



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

NOTICES

Disclaimers

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorized documents.

Citation of manufacturer's or trade names does not constitute an official endorsement or approval of the use thereof.

Destroy this report when it is no longer needed. Do not return it to the originator.

Army Research Laboratory

Aberdeen Proving Ground, MD 21005-5069

ARL-MR-711**January 2009**

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

Jian H. Yu, Peter G. Dehmer, and James M. Sands
Weapons and Materials Research Directorate, ARL

REPORT DOCUMENTATION PAGE				Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing the burden, to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.					
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

Contents

List of Figures	iv
List of Tables	iv
1. Materials and Methods	1
2. Results	2
Distribution List	4

List of Figures

Figure 1. Setup diagram for small spherical projectile impact analysis.	1
Figure 2. Speed determination: overlay of four frames of exposures. The horizontal distance between the cross hairs is 10 mm.	2
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.	3

List of Tables

Table 1. Glass target impact results.	2
--	---

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 $150 \mu\text{s}$ 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, $101.6 \times 101.6 \times 1.11$ mm) was held onto a 1-in-thick Plexiglas* frame with 3M double-sided foam tape on all four edges.

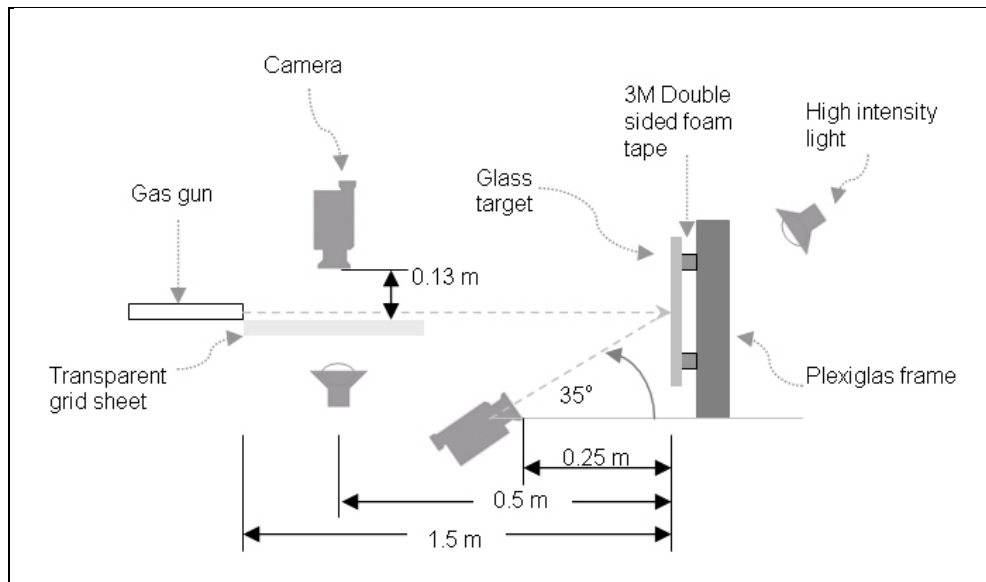


Figure 1. Setup diagram for small spherical projectile impact analysis.

*Plexiglas is a trademark of Rohm & Haas Company.

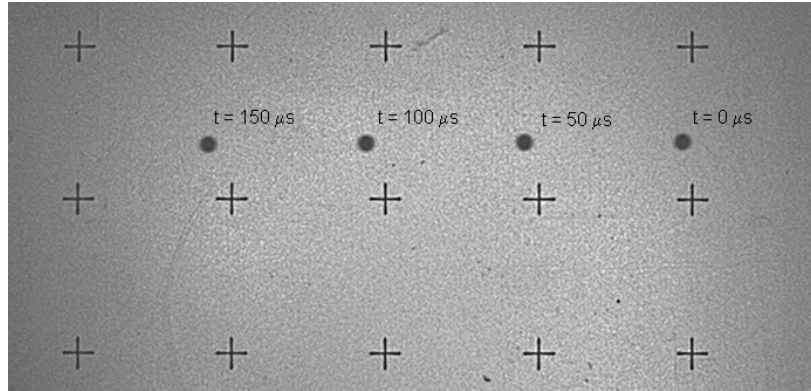


Figure 2. Speed determination: overlay of four frames of exposures. The horizontal distance between the cross hairs is 10 mm.

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.

NO. OF
COPIES ORGANIZATION

1 DEFENSE TECHNICAL
(PDF INFORMATION CTR
only) DTIC OCA
8725 JOHN J KINGMAN RD
STE 0944
FORT BELVOIR VA 22060-6218

1 DIRECTOR
US ARMY RESEARCH LAB
IMNE ALC HR
2800 POWDER MILL RD
ADELPHI MD 20783-1197

1 DIRECTOR
US ARMY RESEARCH LAB
AMSRD ARL CI OK TL
2800 POWDER MILL RD
ADELPHI MD 20783-1197

1 DIRECTOR
US ARMY RESEARCH LAB
AMSRD ARL CI OK PE
2800 POWDER MILL RD
ADELPHI MD 20783-1197

ABERDEEN PROVING GROUND

1 DIR USARL
AMSRD ARL CI OK TP (BLDG 4600)