LLNL-CONF-414270

LAWRENCE LIVERMORE NATIONAL LABORATORY

CHARACTERIZING DETONATING LX-17 CHARGES CROSSING A TRANSVERSE AIR GAP WITH EXPERIMENTS AND MODELING

L. M. Lauderbach, P. C. Souers, F. Garcia, P. Vitello, K. S. Vandersall

June 29, 2009

16th American Physical Society Meeting of the Topical Group on Shock Compression of Condensed Matter
Nashville, TN, United States
June 28, 2009 through July 3, 2009

CHARACTERIZING DETONATING LX-17 CHARGES CROSSING A TRANSVERSE AIR GAP WITH EXPERIMENTS AND MODELING

Lisa M. Lauderbach , P. Clark Souers, Frank Garcia, Peter Vitello and Kevin S. Vandersall

Energetic Materials Center
Lawrence Livermore National Laboratory
Livermore, CA 94550

Abstract. Experiments were performed using detonating LX-17 (92.5% TATB, 7.5% Kel-F by weight) charges with various width transverse air gaps with manganin peizoresistive in-situ gauges present. The experiments, performed with 25 mm diameter by 25 mm long LX-17 pellets with the transverse air gap in between, showed that transverse gaps up to about 3 mm could be present without causing the detonation wave to fail to continue as a detonation. The Tarantula / JWL^{++} code was utilized to model the results and compare with the in-situ gauge records with some agreement to the experimental data with additional work needed for a better match to the data. This work will present the experimental details as well as comparison to the model results.

Keywords: Explosive, TATB, LX-17, air gap, crack
PACS: 47.40.Rs, 47.40.Nm, 82.40.Fp, 62.50.+p

INTRODUCTION

The ability of a detonation to cross a small transverse air gap is of interest for several reasons including understanding the effect of a crack in an explosive part and being able to develop models to predict these effects. In the case of TATB explosives that behave less-ideal than most explosives, these effects can be magnified. Earlier work investigated the effect of air gaps as well as size effect and corner turning [1] and is expanded here by using in-situ gauges. Other researchers have also investigated different configurations of defects [2] as well as using a similar arrangement as shown here using dent plates and streak cameras to observe the effects [3].

EXPERIMENTAL PROCEDURE

Experiments were performed utilizing detonating LX-17 charges consisting of a “donor” placed next to an “acceptor” with a gap between them. A total of 8 experiments have been fired with air gaps of 1.5, 3.0 and 4.0 mm between LX-17 pellets and instrumented by manganin piezoresistive foil gauges.

The experiments were assembled by first gluing up the acceptor assembly with gauge packages on both sides of a nominally 25 mm diameter by 25 mm long LX-17 pellet and backed by a 25 mm diameter Teflon pellet. From this, the detonator, booster, and donor LX-17 pellet are added at the front with a gap between the LX-17 donor and acceptor pellets. The details for the experiments performed, gap widths utilized, and gauge package thicknesses are included in Table 1. A photograph of an assembled experiment showing the air gap between the donor and acceptor pellets is shown in Figure 1.

The manganin piezoresistive foil pressure gauges placed within the explosive sample were "armored" with sheets of Teflon insulation on each side of the gauge. For the gauges that have a package thickness of about 330 μm, the package consisted of two 125 μm sheets of Teflon on each side of the 25 μm foil gauge. For the gauge package thicknesses of about 575 μm, the package consisted of two 250 μm sheets of Teflon on each side of the 25 μm foil gauge. The thicker gauge packages in the later experiments were used to make the gauges survive longer. It should be noted that with thicker insulation, the effective gap will be slightly larger (i.e air plus inert Teflon). Manganin is a copper-manganese alloy that changes electrical resistance with pressure (i.e. piezoresistive). During the experiment, oscilloscopes measure the change of voltage as result of the resistance change in the gauges, which were then converted to pressure using the hysteresis corrected calibration curve published elsewhere [8,9].

The donor geometry consists of an RP-1 detonator initiating a composition B booster that subsequently initiates the donor LX-17. Previously, we used an acceptor with at least 100 mm of LX-17 to confirm the possible re-detonation [1]. This time, the acceptor side is the main gauge, another LX-17 pellet, another gauge and a plastic pellet. In this earlier work, we found the detonation crossed a 2 mm gap but failed the 2.5 mm gap. In this experiment, we used comparable gap widths, where the LX-17-to-gauge distance is the listed gap. We found the detonation crossed at 1.5 mm as expected. The second gauge failed as expected at 4 mm but "detonated" with a 3 mm gap. This does not confirm that re-detonation of a long LX-17 part would have occurred, so that 3 mm is an in-between "possible".

Table 1. Transverse air gap and gauge package thicknesses for the instrumented experiments.

Expt	Air Gap (mm)	Gap Gauge Package Thickness	Back Gauge Package Thickness
GMX-001	1.5	0.329 mm	0.329 mm
GMX-002	1.5	0.328 mm	0.335 mm
GMX-003	1.5	0.340 mm	0.330 mm
GMX-004	1.5	0.341 mm	0.329 mm
GMX-005	1.5	0.576 mm	0.328 mm
GMX-006	1.5	0.577 mm	0.328 mm
GMX-007	3.0	0.576 mm	0.341 mm
GMX-008	4.0	0.576 mm	0.341 mm

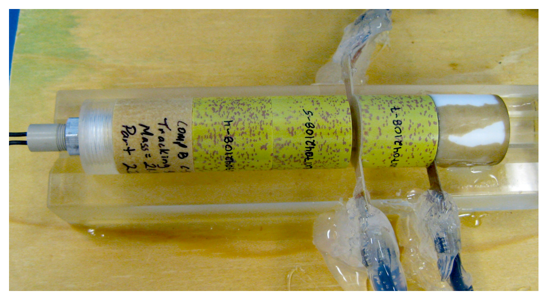

FIGURE 1. Typical description of the experimental arrangement showing the detonator, booster, donor LX-17, gap, acceptor LX-17 and Teflon backing from left to right.

MODELING

The problem was modeled at 40 zones/cm using Tarantula V1 (version 1) in JWL++ [1]. Tarantula is a reactive flow model that uses different reaction rates in different regions of pressure. It slowly initiates, then rapidly ramps up to full detonation. It is calibrated against cylinders, both detonating and failing and double cylinder corner-turning.

We have found that Tarantula reasonably describes the LX-17 detonate/fail behavior on the far side of the gap. It only calculates about one-half the measured delay time, but this is probably the result of the 40 zone/cm zoning. The initiation begins to ramp up too soon in coarse zoning so that the run-to-detonation time is too short.

For a good agreement to the data, the air gap had to be relaxed at all times. For pure Lagrange, meaning the last partially burned zone before the gap splits off and moves across the gap like a flyer. Relaxation breaks this up somewhat, but the model cannot accurately describe the breakup of the donor face into fine particles.

RESULTS/DISCUSSION

Figures 3-5 show the results of experiments GMX-006 through GMX-008 with air gaps of 1.5, 3.0, and 4.0 mm that provided pressures after the gap in the donor of approximately 16, 14, and 13 GPa, respectively. Note that with larger gaps the gauges after the gap show a decrease in the peak pressure observed and while the first two show a detonation in the gauge after the gap at the LX-17 interface with the Teflon backing, the record with a 4.0 mm gap shows only a pressure of about 5 GPa that is much less and shows a lack of detonation 25 mm away from the interface. It can also be seen that the transit time for the largest gap is greater, at over 5 μs for GMX-008 and about 4 μs for the other two experiments shown in Figures 4-5. The increases in pressure at later time (> 1.0 μs) in the gauge after the gap as shown in figures 4 and 5 is likely due to stretching of the gauges due to multi-dimensional effects causing lateral strains in the foil gauge material.

Figure 6 shows all three gap width results. A successful model must show re-detonation of the LX-17 at 14 to 16 GPa but failure at 10 to 12 GPa. In this sense, the experiment is quantitative.

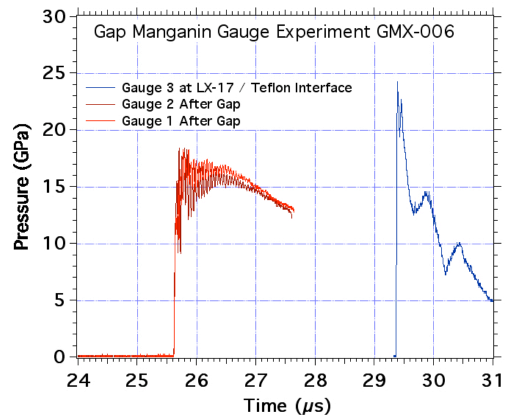

FIGURE 3. Gauge records shown for experiment GMX-006 with an air gap of 1.5 mm.

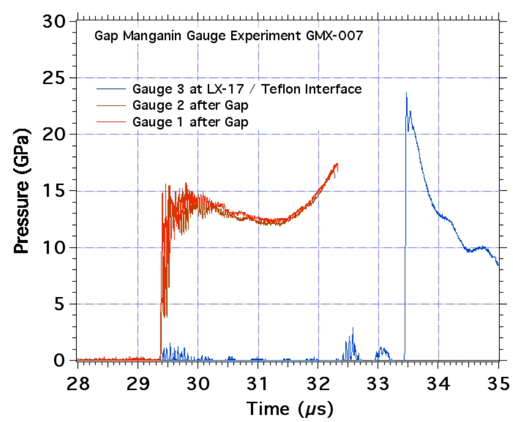

FIGURE 4. Gauge records shown for experiment GMX-007 with an air gap of 3.0 mm

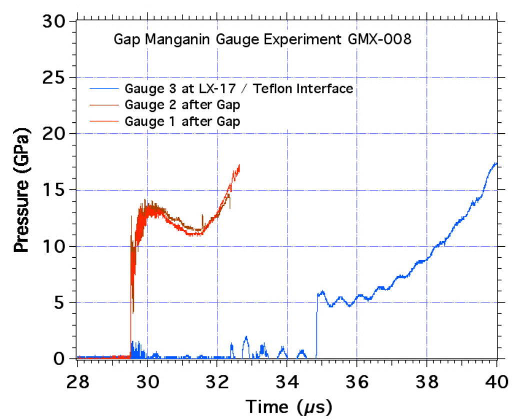

FIGURE 5. Gauge records shown for experiment GMX-008 with an air gap of 4.0 mm

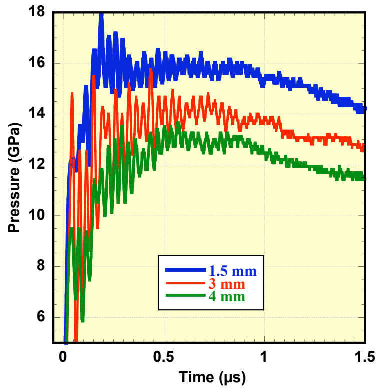

Figure 6. Comparative gauge pressures at three air gap settings. Detonation definitely crossed the 1.5 mm gap but not the 4 mm gap.

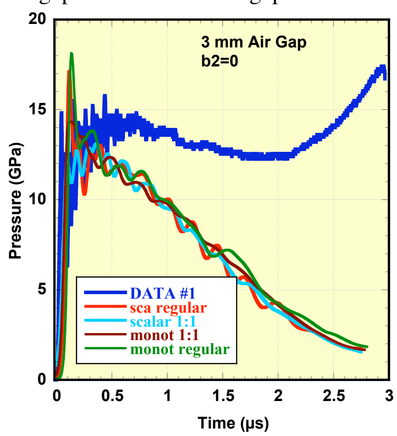

Figure 7. Pressure in the manganin gauge compared to code calculations. All code runs show a declining pressure whereas the actual gauge pressure increases.

Figure 7 shows the 3 mm gap data and model calculation. The model decays too quickly but the peak pressure agrees with the measurement. The model crossed the gap at 1.5 mm and failed at 2 mm. We know that Tarantula V1 (version 1) does not synchronize failure and corner-turning properly, so that improvements must wait to V2 (version 2).

SUMMARY

Experiments were performed using detonating LX-17 (92.5% TATB, 7.5% Kel-F by weight) charges with various width transverse air gaps with manganin peizoresistive in-situ gauges present. The experiments, performed with 25 mm diameter by 25 mm long LX-17 pellets with the transverse air gap in between, showed that transverse gaps up to about 3 mm could be present without causing the detonation wave to fail to continue as a detonation. The Tarantula / JWL^{++} code was utilized to model the results and compare with the in-situ gauge records with some agreement to the experimental data with additional work needed for a better match to the data.

ACKNOWLEDGEMENTS

Special thanks go to the firing crew in the High Explosives Application Facility (HEAF) including Rich Villafana and Bradley Wong. This work performed under the auspices of the U.S. Department of Energy by Lawrence Livermore National Laboratory under Contract DE-AC52-07NA27344.

REFERENCES

1. P. Clark Souers, Andrew Hernandez, Chris Cabacungan, Larry Fried, Raul Garza, Kurt Glaesemann, Lisa Lauderbach, Sen-Ben Liao and Peter Vitello, “Air Gaps, Size Effect, and Corner-Turning in Ambient LX-17,” Propellants, Explosives, Pyrotechnics, **34** [1], 32-40 (2009).
2. Davis, W.C., and Hill, L.G., “Joints, Cracks, Holes, and Gaps in Detonating Explosives,” in *12th International Detonation Symposium*, 2002, pp. 220-229.
3. Salyer, T. R. and Hill, L.G., “The Incidental Effects of Gaps in Detonating PBX 9501,” Shock Compression of Condensed Matter – 2007, AIP Press, 2007, pp. 865-868.
4. Vantine, H.C., Erickson, L.M. and Janzen, J., "Hysteresis-Corrected Calibration of Manganin under Shock Loading", J. Appl. Phys., **51** (4), April 1980.
5. Vantine H., Chan J., Erickson L. M., Janzen J., Lee R. and Weingart R. C., "Precision Stress Measurements in Severe Shock-Wave Environments with Low Impedance Manganin Gauges," Rev. Sci. Instr., **51**. pp. 116-122 (1980).
6. Gibbs, T. R., and Popolato, A., Editors, “LASL Explosive Property Data,” University of California Press, pp. 353-358, 1980.