: aluminum mass matched, oxygen deficient energetic material, oxygen balanced energetic material and oxygen rich energetic material. The aluminum liners were fabricated from Al 1100-0 and all of the liner configurations were mass matched. The liners were precision machined from performs that were well characterized. Figure 3 presents a photograph of an energetic material liner before warhead assembly. The liners were fitted into high precision 81 mm diameter aluminum bodies and subsequently cast loaded using Octol 70/30. Final billet machining was completed on the warheads for the adaptation of existing precision initiation couplers (PICs) in order to assure a prompt and well centered explosive detonation initiation. The liners were made by DE Tech, PA and the warheads were fabricated and tested at American Ordnance, IA. Medium standoff (10 charge diameters) flash radiography was used to obtain the experimental jet characteristics. Figure 4 presents photographs of the final warhead hardware and the long standoff test stand used for the experimentation. Figure 5 presents some resulting flash X-rays. The jet X-rays were reduced using a large digitizing light table. The Barnie warheads were also tested for penetration and damage capability against standard concrete targets. The concrete 152 cm diameter targets were made by casting U.S. Army standard SAC-5 concrete into steel culvert with a 152 cm diameter and a 152 cm depth. The warheads were tested against the targets at a one charge diameter stand-offs for direct comparisons. Figure 6 presents a photograph of an experimental setup.

RESULTS DISCUSSION

All four warhead types left a funnel shaped (spall) hole on the targets front surfaces. The solid aluminum mass matched warhead penetrated the concrete block the furthest (about 25 cm) but did the least collateral damage. The Barnie warhead with the oxygen balanced reactive liner material did the most damage, leaving a crater between 97 cm and 114 cm in diameter at the surface tapered from a center depth of about 19 cm. The other two warheads (oxygen deficient and oxygen rich) caused less damage to the target, but caused significantly more damage than the solid aluminum liner. Figure 7 displays the test fire results. Warheads with the oxygen deficient liners were also fired at a one half-charge diameter and a two-charge diameter standoff. Figure 8 presents these results. There was about the same amount of concrete damage caused at one half-charge diameter than at one charge diameter. Damage dropped off significantly at two charge diameters. The extremely large crater produced by the 81 mm Barnie warhead was compared to previous EFP and shaped charge concrete attack test results [Baker 1996]. The results indicate that the 81 mm diameter oxygen balanced Barnie warhead produced very similar concrete damage (concrete volume removal) as a 127 mm tantalum lined EFP.

CONCLUSIONS

The Barnie design process was successful identifying a reactive liner material and geometric configuration that produces both concrete penetration and subsequent damage due to blast effects. The oxygen balanced reactive liner material provided the most effectiveness in terms of concrete damaging capability over oxygen deficient and oxygen rich compositions giving some indication that energetic material chemical reaction is not occurring significantly during jet formation. The standoff results indicate that the excellent concrete damaging capability is relatively standoff independent in a region between a half and one charge diameter of standoff for the current Barnie design. Further investigation of the Terminal Chemical Energy Warhead (Barnie) concept will concentrate on scaling effects and the use of pressed explosive compositions.

Home
Table of Contents

REFERENCES

Baker, E.L., T. Vuong, and B.E. Fuchs, “EFP and Shaped Charge Concrete Penetration”, Proceedings of the 7th TARDEC Ground Vehicle Survivability Symposium, Monterey, CA, March 1996.

Baker, E.L., L.I. Stiel. 1997. “Improved Quantitative Explosive Performance Prediction Using JAGUAR.”, Proceedings of the 1997 Insensitive Munitions & Energetic Materials Technology Symposium, Tampa, FL (October).

Baker, E.L. 1993. “An Application of Variable Metric Nonlinear Optimization to the Parameterization of an Extended Thermodynamic Equation of State”, Proceedings of the Tenth International Detonation Symposium, Boston, MA (July).

Tipton, R., 1991, “CALE User’s Manual”, CALE Documentation, Lawrence Livermore National Laboratory, Livermore, CA, (July).

Figures

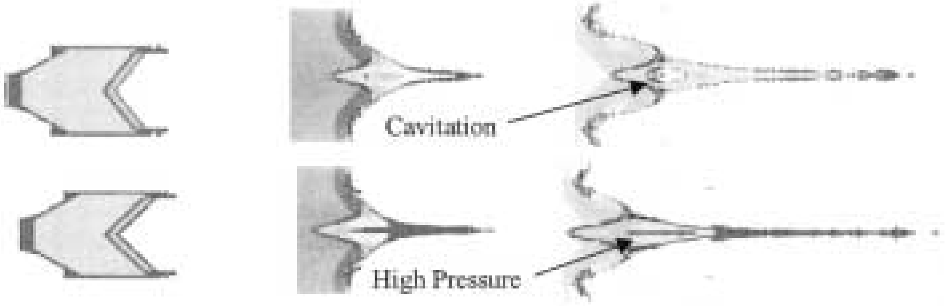


Figure 1. CALE design calculations comparing various jet formation properties.

Figure 2. CALE calculations of the final downselected “Barnie” warhead configuration.

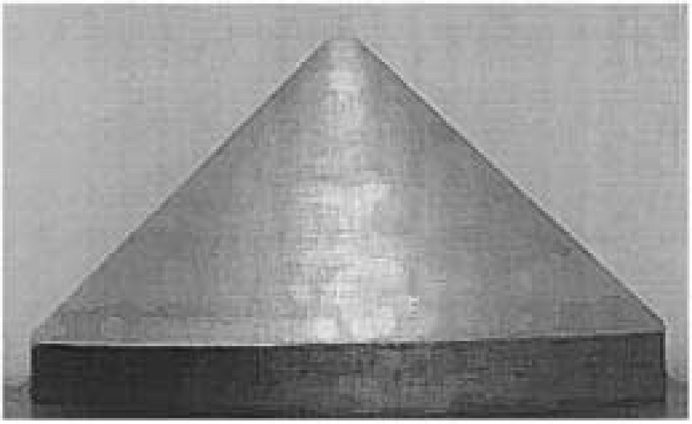


Figure 3. Photograph of an energetic material liner before warhead assembly.

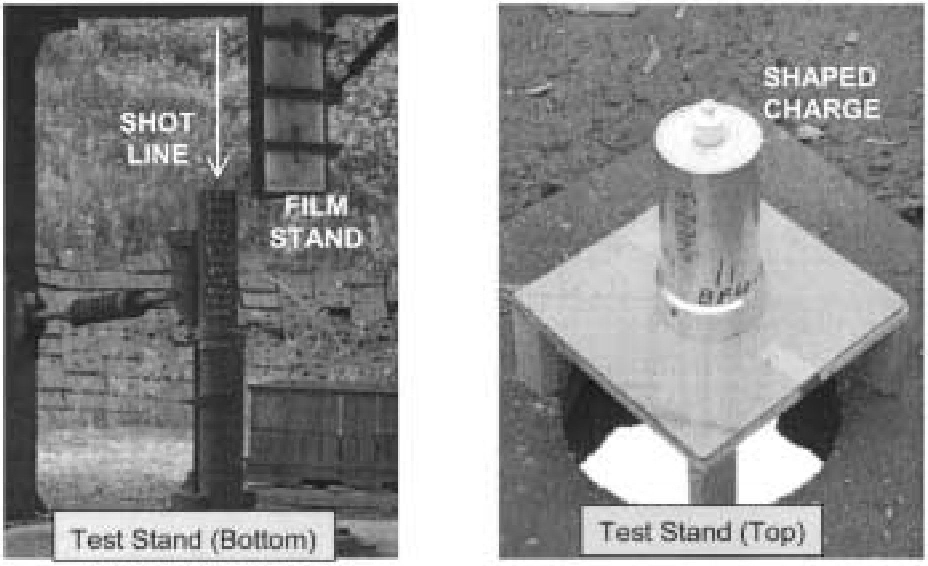


Figure 4. Photograph of the flash X-ray test stand.

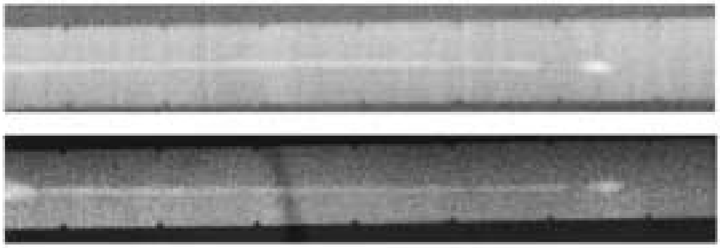
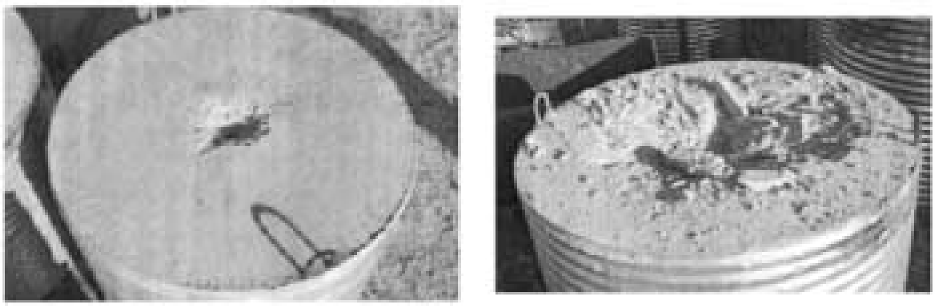


Figure 5. Medium standoff flash X-ray of Al1100-0 (top) and Barnie (bottom) jets.

Figure 6. Test setup for concrete attack experiments.

Home
Table of Contents



AL1100-0 Oxygen deficient

Oxygen balanced Oxygen rich

Figure 7. Concrete attack test fire experimental results.

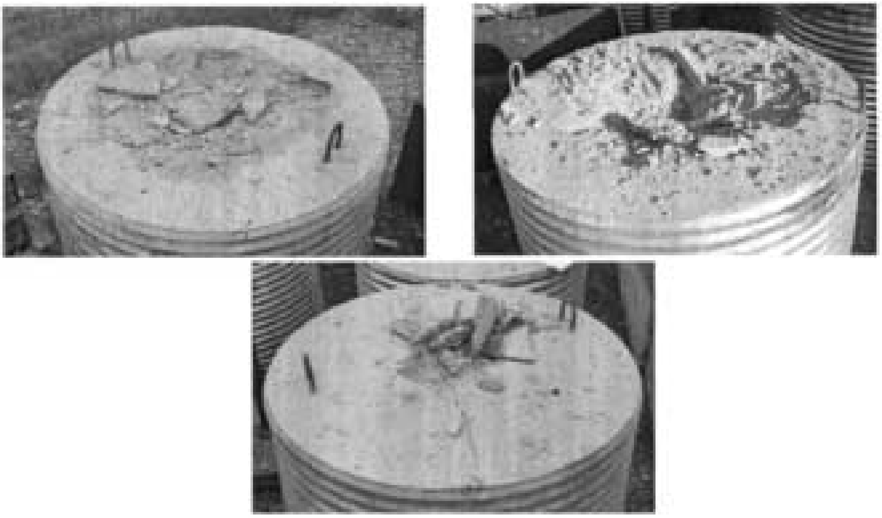


Figure 8. Effects of standoff on performance. (Clockwise – 1/2, 1 and 2 charge diameters)