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APPLICATION OF LINEAR SHAPED CHARGES FOR WARHEAD VENTING

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Results from numerical simulations and experimentation using linear shaped charges (LSCs) show that LSCs can be potentially useful for warhead venting applications. A V-shaped liner can be used either to perforate the case and cause explosive initiation or to provide a non-perforating channel to weaken the body and provide a rupture site for warhead venting under thermal cook-off conditions. Numerical simulations included linear shaped charge jet characterization and target plate penetration. Experimentation included linear jet characterization using flash x-rays, target plate penetration and testing against explosively loaded test fixtures. The explosively loaded test fixture testing resulted in relatively mild explosive response with Comp B4 burning response and significant amounts of unreacted explosive when using Comp A3 and PBXN-9.

INTRODUCTION

Insensitive Munitions (IM) warhead technology is being developed in order to survive unplanned stimuli produced by fires (slow & fast cook-off). This technology development is investigating both passive and active warhead venting. Any successful warhead venting technology must not only vent the burning products, but also must maintain required structural body characteristics and high warhead performance. Passive venting technology incorporating melt venting and pressure rupture are being investigated, as well as warhead IM liner technology using melting materials. Some of the effort is concentrating on venting design capability development through small scale laboratory hardware experimentation and computer modeling for passive venting [1].

However, active venting approaches are also being pursued, as they can potentially assure warhead structural characteristics and performance will be maintained, as they could be implemented externally to the warhead.

A linear shaped charge (LSC) is a linearly arranged explosive charge with a metal lined cavity, usually V-shaped, as shown in figures 1 and 4. LSCs are commonly used in the cutting sheet metals and other structural targets. Linear shaped charges have long been used for line cutting metal applications [2, 3, 4]. The use of linear shaped charges (LSCs) for warhead venting is envisioned as an active mitigation scheme in order to achieve a mild response to thermal cook-off. The implemented concept is to monitor and identify when cook-off level temperatures occur and than to actively fire the LSC. The LSC would than cut open or weaken the warhead body to greatly reduce explosive confinement. The greatly reduced explosive confinement is desired in order to assure a mild explosive burn. ARDEC has completed numerical simulations and experimentation studies of LSCs for warhead venting applications. Experimentation included steel target penetration and testing against explosively loaded test fixtures.

NUMERICAL SIMULATION

Numerical simulations included linear shaped charge jet characterization and target plate penetration. The high rate continuum model CTH [5] was used to model the LSC configuration. The LSC used for these studies is about 25mm wide with a 90 degree steel liner configuration. The LSC is hand packed with Comp C4 explosive and initiated at the center. The steel liner was modelled using the Johnson-Cook strength model. The Comp C4 explosive was modelled using the Jones-Wilkins-Lee (JWL) detonation products equation of state. Figure 1 presents LSC jet formation with 5cm grid spacing at 0, 10μs, 30μs and 50μs. Figure 2 presents LSC jet side view with 5cm grid spacing at 30μs and 50μs. The calculated jet tip velocity is 2.25Km/s. Figure 3 presents LSC target penetration with 5cm grid spacing at 0, 10μs, 30μs and 40μs. Various amounts of target buffering were modeled. Target buffering is additional target material placed before the main target. Target buffering was used to reduce the main target penetration to the minimal amount associated with the case thickness surrounding an explosive billet. Target buffering was investigated to determine appropriate buffering thickness to allow appropriate case rupture, but to avoid significant explosive penetration that could result in a violent explosive response.

EXPERIMENTATION

Experimentation included linear jet characterization using flash x-rays, target plate penetration and testing against explosively loaded test fixtures. The target buffering used in the explosive loaded test fixture configurations was based on both numerical simulation and initial target penetration testing. Figure 4 presents photographs of the initial LSC penetration testing setups and penetration results.

Figure 5 presents LSC jet x-rays at 52μs and 76μs. The experimental jet tip velocity is about 2.3Km/s. Figure 6 presents the LSC target buffering plate penetration test setup and results Figure 7 presents the confined explosive cylinder cutting test setup. The test configuration consisted of 50mm diameter by 100mm long explosive billets confined in standard schedule 40 steel plumbing fixtures. The steel wall thickness is about 3.2mm. The end caps are also standard schedule 40 cast steel threaded parts. Figure 8 presents the test result using Comp B4 filled explosive test fixtures. As designed, the 2 buffer plates are clearly cut. The steel test fixture body has been cut open and the Comp B4 burnt. This is evident, as the steel body results in two large pieces and does not produce fine fragmentation. The end cap pieces are somewhat fragmented, which is not surprising due to their extremely brittle nature, as they are somewhat lower density cast steel parts. Figure 9 presents the test result of Comp A3. Again the 2 buffer plates are clearly cut. The steel body remains in a single cut piece with no evident fragmentation produced. A significant amount of unreacted Comp A3 is noted to remain within the body and large amounts of unreacted Comp A3 were found scattered around the test fixture position. The end cap again fractures into pieces, due to brittle nature of the cast steel. Figure 10 presents the test result of PBXN-9. Again the 2 buffer plates are clearly cut. Similar to the Comp A3 result, the steel body remains in a relatively intact as a single piece that has been cut, with no fragmentation. Even more unexploded explosive was found scattered, as well as some entrapped in test fixture body. As before, the end cap is fractured into pieces, due to its brittle nature.

LSC VENTING DISCUSSION

Results from the numerical simulations and experimentation show that LSCs can be successfully applied for warhead venting applications. A V-shaped liner can be used either to perforate the case, cause explosive initiation or to provide a non-perforating channel to weaken the body and provide a rupture site for warhead venting. LSC venting design included shaped charge geometry, shaped charge standoff and target buffering considerations. Through proper LSC venting configuration design, testing resulted in relatively mild explosive responses. The Comp B4 tests resulted in all of the

Comp B4 burning in the test fixture without explosive detonation. The Comp A3 and PBXN-9 tests resulted in some portion of the explosive burning and a large amount of the explosive remaining unreacted.

These successful results support another potential approach, using W-shaped liner LSCs to produce spalling at the center line of the two jets impact locations. This spalling would be due to the tensile stresses produced by the interaction of two shock waves in the case that the jets cannot cut the metal target. This spalling could potentially provide a damaged location in the metal munition case, providing a rupture site for warhead venting under thermal cook-off conditions.

SUMMARY

This effort demonstrated the viability of using LSCs for warhead venting as method for the mitigation of violent cook-off response. Previous studies have shown that if sufficient venting is achieved, a non-violent response to cook-off occurs [1]. This new method of warhead venting is being transferred to the U.S. Army PEO Ammunition Insensitive Munitions Initiative, through a Warhead Venting Thrust concepts demonstration effort. Larger scale munitions venting demonstrations using LSCs are planned under that effort. This new technology will be applicable to both gun fired and missile munitions (artillery, mortars, large and medium caliber, missiles and rockets).

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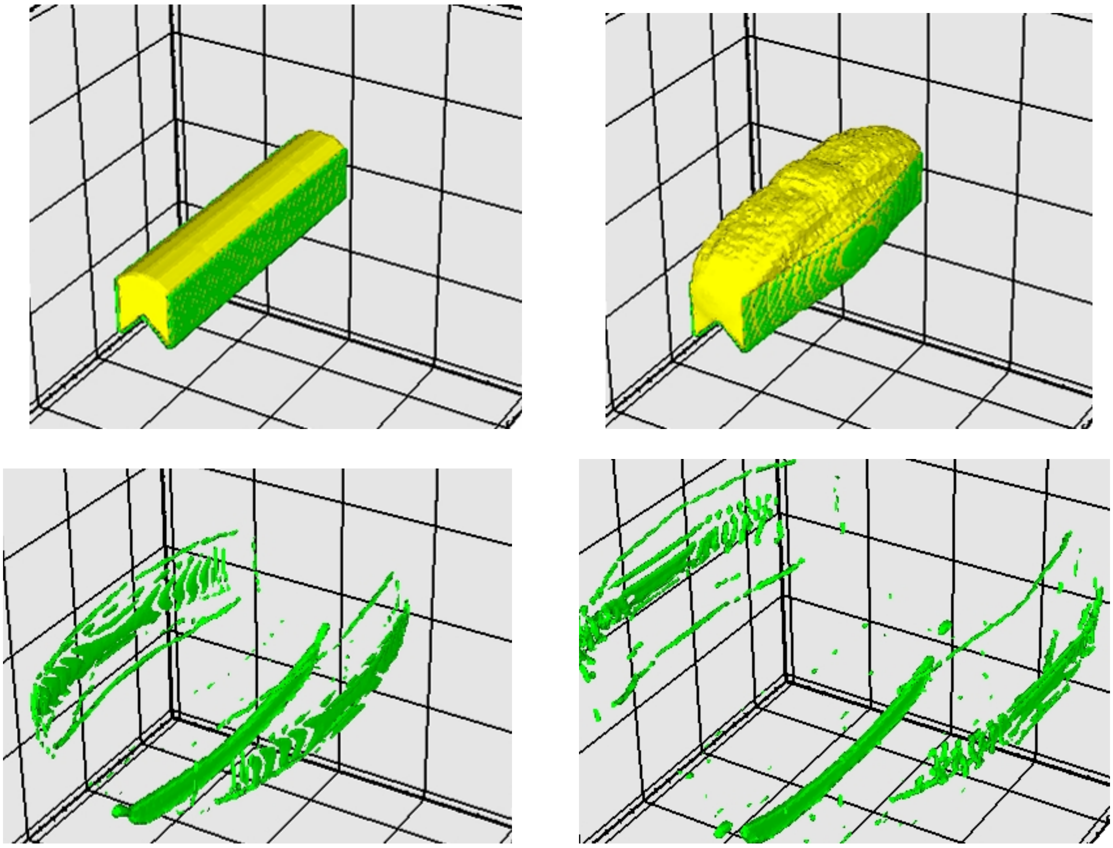

Figure 1. Linear shaped charge (LSC) jet formation with 5cm grid spacing at 0, 10μs, 30μs and 50μs.

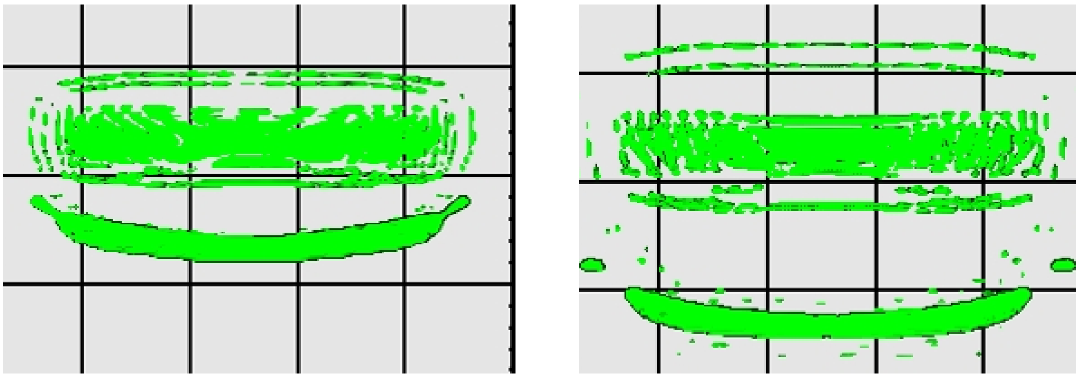

Figure 2. Linear shaped charge (LSC) jet side view with 5cm grid spacing at 30μs and 50μs. Calculated jet tip velocity=2.25Km/s.

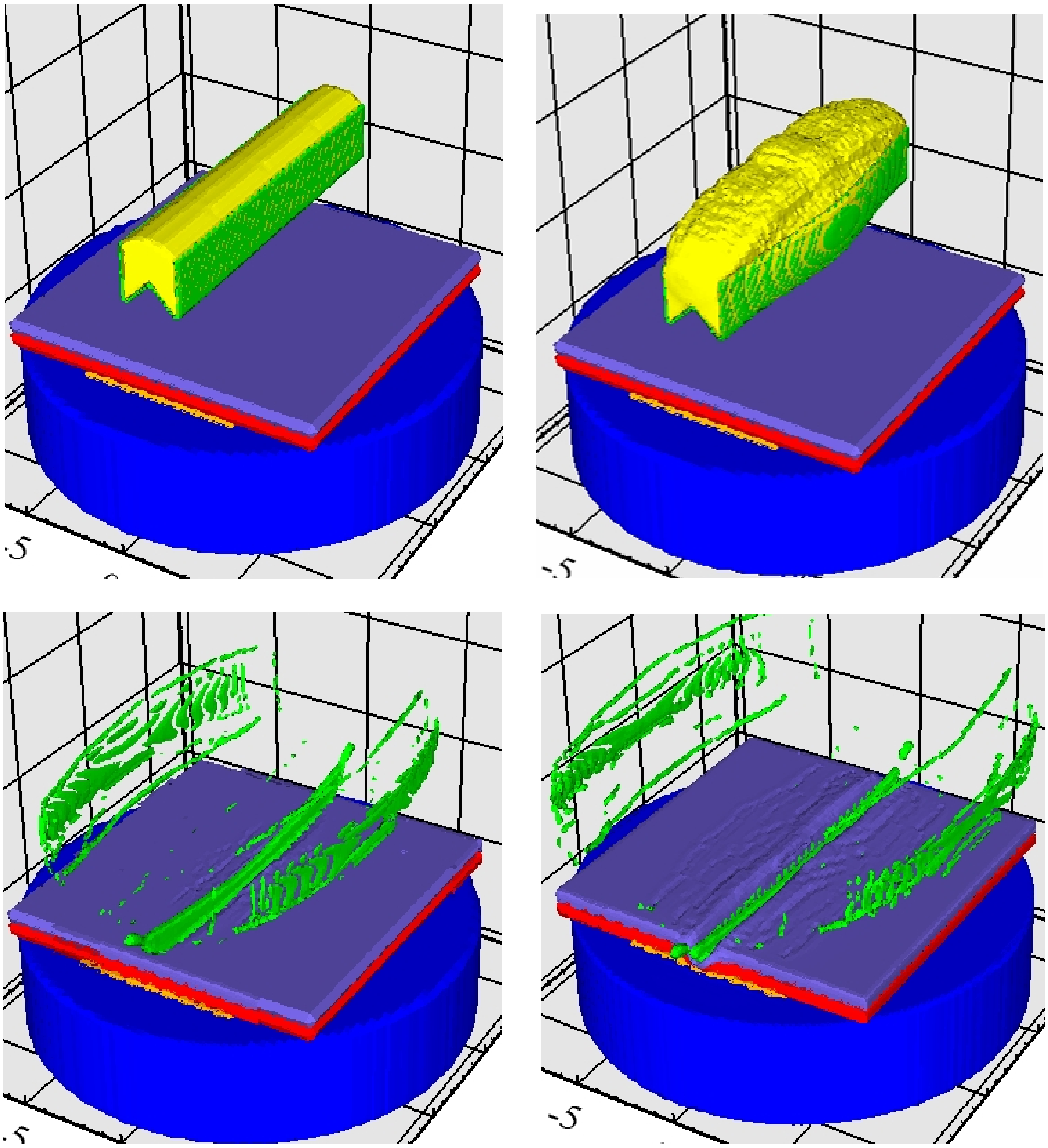

Figure 3. Linear shaped charge (LSC) target penetration with 5cm grid spacing at 0, 10μs, 30μs and 40μs.

Figure 4. Initial LSC penetration testing.

Figure 5. LSC jet x-rays at 52µs and 76µs. Jet tip velocity: experimental=2.3Km/s, calculated =2.25Km/s.

Figure 6. Initial LSC target buffering plate penetration test setup and results

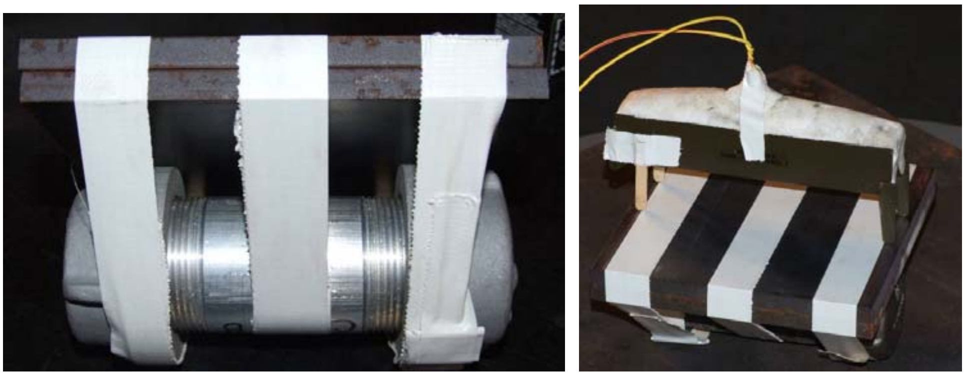

Figure 7. Confined explosive cylinder cutting test setup, bottom view (left), top view (right).

Figure 8. Test result of Comp B4: 2 buffer plates (left), steel body (center), end cap pieces (left).

Figure 9. Test result of Comp A3: 2 buffer plates (left), steel body (center), end cap pieces (left).

Figure 10. Test results of PBXN-9: 2 buffer plates (left), steel body (center left), end cap pieces (center right) unreacted explosive (right).