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Role of Bimodal RDX in LOVA Gun Propellant Combustion

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ABSTRACT

Present investigation reports the results of systematic studies on the use of bimodal RDX in low-vulnerability ammunition (LOVA) gun propellants. Several formulations based on bimodal RDX as oxidiser, cellulose acetate as binder, and dioctyl phthalate or triacetin as plasticizer were processed with different proportions of 5 µm and 20 µm particle size of RDX samples in the range 100:0 to 60:40 ratios. The effect of varying the proportion of fine RDX of the two particle sizes on propellant burning behaviour was found to be quite significant. The study concluded that by using bimodal RDX, it is possible to modify burning behaviour without sacrificing low-vulnerability aspects of LOVA propellants.

NOMENCLATURE

CA	Cellulose acetate
CAB	Celluose acetate butyrate
DOP	Dioctyl phthalate
GAP	Glycidyl azide polymer
TA	Triacetin
CV	Closed vessel
F	Force constant
α	Pressure exponent
β_1	Linear burning rate coefficient
d_p/d_t	Rate of rise in pressure w.r.t. time
r	Burning rate

1. INTRODUCTION

The conventional nitrate ester-based gun propellants are quite satisfactory as far as their ballistic performance is concerned. The major disadvantage with these propellants is their high sensitivity to heat, impact and friction. The literature on low-vulnerability ammunition (LOVA) gun propellants reported earlier appears to be quite relevant[1-4]. These propellants use nitramine dispersed into inert or energetic polymeric binder-plasticizer matrix. Propellants based on such formulations have realised higher ignition temperatures and less sensitivity to impact and friction as compared to the conventional propellants[5]. Their ballistic performance and chemical stability are found to be superior to the nitrate ester-based propellants in use currently.

The energy level of LOVA gun propellants depends mainly on the percentage of nitramine. Because of its easy availability and comparatively low-cost, RDX has been preferred to HMX in many compositions reported earlier. It is known that the burning behaviour of nitramine propellant depends upon the particle size of nitramine used in the propellant. However, a few studies have dealt with the effect of particle size of RDX on the burning behaviour of the propellant. Pillai[6], *et al.* have reported that increase in particle size of RDX increased the burning rate as well as the pressure

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exponent of the nitramine gun propellant. Juhasz and Rocchio[1] have reported the use of bimodal HMX or RDX with polyurethane or polybutadiene as binder and observed that the use of bimodal nitramine system helped in minimising well-known slope break effects of nitramine. Mackowiak[7] has studied the effect of grain size of RDX on the performance of the propellant based on RDX/GAP, RDX/CAB and RDX/polybutadiene that are using unimodal RDX systems only. Lu Anfang and Liao Xin[8] have reported the effect of RDX particle size on the errosivity of the propellants, but this work dealt with only unimodal systems, where particle size variation was from 4.86 to 25.5 µm. Lussier,[9] *et al.* also used bimodal RDX in their studies, but their objective was to study the effects of grain length, igniter type, and conditioning temperature on the burning behaviour of the propellant. Thus, the literature survey clearly indicated that no systematic studies were carried out on the formulations based on bimodal RDX with respect to variation in the proportion of two particle sizes in a given system.

In the present investigation, systematic studies have been carried out on the effects of varying the proportion of 5 µm and 20 µm fine RDX in bimodal form on the burning behaviour of LOVA gun propellant as well as on different binder-plasticizer combinations.

2. EXPERIMENTAL PROCEDURE

Two series of LOVA gun propellant formulations based on RDX/CA/NC/DOP and RDX/CA/NC/TA compositions, with varying proportion of 5 µm to 20 µm RDX from 100:0 to 60:40 but keeping overall quantity of RDX in all formulations at constant level (77 per cent w/w) were processed. The percentages by weight of each ingredient in all the formulations were:

Bimodal RDX	77 %
CA	13 %
TA or DOP	6 %
NC (N_2 : 12.2 %)	4 %

The batch size in each case was about 2 kg. A sigma blade incorporator (5 l) was used for propellant processing by solvent method. The propellant dough was extruded into heptatubular strands with the help of a vertical hydraulic press using a suitable die-pin assembly. The strands after drying were cut into grains of suitable size length-to-diameter ratio (2.3) and the propellant formulations were subjected to closed vessel (CV) firing test and determination of vulnerability.

Table 1 (a). Effects of variation of bimodal fine RDX ratio on burning behaviour of LOVA gun propellants based on RDX/CA/NC/TA system (CV test vessel capacity: 700 cc, loading density: 0.2 g/cc)

Composition	I	II	III	IV	V
Proportion of 5 µm to 20 µm RDX	100:0	90:10	80:20	70:30	60:40
Percentage of 20 µm RDX in propellant composition	0	7.7	15.4	23.1	30.8
Force constant (J/g)	1047	1050	1059	1051	1055
Linear burning rate coefficient (β_1) (cm/s/MPa)	0.06	0.088	0.13	0.14	0.16
Pressure exponent (α)	0.74	0.844	0.96	1.02	1.05
(dp/dt) max (MPa/ms)	33.54	44.76	57.51	61.12	65.32
Burning rate (*r*) cm/s at 154 MPa	13.75	17.86	23.00	23.32	26.53
Average vivacity (10^{-3}) (Mpa x ms)	0.597	0.798	1.036	1.071	1.195

3. RESULTS & DISCUSSION

All propellant formulations were processed under identical conditions with grains having same geometry (heptatubular) and length-to-diameter ratio (2.3 ± 0.2). The replacement of 5 µm RDX with certain percentage of 20 µm RDX did not make any significant change in the process conditions, especially during the extrusion stage. The extrusion pressure during all experiments remained in the range 60-70 kg/cm^2, as normally observed. The CV firing data were obtained using same igniter powder in all cases and the propellant samples conditioned at room temperature (27 °C) were used in all experiments. Thus, except the proportion of indicates that low-vulnerability aspects have not been sacrificed at all while replacing unimodal RDX by bimodal RDX in a LOVA composition. Bimodal RDX-based propellants reported here are also found to be less vulnerable to heat, impact and friction than the conventional propellant like NQ.

4. CONCLUSION

LOVA propellant formulations using fine RDX (5 μm) may give better processibility, but lead to low burning rates. On the other hand, the composition with 20 μm RDX alone has undesirable burning behaviour (high α values). The present study indicates that the use of bimodal RDX-based composition with appropriate proportion of the two particle sizes was found to be quite useful to achieve desired burning behaviour and low-vulnerability aspects for LOVA gun propellants, without sacrificing energy level. Between the two series of propellants studied here, the bimodal RDX/CA/NC/TA-based compositions were found to be superior to bimodal RDX/CA/NC/DOP-based compositions, for gun applications.

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