AIM

Association for Information and Image Management

1100 Wayne Avenue, Suite 1100
Silver Spring, Maryland 20910
301/587-8702

Centimeter

Inches

MANUFACTURED TO AIM STANDARDS
BY APPLIED IMAGE, INC.

1 of 1

2

Conf-930676--2

UCRL-JC-113130
PREPRINT

RECEIVED
JUL 19 1993
OSTI

Six-mm, Plane-Wave Shock Driver

A. M. Frank
H. H. Chau

This paper was prepared for presentation at the
Joint AIRAPT/APS Conference on High Pressure Science and Technology
Colorado Springs, CO
June 28-July 2, 1993

June 14, 1993

This is a preprint of a paper intended for publication in a journal or proceedings. Since changes may be made before publication, this preprint is made available with the understanding that it will not be cited or reproduced without the permission of the author.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This document was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor the University of California nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial products, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or the University of California. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or the University of California, and shall not be used for advertising or product endorsement purposes.

SIX-MM, PLANE-WAVE SHOCK DRIVER

Alan M. Frank

Henry H. Chau

Lawrence Livermore National Laboratory
P. O. Box 808, Livermore, CA, 94551, USA

A 6-mm-diameter, plane-wave shock generation system has been developed and characterized as a laboratory bench driver for small scale experiments. The driver is based on an exploding-foil-driven slapper used either directly or to initiate an HE pellet. The slapper is driven by a low-inductance fireset with burst currents on the order of 30 kA and burst times of about 250 ns, with a time-to-burst jitter under 10 ns. Both the slapper impact and the detonation breakout of the pellet have been measured to be flat to within 10 ns over a 6-mm diameter. Fabry-Perot velocimetry of impacts with LiF crystals were used to characterize shock pressures and durations. Attenuator plates and flyers driven by the HE were also measured, which provided a variety of available pulse shapes and data for modeling efforts.

INTRODUCTION

A well characterized, 6-mm-diameter plane-wave shock generator was developed as a tool for the small scale examination of equation of state, material shock response, and initiation and propagation of energetic materials. Of particular interest are materials of short scale length that are typically too fast for normal testing techniques. Advances in high speed microscopic techniques in the Micro Detonics Facility (μ DF)¹ have spurred interest in small scale experiments.

DESIGN

The concept of the generator is that a thin flyer plate (slapper) launched by an electrically exploded foil (electric gun) can simultaneously initiate a high explosive (HE) pellet over its entire diameter.² If the explosive has a short run-to-detonation (RTD) distance, the pellet can be kept thin and the effects of the edge rarefaction minimized. This provides a planar shock wave over a reasonably large fraction of the diameter. The shock pressure is determined by the HE detonation pressure and can be attenuated using a suitably mismatched layer. The system can also be used to launch a dense slapper (attenuator) to provide impact pressures well above the detonation pressure (Fig. 1).

The choice of a 6-mm system was guided by the nominal scale sizes of μ DF experiments as well as component availability. The maximum field of view at full resolution (2 μ m) is about 2 mm for the μ DF frame and streak cameras. To maintain a planar experiment, the driver should be flat over a significantly larger diameter. With our low-inductance, 12 kV/1 μ F capacitive discharge unit (fireset), we could launch a 7- to 8-mm-diam flyer at a sufficient velocity (2.5 to 3 km/s) to initiate an HE pellet. With the availability of a 1/4-in. (6.34-mm) HE pellet press, a 6-mm system became the obvious choice.

The electric gun was optimized using R. S. Lee's models, which predict flyer velocity as a function of fireset

parameters and gun construction parameters.³ The resulting gun consists of a copper foil bridge, 4.5- μ m thick and 6.4-mm square, deposited on Kapton (polyimide). As the copper is vaporized, a 50- μ m Kapton over layer becomes the slapper and is accelerated through a 400- μ m-long barrel. The foil and barrel thicknesses were chosen to provide a 3-km/s flyer velocity at the exit of the barrel. The barrel is simply an 18-mm-square sheet of tantalum (Ta), with a 6.4-mm hole, bonded to the flyer layer of the gun. Backing the bridge are three 50- μ m Kapton layers that provide a 12-kV standoff from the 50- μ m-thick ground plane. Three additional 50- μ m Kapton layers isolate the

Figure 1. Six-mm plane-wave generator system.

ground plane from the tool steel reaction mass and mounting plate. The connecting cable is integral to the bridge assembly, which consists of two 50- μm by 18-mm copper layers insulated with 32-mm-wide Kapton as above. The entire Kapton-copper, gun-cable assembly is hot pressed into a single, 300-mm-long planar ribbon, which is then clamped to the mounting plate.

With the fireset charged to 12 kV, the guns draw 30 to 32 kA. The foils burst in just under 250 ns after the closing of the spark-gap switch. The spark gap is driven with a Krytron switch at 6 kV through a voltage tripler. The resulting $\sim 18\text{-kV}$ spark-gap trigger pulse reduces jitter in the gun system to about 10 ns.

The HE pellet is LX-16, which is 96% PETN (propanediol dinitrate) and 4% copolymer vinyl chloride binder (OXY-461). LX-16 was chosen for its rapid run to detonation characteristics, good mechanical properties, and ease of pressing and handling. The pellets are pressed for 3 min at 30 ksi, in a die heated to 60°C, to a density of 1.55 g/cm³. They are 6.4-mm in diameter by 3.2-mm thick and weigh 155 ± 2 mg. The pellet is both confined and mounted in a Lucite (polymethyl methacrylate) barrel. The barrel is an 18-mm-square sheet of stock 3.2-mm material with a 6.4-mm hole into which the pellet is pressed. The pellet/barrel assembly is bonded to the gun barrel before use.

Similarly, attenuators or dense slappers are also mounted in Lucite barrels. These barrels are appropriately milled to the thickness of the attenuator or the combined thickness of the slapper and flight path. The final result is a bonded stack with an 18-mm-square top surface, which is the test reference surface to which an experiment can be mated.

TESTING AND DATA

Performance verification experiments were of three different types. Slapper impact and detonation breakout flatness were measured with the streak microscope observing a reflecting surface bonded to the reference surface. Shock pressure was calculated from the measured particle velocity in an impacted lithium fluoride (LiF) crystal using a Fabry-Perot interferometer (FPI).⁴ Slapper velocity measurements were made directly with the FPI.⁵

The impact and breakout measurements use an aluminized 0.15-mm-thick microscope cover glass. The aluminized surface is placed in contact with the reference surface. A reference grid with a 250- μm wire spacing was bonded to the back side as a spatial reference. A one-watt argon laser was focused to a line across the diameter of the experiment. The experiment is arranged so that the aluminized surface is at the focal plane of the streak microscope and the laser line is viewed in specular reflection. Temporal calibration is provided by a short pulse YAG laser through fiberoptic delay line stack.

The impact record of the electric gun flyer shown in Fig. 2(a) revealed only small scale perturbations of about 7 ns across the 6-mm diameter. With a flyer velocity of

Figure 2. Impact and breakout planarity for (a) electric gun flyer, (b) initial LX-16 pellet, and (c) modified LX-16 pellet.

3 km/s, the observed perturbations are consistent with the surface variations of a few microns in the rolled Kapton material. Thus further improvement in the electric gun flyer flatness will require entirely different fabrication techniques.

The breakout of the detonation wave from the initial LX-16 pellet resulted in a large scale delay (~ 125 ns) at the center [Fig. 2(b)]. This result was a clear indication of a radial density gradient often seen in pressed pellets. The initial pellets were pressed to a density of 1.7 g/cm³ or 96% of theoretical maximum density. Although the RTD distance is not well characterized for this regime, it is known that both the variation and the slope of the variation of the RTD increase with density.⁶ As the sensitivity to shock initiation increases with decreasing density, it was decided to decrease the pellet density to 1.55 g/cm³. Furthermore, the pressing procedure was modified to require an initial leveling of the molding powder and heating the die. A single acting press also produces an axial gradient of increasing density from the anvil to the ram. Thus we also oriented the pellet so that the flyer impacted the low-density (anvil) end. The resulting pellet breakout was planar to within 10 ns [Fig. 2(c)].

The shock and impact pressure measurements are made in a LiF crystal that is in contact with the reference plane. What is actually measured is the particle velocity in the LiF at the interface to a thin aluminum foil pressed to the surface of the crystal. The foil is necessary to provide a reflective surface for the FPI. The shock pressure is then computed through the Hugoniot equations. LiF is used because its shock impedance is matched to many explosive products and its Hugoniot is well known.⁷

Figure 3. Impact of a 51- μ m-thick Kapton flyer into LiF with 12- μ m Al.

The pressure pulse caused by the impact of the electric gun flyer peaked at about 18 GPa in an 8 ± 1 -ns pulse (Fig. 3). The step in the decay of the pulse was caused by the aluminum layer on the LiF, which at 12 μ m is significant with respect to the 50- μ m Kapton flyer. This experiment should be repeated with an evaporated layer on the LiF. The 8-ns pulse width also stressed the temporal resolution capabilities of the FPI. Shock pressure produced by the HE pellet peaked at 32 GPa and was reduced to 22 GPa through a 2-mm aluminum moderator (Fig. 4).

Before measuring the impact pressures for the Ta flyers, flyer velocities were measured. This was accomplished by directly viewing the Ta surface with the FPI. The Ta flyers, 100- and 240- μ m thick, respectively, were flown in 3-mm Lucite barrels. They were followed from the bottom of the barrel for as long as the FPI could keep them in focus, between 2 and 3 mm (Fig. 5). The magnitude of the observed internal ringing, or the surface pull back, caused considerable consternation in that it exceeded the predictions for spall. Yet there was no evidence of spall in either shot.

Measuring the impact pressures created by a Ta flyer was complicated by the sudden loss of reflectivity at the Al/LiF interface upon impact. It was concluded that although the computed impact pressure was well below the 65-GPa impact melt threshold in aluminum,⁸ melting was indeed occurring. This is because the flyer is traveling through the strong magnetic field (est. 20 kG) of the electric gun. As the flyer approaches the foil, field compression causes eddy current heating of the foil, thus lowering the threshold for shock melting. By increasing the foil thickness to 100 μ m and adding a shield around the foil, the impact melting was eliminated. However, a pre-impact velocity of the foil of 0.1 to 0.2 km/s was observed.

Figure 4. Pressure in LiF in contact with sample.

Figure 5. Tantalum flyer velocity.

The impact pressures of the 100- and 240- μ m Ta flyers were measured to peak at 43 and 21 GPa, respectively (Fig. 6). Both flyers were mounted in 2.4-mm Lucite barrels so that the flight path was just over 2 mm. This distance was chosen to allow damping of the internal ringing and to allow the flyer to approach maximum velocity. In both shots, the step in the decaying pressure pulse is attributed to the aluminum foil.

Figure 6. Tantalum flyer impacts into LiF.

ACKNOWLEDGMENTS

The authors wish to acknowledge the contributions of Ronald Lee, Harold Zimmerman, Ralph Hodgins, Ralph Boberg, and Jeff Davis. Work performed under the auspices of the U.S. Department of Energy by the Lawrence Livermore National Laboratory under Contract W-7405-Eng-48.

REFERENCES

- [1] A. M. Frank, "High Speed Microphotographic Laboratory," *Proc. 18th Int. Congress, High Speed Photography & Photonics*, Xian, China, 1988.
- [2] H. H. Chau, G. R. Dittbenner, W. W. Hofer, C. A. Honodel, D. J. Steinberg, J. R. Stroud, R. C. Weingart, and R. S. Lee, "The Electric Gun: A Versatile Tool for High Pressure Shock Wave Research," *Rev. Sci. Instr.* 51, p. 1676 (1980).
- [3] R. S. Lee, "Simple Models for Electric Gun Operating Characteristics," *Proc. 3rd Int. Symp. on High Dynamic Pressure*, Paris, France, 1989, p. 297.
- [4] D. J. Steinberg and H. H. Chau, "A New Approach for Studying the Expansion of Detonation Products," *The 8th Int. Symp. on Detonation*, 1985, Reprints vol. 3, p. 1009.
- [5] H. H. Chau, C. F. McMillan, and J. E. Osher, "Application of Fabry-Perot Velocimeter to High Speed Experiments," *High Speed Photography & Photonics*, 1988, SPIE, vol. 1032, p. 540.
- [6] B. M. Dobratz and P. C. Crawford, *LLNL Explosives Handbook*, Lawrence Livermore National Laboratory, Livermore, CA, UCRL-52997 (Rev. 2), pp. 9-55 (1985).
- [7] S. P. Marsh, *LASL Shock Hugoniot Data*, Berkeley, CA: University of California Press, 1980.
- [8] R. Kinslow, *High-Velocity Impact Phenomena*, New York, NY: Academic Press, 1970.

**DATE
FILMED**

9 / 10 / 93

END