BINDER STUDIES FOR IMPROVED BULLET IMPACT

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Abstract:

Bullet impact is a key test called out in MIL-STD 2105 and STANAG 4439. It is critical that new munitions or warheads react in a mild fashion when subjected to small arms fire. While it is recognized that IM compliance normally requires a system level solution it is important that the high explosive in new munitions have the best possible balance between performance and sensitivity. To address this issue ATK and ARDEC researchers have teamed together to develop a new pressed explosive which responds in a mild fashion in bullet impact testing while maintaining a very high level of performance. As an added benefit this explosive was also found to have a mild response in subscale cook-off testing.

Introduction

For several years LX-14 has been the baseline against which pressed explosives are compared. This composition has excellent processing characteristics, high performance, and machines and handles in a reproducible manner. However, LX-14 was developed prior to the current emphasis on insensitive munitions (IM) and its response when subjected to cook-off and bullet impact threats is more violent than desired. With this background in mind researchers at US Army ARDEC and ATK Thiokol focused a long term intiative with the goal of developing new pressed explosives that have higher performance and better IM response than LX-14. To achieve this goal the team selected CL-20, a high energy nitramine, as the basis for the new formulations. Because CL-20 has a higher energy density than HMX its use allows the formulation chemist more lattitude in the choice of binder systems and solids loading while mainting the high level of performance exibited by LX-14. For comparative purposes a summary of calculated performance characteristics of neat CL-20, LX-14 and two previously developed CL-20 based explosives, PAX-11 and PAX-12, are shown in Table I.

Table I. Calculated Performance of CL-20 and Three Selected Explosives

	Total Energy (kJ/cc)	CJ Pressure (kbar)	Detonation Vel. (km/s)	V/Vo @6.5 (kJ/cc)	99% TMD (g/cc)
CL-20	12.4	463	9.82	10.8	2.02
PAX-11	11.4	423	9.38	9.88	1.96
PAX-12	10.9	391	9.16	9.33	1.92
LX-14	10.1	353	8.98	8.47	1.84

Bullet Impact Studies

Prior to beginning actual formulation work the research team took time to evaluate potential reactions to bullet impact. The conclusion of the team was that deflagration was the most common response to bullet impact. Several variables were identified which can influence reaction violence and were organized in a fishbone diagram (see Figure 1). As shown in Figure 1 the majority of variables identified were processing, formulation or test related. Subsequent formulation and processing changes made during this study focused on the variables identified in this activity in an effort to reduce reaction violence in a systematic and orderly manner.

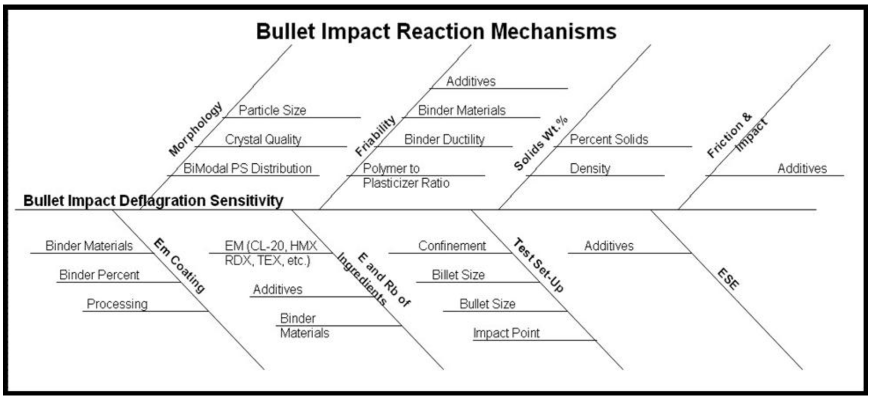


Figure 1. Formulation and process variables expected to effect bullet impact reaction violence.

To evaluate the selected changes candidate explosives were pressed into billets 2-inches in diameter and nominally 2-inches long. The explosive charge was placed directly on a steel witness plate and then on a pedestal three feet above the ground. Piezoelectric pressure gauges were placed at two different distances to measure any overpressure generated during testing and the entire event was recorded using high speed digital

Figure 2. Bullet Impact Test Setup

photography. A photograph showing the test setup is shown in Figure 2.

PAX-11 was selected as the baseline CL-20 composition to begin new explosive development. This explosive was selected as it had significantly higher performance than LX-14 and was well characterized. In the initial formulation test series three new formulations were made which were expected to have improved friction sensitivity (PAX-11c (1), -(2) and -(3)) and two additional formulations were made which were expected to have improved friability and coating properties (PAX-11c (4), and -(5). When these formulations were tested it was learned that the first four formulations actually produced more overpressure than the baseline explosive. However, the reaction violence of PAX-11c (5) was substantially reduced as shown in Figure 3.

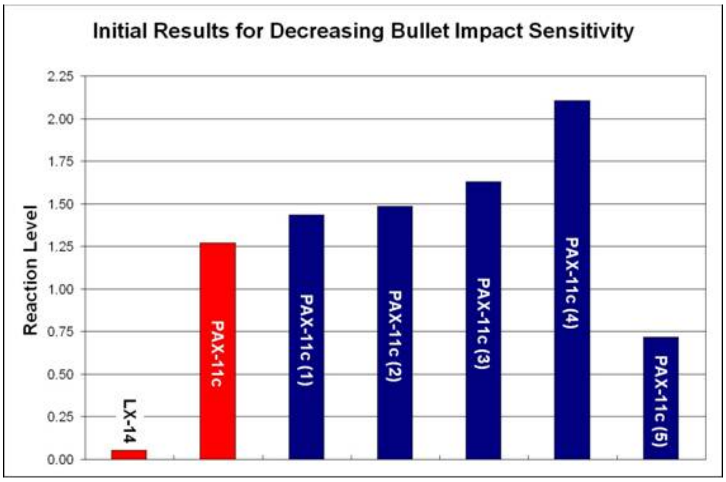
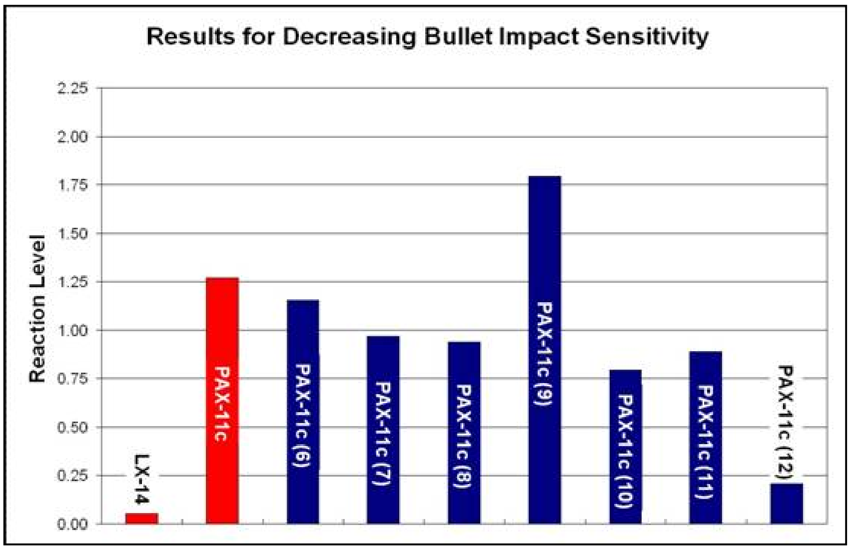


Figure 3. Initial bullet impact results.

Based on successful trend observed with PAX-11c (5) six additional formulation variables were evaluated. The relative improvements observed in PAX-11c (5) were observed in five of the six compositions tested. Based on the results of these tests the most promising individual approaches were combined into PAX-11c (12) which had the least violent response to bullet impact of any formulations tested. A summary of changes made to key formulation variables in these mixes is listed below and the relative reaction level of these explosives is shown in Figure 4.

PAX-11c (6): Friability by adjusting polymer to plasticizer ratio
PAX-11c (7): Energy and burn rate of ingredients through additives and binder materials
PAX-11c (8): Energy and burn rate of ingredients through additives and binder materials
PAX-11c (9): Changes in energetic material coating by changing binder materials
PAX-11c (10): Changes in friability by changing binder materials
PAX-11c (11): Changes in friability by changing binder materials
PAX-11c (12): Combined best ingredients from previous testing

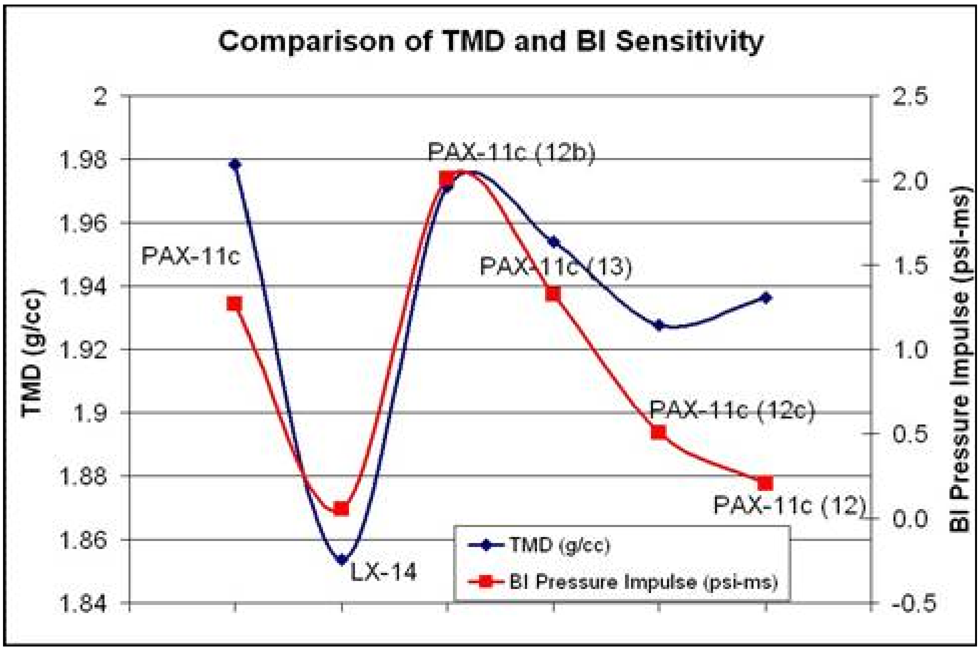


As shown in Figure 4 PAX-11c (12) is almost as insensitive to bullet impact as LX-14 and produces nearly an order of magnitude less overpressure than baseline PAX-11c. These results for PAX-11c (12) are particularly encouraging because the prediced detonation pressure for this explosive is 12% greater than that of LX-14. Additionally PAX-11c (12)'s calculated cylinder expansion energy is 10% higher than that calculated for LX-14. These calculations and a summary of the measured bullet impact peak pressure and impulse are presented in Table II.

Table II. Summary of Performance Calculations and Bullet Impact Results.

	LX-14	PAX-11c (12)	PAX-11c
C-J Pressure: (Gpa)	34.43	38.69	42.33
Cylinder Expansion:	8.47	9.26	9.88
BI Peak Pressure (psi)	0.46	0.88	2.82
BI Pressure Impulse (psi-s)	0.054	0.28	1.27

While analyzing these data the theoretical maximum density for several candidate explosives were plotted versus the measured impulse generated in bullet impact testing. For several candidate explosives these two variables tracked each other very well. However, PAX-11c (12) was found to have a most favorable of high density and low impulse. The results of this analysis are shown in Figure 5.



Cook-Off Test Results

Although the primary focus of the research presented in this paper was directed at improving the response of pressed explosives to bullet impact a secondary thrust was targeted at improving cook-off response. The Variable Confinement Cookoff Test (VCCT) was selected as the vehicle to evaluate the cook-off response of candidate explosives. This test allows researchers to vary the degree of confinement in a test by simiply changing an outer steel confinement sleeve. In most explosives as confinement increases the reaction violence increases.

Baseline testing was conducted with LX-14 with outer sleeve thicknesses of 0.030", 0.045", 0.060" and 0.075". LX-14 tested using 0.030" thick sleeves gave a mild burning reaction; however, when the confinement was increased to 0.075" LX-14 detonated. The reaction violence for the baseline CL-20 based explosive, PAX-11c, was essentially identical to that observed with LX-14. However, when PAX-11c (12) was evaluated in the VCCT it gave a considerably milder response at 0.075" confinement. These results were particularly encouraging in because of the high performance of the new explosive. A photographic summary of test results for LX-14, PAX-11c and PAX-11c (12) is shown in Figure 6.

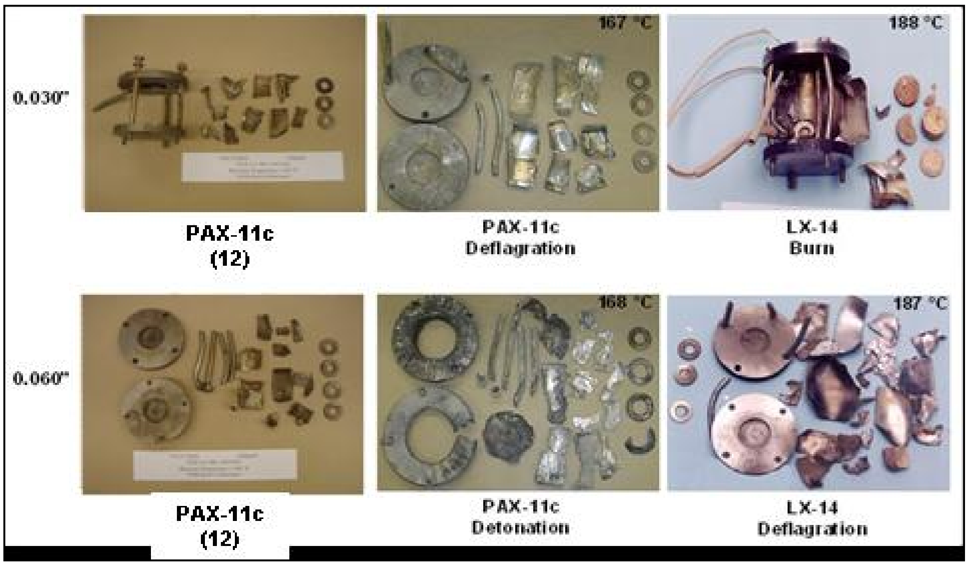


Figure 6. Photographs of VCCT hardware at 0.030" and 0.060" confinement.

Summary

Through a carefully designed series of experiments researchers at ARDEC and ATK have completed the initial development of a promising pressed explosive. This explosive PAX-11c (12) has an excellent blend of high performance and low bullet impact sensitivity. It is planned to continue development of this excellent formulation and the general formulation approach.