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OF PLATES DRIVEN BY REACTING AND DETONATING
RX-03-BB AND PBX-9404

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FREE-SURFACE VELOCITY MEASUREMENTS OF PLATES DRIVEN
BY REACTING AND DETONATING RX-03-BB AND PBX-9404

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ABSTRACT

Copper plates 90 mm in diameter, of thickness 0.25 mm and 0.5 mm, were accelerated by an adjacent 17 mm thick cylinder of RX-03-BB or PBX-9404-03. The explosive was initiated by impact of a thick flyer from the LLNL 102 mm gun, providing either a reactive or fully detonating wave, by appropriate choice of flyer velocities up to 1.30 mm/ μ s. The free-surface velocity of the plates were measured with a Fabry-Perot velocimeter. We have obtained excellent experimental free-surface velocity histories. Our calculations of this history employing beta-burn and nucleation and growth high explosives models are in good agreement with fully detonating experiments. For reacting RX-03-BB, adjustments in the parameter are needed. We have an experimental technique that gives records whose agreement with calculation is sensitive to the model and is therefore a good way of testing new high explosive models. Also, this method allows us to infer information about the reaction zone length.

INTRODUCTION

Several workers have reported the measurement of the jump-off velocity of metal plates accelerated by high explosives.^{1,2,3} For thick plates, these measurements allow the inference of the Chapman-Jouget pressure. With thin plates, that is plates of the order of the reaction zone thickness, inferences about the reaction zone structures can be made. The interpretation of these records has been the subject of some controversy.^{3,4,5} At issue is the interpretation of breaks in a plot of jump-off velocity versus plate thickness. These issues are resolved only when one considers the structure of the evolving wave and the interaction of the HE/plate interface with the reaction zone. We sought to measure the entire velocity history of the plate and not just the jump-off velocity. This would indicate the wave structure seen in the plate.

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We measured the velocity history of copper plates pushed by PBX-9404 and RX-03-BB explosives. The plate velocity was measured by reflecting an Argon ion laser off the plate and measuring the wave-length shift with a Fabry-Perot interferometer. This method allows us to infer both information about the reaction zone structure and information about explosive performance.

EXPERIMENT

Figure 1 is a sketch of the experimental setup. A 0.6 cm thick copper flyer traveling at speeds up to 1.30 mm/ μ s was launched into the target chamber by the 102 mm gun. The targets consisted of 90 mm diameter by 17 mm thick disks of high explosive, PBX-9404 of density 1.840 g/cm³ or RX-03-BB of density 1.907 g/cm³. On the back of each high explosive disk was bonded a 80 mm diameter flat metal disk of oxygen free high conductivity copper of nominal thickness 0.5 mm, or 0.25 mm. The adhesive used was Shell 815 epoxy with T-1 catalyst.⁶ For the experiments reported herein, Table I gives the experimental configurations. In Experiment No. 3769, a PBX-9404 disk was bonded onto the front of the RX-03-BB in order to achieve full detonation.

Figure 1. Experimental setup of free-surface velocity measurements using a Fabry-Perot velocimeter.

Table I Experimental configuration

Experiment Number	High Explosive Type	Thickness (mm)	Plate Thickness (mm)	Flyer Velocity (mm/ μ s)
3815	PBX-9404	17.007 $\pm$.003	.501 $\pm$.001	1.27
3816	PBX-9404	16.851 $\pm$.001	.250 $\pm$.002	1.25
3769	RX-03-BB	14.015 $\pm$.002	.433 $\pm$.005	1.14
	PBX-9404	3.025 $\pm$.002		
3777*	RX-03-BB	17.00 $\pm$.02	.4 $\pm$.1	1.30

*Reacting

The flyer velocity was measured by a flash x-ray photographic technique, and independently with crystal pins near the target impact plane. The velocity measurements were accurate to 1 percent.⁷ Flyer tilt was measured by crystal pins placed on a 95 mm radius circle with respect to the target axis at the target impact plane, and was typically on the order of 1 mrad. Plate jump-off time was recorded by anodized aluminum shorting pins, in contact with the metal plate, on a 17 mm radius circle. Time measurements are typically good to $\pm 0.01 \mu\text{s}$.

The Fabry-Perot velocimeter⁸ is an instrument for measuring and recording Doppler-shifting light from moving targets. The beam spot size at the target is $\sim 0.3 \text{ mm}$. The lensing system converts the usual Fabry-Perot output ring pattern into a series of bright dot pairs, which is streaked to produce a set of lines whose separation is proportional to the target velocity. At velocities of a few $\text{mm}/\mu\text{s}$, resolution of 2 percent in velocity and 7 ns in time are achieved. Figure 2 is the raw data Fabry-Perot velocity record obtained in Experiment No. 3815.

Figure 2. Raw-data Fabry-Perot velocity record of experiment No. 3815.

Figure 3. Free-surface velocity record of experiment No. 3815, and nucleation and growth calculation.

CALCULATIONS

All calculations of the front surface velocity experiments were done with the computer code KO⁹. The metal was modeled by a Gruneisen equation-of-state with a sophisticated elastic-plastic

model. The high explosives were modeled either by the "beta-burn" model,¹⁰ or by a "nucleation and growth" model.¹¹ The copper flyer was given the experimentally observed velocities.

Figure 3 shows free surface velocity V_{fs} versus time for Experiment No. 3815, and calculation CR153A. We see excellent agreement in the free-surface jump-off time (2.20 ± 0.03 μ s, experimentally; 2.174 μ s, calculationally), and the shock reverberation time in the copper plate. Also late time velocities agree to within a few percent. Thus, we believe that the copper equation-of-state is reasonable, and the explosive equation-of-state gives the correct energy delivery to the plate to within a few percent. The spike seen in the first velocity jump in the calculation is due to the spike that is present in the nucleation and growth model.¹² The adhesive layer, typically 0.05 mm thick, lowers the calculated velocity by ~2 percent.

We obtained agreement to within approximately 10 percent with Experiment No. 3777 (reacting RX-03-BB) at calculational flyer velocity of 1.37 mm/ μ s. Calculations also indicate that we may have observed an experimental "reverse detonation," i.e., detonation of the high explosive by the shock reflected from the plate.

CONCLUSIONS

We have obtained excellent experimental free-surface velocity records using the Fabry-Perot velocimeter. Our calculations of this velocity employing beta-burn and nucleation and growth high explosive models are in good agreement with fully detonating PBX-9404 and RX-03-BB experiments. Improved agreement will require adjustments in the high explosives equation-of-state, and in the nucleation and growth parameters. We have an experimental technique that gives records whose agreement with calculations are sensitive to the model and is therefore a good way of testing high explosive models.

Measurement of the reaction zone length is possible using a technique reported by Duff and Houston.¹ By use of their equation, we have made a rough estimate of the reaction zone length in PBX-9404 to be less than 0.25 mm. Experiments with thinner plates of various materials are planned.

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