# Engineering Notes

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## Gas Gun Study of Polyethylene Buffers for Spall Fracture Reduction in Missile Materials

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### I. Introduction

THE warhead of a missile is commonly located inside an outer skin or shroud covering. After detonation of the warhead, the fragments must break through the shroud to reach the target. The interaction of the fragments with the shroud may cause fragment spall fracture and decreased fragment velocity. The purpose of this Note is to report an investigation of the effect of placing a buffer material on the inside surface of the shroud to reduce fragment spall. A 40-mm-bore gas gun was used for this work.[1] Gas gun impact techniques are commonly used to investigate spall fracture phenomena.[2,3] Composite specimens that simulated the shroud were impacted by steel disks. The impactor disks were soft recovered, sectioned, and examined for fracture damage. Experiments were performed using various thicknesses of polyethylene buffer layers.

### II. Experimental Techniques

Figure 1 is a schematic of the muzzle region of the gas gun with a target assembly containing a buffered composite specimen. The composite specimens consisted of a wire harness layer, a 7075-T6 aluminum layer, a honeycomb layer, and another 7075-T6 aluminum layer. The average projectile velocity at impact was measured with the three charged pins in the side of the barrel.

The impactor disks were fabricated from AISI C 1026 hot-rolled seamless tubing. The manufacturer's mechanical properties are 300 MPa yield strength, 540 MPa ultimate tensile strength, and 28% elongation. The measured impactor density was 7.82 Mg/m$^3$. The wire harness layer consisted of a series of parallel wires located 6.35 mm apart and sealed between two thin plastic sheets. The honeycomb layer consisted of a plastic honeycomb material with a density of 0.072 Mg/m$^3$. Fast-setting epoxy was used to attach the four layers of a composite specimen together and also to attach the polyethylene buffer layer to the specimen.

Six gas gun shots were fired. The average impactor thickness was 9.0 mm. The average specimen thickness was 9.2 mm (1.70-mm-thick wire harness layer, 1.60-mm-thick 7075-T6 aluminum layer, 5.11-mm-thick honeycomb layer, and 0.80-mm-thick 7075-T6 aluminum layer). The polyethylene thicknesses ranged from 1.02 to 9.12 mm. The measured polyethylene density was 0.954 Mg/m$^3$. The average diameter of the impactors and composite specimens was approximately 30 mm.

Vacuum degassed epoxy was used to secure a buffered specimen inside a Lucite target holder. Prior to the epoxy pour, transparent tape was placed around the edge of the specimen to prevent the epoxy from flowing into the wire harness and honeycomb regions. The steel disks were soft recovered after impact to minimize any unintentional damage. The soft recovery arrangement consisted of two bales of rags (approximately 0.5 m on a side) that were placed in the recovery area near the muzzle of the gas gun.

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### III. Results and Discussion

Table 1 summarizes the gas gun recovery experiments. The average impactor velocity was 0.87 km/s. The initial impactor stress was calculated for each shot using known Hugoniot equations of state and the measured impactor velocities. For these impact stresses it is expected that both elastic and plastic waves were generated in the steel impactor disks. The spall fracture that occurred in the disks was produced by tensile stresses resulting from the interaction of relief (decompression) waves.

The average hardness value for the impact surfaces of the recovered disks was $R_B$ 99; the average value for the free surfaces was $R_B$ 84. The difference can probably be attributed to the larger deformation of the impact surface. These values can be compared with a hardness value of $R_B$ 78 obtained for an unshocked 1026 steel disk.

The recovered disks for the shots were sectioned on a diameter, polished, and examined microscopically to reveal any internal fracture damage. Photographs of these polished surfaces are shown in Fig. 2. These sectioned disks show that the fracture damage decreases as the buffer thickness increases. A quantative description of this fracture damage is given in Table 1. Damage was limited to the central region of a disk due to stress relief wave effects at the disk edge. The full-spalled disk for Shot 165 in Fig. 2a was impacted on an unbuffered specimen. Complete separation occurred in this disk at about 6.4 mm from the impact surface. The fracture damage for the Shot 169 disk in Fig. 2b was centered about 6 mm from the disk impact surface. Figures 2c and 2d show the reduced fracture damage that occurred when the buffer thickness was increased to 1.52 and 2.31 mm, respectively. For these disks the region of maximum damage again occurred about 6 mm from the impact surface. Very few cracks were observed in the Shot 168 disk in Fig. 2e after impact with the 3.43-mm-thick layer. The region of fracture damage was centered about 5 mm from the disk impact surface. No cracks were observed in the Shot 166 disk in Fig. 2f after impact with the 9.12-mm-thick layer.

In summary, these results indicate that polyethylene buffer thicknesses of at least 3.4 mm are needed to prevent extensive fracture damage in the impactor disks.

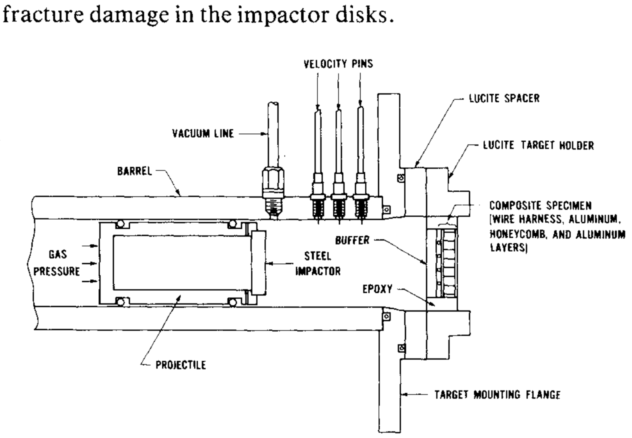
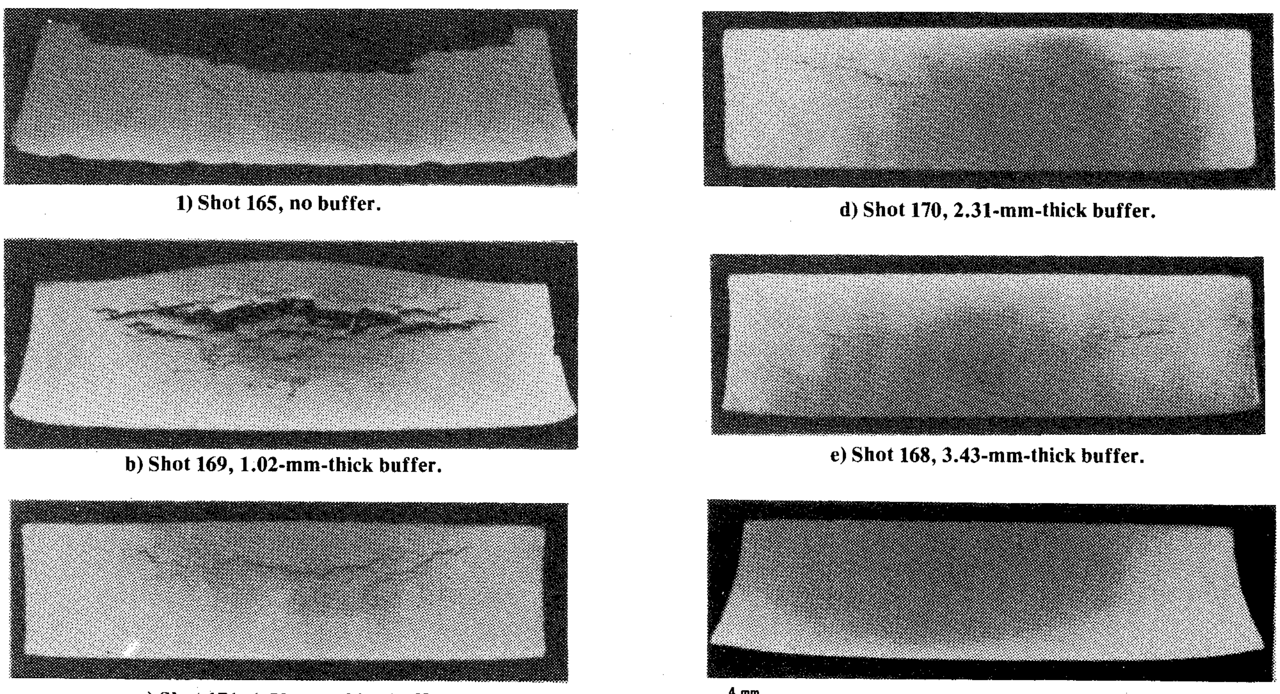



**Fig. 1 Schematic of muzzle region of gas gun showing a steel impactor disk and a buffered composite specimen.**

**Table 1 Summary of gas gun impact and soft recovery experiments**

| Shot no. | Impactor velocity,[a] km/s | Initial impactor stress,[b] GPa | Initial impactor thickness, mm | Final impactor thickness,[c] mm | Buffer material | Initial buffer thickness, mm | Qualitative description of impactor fracture damage |
|---|---|---|---|---|---|---|---|
| 165 | 0.873 | 10.2 | 9.06 | 8.4 | None | – | Complete separation |
| 169 | 0.873 | 3.1 | 9.04 | 10.34 | Polyethylene | 1.02 | Heavy |
| 171 | 0.864 | 3.1 | 9.02 | 8.93 | Polyethylene | 1.52 | Medium |
| 170 | 0.887 | 3.2 | 9.04 | 8.84 | Polyethylene | 2.31 | Medium to light |
| 168 | 0.861 | 3.1 | 9.04 | 8.80 | Polyethylene | 3.43 | Light |
| 166 | 0.871 | 3.1 | 9.09 | 8.90 | Polyethylene | 9.12 | No damage |

[a] Estimated uncertainty is 1%.
[b] Estimated uncertainty is 5% to 10%. Hugoniot of Armco iron (Refs. 4 and 5) used since 1026 steel Hugoniot not available. Hugoniot of 6061-T6 aluminum (Ref. 6) used for Shot 165 since 7075-T6 aluminum Hugoniot not available. Calculated stress for Shot 165 corresponds to direct impact of steel onto aluminum. Polyethylene Hugoniot (Ref. 4) used for Shots 166 and 168-171.
[c] Measured in the central region of the specimens. Thicknesses of spalled pieces for Shot 165 were 6.4 and 2.0 mm.




1) Shot 165, no buffer.
b) Shot 169, 1.02-mm-thick buffer.
c) Shot 171, 1.52-mm-thick buffer.
d) Shot 170, 2.31-mm-thick buffer.
e) Shot 168, 3.43-mm-thick buffer.
f) Shot 166, 9.12-mm-thick buffer.

**Fig. 2 Comparison of impactor fracture damage for the polyethylene buffers. The disks are shown as a function of increasing buffer thickness. The bottom edge of each disk is the impact surface.**

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## References

[1] Mock, W. Jr. and Holt, W.H., "The NSWC Gas Gun Facility for Shock Effects in Materials," Naval Surface Weapons Center, Dahlgren, Va., NSWC/DL TR-3473, July 1976.

[2] Butcher, B.M., Barker, L.M., Munson, D.E., and Lundergan, C.D., "Influence of Stress History on Time-Dependent Spall in Metals," *AIAA Journal*, Vol. 2, June 1964, pp. 977-990.

[3] Seaman, L., Barbee, T.W. Jr., and Curran, D.R., "Dynamic Fracture Criteria of Homogeneous Materials," Air Force Weapons Laboratory, Kirtland Air Force Base, N. Mex., Contract Report No. AFWL-TR-71-156, Dec. 1971.

[4] Kohn, B.J., "Compilation of Hugoniot Equations of State," Air Force Weapons Laboratory, Kirtland Air Force Base, N. Mex., AFWL-TR-69-38, April 1969.

[5] Barker, L.M., "α-Phase Hugoniot of Iron," *Journal of Applied Physics*, Vol. 46, June 1975, pp. 2544-2547.

[6] Christman, D.R., Isbell, W.M., Babcock, S.G., McMillan, A.R., and Green, S.J., "Measurements of Dynamic Properties of Materials, Vol. III, 6061-T6 Aluminum," General Motors Technical Center, Warren, Mich., DASA 2501-3, Nov. 1971.