8 May 2018

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Manufacturing and Evaluation of Kraft AFP001 Propellant

Lucas Lopez, Mo Elalem
U.S. Army ARDEC
Picatinny Arsenal, NJ 07806 USA

8th Nitrocellulose Symposium

5-7th June 2018 – Bergerac, France

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AGENDA

1. Introduction
   - Background
2. Coating Design of Experiment
   - Closed Bomb Results
   - Statistical Analysis
   - Gun Firing Verification
3. Processing Study
4. Conclusions

KRAFT AFP001 GENERATED EXTREMELY HIGH PRESSURES AT AMBIENT

Blend	CW (grams)	Velocity (ft/sec)	Pressure (PSI)
Sulfite	145	3022	31510
Kraft	140	3428	63986

Kraft 5.4% MC component burn extremely fast.

Sample	% MC	% Retention
AFP-001 Kraft 5.5% coated	3.19	59
AFP-001 Sulfite 5.4% coated	4.8	89

Kraft AFP001 propellant retained 33% less MC than the baseline as result burned too fast.

COATING DESIGN OF EXPERIMENT

Run	Coating Time (min)	Liquor/Propellant Ratio	Alcohol/Water Ratio
1	1	1	high
2	1	2	high
3	1	1	low
4	1	2	low
5	2	1	high
6	2	2	high
7	2	1	low
8	2	2	low
9	1	1	1.0

A three factors, two level full factorial, was conducted to identify the levels of selected coating parameters that will minimize RQ.

OPTIMIZED COATING PARAMETERS DID NOT SLOW PROPELLANT

RQ and %MC retained for samples coated at 5.4% methyl centralite.

	Run 1	Run 2	Run 3	Run 4	Run 5	Run 6	Run 7	Run 8	Run 9	Baseline
RQ	92	102	91	98	84	99	90	93	89	79
%MC	3.13	1.43	2.99	2.49	3.73	1.70	3.14	3.08	3.38	4.66

Only coating run #5 produced a RQ similar to the baseline (RQ 78.96).
Run #5 retained 25% less MC than the baseline.

5.4% MC component ballistics were faster than the baseline

Sample	CW	Velocity	Vsd	Pressure	Psd
TEM-1	145	3132.5	8.8	38199	498
RAY-5	145	3240.6	5.7	45066	391
RAY-1	145	3233.1	5.9	44246	707
RAY-3	145	3380.0	2.4	55332	319
RAY-7	145	3412.7	10.5	57876	1183
RAY-9	145	3338.6	6.6	51144	527

Baseline 5.4% MC component:

Velocity: 3022 ft/sec, pressure of 31,500 psi at a charge weight , 147g.

A New Approach: Reduce porosity of the grains by improving processing parameters.

Factors	AFP001 Baseline	Run 1	Run 2	Run 3	Run 4	Run 5
Mix time	1	2	2	2	2	2
Web	1	2	2	2	3	3
Die length	1	1	1	2	2	2
Solvent Recovery hold time	1	1	2	2	2	2
Solvent Recovery ramp time	1	1	2	2	2	2
Mix Solvent Ratio	1	1	1	1	1	2

Kraft fibers are coarser than sulfite fibers, allowing for greater inter-fiber space providing less bonding area that results in a more porous surface.

Selected processing parameters were studied to determine factors that impact porosity with the objective of reducing the burning rate of the base grain.

SIGNIFICANT INCREMENT IN MC RETENTION

Parameter	RAY BG-1	RAY BG-2	RAY BG-3	Baseline 171127-02	G00001 MC	B00002 MC	P00003 MC	Baseline 171127-01
% RS	0.76	0.69	0.85	0.70	0.48	0.42	0.63	0.58
RQ	103.4	106.8	101.5	108	80.4	85.9	75.9	81.9
%MC	--	--	--	--	3.77	3.70	4.15	4.44
% MC Retention	--	--	--	--	69.8	68.5	76.9	82.2

Base grains from Runs 1, 2 and 3 selected for deterrent coating based on closed bomb results

RQ for base grains RAY BG-1 to BG-3 were similar to slightly slower than the baseline (therefore no conclusion can be drawn for burning characteristics).

Batch P00003 MC was processed with all manufacturing process treatments:

- RQ lower than the other two batches processed with fewer process treatments and the baseline.
- Retained about 10% more MC than the baseline and about 20% more than the samples made for the coating DOE.
- Retained about 7% less MC than the sulfite baseline MC-Comp 171127-01 propellant.

VELOCITY AND PRESSURE RESULTS ARE WITHIN WORKABLE RANGE

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Ballistic of 5.4% MC Component

Sample	CW (grams)	Velocity (ft/sec)	Pressure (PSI)
G00001 MC	145	3108	38084
B00002 MC	145	3216	43107
P00003 MC	145	2988	33137

Three rounds each at a nominal charge weight of 145 grams were gun tested at 70°F.

5.4% MC Component Coating Study

Sample	CW	Velocity	Vsd	Pressure	Psd
TEM-1	**145**	3132.5	8.8	38199	498
RAY-5	**145**	3240.6	5.7	45066	391
RAY-1	**145**	3233.1	5.9	44246	707
RAY-3	**145**	3380.0	2.4	55332	319
RAY-7	**145**	3412.7	10.5	57876	1183
RAY-9	**145**	3338.6	6.6	51144	527

Sulfite 5.4 % MC baseline:
Velocity ~ 3022 ft/sec
Pressure ~31,500 PSI.

All three samples showed significantly lower velocity and pressure than the samples generated from the Coating study

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First Iteration

Charge weight 145 grams.

Lot	Blend Ratio MC-BG	No. Rounds	Test Temp. F	Velocity (ft/sec)	Pressure (sd) PSI	Action time (sd) msec
G00001MC/BG	84/16	4	70F	3317 (7.4)	50189 (528)	4.15 (0.049)
G00001MC/BG	84/16	4	-65F	3145 (13.3)	40474 (756)	4.76 (0.072)
G00001MC/BG	84/16	4	160 F	3450 (6.2)	59372 (637)	3.83 (0.040)
P00003MC/BG	78/22	3	70F	3290 (10.3)	49630 (464)	4.34 (0.087)
P00003MC/BG	78/22	3	160F	3409 (2.9)	56570 (219)	4.09 (0.036)
B0002MC/BG	93/7	4	70F	3336 (4.2)	51202 (428)	4.29 (0.079)
B0002MC/BG	93/7	3	-65F	3206 (23.5)	43425 1576)	4.82 (0.094)
B0002MC/BG	93/7	3	160 F	3436 (4.9)	56850 (630)	4.10 (0.081)

Lots of AFP001 are made following an iterative procedure consisting of blending amounts of 5.4% MC coated propellant with their respective base grain and verifying that the blend meets target velocity at ambient. Ratios are corrected as needed.

Three blends were made and fired. For example, blend G84-16 means, 84% coated propellant and 16% base grain. Velocity was targeted at 3320 ft/sec at about 51,000 PSI using a 145 g charge weight.

ALL THREE SAMPLES MET THE REQUIREMENT OF THE SPECIFICATIONS FOR 30MM GAU-8 ROUND

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Sample	MC Coat	%BG	Rounds	CW	Vel	Vsd	P	Psd	P +3sd	AT	ATsd
BSO18C-S73378	G83/17	17	3	145	3292.9	11.2	47836	577	49567	4.177	0.049
BSO18C-S73378	G83/17	17	3	147	3333.6	13.4	49511	1073	52730	4.056	0.073
									0		
BSO18C-S73379	B93/7	7	3	145	3327.2	6.7	49010	393	50189	4.106	0.035
BSO18C-S73379	B93/7	7	3	147	3365.3	2.2	52635	78	52869	4.022	0.045
BSO18C-S73380	P75/25	25	3	145	3314.6	4.9	49962	768	52266	4.175	0.03
BSO18C-S73380	P75/25	25	3	147	3343.6	4.4	51213	374	52335	4.205	0.048

Sulfite calibration lot at 147 grams: Velocity 3334 ft/sec and pressure of 51,707 PSI

Blended propellant lots with the selected ratios loaded at 145 and 147 grams respectively for charge establishment.

Green Lot BSO18C-S73378 corresponds to batches 1MC (coated) and 1BG (base grain).
Blue Lot BSO18C-S73379 corresponds to batches 2MC (coated) and 2BG (base grain)
Salmon Lot BSO18C-S73380 corresponds to batches 3MC (coated) and 3BG (base brain).

Key 30mm GAU-8 Ballistic Limits
Velocity at 70 F = 3350 +/- 25 ft/sec
P+3sd < 60,400 psi at 70F and -65F
P+3sd < 65,600 psi at 160F
Action Time < 5.1 msec at 70F at 160F
Action Time < 5.5 msec at -65F

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Charge Verification Test Plan

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Lot Number	Blend Ratio	No. Rounds	Test Temp °F	Charge Weight Grams	Target Velocity ft/sec	Expected Pressure Psi
BSO18C-S73378	83/17 MC-BG Blend	5	70°F	147.6	3345	50,100
BSO18C-S73378	83/17 MC-BG Blend	5	160°F	147.6		
BSO18C-S73379	93/7 MC-BG Blend	5	70°F	146.0	3346	50,800
BSO18C-S73379	93/7 MC-BG Blend	5	160°F	146.0		
BSO18C-S73380	75/25 MC-BG Blend	5	70°F	147.1	3345	51,300
BSO18C-S73380	75/25 MC-BG Blend	5	160°F	147.1		

Charge weight adjusted for a target velocity value of 3345 ft/sec and about 50,000 - 51000 PSI.

As expected, all three blended lots expected to meet the ballistic requirements of the specification.

The delta pressure from ambient to hot condition is expected to be similar to that of the baseline sulfite AFP001.

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Thus far, all three Rayonier Kraft AFP001 propellant lots met all 70°F requirement of the specifications.

Pending Charge Verification gun tests will confirm charge weight and hot 160°F ballistics

Path Forward

The best two candidates from the charge verification test with be subjected to a LAT type gun test.

A parallel effort is under way to make APF001 with Buckeye cellulose.