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SHOCK INITIATION EXPERIMENTS ON THE HMX BASED EXPLOSIVE LX-10 WITH ASSOCIATED IGNITION AND GROWTH MODELING

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Abstract. Shock initiation experiments on the HMX based explosives LX-10 (95% HMX, 5% Viton by weight) and LX-07 (90% HMX, 10% Viton by weight) were performed to obtain in-situ pressure gauge data, run-distance-to-detonation thresholds, and Ignition and Growth modeling parameters. A 101 mm diameter propellant driven gas gun was utilized to initiate the explosive samples with manganin piezoresistive pressure gauge packages placed between sample slices. The run-distance-to-detonation points on the Pop-plot for these experiments and prior experiments on another HMX based explosive LX-04 (85% HMX, 15% Viton by weight) will be shown, discussed, and compared as a function of the binder content. This parameter set will provide additional information to ensure accurate code predictions for safety scenarios involving HMX explosives with different percent binder content additions.

Keywords: Explosive, HMX, LX-10, shock to detonation transition, ignition and growth
PACS: 82.33.Vx, 82.40.Fp

INTRODUCTION

The shock initiation of HMX (octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine) explosives has a wide interest due to general safety concerns. Prior experiments on LX-10 (95% HMX, 5% Viton by weight) have been performed [1,2], but the pressure regime of these experiments was limited and questions existed on the extrapolation to lower pressures. Other HMX explosives have also been studied [3] including some common explosives such as PBX 9501 [4,5] and LX-04 [6,7] using wedge tests, electromagnetic velocity gauges, manganin gauges at ambient and elevated temperatures. In this work, the shock sensitivity of LX-10 was measured using in-situ pressure gauges and modeled using Ignition and Growth.

EXPERIMENTAL PROCEDURE

Shock initiation experiments were performed on the explosive HMX based explosive LX-10 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 6061-T6 Aluminum flyer plate on the impact surface. As seen in Figure 1, the target includes buffer plates in contact with the high explosive at both the front and rear of the assembly to hold the material in place and sandwich the nichrome heater foils. The explosive was in the form of thin disks (with starting density approximately 1.82 g/cm^3) with gauge packages inserted in between with the total explosive thickness being 20 mm. 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 change of voltage as result of 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” showing the run-distance-to-detonation as a function of the input pressure in log-log space.

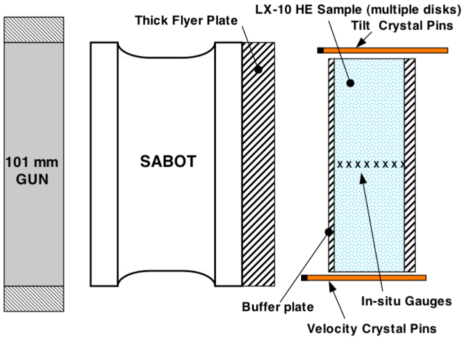

FIGURE 1. Typical description of a shock initiation experiment.

REACTIVE FLOW MODELING

The Ignition and Growth reactive flow model [10] uses two Jones-Wilkins-Lee (JWL) equations of state, one for the un-reacted explosive and another one for the reaction products, in the form:

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

where p is pressure in Megabars, 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. The equations of state are fitted to the available shock Hugoniot data. Table 1 contains the modeling parameters and reaction rate constants for these experiments. The reaction rate equation is:

$$dF/dt = \underbrace{I(1-F)^b(\rho/\rho_0 - 1 - a)^x}_{0<F<F_{Ig\max}} +$$

$$\underbrace{G_1(1-F)^c F^d p^y}_{0<F<F_{G_1\max}} + \underbrace{G_2(1-F)^e F^g p^z}_{F_{G_2\min}<F<1} \qquad (2)$$

Table 1. Ignition and Growth modeling parameters.

MATERIAL PARAMETERS	
Shear Modulus=0.05 Mbar	Yield Strength=0.002 Mbar
ρ_0=1.862 g/cm^3	T_O = 298ºK
REACTION RATES	
a=0.0794	x=4.0
b=0.667	y=2.0
c=0.667	z=3.0
d=0.667	F_{igmax}=0.02
e=0.333	F_{G1max}=0.5
g=1.0	F_{G2min} =0.5
I=20000 μs^{-1}	G_1=250 Mbar^{-2}μs^{-1}
-	G_2=320 Mbar^{-2}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
6061-T6 Al	2.703	5.24	1.4	0.0	0.0	1.97	0.48
Teflon	2.15	1.68	1.123	3.98	-5.8	0.59	0.0

where F is the fraction reacted, t is time in µs, ρ is the current density in g/cm^3, ρ_0 is the initial density (calculated based on thermal expansion data), p is pressure in Mbars, and I, G_1, G_2, a, b, c, d, e, g, x, y, and z are constants. This reaction rate law models the three stages of reaction generally observed during shock initiation of solid explosives. Table 2 details the Gruneisen parameters used.

RESULTS/DISCUSSION

Table 3 contains the experimental flyer velocities, impact pressures, and run distances to detonation for the experiments.

Table 3. Summary table of LX-10 gun experiments.

SHOT	IMPACT VELOCITY	INPUT PRESSURE	RUN TO DET
4714	0.732 km/s	2.1 GPa	>29 mm
4715	0.981 km/s	3.1 GPa	14.4 mm
4717	0.625 km/s	1.7 GPa	>40 mm
4723	1.238 km/s	7.0 GPa	2.7 mm
4725	0.950 km/s	4.8 GPa	6.7 mm
4726	0.943 km/s	2.9 GPa	20.5 mm
4727	0.733 km/s	2.1 GPa	30.8 mm

The resulting data points are plotted on the Pop-plot as shown in Figure 2. The in-situ gauge records are shown compared with the modeling results in Figures 3-5 that span a range of run distances to detonation. An increase in pressure can be observed as the shock progresses through and reacts the explosive material until a full detonation is observed. From comparing these records a somewhat reasonable agreement can be seen with room for improvement in the fit. The wave arrival times for the model arrive earlier than the data, especially for the lower pressures.

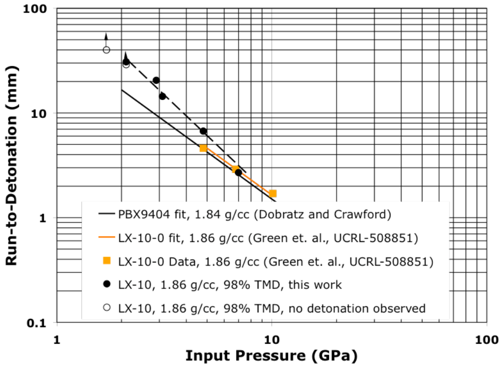

FIGURE 2. Pop-Plot comparing the data from this work with that of previous experiments.

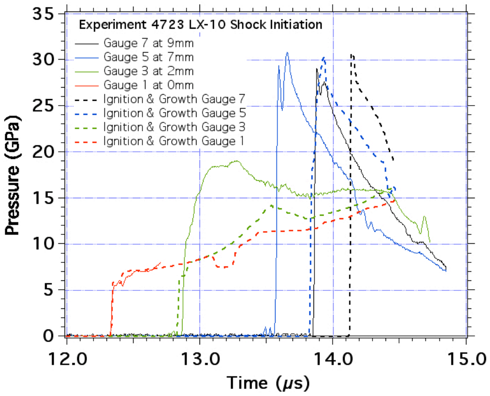

FIGURE 3. Experimental and calculated pressure histories for experiment 4723.

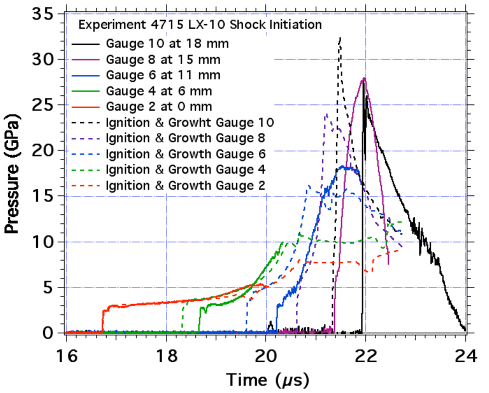

FIGURE 4. Experiment and calculated pressure histories for experiment 4715.

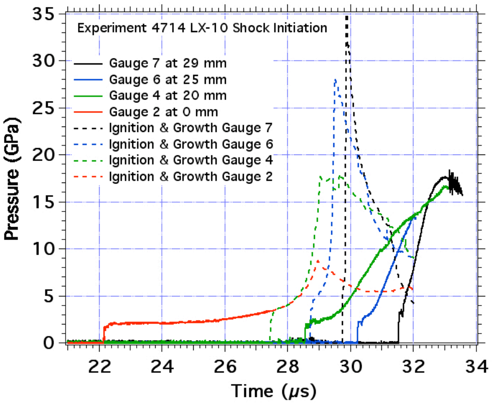

FIGURE 5. Experimental and calculated pressure histories for experiment 4714.

SUMMARY

Shock initiation experiments on the HMX based explosives LX-10 (95% HMX, 5% Viton by weight) was performed to obtain in-situ pressure gauge data, run-distance-to-detonation thresholds, and Ignition and Growth modeling parameters. The modeling fits showed somewhat reasonable agreement to the experimental data with room for improvement. Future work is needed to adjust the model to obtain a better fit to the data.

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