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SHOCK INITIATION EXPERIMENTS ON THE TATB BASED EXPLOSIVE RX-03-GO WITH IGNITION AND GROWTH MODELING

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Abstract. Shock initiation experiments on the TATB based explosive RX-03-GO (92.5% TATB, 7.5% Cytop A by weight) were performed to obtain in-situ pressure gauge data, characterize the run-distance-to-detonation behavior, and calculate Ignition and Growth modeling parameters. A 101 mm diameter propellant driven gas gun was utilized to initiate the explosive sample with manganin piezoresistive pressure gauge packages placed between sample slices. The RX-03-GO formulation utilized is similar to that of LX-17 (92.5% TATB, 7.5% Kel-f by weight) with the notable differences of a new binder material and TATB that has been dissolved and recrystallized in order to improve the purity and morphology. The shock sensitivity will be compared with that of prior data on LX-17 and other TATB formulations. Ignition and Growth modeling parameters were obtained with a reasonable fit to the experimental data.

Keywords: Explosive, TATB, RX-03, LX-17, shock to detonation transition, Ignition and Growth
PACS: 82.33.Vx, 82.40.Fp

INTRODUCTION

Shock sensitivity data of new explosive formulations is desired to determine the relative safety under shock. The explosive RX-03-GO is similar in formulation to another TATB based explosive LX-17 (92.5% TATB and 7.5% Kel-F by weight), [1-4], and has been studied on a somewhat limited basis [5-7]. The difference is that the TATB is dissolved in an ionic liquid followed by re-crystallization to improve the purity and morphology. This paper will detail recent shock initiation results on the TATB based formulation RX-03-GO-IL4 (92.5% TATB recrystallized from an ionic liquid (72.5% course and 27.5% fine particle size) and 7.5% Cytop A by weight) by providing run-distance-to-detonation data, in-situ pressure gauge records, and Ignition and Growth modeling results with fits to the data.

EXPERIMENTAL PROCEDURE

Shock initiation experiments were performed on the TATB based explosive RX-03-GO using the 101 mm diameter propellant driven gas gun at Lawrence Livermore National Laboratory (LLNL). Figure 1 shows a description of a typical experiment. The projectile consisted of a polycarbonate sabot with a 304 stainless steel flyer plate on the impact surface. As seen in Figure 1, the target included a 304 stainless steel buffer plate at the front of the explosive and a Teflon backing plate at the rear of the assembly. The explosive was in the form of disks nominally 5 mm thick by 50.8 mm diameter (starting density of 1.91 g/cm^3) with gauge packages inserted in between. The manganin piezoresistive foil pressure gauges placed within the explosive sample were "armored" with sheets of Teflon insulation on each side of the gauge. Manganin is a copper-manganese alloy that changes electrical resistance with pressure (i.e. piezoresistive). Also used were PZT crystal pins to measure the projectile velocity and tilt (planarity of impact). 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]. From the data of the shock arrival times of the gauge locations, a plot of distance vs. time ("x-t plot") is constructed with the slope of the plotted lines yielding the shock velocities with two lines apparent, a line for the un-reacted state as it reacts and a line representing the detonation velocity. The intersection of these two lines is taken as the "run-distance-to-detonation," which is then plotted on the "Pop-plot" [10] showing the run-distance-to-detonation as a function of the input pressure in log-log space.

REACTIVE FLOW MODELING

The Ignition and Growth reactive flow model [11] uses two Jones-Wilkins-Lee (JWL) equations of state, in the form:

$$p = Ae^{-R_1 V} + Be^{-R_2 V} + \omega C_V T/V \quad (1)$$

where p is pressure, V is relative volume, T is temperature, ω is the Gruneisen coefficient, C_V is the average heat capacity, and A, B, R_1 and R_2 are constants. Table 1 contains the material parameters and reaction rate parameters for RX-03-GO at 25°C. The reaction rate equation is:

$$dF/dt = \underbrace{I(1-F)^b(\rho/\rho_0 - 1 - a)^x}_{0<F<F_{Ig\max}} + \underbrace{G_1(1-F)^c F^d p^y}_{0<F<F_{G_1\max}} + \underbrace{G_2(1-F)^e F^g p^z}_{F_{G_2\min}<F<1} \quad (2)$$

where F is the fraction reacted, t is time in µs, ρ is the current density, ρ_0 is the initial density, p is pressure in Mbars, and I, G_1, G_2, a, b, c, d, e, g, x, y, and z are constants. Table 2 details the Gruneisen parameters used.

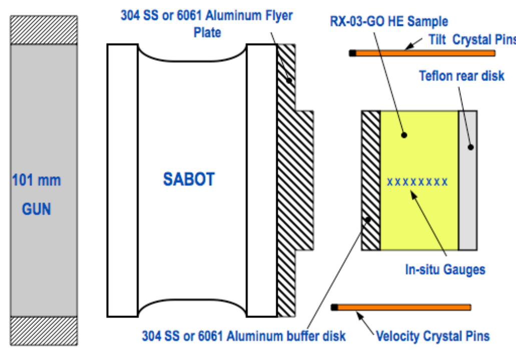

FIGURE 1. Typical description of a shock initiation experiment.

Table 1. Ignition and Growth modeling parameters.

MATERIAL PARAMETERS	
Shear Modulus=0.0354 Mbar	Yield Strength=0.002 Mbar
T_0 = 298°K	ρ_0=1.91 g/cm^3 at 25°C
REACTION RATES	
a=0.22	x=7.0
b=0.667	y=1.0
c=0.667	z=3.0
d=0.111	F_{igmax}=0.5
e=0.333	F_{G1max}=0.5
g=1.000	F_{G2min} =0.0
I=4.4 x 10^5 µs^{-1}	G_1=0.6 Mbar^{-1}µs^{-1}
-	G_2=400 Mbar^{-3}µs^{-1}

Table 2. Gruneisen parameters for inert materials.

INERT	ρ_0 (g/cc)	C (km/s)	S_1	S_2	S_3	γ_0	a
Teflon	2.15	1.68	1.123	3.98	-5.8	0.59	0.0
304 SS	7.90	4.57	1.49	0	0	1.93	0.5

Table 3. Summary of RX-03-GO gun experiments.

EXPT	IMPACT VELOCITY	INPUT PRESSURE	RUN TO DET
4753	1.634 km/s	13.2	12.4 mm
4754	1.702 km/s	14.1	8.9 mm

Table 3 contains the experimental flyer velocities, impact pressures, and run distances to detonation for the RX-03-GO shots performed at 25°C. The resulting data points are plotted on the Pop-plot as shown in Figure 2 and shows that RX-03-GO-IL4 has a similar or slightly less shock sensitivity than LX-17 at the same density.

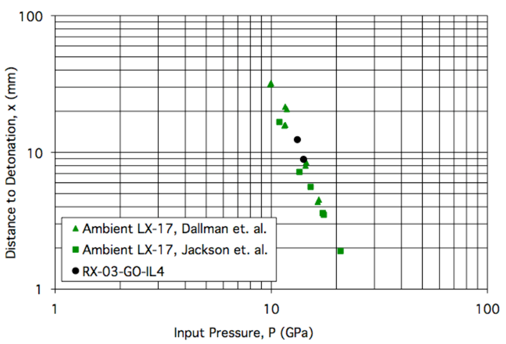

FIGURE 2. Pop-Plot comparing the data from this work with that of previous experiments.

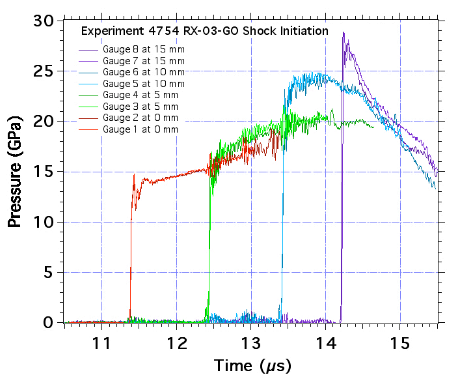

FIGURE 3. Experimental gauge records for Experiment 4754.

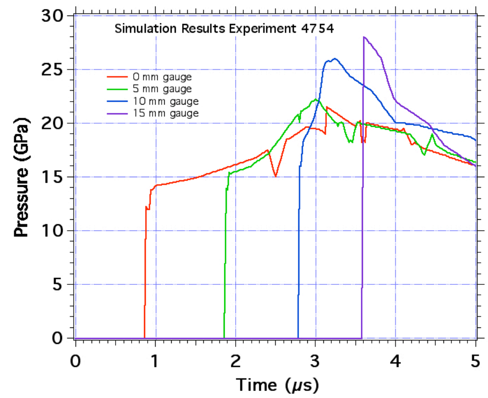

FIGURE 4. Simulated gauge records for Experiment 4754.

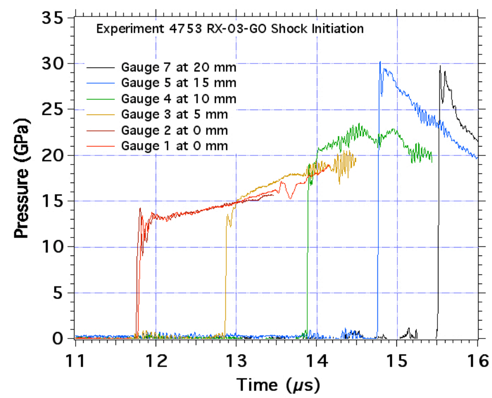

FIGURE 5. Experimental gauge records for Experiment 4753.

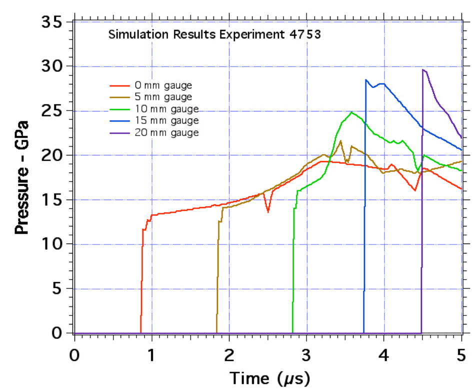

FIGURE 6. Simulated gauge records for Experiment 4753.

RESULTS/DISCUSSION

As a first approximation, the LX-17 ignition and growth parameters were utilized to create simulated gauge records. A comparison of the in-situ gauge records is shown in Figure 3 and 5 with the Ignition and Growth modeling results in Figures 4 and 6 show a reasonable fit. Additional experiments are in progress to add additional records to optimize the modeling parameters over a larger range of shock pressures.

SUMMARY

Shock initiation experiments on the explosive RX-03-GO (92.5% TATB recrystallized from an ionic liquid and 7.5% Cytop A by weight) were performed to obtain in-situ pressure gauge data and Ignition and Growth modeling parameters. The run-distance-to-detonation points on the Pop-plot for these experiments and in-situ gauge records showed the material is similar to and possibly slightly less shock sensitive than previously published data on LX-17. Further work is in progress to expand this data set and also update the Ignition and Growth modeling parameters.

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