RE-SHOCK EXPERIMENTS IN LX-17 TO INVESTIGATE REACTED EQUATION OF STATE

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Abstract. Experimental data from measurements of the reacted state of an energetic material are desired to incorporate reacted states in modeling by computer codes. In a case such as LX-17, where the time dependent kinetics of reaction is still not fully understood and the reacted state may evolve over time, this information becomes even more vital. Experiments were performed utilizing a 101 mm gun to measure the reacted state of LX-17 using a re-shock method. This method involves backing the energetic material with thin plates (of a known equation of state) that reflect a shock back into the detonated material. Thus, by measuring the parameters of this reflected wave, information on the reacted state can be obtained. The experiments were driven by a projectile to near the CJ state ensuring a quick transition to detonation near the front of the sample. Embedded manganin piezoresistive gauges were used to measure the pressure profiles at different Lagrange positions during the event. A discussion of this work will include the experimental setup utilized, pressure gauge profiles, data interpretation, and future experiments.

INTRODUCTION

The main question posed by this research is: what role does kinetics play in the reacted state of an energetic material? A TATB based energetic material, LX-17 (92.5% TATB/ 7.5% Kel-F), was selected to help answer this question, because TATB-based explosives are considered somewhat non-ideal due to the presence of a 3-4 mm reaction zone. The re-shock technique was chosen because it provides a method for gaining a measure of the reacted state via the re-shock wave speed and pressure profiles. If the reaction in the initial shock is fast and complete, then the measured re-shock velocity should be equal to the isentropic (sound) wave speed in the material [1]. However, if reaction is incomplete, interpretation is necessary to correlate the re-shock wave speed to the true isentropic wave speed in the material. This data will be used to provide an accurate isentrope of LX-17 reacted products, which can then be incorporated into the computer codes for improved models.

Previous reflected wave experiments have been performed by McQueen and Fritz [2-4], in which they characterized the point at which the rarefaction release wave catches up with the reacting energetic material using an optical technique. Transient effects and structure in the release profiles were observed and a ratio of the shock wave velocity to the rarefaction velocity was obtained. Some reflected wave experiments have also been performed above the Chapman-Jouguet (CJ) pressure (referred to as “supracompression” or “overdriven”) [5-6]. Additional work by Tarver et. al. investigated the initiation of energetic material by reflected shocks at pressures driven below the CJ pressure [7-8]. This work, however, focuses on the region at or near the CJ pressure in the energetic material. This paper will discuss experimental setup
used, pressure gauge profiles, data interpretation, and future work.

**EXPERIMENTAL PROCEDURE**

Experiments were performed using the 101 mm diameter propellant driven gas gun at Lawrence Livermore National Laboratory (LLNL). Figure 1 shows a schematic of the rear reflector re-shock setup that was used. The projectile consisted of a polycarbonate sabot with a 15 mm thick silicon carbide (SiC) flyer plate. The target included a 3.2 mm thick SiC buffer plate in contact with 13 mm of LX-17 (TATB based high explosive) next to another 5 mm thick plate of SiC with 5 mm of Al$_2$O$_3$ at the rear. Manganin gauges were placed (2 at each level) at the buffer interface (0 mm), 4, 7, 9, 11, and 13 mm within the LX-17 sample with 125 µm Teflon insulation on each side of the gauge. The SiC plates were SiC-‘B’ produced by Cercom, Inc. and the Al$_2$O$_3$ plate was AD998 produced by Coors Ceramics. In the experiment, the first SiC plate at the back of the LX-17 acts as the first reflector plate since it has shock impedance (product of the shock wave speed at pressure and the density) higher than the LX-17, and the Al$_2$O$_3$ will act as a second reflector material since it has a slightly higher shock impedance than the SiC plate. Because of this, the manganin gauges will measure the initial increase in pressure from the initial shock traveling through the target and then both reflections from the LX-17/SiC and SiC/Al$_2$O$_3$ interfaces respectively. Using two reflector materials ensures that a double re-shock is observed and enables two measurements to be made in the same experiment.

In this experiment, the impact velocity was chosen to result in a pressure at or very near to the CJ pressure for the LX-17 sample. Therefore, with the LX-17 driven near CJ state and the 15 mm thick SiC flyer acting as a piston, a supported shock propagates through the sample. As shown in Figure 1, PZT Crystal pins were used to measure the projectile velocity and tilt (planarity of impact). The measured impact velocity was 2.33 mm/µs with the crystal pins located at the impact surface and at a 15 mm standoff. The manganin gauges were analyzed using a hysteresis corrected fit published elsewhere [9,10]. An experiment was first performed with just SiC plates backed by an Al$_2$O$_3$ reflector material to show the feasibility of the re-shock method, however, the results are not included here for brevity.

![FIGURE 1. Schematic of rear reflector re-shock experiment setup.](image)

**RESULTS AND DISCUSSION**

Figure 2 displays the modeling results (shown as dashed lines). The initiation and growth model [8] was used along with a model developed by Steinberg [11] for SiC. In short, the re-shock wave speeds are determined from the travel time between
the reflected shock peaks at the gauge locations. The modeling was performed before the experiment to ensure that the reflected re-shock states could be measured before any release waves arrive. The Teflon gauge packages were inserted into the model.

Figure 3 (a) shows the results from the experiment (solid lines) and modeling (dashed lines) combined together in one trace with only the gauges at 7, 9, 11, and 13 mm shown in Figure 3 (b) for clarity of the region of interest. It can be observed that the model and experiment do not match exactly, but the main features are reproduced reasonably well. The model predicts earlier initiation and faster detonation than the experiment. This is most likely due to the interference of the teflon gauge packages with the developing reactive flow [12]. Thinner and fewer gauge packages and longer LX-17 charges will be used in future experiments. Aligning the initial wave arrival times in Fig. 3 (b) shows that the calculated and measured reflected shock velocities are in good agreement.

The re-shock wave speeds were calculated for both the modeling and experimental results from travel time between reflected shock peaks in gauge traces. To be consistent, the wave speed was calculated from the times at 1/2 the maximum time from the toe to peak of the increase in pressure the re-shock event provides. The propagation time through the Teflon insulation was subtracted using the insulation thickness and shock wave speed at pressure. The average pressure value from the first re-shock peak value to the second re-shock peak was used. The re-shock wave speeds and pressures from the modeling are 6.63 mm/μs at 31.5 GPa, 6.74 mm/μs at 32.3 GPa, 7.24 mm/μs at 35.5 GPa from gauges located from 7 mm to 9 mm, 9 mm to 11 mm, and 11 mm to 13 mm, respectively. From the experiment, the calculated wave speeds from 7 mm to 9 mm and 9 mm to 11 mm respectively are 6.9±0.2 mm/μs at 31.9±0.2 GPa and 7.8±0.2 mm/μs at 39.4±0.1 GPa. A complete analysis of the errors associated with the experiment will be done later. It will include factors such as gauge performance during the re-shock environment and effects of the gauge insulation thickness.

Impacting future experiments at a slightly higher velocity than was used in this experiment to allow steady state to be reached faster would be beneficial to allow measurement where time dependent flow is not occurring.

FIGURE 3. Results of LX-17 rear reflector re-shock experiment showing experiment with (a) all of the gauge levels and (b) the gauges in the region of interest showing the reflected shock characteristics.

SUMMARY AND FUTURE WORK

The re-shock method was used to measure re-shock wave speeds in LX-17. Further analysis is needed to analyze and minimize the errors involved and correlate the re-shock wave speeds with the isentropic (sound) speed in the reacted products.
Figure 4 outlines a schematic design of a future experiment in which the re-shock is directed from the rear of the flyer plate instead of reflecting off the rear of the sample. Ongoing work to validate the current research is in progress to conduct a similar set of experiments using electromagnetic velocity (EMV) gauges.

**FIGURE 4.** Schematic of experiment for future work where the shock is reflected from the front behind the flyer plate.

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### REFERENCES


