Available online at www.sciencedirect.com
ScienceDirect
Journal of Hazardous Materials 143 (2007) 532–534
Journal of Hazardous Materials
www.elsevier.com/locate/jhazmat

HMX based enhanced energy LOVA gun propellant

R.R. Sanghavi *, P.J. Kamale, M.A.R. Shaikh, S.D. Shelar, K. Sunil Kumar, Amarjit Singh

High Energy Materials Research Laboratory, Pune 411021, India

Received 12 February 2006; received in revised form 7 August 2006; accepted 22 September 2006
Available online 7 October 2006

Abstract

Efforts to develop gun propellants with low vulnerability have recently been focused on enhancing the energy with a further improvement in its sensitivity characteristics. These propellants not only prevent catastrophic disasters due to unplanned initiation of currently used gun propellants (based on nitrate esters) but also realize enhanced energy levels to increase the muzzle velocity of the projectiles. Now, in order to replace nitroglycerine, which is highly sensitive to friction and impact, nitramines meet the requirements as they offer superior energy due to positive heat of formation, typical stoichiometry with higher decomposition temperatures and also owing to negative oxygen balance are less sensitive than stoichiometrically balanced NG. RDX has been widely reported for use in LOVA propellant. In this paper we have made an effort to present the work on scantily reported nitramine HMX based LOVA gun propellant while incorporating energetic plasticizer glycidyl azide polymer to enhance the energy level. HMX is known to be thermally stable at higher temperature than RDX and also proved to be less vulnerable to small scale shaped charge jet attack as its decomposition temperature is 270 °C. HMX also offers improved impulse due to its superior heat of formation (+17 kcal/mol) as compared to RDX (+14 kcal/mol). It has also been reported that a break point will not appear until 35,000 psi for propellant comprising of 5 μm HMX. Since no work has been reported in open literature regarding replacement of RDX by HMX, the present studies were carried out.
© 2007 Published by Elsevier B.V.

Keywords: HMX; Gun propellant; LOVA; Enhanced energy; Low vulnerability

1. Introduction

Efforts to develop gun propellants with low vulnerability have recently been focused on enhancing the energy with a further improvement in its sensitivity characteristics. These propellants not only prevent catastrophic disasters due to unplanned initiation of currently used gun propellants (based on nitrate esters) but also realize enhanced energy levels to increase the muzzle velocity of the projectiles. Now in order to replace nitroglycerine, which is highly sensitive to friction and impact, nitramines are used. Nitramines offer superior energy due to positive heat of formation, typical stoichiometry with higher decomposition temperatures and also possess negative oxygen balance. They are less sensitive than stoichiometrically balanced NG. RDX has been widely reported for use in LOVA propellant. In this paper we have made an effort to present the work on HMX based LOVA gun propellant while incorporating energetic plasticizer glycidyl azide polymer to enhance the energy level, since very less information is available in open literature. HMX is known to be thermally stable at higher temperature than RDX and also proved to be less vulnerable to small scale shaped charge jet attack as its decomposition temperature is 270 °C. HMX also offers improved impulse due to its superior heat of formation (+17 kcal/mol) as compared to RDX (+14 kcal/mol). It has also been reported that a break point will not appear until 35,000 psi for propellant comprising of 5 μm HMX. The present experiments were carried out to study the ballistic and vulnerability behaviour by incorporating HMX in LOVA propellant formulations.

2. Experimental procedure

Cellulose acetate (CA) was selected as the inert binder and glycidyl azide polymer (GAP) was used as the energetic plasticizer. Nitrocellulose (NC) of lower nitrogen content (N_2 12.2%) was used alongwith inert binder. Fine RDX (5 μm) was selected as the energetic ingredient which was then replaced by fine

* Corresponding author. Tel.: +91 20 26120673; fax: +91 20 25869316.
E-mail address: sanghavirr@yahoo.co.uk (R.R. Sanghavi).

0304-3894/$ – see front matter © 2007 Published by Elsevier B.V.
doi:10.1016/j.jhazmat.2006.09.087

HMX. Carbamite served the purpose of stabilizer. A two-stage process was adopted for propellant processing. In the first stage of this process, a basic composition of all the ingredients except carbamite were prepared in the wet stage and finally dried. In the second stage this dried basic mix alongwith carbamite was used to prepare the dough by the solvent method using acetone and alcohol in 70:30 ratio. The propellant dough was then extruded into propellant strands having heptatubular geometry and this was granulated to the required size. The chemical formulation is given in Table 1 and the process flow chart in Fig. 1. The theoretical thermochemical calculations by using Thermo G1 computer program [1] are given in Table 2. The finished propellant was evaluated for studying the ballistic behaviour by closed vessel firing in a 700 cm^3 vessel at 0.18 g/cm^3 density of loading. Results are given in Table 3. Mechanical properties (compression strength and percentage compression) of the propellant were determined by ASTM standard by using Hounsfield H24KS Material Testing machine having a capacity of 25 KN. The results are given in Table 4. Vulnerability properties were determined by testing the propellant samples w.r.t. height for

Table 1
Fine HMX based LOVA propellant formulations

Ingredients (nominal %)	I	II	III	IV
Fine RDX	70–75	45–50	20–25	–
Fine HMX	–	20–25	45–50	70–75
NC (A)	10–15	10–15	10–15	10–15
CA	8.5	8.5	8.5	8.5
Carbamite	0.5	0.5	0.5	0.5
GAP (low mol. wt.)	6	6	6	6

Table 2
Theoretical thermochemical calculations

Composition	I	II	III	IV
Force constant (J/g)	1206	1203	1201	1198
Flame temperature (K)	3214	3206	3199	3192
P_{max} (MPa)	265	264	264	263
Co-volume (cm^3/g)	1.0040	1.0040	1.0041	1.0041
Specific heat ratio (γ)	1.2604	1.2604	1.2604	1.2604
Moles of product gases (n) (mol/g)	0.0451	0.0451	0.0451	0.0451

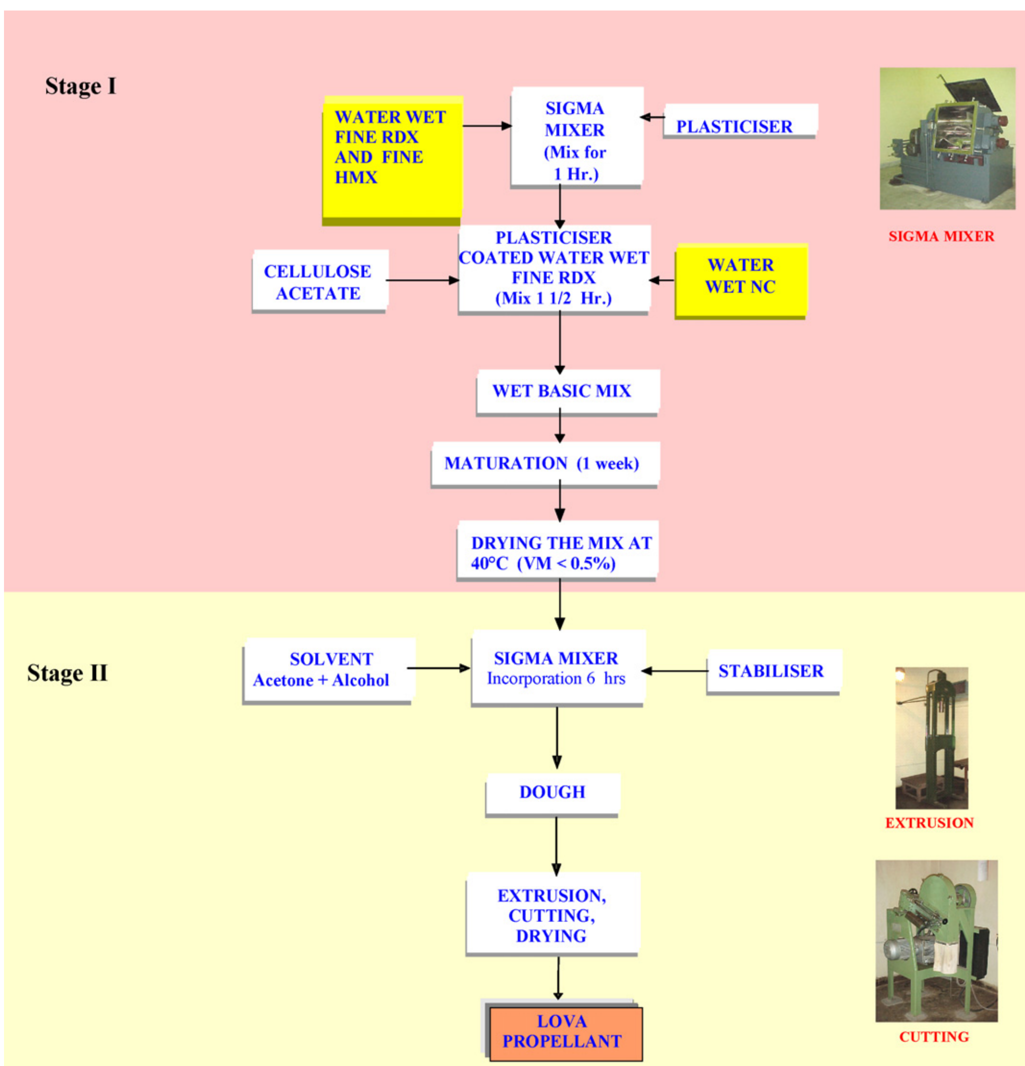

Fig. 1. Process flow chart for enhanced energy LOVA propellant.

Table 3
Results of closed vessel evaluation

Composition	I	II	III	IV
Force constant (J/g)	1191	1193	1195	1198
Flame temperature (K)	3200	3192	3185	3177
Pressure exponent, α	0.83	0.88	0.95	0.99
β_1 (cm/s/MPa)	0.132	0.143	0.148	0.173
dP_{max} (MPa/ms)	49	52	62	65

Table 4
Results of mechanical properties

Composition	I	II	III	IV
Compressive strength (kg/cm^2)	332	297	250	257
%Compression	8	12.3	13.1	15.4

Table 5
Results of vulnerability results

Composition	I	II	III	IV
h_{50} (cm)	32	34	36	38
Friction insensitive up to (kg)	32.4	32.4	32.4	36
Ignition temperature (°C)	>220	>220	>220	>250

Table 6
Stability test results

Composition	I	II	III	IV
Heat test, 71.1 °C	20	21	21	22
MV test, 120 °C, NBF	50	55	75	>180
B&J, 120 °C (cm^3/5 g)	0.6	0.5	0.4	0.3

50% explosion by 2 kg falling weight, friction sensitivity and ignition temperature by Julius Peter apparatus. The results are given in Table 5. The stability of the propellant was studied by conducting heat test at 71.1 °C and Bergman & Junk test at 120 °C. The results of these tests are given in Table 6.

3. Results and discussion

The results presented in Table 3 indicate that on replacing RDX by HMX the force constant is more or less unchanged (1190–1200 J/g) but there is rise in linear burning rate coefficient from 0.132 to 0.173 cm/s/MPa, pressure exponent from 0.83 to 0.99 and dP_{max} from 49 to 65 MPa/ms. The reason for rise in linear burning rate coefficient, pressure exponent and dP_{max} may be attributed to higher particle size of HMX (16.5 μm) as compared to RDX (5 μm). These results are in agreement with those reported by Barnes and Kristofern [2] and Pillai et al. [3]. As seen from the data given in Table 3 the force constant determined experimentally is in close agreement with the theoretically predicted values. It is also seen that the flame temperature of HMX (75%) based propellant is less (23 K) than RDX (75%) based propellant which is encouraging from application point of view. The mechanical properties results have shown rise in percentage compression from 8 to 15.4% with decrease in compression strength from 332 to 250 kg/cm^2. HMX based propellant is more insensitive as indicated by h_{50} of 38 cm, friction insensitive up to 36 kg and ignition temperature is greater than 250 °C. This correlates with UK experience [4,5] that for a given high impetus level, HMX based propellants are less vulnerable than their RDX based equivalents. HMX based propellant is highly stable as no brown fumes observed till 180 min when undergone MV Test and also only 0.3 g/cm^3 per 5 g gas released at 120 °C by B&J test. This heat resist behaviour is also being highlighted by Anfang and Xin [6] mentioning this as the main difference between RDX and HMX-LOVA propellants.

We intend to continue this research work on HMX based formulations with 5 μm particle size as it has been reported that a break point will not appear until 35,000 psi and it will also assist in lowering the pressure exponent value [7].

4. Conclusion

HMX based propellant have shown considerable improvement in terms of vulnerability, stability properties and percentage compression while exhibiting slight decrease in flame temperature.

References

[1] J.S. Karir, Calculation of Thermochemical Constants of Gun Propellants by Computer Program Thermo G1, HEMRL, Pune, 2001.
[2] M. Barnes, C. Kristofern, Low Vulnerability Gun Propellant, US Patent 4,456,493, 4P, Thiokol Corporation, Chicago (1984).
[3] A.G.S. Pillai, R.R. Sanghavi, C.R. Dayanandan, M.M. Joshi, S.P. Velapure, Amarjit Singh, Studies on effect of RDX particle size on LOVA gun propellants, propellants, explosives, Pyrotechnics 26 (2001) 226–228.
[4] C. Leach, D. Debenham, J. Kelly, K. Gillespie, Factors affecting vulnerability of composite LOVA gun propellants, in: International Symposium on Energetic Materials Technology Proceedings, The American Defense Preparedness Association, 1995, pp. 132–138.
[5] C. Leach, D. Debenham, Advances in poly NIMMO composite gun propellants, propellants, explosives, Pyrotechnics 23 (1998) 313–316.
[6] A. Lu, X. Liao, Investigation of the properties of LOVA propellants, in: 24th International Annual Conference 1993 on Energetic Materials Insensitivity & Environmental Awareness, 1993, pp. 86/1–186/11.
[7] N.S. Cohen, L.D. Strand, Nitramine Propellant Research National Aeronautics and Space Administration, Technical Memorandum 33-801 Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California, October 1976.