2007-04

Low-Cost Explosive Ordnance Destruct Tool / 23rd International Symposium on Ballistics

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LOW-COST EXPLOSIVE ORDNANCE DESTRUCT TOOL

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The feasibility and engineering design of a conceptual "non-explosive" explosive shaped charge tool that can be adapted for purposes of mitigating and neutralizing explosive ordnance during military and homeland security operations is reported. Nitromethane, a low-cost commercial solvent, is used as the energetic material. This inexpensive liquid is ideally suited for the application because of its relative insensitivity and ease of loading. The conceptual device is packaged in a shaped plastic container with a hollow-cavity that is sufficiently flexible to permit a wide range of liners of equal included volume which can be added just prior to deployment, along with automated injection of a sensitizer.

The range of performance of a 25mm device against Composition B and TNT is reported. There are also reported effects on key design parameters such as sensitizer concentration, charge diameter, initiation front geometry, run-up distance, charge confinement, liner configuration, and charge performance.

Observed variations in detonation velocity during initial stages of run-up and the use of the Lee-Tarver model in correlating jet impact initiation are also reported.

INTRODUCTION

There is an alarming growth of explosive hazards throughout the world from the aftermath of wars and regional conflicts, terrorism, and criminal activity. The ever-growing nature of the problem is exemplified by the number of land mines. Landmines are purported to number in the tens to hundreds of million causing upwards of tens of thousands of casualties annually, and denying access and utilization of valuable natural resources. Although there are numerous technologies and techniques for mitigating and neutralizing these explosive threats, such as high energy precision shaped charges. Most are either too expensive and/or present potential threats if fallen into wrongful hands. A device that can potentially overcome these problems is the subject of this report. The concept (see Figure 1) is built around the use of nitromethane as an energetic source for a precision shaped charge. The key characteristics of this liquid that make it an attractive component is its relatively low cost, relative insensitivity to detonation in plastic containers of the sizes of interest, and ease at which it can be loaded compared with the expensive casting and/or pressing operations required for solid explosive charges. Other components, which are to be separately packaged, include a sensitizer, a slide-on confinement body, an insertable liner, a standoff fixture, and detonator. These separately packaged components are to be assembled in-situ, just prior to operation. In some respects the charge is similar to one designed by Majerus and Brown [1,2] for a mine clearing net and humanitarian demining, with the exception that this new concept is much safer and the separate packaging reduces the opportunities of unintended use.

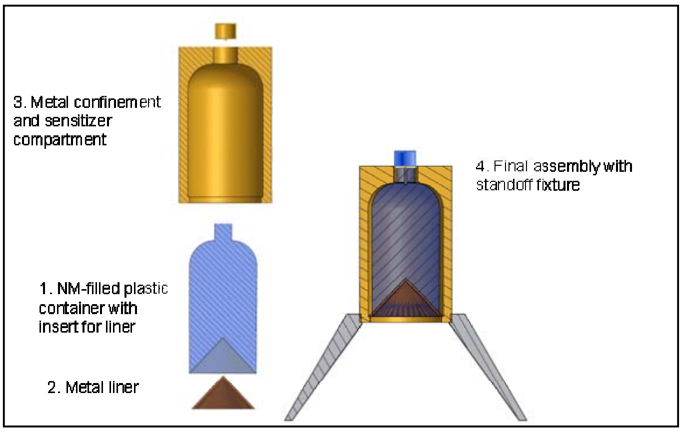

Figure 1. Conceptual explosive destruct tool. (needs to be fixed)

In this paper we report the initial results of our investigation primarily directed towards demonstrating the feasibility of the concept.

TECHNICAL DISCUSSION

This report covers critical design and performance issues pertaining to safety, charge design and terminal effectiveness.

Safety and Initiation Reliability

An essential feature of the concept limits the material and diameter of the vessel that houses the nitromethane (NM) content. The reported data, summarized by Cooper [3], indicates that the critical diameter of NM in glass and plastics is as large as 36mm at 298^{o}C. In consistence with this data, we were only able to achieve one high-order detonation using RISI RP-81 detonators out of five attempts in 8-25mm diameter plastic and brass cylinders. We were totally unsuccessful in achieving high order detonation by adding small amounts of acetone, a reported sensitizer [4]. On the other hand, initiation to high order was achieved 20 out of 20 times by the addition of 0.1% of reagent grade diethylenetriamine (DETA) in 25mm diameter vessels; encouraging results associated with the perceived safety feature of NM.

The potential effect of a detonation of a plastic encased and plastic lined shaped charge containing pure nitromethane at diameter 25mm was estimated using the Eulerian processor in Century Dynamics AUTODYN finite difference code. This code has been experimentally validated over a wide range of shaped charge simulations. The purpose of these computations was to estimate the maximum hazard in terms of steel penetration in case of an accidental detonation and shaped charge function. The results show that substituting a plastic liner of equal mass for a copper liner in a steel confined 42-degree Octol explosive charge should decrease penetration performance into steel by 32 percent. Replacing the steel confinement with thin plastic should decrease penetration by 76 percent. This result highlights one of the key premises of the concept with respect to the potential effect of accidental detonation. That is, a plastic encased and lined NM charge component will be much less dangerous than a charge containing a high energy solid explosive if accidentally detonated.

Detonation Velocity of DETA/NM

The effect of diameter on detonation run-up is important to charge design. For example, axial alignment of the detonation is dependent on the diameter and length of the upper channel of the device that interfaces with the detonator. It should be narrow and as long as practical. Also detonation run-up distance will govern minimum head height and overall length of an optimum design solution.

A series of tests in vessels of diameter ranging from 6 to 18mm were performed using ionization probes to detect detonation front advance. Based on the results, there appeared to be an indication of either a small diameter effect, consistent with Pop-plot "run-to-detonation" [3], or a statistical artifact. Our estimate of limit detonation velocity for a 0.1% DETA mixture is 6.287mm/μsec versus reported value for pure NM of 6.299mm/μsec. Taking into account the small dilution of DETA, a velocity of 6.294mm/μsec would be expected.

Shaped Charge Jetting and Penetration

The applicability of a NM shaped charge is dependent on a design that can produce a jet that can impact initiate explosive threats encased and hidden behind various types of common barriers. Thus, one of the first questions addressed was directed towards determining the approximate penetration potential of a 25mm NM charge; a maximum caliber chosen in order to minimize accidental detonation probability. A point-initiated copper trumpet lined shaped charge was shown to penetrate 100mm through steel and slightly more than 170mm through aluminum at 2 charge diameters (CD) standoff. The charges tested were contained in brass bodies varying in thickness between 1 and 25mm. The effect of body thickness on penetration was very small, leading to a conclusion that the addition of only small thicknesses of metal around a plastic encased NM charge would be required for reliable jet formation. The jet tip velocities from these charges were between 4.9 and 5.1 km/sec. An example of the excellent comparison between predicted penetration (incl., jet formation), using the AUTODYN Eulerian processor, and experiment is shown in Figure 2, where the early time penetration of the copper jet through an instrumented steel target is plotted.

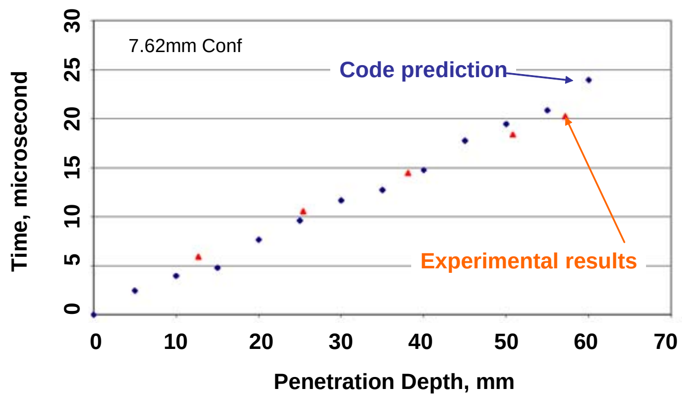

Figure 2. Correlation between predicted and observed partial penetration through aluminum by the jet from the trumpet-shaped nitromethane shaped charge.

Charge Design Modifications for Enhancing Impact Initiation Potential

The observed penetration performance of the baseline 25mm NM charge clearly show that a nitromethane charge, at the selected caliber, is sufficiently powerful to penetrate through barriers much thicker than might be encountered in the field of operation. However, the velocity and kinetic energy of a jet that survives after penetrating a barrier or casing that protects an explosive threat must be great enough to neutralize the explosive. Our purpose is to initiate detonation. Composition B (60/40) and TNT are chosen as typical explosive threats.

In a rather rudimentary set of design excursions, we show the possibilities of increasing jet tip velocity (and as a consequence jet elongation) from 5 to close to 6mm/µsec by altering liner geometry and incorporating peripheral initiation. The effect of these changes on jet velocity and cumulative mass distribution are shown in Table 1.

The actual hardware design required to support an attenuator necessary to affect ring initiation is not trivial however. Attenuator components in a solid explosive charge can be directly supported by the explosive, which is not possible in a liquid explosive charge. The design solution encompasses a thin but rigid, spider arrangement that holds an inert, plastic attenuator in place at the union of a two-part sealed plastic body.

Design #2 offers a substantial increase in jet velocity and stretch as compared with the initial design. Additional gains in jet velocity, although modest, result from ring initiation.

A circumferential initiator, similar to that demonstrated by Sellam [5] is also under investigation. In this case, it is possible to increase detonation velocity and pressure of NM to levels approaching RDX and HMX.

Table 1. Comparison of jet Characteristics of Point and initiated charge designs

Liner Design	Initiation Geometry	Tip Velocity (mm/μsec)	Cumulative Mass* (g)
Design #1	Point	5.10	(no data)
Design #2	Point	5.90	1.01
	Ring Head Height		
	70%	6.02	0.90
	60%	6.11	0.80
	50%	6.21	0.78
	40%	6.31	0.75

*Cumulative mass is between jet tip and jet velocity at 3mm/μsec.

Estimated Impact Initiation Requirements and Potential

Rather than performing tests immediately against explosive targets, where results would be dependent on the cumulative effects of jet impact and therefore difficult to assess, the following approach was taken. Initiation potential is estimated using the Lagrangian processor in AUTODYN [6] and the Lee-Tarver ignition and growth model [7]. Computations were first performed to quantify the predictability of impact and shock initiation data. Experiments reported by Moulard [8] and Kubota [9] were simulated. The pressure growth or decline following impact or shock in these simulations is used as an indication of go or no-go, respectively. That is, continued pressure increase is indicative of growth to full detonation (i.e., “go” reaction); pressure buildup that is not sustained is an indication of eventual failure (i.e., “no-go”) [10]. Using this approach we are able to accurately reproduce the experimental results reported by

Kubota and Moulard. Having validated the approach, we use the same technique along with the Held jet impact initiation model [11] to explore the potential of the new NM charges.

Using these validated approaches, the threshold impact velocities of short 2mm diameter L/d=1 copper jet segments required to initiate 60/40 Composition B and TNT are estimated. Against Composition B the predicted threshold is close to 4 km/sec or $v^2d \geq 32$ mm^3/µsec^2. An example of the data used for this prediction are shown in Figures 4 and 5, where Lee Tarver reaction profiles are shown (i.e., parameter "alpha") at off axial positions, resulting from impacts at 3 and 6mm/µsec. The predicted threshold is consistent with a reported value of 29 reported by Chick [12] for a 0.75mm diameter jet. It appears, in this case, the Held parameter increases slightly with jet diameter based on a value of 40 estimated by Chick for larger diameter jets. For TNT we estimate v^2d between 50 and 72mm^3/µsec^2 for the impact of a 2 mm copper particle. Reported values range between13 and 65. These values of the Held parameter for TNT are apparently dependent on density [11].

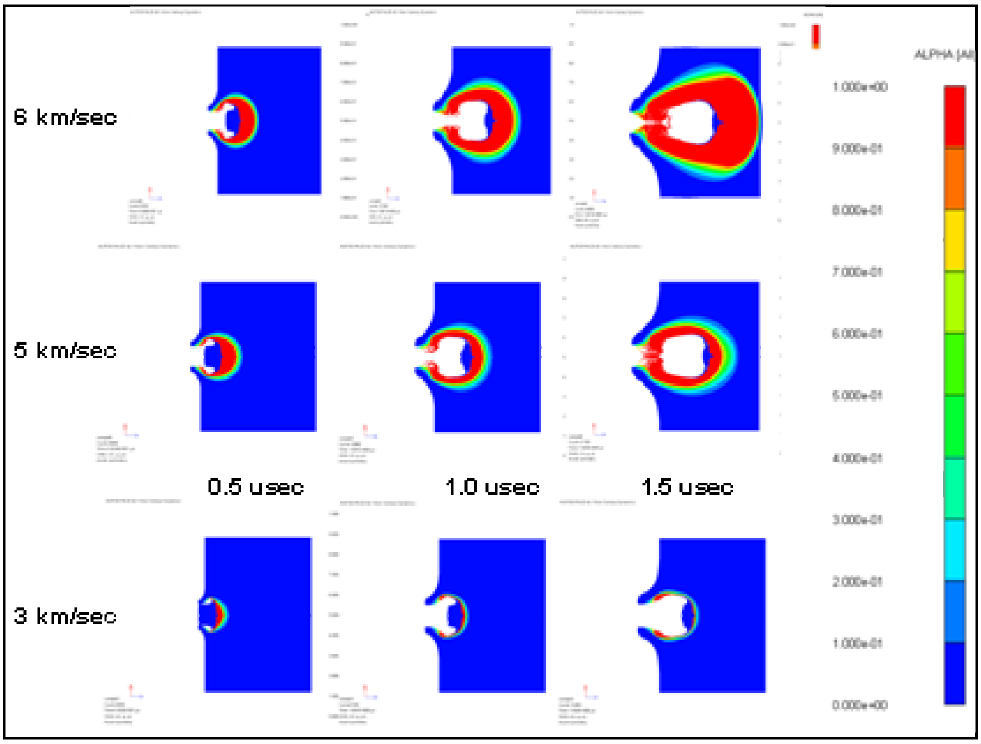

Figure 4. Predicted regions of reaction in Composition B resulting from a 2mm, L/D=1 copper penetrator simulating a segment of jet from a NM charge: Color shading is indicative of the degree of reaction, a, according to the Lee-Tarver ignition and growth model.

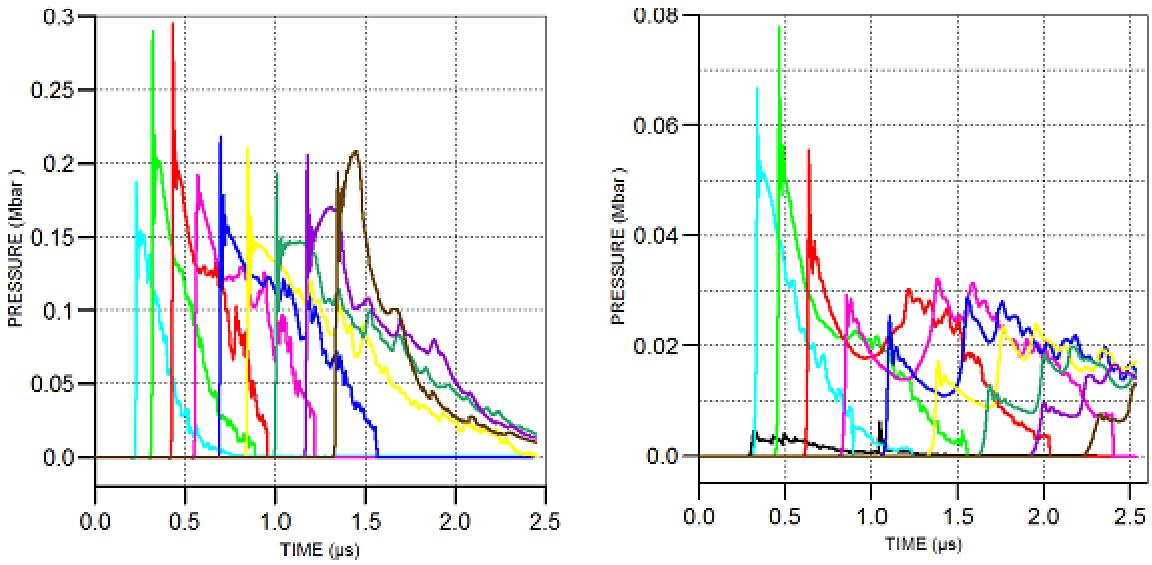

Figure 5. Predicted pressures along a radial distance of x mm above the axis of symmetry in Composition B resulting from copper particle impacts at 6 and 3 km/sec: Impact conditions are identical to those described in Figure 4.

CONCLUSIONS

The basic feasibility of the conceptual explosive destruct system is shown. From a cost standpoint, liquid nitromethane is an ideal energetic material. Not only is the raw material low-cost but also the expense of accurate and precision explosive loading is avoided, since there is only pouring and sealing operations required. From the standpoint of hazard, it is shown that pure nitromethane is difficult to initiate and computational predictions show that the hazards associated are greatly reduced from those of high energy RDX and HMX-based explosives charges. The initiation reliability with the addition of diethylene triamine is close to 100 percent. It is shown that a point-initiated non-optimized trumpet-shaped copper liner is capable of penetrating nearly 7 charge diameters through aluminum and slightly over 4 charge diameters through steel. There is computational and experimental evidence that the incorporation of a ring-initiation mechanism can be used to enhance penetration capability. It is also shown that a NM shaped charge at 25mm caliber might be effective against Composition B and TNT threats. The effect of imposing barriers between the charge is a remaining critical issue.

ACKNOWLEDGEMENTS

The work reported herein was partially supported by the Office of Naval Research under the direction of Dr. Brian Armquist, and by graduate educational funding from Naval Postgraduate School. The authors thank Dr. Ernie Baker of the US Army Research, Engineering and Development Command and Dr. Brendon Grove, Schlumberger Oil Perforating Center, for their generous contribution of the liners tested in this program.

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