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DEVIATION FROM FLAT IMPACT WITH LLL'S TWO-STAGE LIGHT GAS GUN DUE TO PROJECTILE TILTING AND DISTORTION

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DEVIATION FROM FLAT IMPACT WITH LLL'S TWO-STAGE LIGHT GAS GUN DUE TO PROJECTILE TILTING AND DISTORTION

ABSTRACT

The two-stage light gas gun at LLL is designed to produce a flat impact between the planar surfaces of the accelerated projectile (impactor plate) and a stationary target. Tilt and surface distortion of the projectile cause some deviation from a flat impact, with corresponding variations in impact time from one point to another on the impacting surfaces. We have measured these point-to-point variations in impact time for impactor plates accelerated to a velocity of 7 mm/ μ sec, near the gun's top velocity. The time variations due to surface distortion were within about ± 3 nsec, and those due to tilt of the projectile were within ± 20 nsec, across a central 1.8-cm diameter of the 2.4-cm-diam impactor plate.

INTRODUCTION

The two-stage light gas gun at LLL is used to accelerate an impactor plate into a target plate for shock propagation experiments to determine equation-of-state data. Ideally, all points on the flat surface of the impactor plate should strike the flat surface of the target plate simultaneously. However, in reality some tilting of the impactor plate and distortion of its flat surface occur during its acceleration toward the target. There has been considerable speculation concerning the amount of deviation from simultaneity of impact as a result of this tilting and surface distortion of the impactor plate, but to our knowledge there are no published measurements of either effect. Since such information would be valuable in interpreting experiments done with the gas gun, we decided to run some tests to determine the effects of tilt and surface distortion.

DESCRIPTION OF THE GUN SETUP

The projectiles for the gas gun are composed of three parts: the impactor at the front, usually a thin metallic plate; the sabot, a polycarbonate cylinder holding the impactor plate; and, at the rear, a polyethylene gas seal. Since this gun¹ has been at LLL we have used two projectile designs. The first is shown in Fig. 1(a). Here the impactor plate is held in place by an outer ring glued to the sabot. The second design is shown in Fig. 1(b). To achieve more strength, the impactor here is made an integral part of the sabot by a die-casting technique,² thus eliminating the glued outer ring.

Fig. 1. Sabot design for carrying flat-plate impactors..

Fig. 2. Gas pressure on accelerating projectile.

As part of the effort to obtain equation-of-state data, the projectile velocity before impact is determined by measuring the distance traversed by the projectile during a known period of time. This distance is measured from radiographic images taken on film, which are obtained by pulsing two flash-x-ray units at a known time interval.³ The distance between x-ray units is approximately 30 cm. The total distance traveled by the projectile after leaving the gun's muzzle and before impacting the target is normally about 45 cm.

To minimize any effect of tilt and distortion the projectile's free flight was shortened to about 24 cm for some of our experiments. Only one x-ray port could be used in this case, and so the timing interval was measured between this x-ray pulse and an electrical shock pin mounted on the target.

A dc x-ray fiducial pulse generator is used to turn on the flash x rays.⁴ This is accomplished by the interruption of a dc x-ray beam by the projectile. This system has been functioning excellently, as it is insensitive to light produced either from hot gases or from gas shocks.

In operation of the two-stage gas gun, an 88-cm-diam piston in the pump tube is accelerated to highly compress the working gas.⁵ A diaphragm separating the pump tube section from the launch tube section ruptures at a critical pressure and exposes the projectile to the accelerating gas. The calculated time dependence of the accelerating force acting upon the projectile is shown in Fig. 2.⁶ As can be seen, the force acting upon the projectile is a few kilobars. This force has to be minimized to reduce distortion of the projectile.

EXPERIMENTS

We carried out a series of experiments to measure the tilt and distortion of the impactor. In these experiments bias pins were mounted flush with the target surface. Two pin configurations were employed. The first configuration used pins which were mounted in a cross arrangement to obtain distortion and tilt information. In the second configuration all pins were mounted on an outer circumference in a ring configuration. The signals from three or four pins were delayed with respect to each other, combined with a fiducial pulse, and fed into oscilloscopes (see Fig. 3). The sweep rate was 100 nsec/cm, calibrated with time-mark pulses generated at 50-nsec intervals.

The pin signals from the ring configuration experiments were recorded on a master/slave oscilloscope system. This system recorded each pin signal twice with a resultant reduction in the calibration and reading error. Time intervals were measured to ± 2 nsec consistently.

Fig. 3. Electronic diagnostic system.

DISCUSSION

The data presented were taken using a tantalum impactor plate 2.4 cm in diameter and 0.15 cm thick which was accelerated to a velocity of approximately 7 mm/ μ sec, near the upper velocity limit of this gun. Results shown in Fig. 4 were obtained with the cross configuration on the target, which was impacted at 43 cm from the gun's muzzle. Projectiles used in these experiments were the first design, with glued components. The first three experiments in Fig. 4 show very little deviation from straight-line fit, indicating a minimum of impactor plate warpage, whereas experiments 4 and 5 show considerable distortion of the impact plate. A possible reason for this apparent distortion may be that the outermost pins were prematurely shorted by the plastic ring.

In these experiments the second flash-x-ray radiograph showed the outer glued plastic ring of the sabot separating and moving ahead of the main body. The sabot cylinder and gas seal are also seen to be separating in Fig. 5. Both of these separations could result from a relieving of the stresses in the projectile during its free flight. These stresses could account for the warping of the impactor indicated in Fig. 4 by the deviations from straight-line fits. However, if the extreme outer edges of the impactor plate are ignored and a maximum diameter of 1.8 cm is used, then the maximum distortion is only about 3 to 5 nsec.

In Fig. 6 (experiments 6, 7, and 8) the pins were mounted on a 1.8-cm-diam circle on the target plate. Experiments 6 and 7 employed the first glued-ring projectile design. In an attempt to minimize the tilt and distortion of the impactor, the target for these experiments was positioned 24 cm from the muzzle. For experiments 8, 9, and 10 the new die-cast projectile was used. On experiments 9 and 10, foil switches on a circle 2.4 cm in diameter replaced the shorting pins.

A plane was fitted through each set of data points in Fig. 6. The time differences between the plane and the data points are shown in Fig. 7. The results indicate that the maximum tilt is about ± 20 nsec, and the maximum distortion is approximately 3 nsec.

CONCLUSIONS

These data have shown the tilt and distortion of impactors accelerated to 7 mm/ μ sec by the LLL two-stage gas gun. The distortion measured across the central 1.8 cm of the target's 2.4-cm diameter was less than 3 nsec. The die-cast projectile shows a distortion of 3 nsec or less, even when the tilt is ± 20 nsec across the central 1.8-cm diameter. Therefore, the tilt has been determined to be the most important consideration in error analysis. With proper design of experiments to minimize tilt and surface distortion, the accelerated impactors from this device can provide fairly precise one-dimensional impacts.

Fig. 4. Variations in impact time measured with cross configuration of pins. Projectile free-flight distance was 43 cm.

Fig. 5. Flash-x-ray photo of projectile in flight about 40 cm after leaving muzzle of gun, showing separation of sabot and gas seal.

Fig. 6. Variations in impact time measured with ring configuration of pins. Projectile free-flight distance was 24 cm.

Fig. 7. Distortion of impactor plate, obtained by fitting data of Fig. 6 to plane surfaces and plotting deviation of individual points from the plane.

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