Defence Science Journal, Vol 42, No 4, October 1992, pp 253-257

Effect of High Energy Materials on Sensitivity of Composite Modified Double-Base (CMDB) Propellant System*

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ABSTRACT

The shock sensitivities (viz, impact and friction) of composite modified double-base (CMDB) ingredients, double-base (DB) matrix (SNC:CL) and the effect of high energy materials like ammonium perchlorate (AP), cyclotrimethylene trinitramine (RDX), cyclotetramethylene tetranitramine (HMX) and pentaerythritol tetranitrate (PETN) on a CMDB system, have been studied. Individual ingredients of DB matrix, i.e., spheroidal nitrocellulose (SNC) and desensitised nitroglycerine (casting liquid (CL)), do not appear to be very sensitive to impact and friction, impact height of 50 per cent explosion being 144.0 and 166.0 cm, respectively and friction figure of insensitivity of 36.0 kg each. Various DB mixtures gave impact ranging between 56.5 to 61.5 cm and friction insensitivity of 36.0 kg for all the formulations. But addition of AP to DB matrix increases the impact and friction sensitivity tremendously, impact ranging from 15 to 24 cm and friction from 2.0 to 3.2 kg. Sensitivity-wise addition of RDX, HMX, and PETN to DB matrix follows AP while the addition of *Al* slightly reduces the sensitivity.

1. INTRODUCTION

Composite modified double-base (CMDB) propellants are comparatively of recent origin among solid rocket propellants. CMDB propellants besides containing double-base (DB) matrix of nitrocellulose (NC) and nitroglycerin (NG) may also contain high energy materials/oxidisers like ammonium perchlorate (AP), cyclotrimethylene trinitramine (RDX), cyclotetramethylene tetranitramine (HMX), pentaerythritol tetranitrate (PETN), etc. The presence of these high energy materials makes the system sensitive to shock stimulus like impact and friction. This paper deals with effect of these high energy additives on DB matrix and the final CMDB compositions containing *Al*. Data on some CMDB ingredient formulations has already been reported[1].

2. EXPERIMENTAL

Impact tests were carried out on Bruceton Staircase[2] type apparatus and results are reported as heights of 50 per cent explosion in cm for 2 kg hammer weight. Friction tests were carried out on Julius-Peters apparatus using BAM method[3]. The results are reported in kg. Spheroidal NC (SNC) was made as per the established procedure[4]. Casting liquid (CL) consisted of desensitised NG containing DEP and carbamite. AP was procured from trade having particle size of 200 μm. RDX and PETN of 200 μm size were procured from Indian Ordnance Factories. HMX of 200 μm was made in Pilot Plant at the Explosives Research & Development Laboratory, Pune. Aluminium of 16 μm was procured from MEPCO, Madurai. All the ingredients were of minimum 99 per cent purity. All the tests were carried out at ambient temperature, i.e., 30 ± 2 °C and relative humidity of 55 to 65 per cent. The friction sensitivity has been reported as figure of insensitivity, i.e., the weight at which explosives does not initiate. The term 'fall energy' denotes the product of fall height in metres and 'fall weight' in kg. Theoretical oxygen balance (OB) and calorimetric value (cal-val) have also been included in tables.

Received 23 June 1992
* Invited paper for the DSJ Special Issue on High Energy Materials (July 1992)

3. RESULTS AND DISCUSSION

Initially the impact and friction sensitivities of individual CMDB ingredients were tested, followed by various combinations of DB matrix (SNC:CL). The effect of high energy materials on the sensitivity of DB matrix and CMDB compositions containing *Al* was also studied.

Table 1 presents the impact and friction sensitivity of individual ingredients. The results show that the individual ingredients like SNC, CL and AP are not very sensitive to shock stimuli giving impact heights of 144.0, 166.0 and 93.0 cm respectively for 50 per cent explosion and friction insensitivity up to 36.0 kg (limit of the machine); RDX and HMX have more or less same impact sensitivity, i.e., 26.5 and 26.0 cm, respectively and friction insensitivity of 18.0 and 14.4 kg, respectively, whereas the PETN is most sensitive among all the ingredients (height of 50 per cent explosion 24.5 cm and friction 8.0 kg).

Table 2 gives the sensitivities of SNC:CL mixtures. The various combinations of DB matrix show almost same impact sensitivity for all the combinations, i.e., height of 50 per cent explosion varying from 56.5 to 62.0 cm and all the formulations are seen to be insensitive to friction giving the same figure of insensitivity of 36.0 kg. This may be due to the negligible difference in OB of various combinations (38.9 to 39.7 per cent).

Inclusion of AP in DB matrix of SNC:CL makes the system very sensitive to impact and especially to friction. Various combinations give 50 per cent explosion heights from 15 to 24 cm and friction insensitivity of as low as 2.0 to 3.2 kg. The results have been shown in Table 3.

Table 4 shows the results of the effect of RDX on shock sensitivity. It is evident that the impact sensitivity of various combinations of SNC:CL:RDX varies from 21 to 27 cm as against 56 to 62 cm for SNC:CL (DB matrix) mixtures and the friction sensitivity lies between 19.0 and 36.0 kg as against 36.0 kg for all combinations of SNC:CL. Further it is seen that as the OB of composition increases, the shock sensitivity also increases.

Table 5 gives the results of the effect of HMX on shock sensitivity of DB matrix. The effect is almost same as that of RDX, the heights of 50 per cent explosion lie between 22.0 and 27.5 cm and the figure of insensitivity between 19.2 and 28.8 kg. The same trend is observed with respect to OB percentage.

Table 6 gives the values of the effect of PETN on the sensitivity of DB matrix. This again shows the same trend as found with RDX and HMX, in respect of the effect of OB on shock sensitivity of various formulations. The impact heights range between 25.0 and 32.5 cm and friction between 4.8 and 12.0 kg.

Table 7 gives the results of the shock sensitivity of various CMDB formulations. In all these formulations, solid to liquid ratio is maintained at 65:35 and AP:*Al* ratio at 3:2 which is generally used in a CMDB system. Compositions containing AP and *Al* show the shock sensitivity comparatively less than the compositions without *Al*. The compositions containing RDX and *Al* also show the same trend, i.e., the compositions with *Al* are less sensitive than those without *Al*. Keeping this in view it is desirable for a CMDB formulator to

Table 1. Shock sensitivities of individual CMDB ingredients

Ingredient	O/B	Cal-val	Impact		Friction
			Height of 50% explosion	Fall energy	Figure of insensitivity
	(%)	(cal/g)	(cm)	(kg.m)	(kg)
SNC	-42.7	830	144.0	2.88	36.0
CL	-36.2	1038	166.0	3.32	36.0
AP	+34.0	1605	93.0	1.86	36.0
RDX	-21.6	1360	26.5	0.53	18.0
HMX	-21.6	1320	26.0	0.52	14.4
PETN	-10.1	1535	24.5	0.49	8.0

Table 2. Shock sensitivities of various combinations of DB matrix

Ingredient	Ratio	OB (%)	Cal-val (cal/g)	Impact: Height of 50% explosion (cm)	Impact: Fall energy (kg.m)	Friction: Figure of insensitivity (kg)
SNC:CL	25:35	-38.9	951	61.5	1.23	36.0
SNC:CL	30:35	-39.2	942	62.0	1.24	36.0
SNC:CL	35:35	-39.5	934	56.5	1.13	36.0
SNC:CL	40:35	-39.7	927	58.0	1.16	36.0

Table 3. Effect of AP on shock sensitivity of DB matrix

Ingredient	Ratio	OB (%)	Cal-val (cal/g)	Impact: Height of 50% explosion (cm)	Impact: Fall energy (kg.m)	Friction: Figure of insensitivity (kg)
SNC:CL:AP	25:35:20	-20.7	1114	24.0	0.48	3.2
SNC:CL:AP	25:35:25	-17.5	1143	21.0	0.42	2.8
SNC:CL:AP	25:35:30	-14.6	1169	19.0	0.38	2.4
SNC:CL:AP	25:35:40	- 9.8	1212	15.0	0.30	2.0

Table 4. Effect of RDX on shock sensitivity of DB matrix

Ingredient	Ratio	OB (%)	Cal-val (cal/g)	Impact: Height of 50% explosion (cm)	Impact: Fall energy (kg.m)	Friction: Figure of insensitivit (kg)
SNC:CN:RDX	25:35:20	-34.6	1054	27.0	0.54	36.0
SNC:CL:RDX	25:35:25	-33.8	1072	24.5	0.49	32.4
SNC:CL:RDX	25:35:30	-33.1	1088	23.5	0.47	28.8
SNC:CL:RDX	25:35:40	-32.0	1115	21.0	0.42	19.0

Table 5. Effect of HMX on shock sensitivity of DB matrix

Ingredient	Ratio	OB (%)	Cal-val (cal/g)	Impact: Height of 50% explosion (cm)	Impact: Fall energy (kg.m)	Friction: Figure of insensitivity (kg)
SNC:CL:HMX	:35:20	-34.6	1044	27.5	0.55	28.8
SNC:CL:HMX	:35:25	-33.8	1060	24.5	0.49	25.2
SNC:CL:HMX	:35:30	-33.1	1074	24.0	0.48	21.6
SNC:CL:HMX	:35:40	-32.0	1099	22.0	0.44	19.2

Table 6. Effect of PETN on shock sensitivity of DB matrix

Ingredient	Ratio	O/B	Cal-val	Impact		Friction
				Height of 50% explosion	Fall energy	Figure of insensitivity
		(%)	(cal/g)	(cm)	(kg.m)	(kg)
SNC:CL:PETN	25:35:20	-31.7	1097	32.5	0.65	12.0
SNC:CL:PETN	25:35:25	-30.5	1123	29.5	0.59	11.2
SNC:CL:PETN	25:35:30	-29.3	1145	27.5	0.55	9.6
SNC:CL:PETN	25:35:40	-27.4	1184	25.0	0.50	4.8

Table 7. Shock sensitivity of various CMDB formulations

Ingredient	Ratio	OB	Impact		Friction
			Height of 50% explosion	Fall energy	Figure of insensitivity
		(%)	(cm)	(kg.m)	(kg)
SNC:CL:AP:*Al*	25:35:24:16	-29.4	24.0	0.48	4.8
SNC:CL:AP:*Al*	30:35:21:14	-30.8	22.5	0.45	4.2
SNC:CL:AP:*Al*	35:35:18:12	-32.2	20.5	0.41	3.6
SNC:CL:AP:*Al*	40:35:15:10	-33.5	24.0	0.48	3.2
SNC:CL:RDX:*Al*	25:35:24:16	-42.8	27.5	0.55	16.0
SNC:CL:RDX:*Al*	30:35:21:14	-42.5	28.5	0.57	28.8
SNC:CL:RDX:*Al*	35:35:18:12	-42.2	29.5	0.59	32.4
SNC:CL:RDX:*Al*	40:35:15:10	-41.9	30.5	0.61	32.4

add AP or RDX in the slurry after addition of *Al*, so as to reduce the risk of accidents.

4. CONCLUSION

The study shows that even though the individual CMDB ingredients are not very sensitive to impact and friction, the addition of high energy materials like AP, RDX, HMX and PETN to DB matrix makes the system quite sensitive to impact and friction stimuli. This also makes the CMDB propellant system more sensitive than DB and composite propellants. The comparison between the three systems has been already reported[1]. The effect of AP on shock sensitivity of DB matrix is seen to be the most profound, followed by RDX, HMX and PETN in that order. The studies also show the dependence of shock sensitivity on energetics of the propellant system, like OB, cal-val, etc[5-7].

The results also reveal that the addition of *Al* slightly reduces the shock sensitivity of the system. Hence it is desirable to add high energy materials after the addition of *Al* to DB matrix mixture. For the sake of continuity some data has been included in this text from the literature[1,8]. The impact and friction sensitivity of a complete CMDB system has been reported earlier[9]. These studies necessitate the utmost care and precaution to be taken by the operator while processing and handling CMDB propellants.

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