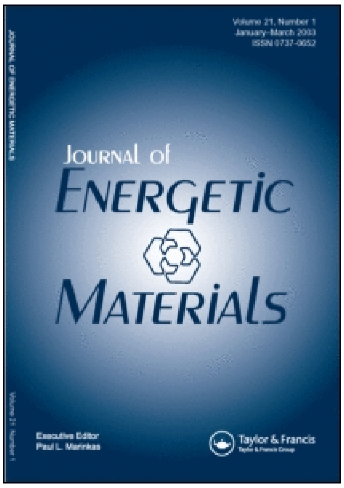

Journal of Energetic Materials
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713770432

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To cite this Article Mehilal, Labade, M. S. , Singh, S. N. and Agrawal, J. P.(2001) 'Evaluation of some thermal, mechanical and explosive properties of plastic bonded explosives based on epoxy resin', Journal of Energetic Materials, 19: 2, 255 — 272

To link to this Article: DOI: 10.1080/07370650108216129

URL: http://dx.doi.org/10.1080/07370650108216129

Evaluation of Some Thermal, Mechanical and Explosive Properties of Plastic Bonded Explosives Based on Epoxy Resin.

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ABSTRACT

RDX/HMX based Plastic Bonded Explosives (PBXs) with epoxy resin as a binder have been formulated and studied in detail for their explosive, mechanical and thermal properties. The effect of pressure on the moulding powder has also been optimized to achieve maximum loading density and compression strength. Further, these PBXs have been analysed for homogeneity and coating of binder over RDX/HMX crystals. The data suggest that epoxy resin based PBXs have higher loading density, higher mechanical strength and higher velocity of detonation (VOD) as compared to polyurethane based PBXs.

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Journal of Energetic Materials Vol. 19, 241-257 (2001)
Published in 2001 by Dowden, Brodman & Devine, Inc.

INTRODUCTION

The chief disadvantages of explosive charges manufactured from 2,4,6-trinitrotoluene (TNT)/RDX/HMX based formulations are their propensity to crack when roughly handled, their inherent high explosiveness and sensitiveness, inhomogeneity and low temperature resistance. Further, temperature of the charge in a high velocity missile may rise to more than 100°C due to aerodynamic heating, resulting in unreliable functioning of TNT based formulations. Similarly, many ordnance systems are required to remain safe if dropped from a considerable height or exposed to an accidental fire and again, TNT-based systems are not satisfactory. The improvement of modern explosive charges in such respects has led to the development of plastic bonded explosives (PBXs) which have better heat resistance than melt-cast explosives. Also, these PBXs have better strength, dimensional stability and cracking resistance. These PBXs contain a large amount of basic explosives such as 1,3,5-trinitro-1,3,5-triazacyclohexane (RDX), 1,3,5,7-tetranitro-1,3,5,7-tetrazacyclooctane (HMX), 2,2',4,4',6,6'-hexanitrostilbene (HNS) or Pentaerythritoltetranitrate (PETN) coated with a polymeric binder such as polyester, polyurethane, nylon, polystyrene, various types of rubbers, NC or teflon[1].

A literature survey reveals that first true PBX was prepared from RDX and polystyrene[2,3] followed by several PBXs based on polyacrylate[4] and poly(hexamethyleneadipamide). Further, a number of PBXs using PETN and Epikote 871 (epoxy resin)[5] with diethylenetriamine as a curing agent have also been reported. This work has further been extended to the use of nitrofluoroalkyl epoxide (epoxy ether explosive)[6] as a binder resulting in PBXs which are heat-resistant and insensitive to impact. The prime object to choose epoxy resins as binder for PBXs is their versatility, easy curing, high adhesive properties due to presence of ether (-C-O-C-) & aliphatic hydroxyl (-C-OH) groups in uncured as well as cured system, leading to less shrinkage and better mechanical properties. Further, due to presence of ether groups and benzene rings, it becomes chemically inert[7] which may be useful for enhancing the storage life of explosive formulations. As chemical properties of a binder play a vital role in coating an explosive[8-12], loading density of a PBX may be improved by selecting suitable particle size combinations of the basic explosive[13]. In view of better mechanical and chemical properties of epoxy resins as compared to polyurethane binders[14], attempts have been made to formulate a number of PBXs in small batches and study their thermal, mechanical and explosive properties in detail.

The present paper reports the data on various properties of epoxy resin & RDX/HMX based PBX formulations and their comparison with polyurethane (PU) based PBX formulations.

EXPERIMENTAL

Impact sensitivity was determined by Fall Hammer method using 2.0 kg drop weight and friction sensitivity was determined by Julius Peter's apparatus[15]. The sensitivity to spark was determined by spark sensitivity instrument. The velocity of detonation was measured by using Pin Oscilloscopic[16] method and detonation pressure was calculated as per reported method[17].

Shock sensitivity[18] was determined by "Small Scale Gap test" using tetryl as a donor where dimensions of donor and acceptor were kept identical (17.7 mm dia and 17.0 mm height). Cellulose acetate was used as an attentuater. Explosion and no-explosion were determined by varying the thickness of cellulose acetate sheet and thickness for all PBXs for 50% explosion is reported.

Deflagration temperature[19] was determined by Wood's metal bath taking 0.02 g of sample in a glass tube at a heating rate of 5°C/min. The temperature at which sample got ignited was recorded as a deflagration temperature.

Differential thermal analysis (DTA) was recorded using DTA apparatus (locally fabricated) at a heating rate of 10°C/min with 10 mg of sample in the presence of static air. Vacuum stability was carried out by heating 5 g of sample in vacuum at 120°C for 40 hrs and measuring the total volume of gaseous products obtained at S.T.P.

The PBX pellets were pressed by using Single Action Technique. In this process, weighed quantity of moulding powders were transferred to 30 mm mould which was kept under hydraulically operated ram at ambient temperature by applying 16 ton dead load (2.26 ton/cm^2) and dwell time ≈ 10-12 seconds. The pellets pressed by this technique were used for the determination of density, compression strength and shock sensitivity of PBX Formulations.

Compression strength of PBX pellets pressed at 16 tonnes dead load (pellet dia ~ 30 mm and height ~ 30 mm) was determined by using "Universal Instron", Model – 1185 at a constant speed of 50 mm/min and results reported are mean value of five crushed pellets.

All the PBXs were analyzed by soxhlet method using acetone as a solvent to confirm the homogeneity of the sample.

Materials

RDX with a melting point of 202-204°C, procured from Ordnance Factory, Bhandara, was used in bimodal form i.e. 125 μm to 250 μm (70%) and 88 μm to 125 μm (30%). Similarly, HMX with a melting point of 274-276°C (prepared in the laboratory) was also used in bimodal form i.e. 125 μm to 250 μm (70%) and 88 μm to 125 μm (30%). Epoxy resin (Dobeckot – 504) having specific gravity 1.16, viscosity 450 – 470 cPs and 330 ± 20 epoxy equivalent and Hardener (Dobeckot 756 polyamine) having viscosity 50 – 60 cPs were procured from Dr. Beck and Co., Pune.

Procedure : (RDX/Epoxy resin 90/10) :

50 g of epoxy resin (Dobeckot – 504) was transferred into sigma mixer (Cap. 2 lit) followed by 450 g of RDX (dried at 75°C in water jacketed oven) in three equal installments (fine particles followed by coarse particles i.e. 30 parts fine and 70 parts coarse) with continuous mixing. After complete addition of RDX, it was mixed for an hour to get homogenous coating of binder over RDX particles. After an interval of one hour, 5 g of Hardener (Dobeckot – 756) was added to sigma mixer and mixed further for half an hour (Resin to Hardner ratio was kept 100:10). Homogeneously mixed composition was taken out from the mixer and spread in stainless steel tray for curing at room temperature. The cured composition was sieved through 30 BSS to get homogeneous mixture for evaluation of different properties of PBXs. Different

Formulations of RDX/HMX using epoxy resin as a binder were prepared similarly and are presented in Table-1.

RESULTS AND DISCUSSION

The data on analysis of all PBXs (Table-1) indicates better homogeneity and proper coating of binder over explosive crystals.

The data on sensitivity to impact, friction, spark and shock (Table-2) shows that epoxy resin based PBXs are more insensitive to impact than PU based PBXs while their friction sensitivity is comparable. Further, on increasing the solids loading, there is a slight increase in impact sensitivity whereas practically no change towards friction sensitivity suggesting maximum solids loading with safe handling. The spark sensitivity data of all the epoxy resin based PBXs as well as PU based PBXs are in the same range i.e. insensitive upto 5 Joules, suggesting that handling and transportation of these PBXs are safe. Similarly, shock sensitivity values of all PBXs are also in the same range and are comparable to PU based PBXs.

The velocity of detonation (VOD) and detonation pressure (DP) for all PBXs are given in Table-3, indicating high VOD as well as high DP for all PBXs due to higher density and is achieved by better homogeneity of the formulation leading to good compactness of the pellet during pressing. It is also clear from Table-3 that PU based RDX/HMX formulations have comparatively less density, VOD and detonation pressure. Further, detonability test indicates that all the PBXs in the form of pellet detonate without booster suggesting good initiation and therefore, better reproducibility.

Thermal properties of the PBXs are given in Table-3 and it is clear that all the PBXs deflagrate at the decomposition temperature of explosives used, indicating that thermal stability is totally dominated by explosive present in the PBX and epoxy binder does not degrade the thermal stability, and this is also supported by DTA values. The vacuum stability data indicates that all the PBXs have good stability under vacuum at 120°C for 40 hrs and gaseous products obtained are in the range of 1.20 to 1.66 cc for 5 g sample (maximum permissible gaseous products for 5 g of sample under the same conditions for high explosives is ~ 5 cc) inferring good compatibility of explosives with epoxy binder.

The experimental values of compression strength of PBXs at ambient temperature are given in Table-3 and it is evident that all the PBXs have higher compression strength than PU based PBXs. It is also seen that an increase in mechanical strength is prominent with 3-5% binder and there is only marginal improvement in compression strength beyond 5% binder. This trend in mechanical strength may be explained by considering the particle size distribution of ingredients as well as coating technique[20]. This is in agreement with the data generated and reported with the use of different binders like, polyurethane (PU), low density polyethylene (LDPE), ethylene-vinyl acetate (EVA) viton-A, kel-F800 and Kraton-G1650. This is also evidenced by agglomeration of higher percentage of binders over the explosive crystals confirmed by scanning electron microscope (SEM) thereby bringing down the cohesive forces in the pressed pellets.

The effect of pressure on moulding powders for optimizing the maximum loading density has also been studied for RDX based epoxy resin composition i.e. RDX/epoxy resin; 95/5 and 97/3, and results are presented in Table-4 and Fig. 1 which indicate that increase in pressing load improves the loading density of moulding powder upto 16 Tons deadload and then remains constant.

The optimization of compression strength of moulding powder has also been studied at ambient temperature by varying the pressing load. The data indicate (Table-4; Fig. 2) that compression strength increases up to 16 Tons dead load (Diameter of pellet 30 mm and height of pellet 35 mm) and then, there is no increase in compression strength of the pellets.

Thus, it is evident from the data that epoxy resin based PBX formulations have better loading density, higher velocity of detonation and higher mechanical strength than polyurethane based PBX formulations. Thus epoxy resin based PBX formulations are likely to be very useful where better performance is required but space for explosive charge is comparatively less.

CONCLUSION

The data on explosive and mechanical properties of RDX/Epoxy resin (95/5) and HMX/Epoxy resin (95/5) PBXs suggest that these PBXs are better than polyurethane based PBXs. Therefore, these PBXs hold a potential to replace polyurethane based PBXs as boosters.

ACKNOWLEDGEMENT

Authors are thankful to Director, HEMRL for his valuable comments and for granting permission to publish this work. The authors are also thankful to Shri J.S. Gharia for technical discussions.

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Table – 1 : Analysis of PBXs Based on Epoxy Resin (ER) & RDX/HMX

Sr. No.	Composition	Explosive Percent	Binder Percent
1	RDX/ER (90/10)	89.74 ± 0.5	10.26 ± 0.5
2	RDX/ER (95/5)	94.66 ± 0.5	5.34 ± 0.5
3	RDX/ER (97/3)	96.85 ± 0.5	3.15 ± 0.5
4	HMX/ER (95/5)	94.88 ± 0.5	5.12 ± 0.5
5	HMX/ER (97/3)	96.82 ± 0.5	3.18 ± 0.5

Table-2 : FORMULATIONS AND SOME PROPERTIES OF EPOXY RESIN/PU & RDX/HMX BASED PBXs

Sr No	Composition	TMD* (g/cc)	Expl. Density (g/cc)	Achieved % of TMD (%)	Impact Sensitivity (Height for 50% explosion) (cm)	Friction Sensitivity (kg)	Insensitive to spark upto (Joules)	Shock Sensitivity (Small Scale Gap Test) (mm)
1	RDX/ER* (90/10)	1.70	1.64	96.09	95	28.8	5	8.05
2	RDX/ER (95/5)	1.75	1.69	96.59	87	25.2	5	8.50
3	RDX/ER (97/3)	1.77	1.71	96.67	82	21.6	5	9.00
4	HMX/ER (95/5)	1.84	1.77	96.02	79	21.6	5	8.50
5	HMX/ER (97/3)	1.86	1.79	96.03	73	21.6	5	10.0
6	RDX/PU* (95/5)	1.75	1.66	94.85	47.5	21.6	5	9.0
7	RDX/PU (97/3)	1.77	1.67	94.35	45.0	21.6	5	9.0
8	HMX/PU (95/5)	1.82	1.72	94.50	42.0	21.6	5	8.5
9	HMX/PU (97/3)	1.86	1.73	93.01	43.0	21.6	5	8.5

* ER denotes epoxy resin (Dobeckot – 504)

* TMD : Theoretical maximum density

* PU denotes polyurethane U-5731

Table – 3 : Some Explosive, Thermal and Mechanical Properties of PBXs Based on Epoxy Resin & RDX/HMX

Sr No	Composition	Expl. Density (g/cc)	VOD (m/s)	DP (GPa)	Deflagration Temp. (Heating Rate 5°C/min.) (°C)	Vacuum Stability (5g at 120°C for 40 hrs.) (cc)	Peak Exotherm Temp. (°C)	Compression Strength (kg/cm²)
1	RDX/ER (90/10)	1.64	8126	27.09	222	1.66	213	326.39
2	RDX/ER (95/5)	1.69	8384	29.75	219	1.58	215	308.28
3	RDX/ER (97/3)	1.71	8511	31.01	217	1.53	215	268.15
4	HMX/ER (95/5)	1.77	8676	32.50	268	1.22	264	347.45
5	HMX/ER (97/3)	1.79	8768	34.41	267	1.20	263	290.31
6	RDX/PU (95/5)	1.66	8100	27.22	220	0.55	215	134.0
7	RDX/PU (97/3)	1.67	8300	28.76	215	0.62	220	149.0
8	HMX/PU (95/5)	1.72	8450	30.70	252	0.27	264	224.0
9	HMX/PU (97/3)	1.73	8700	32.73	276	0.30	261	245.0

Table – 4 : Effect of Pressure on Loading Density and Compression Strength of PBXs based on RDX/Epoxy resin (95/5 & 97/3)

Sr. No.	Dead Load (Ton)	RDX/Epoxy Resin (95/5)		RDX/Epoxy Resin (97/3)	
		Experimental Density (g/cc)	Compression Strength Kg/cm^2	Experimental Density g/cc	Compression strength Kg/cm^2
1	2	1.53	170.16	1.54	122.24
2	4	1.56	240.30	1.57	160.76
3	8	1.64	275.20	1.65	214.96
4	12	1.67	290.08	1.69	238.65
5	16	1.69	308.18	1.71	268.15
6	20	1.69	305.60	1.71	264.63

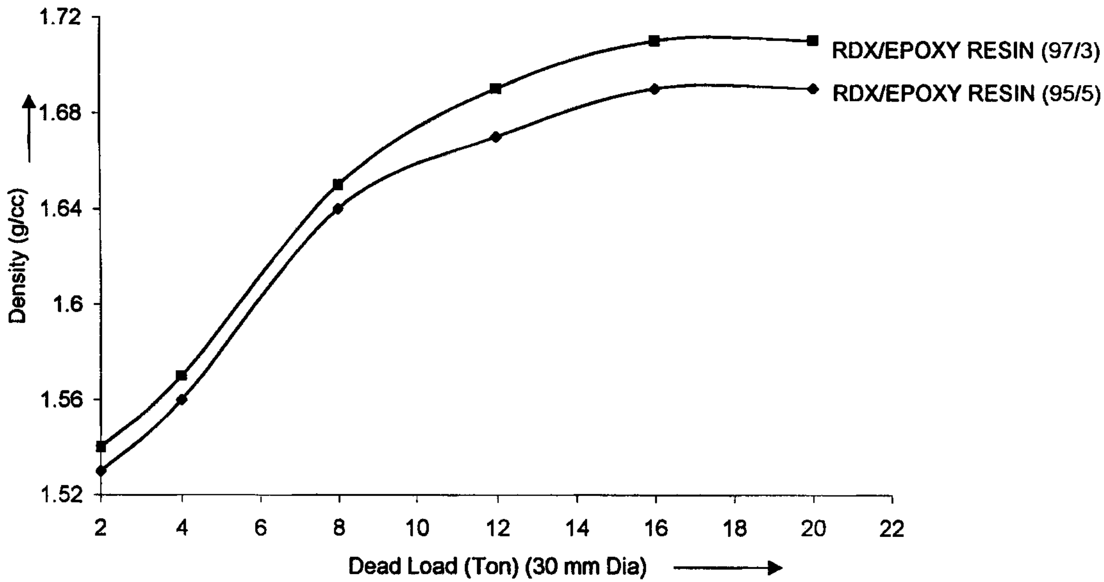

Fig.1 : Effect of Pressure on Density

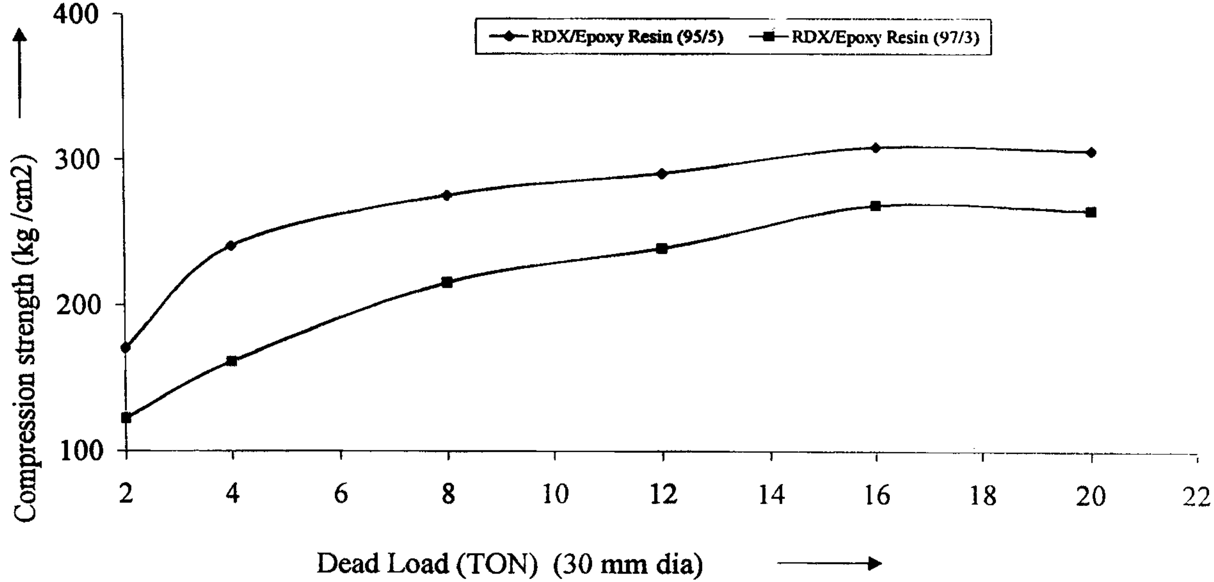

Fig. 2: Effect of Pressure on Compression Strength

NOTES