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Studies on RDX Particle Size in LOVA Gun Propellant Formulations

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Summary

This paper presents the results of systematic studies carried out on the role of fine RDX in determining the burning rate and ballistics of LOVA gun propellants. Propellant formulations containing fine RDX particles with a size of 4.5, 6, 13 and 32 μm as energetic ingredient, cellulose acetate as inert binder, triacetin as inert plasticizer, nitrocellulose of lower percentage nitrogen content as energetic binder and carbamite as stabilizer were made. The evaluation of the propellant batches has been carried out by static firing using closed vessel technique. It indicates the linear relation between the burning rate of the propellant and the fine RDX particle size used in this formulation. The results of the present studies revealed that fine RDX of 4.5 to 6 μm size may be the most suitable for LOVA gun propellant to meet the desired burning rate for satisfactory ballistics.

1. Introduction

During recent times, Low Vulnerable Ammunition (LOVA) has assumed great importance because accidental initiation of on board conventional ammunition (single base, double base, triple base propellants) in the fighting compartments of armoured vehicles can lead to catastrophic accidents which cause heavy casualties of the crew and the loss of costly equipments[1–4]. LOVA propellants are developed using a reduced amount of nitric esters (which are highly sensitive constituents) in the propellant formulations, as well as using newer ingredients. Inert binders like cellulose acetate, cellulose acetate butyrate, cellulose acetate propionate[5,6] etc., are reported to have been used in propellant formulations along with nitramines (like RDX, HMX etc) which give the required energy output.

It has been reported that RDX exhibits an unconventional burning behaviour and the propellant burning rate depends on the particle size of RDX in the propellant formulation[7]. However, the relevant systematic details are not available in open literature. Hence, a need was felt to carry out systematic studies on the burning rate of LOVA propellant using RDX of different particle sizes so that an appropriate range of fine RDX particle size could be selected for LOVA gun propellants.

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2. Experimental

The average particle size of fine RDX used in the study was determined by a Fischer Sub-Sieve Sizer. The inert binder and plasticizer used were cellulose acetate (CA) and triacetin[8,9]. The LOVA propellant composition consisted of RDX 78%, CA 12%, nitrocellulose (12.2% N_2) 4%, triacetin (TA) 5.8% and ethyl centralite (carbamite) 0.2% (Table 1). The theoretical thermochemical values for the propellant composition at 0.15 g/cm^3 loading density were computed using the Therm program[10] (Table 2).

The propellant dough was made in a sigma blade incorporator by the solvent method using an acetone-alcohol solvent mixture as in detail described elsewhere[11]. Propellant strands were extruded in a heptatubular configuration using a suitable die/pin assembly in a vertical hydraulic press. Extruded strands were pre-dried and then cut into grains of suitable length, using a rotary cutting machine. The propellant grains were dried at elevated temperature (40°C) by blowing hot air, and then subjected to various tests. The evaluation of the different propellant formulations was carried out by closed vessel firing (CV) at 0.15 g/cm^3 loading density in a 700 cm^3 vessel. All samples were conditioned at 27°C for 24 hours before firing.

3. Results and Discussion

The results of the static evaluation of the propellant batches by CV are given in Table 3. The rate of rise of pressure (dp/dt) for the propellant batches was 15.9 MPa/ms for the LOVA formulation with RDX of 4.5 μm particle size and it increased to 73.8 MPa/ms for a LOVA formulation with RDX having a particle size of 32 μm. It has been seen from the computed burning rate constants that as the particle size of fine RDX increased, the β_1 value for the propellant also increased from 0.073 cm/s/MPa for 4.5 μm RDX to 0.36 cm/s/MPa for 32 μm RDX, while the pressure exponent α changed from 0.82 to 1.43. For the LOVA formulation with an RDX particle size of 32 μm the pressure exponent α was found to be 1.43 which is considered unacceptable for gun applications. The significant difference in the values of dp/dt for the LOVA propellants having RDX of varying particle

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Table 1. LOVA Propellant Formulations

Ingredients	%
Cellulose acetate	12
Nitrocellulose (12.2 % N_2)	4
Fine RDX	78
Triacetin	5.8
Ethyl centralite	0.2

Table 2. Theoretical Thermochemical Values

Parameter	Value
Flame temperature (K)	2888
Force constant (J/g)	1105
P_{max} (MPa)	196
Co-volume (cm^3/s)	1.042
n value (mol/g)	0.046
Ratio of specific heats (Υ)	1.262

Table 3. Results of Closed Vessel (CV) Evaluations of LOVA Propellants

RDX Particle Size (μm)	Density (g/cm^3)	P_{max} (MPa)	dp/dt (MPa/ms)	r (max) (cm/s)	β_1 (cm/s/MPa)	α
4.5	1.65	188.0	15.9	9.5	0.073	0.82
6.0	1.65	188.8	17.6	10.0	0.077	0.83
13.0	1.56	189.6	35.8	20.5	0.15	1.07
32.0	1.45	190.0	73.8	46.0	0.36	1.43

sizes can be found from the dp/dt vs pressure profile of the propellant formulations given in Figure 1.

P_{max} values for different LOVA formulations have shown minor variations which can be due to the experimental error. The decrease in the density of the LOVA propellant formulation from 1.65 g/cm^3 (for RDX with particle size 4.5 μm) to 1.45 g/cm^3 (for RDX of 32 μm) was observed on an increase in particle size.

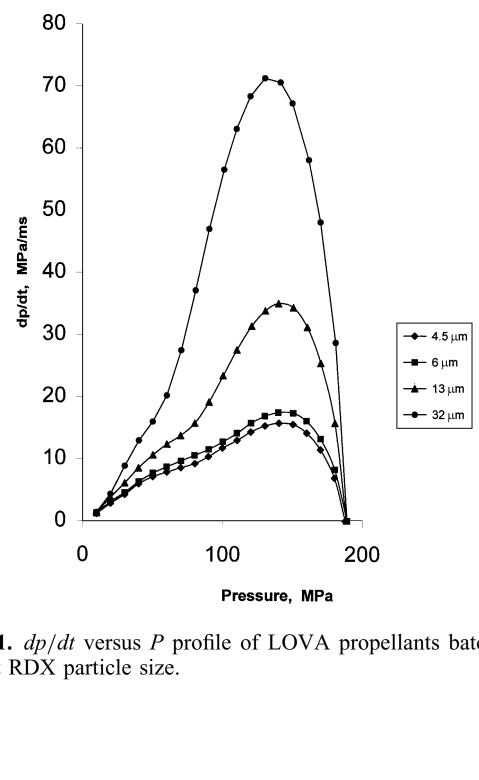

Figure 1. dp/dt versus P profile of LOVA propellants batches with different RDX particle size.

A graph of α versus particle size (Fig. 2) and one of β_1 versus particle size (Fig. 3) clearly indicates that an increase in the particle size of RDX increases the α and β_1, respectively. The increase in burning rate r for a particular composition due to the increase in RDX particle size also increases the α value which is seen in the CV results at Table 3. As in the burning rate law $r = \beta \cdot P^{\alpha}$ any value of α beyond 1 is not desirable and will be disastrous because the pressure increase will be exponential. The RDX particles used in the LOVA propellant formulation determine the ballistic parameters like pressure exponent α, linear burning rate coefficient β_1, rate of change of pressure with respect to the time dp/dt, and the burning rate. The finer the RDX particle size the lower are the ballistic parameters, and the coarser the RDX particle size the higher are the ballistic parameters such as dp/dt, β_1 and α. The results are in

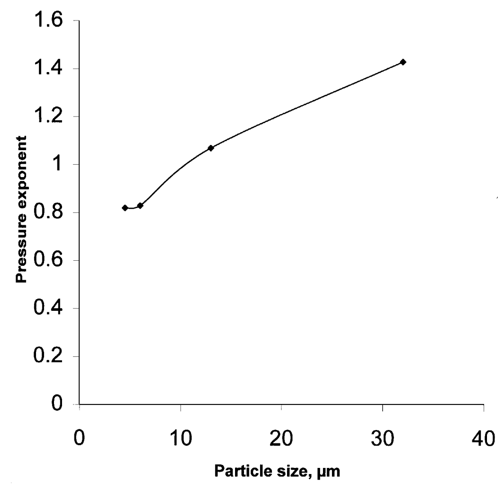

Figure 2. Particle size versus pressure exponent.

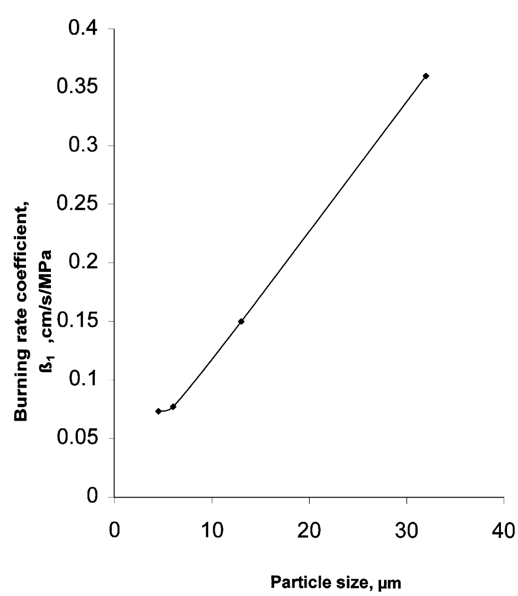

Figure 3. Particle size versus burning rate coefficient.

agreement with those given by other researchers[12]. These results can be explained on the basis of a melt layer phenomenon which was proposed by Cohen and Strand[13] wherein it has been postulated that a fine particle size of RDX results in a thick melting layer which gives a lower burning rate while a coarse size of RDX results in a thin melting layer leading to a high burning rate.

4. Conclusion

1. The particle size of fine RDX plays a significant role in determining the ballistic parameters of LOVA propellants.
2. The coarser the particle size of fine RDX the higher is the burning rate and the pressure exponent and vice-versa.
3. Fine RDX of about 4.5 μm particle size can be used for LOVA propellant formulations.

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