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Damage Assessment of a Small Spherical Projectile Impacting on a Glass Shield

by Jian H. Yu, Peter G. Dehmer, and James M. Sands

ARL-MR-711 **January 2009**

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REPORT DOCUMENTATION PAGE	Form Approved OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*	2. REPORT TYPE	3. DATES COVERED (From - To)
January 2009	Final	1 October 2008–1 November 2008

4. TITLE AND SUBTITLE
Damage Assessment of a Small Spherical Projectile Impacting on a Glass Shield

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Jian H. Yu, Peter G. Dehmer, and James M. Sands

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Research Laboratory
ATTN: AMSRD-ARL-WM-MD
Aberdeen Proving Ground, MD 21005-5069

8. PERFORMING ORGANIZATION REPORT NUMBER
ARL-MR-711

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
A high-speed photographic method was set up to track a small projectile in flight and capture its subsequent impact on a glass shield. A 1.0-mm-diameter steel ball bearing was launched from a compressed helium gas gun. The flight of the projectile and the impact event were captured with high-speed cameras. The glass shield showed visible damage at an impact speed of more than 205 m/s.

15. SUBJECT TERMS
small projectile, glass shield, impact

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Jian H. Yu
UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED	UL	10	19b. TELEPHONE NUMBER (*Include area code*) 410-306-0878

Standard Form 298 (Rev. 8/98)
Prescribed by ANSI Std. Z39.18

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1. Materials and Methods

The projectile is a 1.0-mm-diameter steel ball bearing (E52100 alloy) that weights 4.02 mg. It was launched from a 0.22-cal. gas gun without a sabot. The gas gun was pressurized at different pressures, with helium gas to propel the projectile at different velocities. The speed of the projectile was not controlled precisely; however, higher pressurization generally produced a faster projectile speed. When the projectile passed in front of a transparent grid sheet, the shadow of the projectile was captured by a high-speed camera (Photron SA1). The pictures were taken at a resolution of 512 × 512 dpi, a camera speed of 200,000 frames/second, and an exposure time of 1/551,000 s. The path of the projectile was no more than 5 mm away from the transparent grid sheet (see figure 1). The camera lens (Nikon AF-Nikkor) was set at 85-mm focal length, with an f-stop of 22 to capture the shadow and the grid in focus. The speed of the projectile was determined by measuring the displacement of the shadow in 150 μs using Photron PFV software (see figure 2). The displacement measurement was accurate to ±0.05 mm; the measured speed accuracy was ±10 m/s. Another high-speed camera (same settings as just mentioned) was used to capture the impact of the projectile on the glass target. High-intensity lamps were used to back light the target. The glass target (Schott Borofloat 33 glass, 101.6 × 101.6 × 1.11 mm) was held onto a 1-in-thick Plexiglas* frame with 3M double-sided foam tape on all four edges.

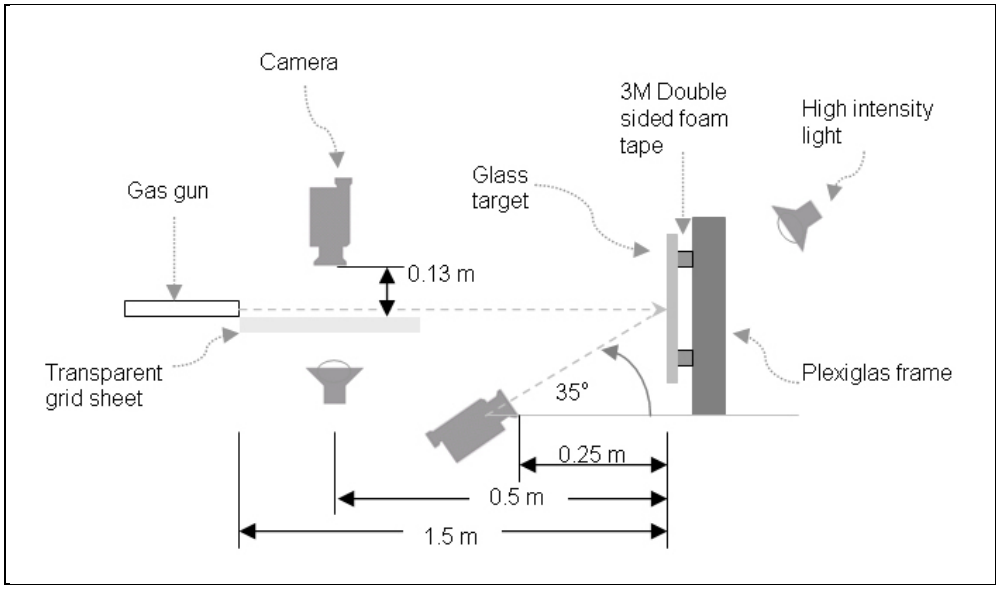

Figure 1. Setup diagram for small spherical projectile impact analysis.

*Plexiglas is a trademark of Rohm & Haas Company.

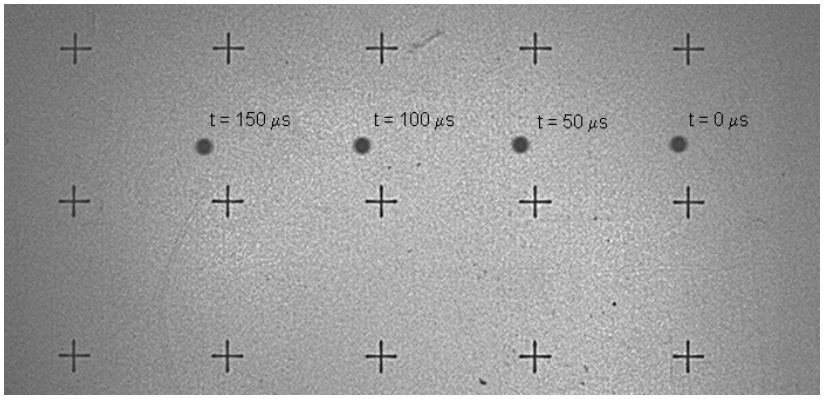

Figure 2. Speed determination: overlay of four frames of exposures. The horizontal distance between the cross hairs is 10 mm.

2. Results

The glass targets were impacted at different projectile speeds ranging from 107 to 250 m/s (see table 1). The maximum recorded speed that produced no damage on the glass target was 186 m/s; the minimum impact speed that caused target failure was 205 m/s. The projectile did not penetrate through the target. Instead, the projectile ricocheted off the target on impact. All the damaged targets had a truncated cone fracture (see figure 3). Lateral cracking also occurred at the damaged area. More lateral cracks were observed at a higher speed.

Table 1. Glass target impact results.

Projectile Speed (m/s)	**Results on Glass Target**
107	No damage
172	No damage
186	No damage
205	Fractured
250	Fractured

Figure 3. Damaged areas on targets: impact speed of 205 m/s (left) and impact speed of 250 m/s (right). The white scale bar is 3.5 mm.

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