U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND – ARMAMENTS CENTER

Effects of Using Fluid Energy Milled HMX in LX-14

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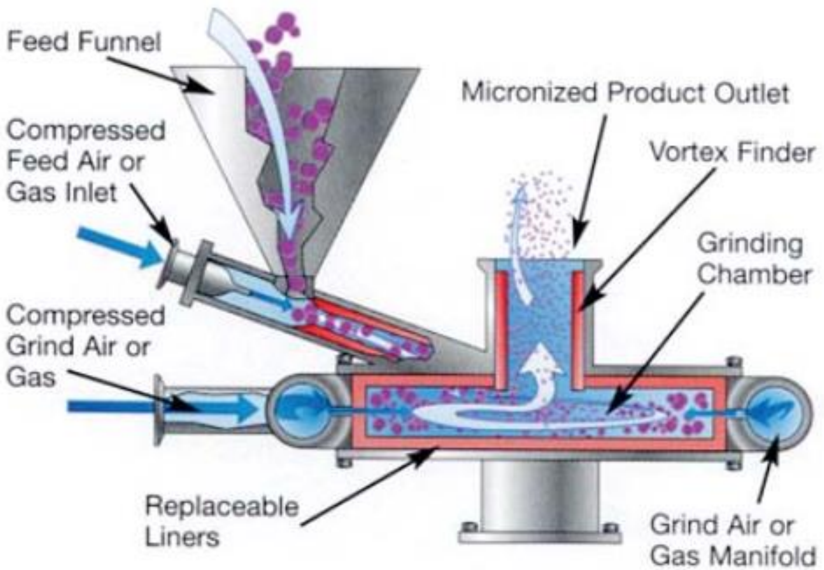
BACKGROUND

- LX-14 is a Lawrence Livermore National Laboratory developed explosive that is used in shape charge and main charge fill for the Hellfire missile, Javelin, TOW 2B, and other platforms.
- Due to its high nitramine content, it is considered a shock sensitive explosive and has witnessed a decline in use for more favorable IM explosives.
- Fluid energy milled (FEM) nitramines are currently being used in some qualified energetic formulations which have demonstrated reduced shock sensitivity in several investigations.
- FEM technology has led to the successful development of the IMX family of explosives, IMX-104 and PAX48.
- Coated Explosive Materials (CXM) also utilize FEM RDX for Navy and USAF products
- This study explores how safety testing and performance testing results of LX-14 made with FEM HMX compare to legacy LX-14 (made with larger granule HMX)

FLUID ENERGY MILL TECHNIQUE

- BAE Systems used a 4-inch Sturtevant Fluid Energy Mill (FEM) to grind HMX Class 1 to a reduced particle size.
- Fluid Energy Mill technology employs compressed air or gas to induce high-speed collisions between particles



- The final particle size range for FEM HMX has shown to 2-6 um[1].

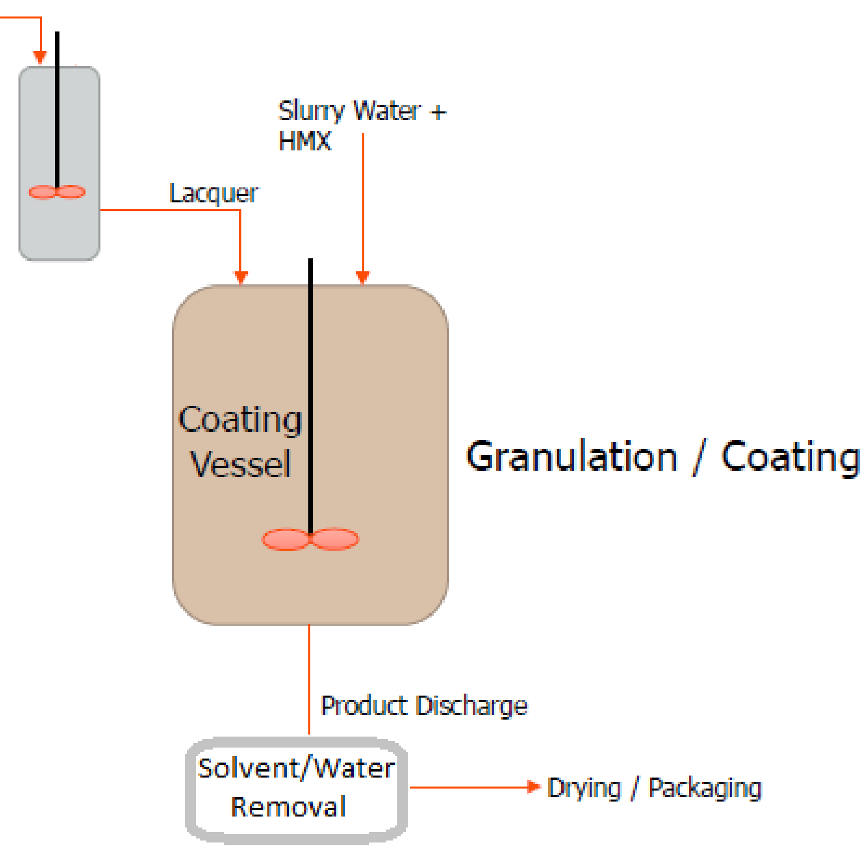
[1] Brian Alexander. Characterization of LX-14 FEM and PBXN-9 FEM High Energy Explosives. BAE Systems. Holston Army Ammunition Plant Kingsport, Tennessee, USA. 2018 Insensitive Munitions & Energetic Materials Technology Symposium Portland, OR

TECHNICAL APPROACH

- LX-14 molding powder was prepared via slurry coating using the milled HMX

- The laboratory slurry coating process development was carried out in the Holston 10 Liter Coating Still.
- This laboratory still is similar in baffle arrangement and agitator design to the larger still used in manufacturing coating operations – so a smooth transition into production is to be expected

SLURRY COATING PROCESS



<u>Slurry Coating Process</u>

1. Input components mixed in a water solvent system
2. Binder components dissolved in organic solvent system (lacquer)
3. Lacquer added to water & HE mixture, where binder components encapsulate the explosives into granule form
4. Solvent is vacuumed off
5. HE/binder granules are filtered and dried

FORMULATIONS AND COMPOSITION ANALYSIS

- The legacy formulation of LX-14 is a proprietary mixture of HMX and Estane
- FEM HMX was utilized in LX-14 using traditional slurry coating process at 100% and 80%, the balance of which (20%) consisted of Class I HMX.
- The amount of FEM HMX was varied to find optimal shock sensitivity
- Certificates of Analysis from HSAAP were obtained for the FEM HMX batches, and the composition analysis results were deemed within the acceptable range of error

SAFETY TEST RESULTS

Formulation	ERL Impact (cm)	BAM Friction (N)	ABL ESD (J)
LX-14 (100% FEM HMX)	54.1	10/10 No Goes @ 360	20/20 No Goes @ 0.120
LX-14 (80% FEM HMX)	49.1	10/10 No Goes @ 324	20/20 No Goes @ 0.090
Legacy LX-14	24.9	10/10 No Goes @ 288	20/20 No Goes @ 0.020
FEM HMX	56.2	10/10 No Goes @ 144	20/20 No Goes @ 0.063
RDX Class I	26.1	10/10 No Goes @ 160	20/20 No Goes @ 0.020
HMX Class I	32.8	10/10 No Goes @ 108	20/20 No Goes @ 0.031

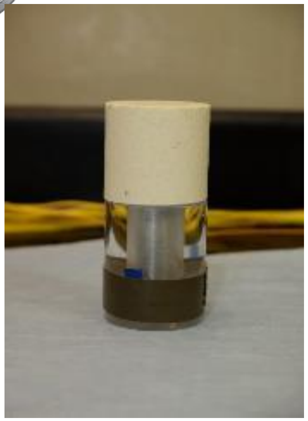
- ERL Impact results are H50 values

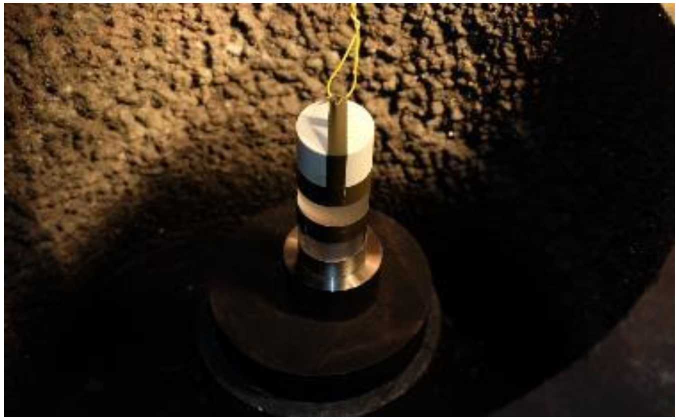
LARGE SCALE GAP TEST

Test	Special Conditions	Testing Facility	% FEM HMX	LSGT (Cards)	LSGT (kbar)	Density (g/cc)
1	None	Picatinny Arsenal	80	177-180	27.22-26.22	1.80-1.81
2	Aged 3 months at 70°C	Picatinny Arsenal	80	177-178	27.22-26.88	1.80-1.81
3	None	Picatinny Arsenal	80	166.5	31.1	1.81
4	None	Picatinny Arsenal	100	161.5	33.19	1.80
5	None	BAE Systems	100	176	27.56	1.67
6	Legacy LX-14	BAE Systems	0	236	14.47	1.784

- Above are the results for LSGTs of formulations with varied proportions of FEM HMX performed by BAE Systems and Picatinny Arsenal.
- MSIAC Newgates utilized for SGT card gap pressure conversion
- The significant density difference between the 100% FEM formulations was caused by the inability to heat the press tooling and pull vacuum at BAE during pellet pressing operations
- Results show significant improvement in insensitivity for formulations which incorporate FEM HMX, compared to legacy LX-14
- Pressing difficulties presented by the 100% FEM formulation indicate possible future production complications for that specific variant.

IHE GAP TEST





- The IHE Gap test was executed per US National Section of AOP-7 (Draft SRD-AOP-7.2) which uses a pressed pentolite explosive (density of 1.56 g/cm^3) donor system
- Test apparatus (above) consists of either two stacked pellets or one pellet (2.0 inches thick and 2.0 inches in diameter), each 1.0-inch thick and 2.0 inches in diameter
- Polymethylmethacrylate (PMMA) spacers are used as the attenuator material between the donor and acceptor charges.
- Utilized MSIAC Newgates for IHE Card Gap pressure conversion
- Results show an improvement in insensitivity when the HMX is milled for LX-14

Formulation	Density (g/cc)	Card Gap	Gap Pressure (kbar)
Legacy LX-14	1.82	225.5	15.93
LX-14 with 80% FEM HMX	1.80	169.5	29.93

LARGE SCALE DETONATION VELOCITY

- Large Scale Detonation Velocity (LSDV) Tests were performed on both formulations and compared to legacy LX-14 at Picatinny Arsenal
- The LSDV test setup is shown to the right.
- In a LSDV test, a booster detonates the main charge pressed into a LSGT tube. When the detonation front passes wires at the inlet and outlet, the times are recorded by a remote signal box on the other end of the wires. The detonation velocity is calculated using the time difference between the pulses and length of the LSGT tube

- Numerical results are shown in the table to the right.
- Both FEM formulations are comparable in performance to Legacy LX-14 and PBXN-9

Formulation	Density (g/cc)	Det. Vel. (mm/us)
LX-14 80 FEM	1.81	8.63
	1.81	8.65
LX-14 100 FEM	1.8	8.63
	1.8	8.63
Legacy LX-14	1.82	8.79
PBXN-9	1.74	8.4

SMALL SCALE FRAGMENT ATTACK RESULTS

- Small-Scale Fragment Attack (SSFA) tests were conducted to determine the reaction violence from a frag attack on LX-14 FEM HMX compared to legacy LX-14
  - ✓ **Result = LX-14 FEM HMX had an improved response compared to legacy LX-14**

Sample	Results w.r.t. Cover Plate Thickness (inches) for Single Liner in RP-4			
	1/4"	5/16"	3/8"	½"
LX-14 (80% FEM)	**Explosion** • No HE recovered	N/A	**Deflagration** • No HE recovered	**Deflagration** • No HE recovered
LX-14 (Legacy)	**Explosion** • No HE recovered	**Explosion** • No HE recovered	**Explosion** • No HE recovered	**Explosion** • 22.73g HE recovered

- Test setup (left)
- A deflagration (right) indicates that a reaction was violent enough to break the tube into a few pieces and break the bolts
- An explosion indicates cover plate perforated, tube split into pieces, rods and closure plate broken

TECHNICAL CONCLUSIONS

- Improved insensitivity and safety results of milled HMX formulations were observed

Formulation	ERL Impact (cm)	BAM Friction (N)	ABL ESD (J)	LSGT	IHE Gap
80% FEM LX-14	49.1	No rxn @ 324 N	No rxn @ 0.09 J	166.5 - 180 cards (31.1 - 26.22 kbar)	169.5 cards (29.93 kbar)
100% FEM LX-14	54.1	No rxn @ 360 N	No rxn @ 0.12 J	161.5 cards (33.19 kbar)	N/A
Legacy LX-14	24.9	No rxn @ 288 N	No rxn @ 0.02 J	236 cards (14.47 kbar)	225.5 cards (15.93 kbar)

- Both milled HMX formulations maintained comparable performance level of Legacy molding powders LX-14 and PBXN-9
  - 80% FEM: LSDV ~ 8.64
  - 100% FEM: LSDV = 8.63

QUESTIONS?

Participants

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