

GUN DEMONSTRATION OF NITROGEN-DOPED BORON PROPELLANTS

TRIPLE BASE PROPELLANT

US ARMY DEVCOM ARMAMENTS CENTER

155MM ARTILLERY

Boron nitride is an interesting potential additive to propellants that could reduce gun wear effects in advanced propellants.

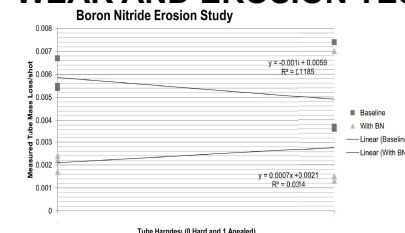
- It has the properties of providing metal coating/lubricating steel hardening properties and nitrogen cooling.
- During propellant 25mm gun firing, the additive will either form hexagonal boron nitride, which can provide a protective coating and lubricating barrier on the inside of the barrel walls, or oxidize to form boron oxide
- Boron oxide could also coat the barrel, or dope the steel with boron.
- Additionally, because of its low molecular weight, boron nitride oxidation could help lower the propellant flame temperature.

PREVIOUS WORK

Concept diagram showing how the propellant additive will provide a regenerative BN coating and hardening of the steel, resulting in decreased wear and erosion.

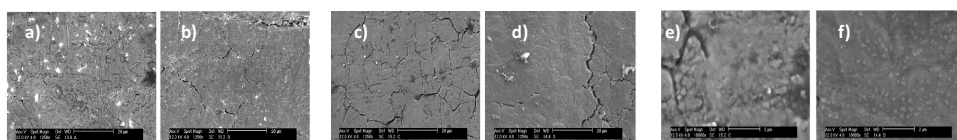


WEAR AND EROSION TESTING



Previous wear and erosion testing have demonstrated the technology provided a 2-3X reduction in wear and erosion, achieving TRL 5.

SCANNING ELECTRON MICROSCOPE



SEM surface images of: hardened steel inserts at 1,250 X magnification fired (a) in standard RPD-380, and (b) with BN / RPD-380 composite; unhardened steel inserts at 1,250 X magnification fired (c) in standard RPD-380, and (d) with BN / RPD-380 composite; unhardened steel inserts at 10,000 X magnification fired (e) in standard RPD-380, and (f) with BN / RPD-380 composite.

MANUFACTURED M31A2 MODIFIED PROPELLANTS



Lot # RDD21A-00385-A1
Graphite Coated and Undeterred

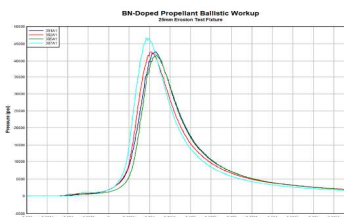


Lot # RDD21A-00385-A2
Graphite Coated and Deterred

BALLISTICS TESTING IN 25MM MANN BARREL

The muzzle velocity generated is a reasonable surrogate for a howitzer (around 3000fps). All shots used only the undeterred propellant variant. The resulting peak chamber pressure and velocity are shown in the following table.

Propellant	Charge Mass grams	Loading Density grams/cc	Chamber Pressure psi	Velocity ft/sec
381A1	65	0.686	42688	2943
383A1	65	0.686	42613	2953
385A1	66	0.696	41745	2927
387A1	65	0.686	46744	3001

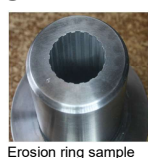


The resulting peak chamber pressure and velocity from IBHVG2 Modelling and Simulations Code. Pressure vs. time curves for all four propellants. All of the propellants were well behaved with no ignition issues or pressure anomalies.

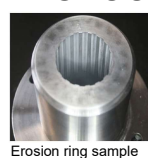
HELMEL COORDINATE MEASURING MACHINE (CMM) AT TEN LOCATIONS ON EACH RIFLING LAND AND GROOVE



Photograph of an unfired insert showing grooves on the landings from machining.



Erosion ring sample #2 after firing 50 shots with propellant 382A1.

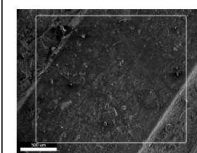


Erosion ring sample #3 after firing 50 shots with propellant 385A1.

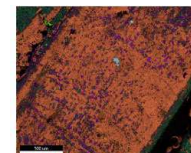


Erosion ring #4 after firing 50 shots with propellant 387A1.

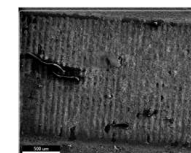
SCANNING ELECTRON MICROSCOPE ANALYSIS



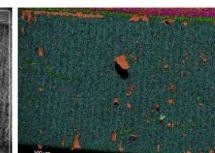
SEM analysis of sample #1 (left is visual image, right is the elemental analysis by mass).



EDAX analysis of sample #1 (left is visual image, right is the elemental analysis by mass).



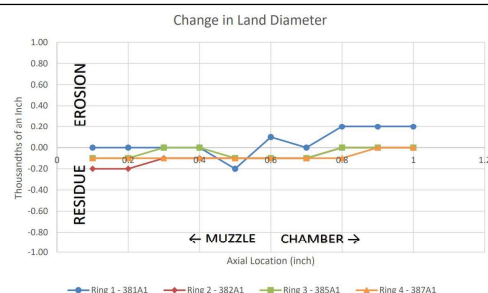
SEM analysis of sample #4 (left is visual image, right is the elemental analysis by mass).



EDAX analysis of sample #4 (left is visual image, right is the elemental analysis by mass).

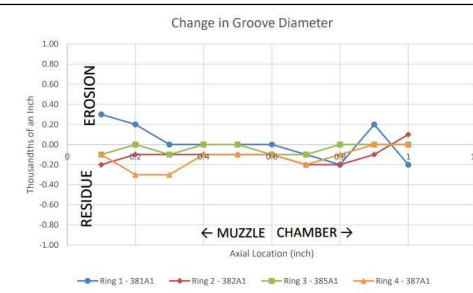
CHANGE IN LAND DIAMETER

Change in land diameter after 50 shots (2nd test series).



CHANGE IN GROOVE DIAMETER

Change in rifling groove diameter after 50 shots (2nd test series)



SUMMARY AND CONCLUSIONS

- SEM and EDAX analysis showed stark differences in surface morphology and composition for samples fired with or without BN additive. Samples fired with BN had a boron oxide surface coating of flat platelets, and seemed to lack significant iron oxide (less than 10%). Samples fired without BN were covered with pits, bumps, and octahedral crystals Indicative of Fe3O4. Hardness testing of the insert surfaces was performed to quantify any differences between samples, but the results for these samples were inconclusive.
- Further wear and erosion testing was conducted at US Army DEVCOM Armaments Center using RPD-380 propellant with and without BN. In these tests, the BN additive was demonstrated to reduce wear and erosion by a factor of 2-3 in the limited testing (up to 4 rounds). Post-test characterization at pH Matter found only a small amount of boron remained on the surface after firing and cleaning. However, ppm levels of boron doping can harden steel, and an increased hardness was observed in unhardened steel fired with boron nitride additive. SEM imaging showed less surface crack density in the samples fired with boron nitride. Important considerations for any further tests are an alternate grain form to allow larger bomb loading density, and the corresponding larger amount of propellant necessary for that condition, as well as to support a sufficient number of firings to generate supportable statistical conclusions.
- In light of the promising results, further wear and erosion testing of the BN propellant additive was conducted in a sub-scale 25-mm gun test to simulate the conditions of 155 mm artillery during a Phase II Enhancement project. The BN additive appeared to have a positive effect on reducing wear and erosion in the gun tests. All compositions showed reduced erosion versus the baseline material, but samples with high BN or BN with other additives showed the most promising results based on SEM imaging and Moh's hardness testing. Further, the analysis techniques all agreed that the sample fired with more BN had significantly more BN coating and the most well-defined machine grooves after firing. These results appear to agree with previous small-scale tests that demonstrated a 2-3X reduction in wear and erosion for propellants containing BN.

FUTURE WORK

The results on the Enhancement work bring the technology to a TRL 6. Recommended future work includes further testing of the additive with more-corrosive propellants and full-scale gun tests.

ACKNOWLEDGEMENT

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US ARMY DEVCOM ARMAMENTS CENTER, PROPULSION TECHNOLOGY

**Dr THELMA G. MANNING, Michael Fair,
Nathan Peabody, Viral Panchal,
Dr Eugene Rozumov, James Barnes,
and Dr Paul Matter**