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TITLE EFFECTS OF BINDER CONCENTRATION ON THE PROPERTIES OF PLASTIC-BONDED EXPLOSIVES

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EFFECTS OF BINDER CONCENTRATION ON THE PROPERTIES OF PLASTIC-BONDED EXPLOSIVES

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A series of plastic bonded explosives (PBX) has been formulated with more binder than is normally contained in high-energy formulations. Adding a relatively small amount of binder to a material such as PBX 9501 [95/2.5/1.25/1.25 wt% HMX/Estane/BDNPA/BDNPF (the BDNPA and BDNPF form a eutectic that is frequently called simply the eutectic)] was found to decrease the shock sensitivity while not decreasing the energy of the explosive. The best compromise for a PBX 9501-type material contains about 92 wt% HMX. Adding additional binder does not continue to decrease the gap sensitivity of the formulation; however, the energy of the PBX decreases as expected. The higher-binder formulations are of potential use because of the possibility of formulating a PBX with energy similar to TATB formulations, such as PBX 9502 (95/5 wt% TATB/Kel-F 800), and with a higher strain to failure.

INTRODUCTION

This study was initiated to determine the effects of binder concentration on the properties of a PBX. The sensitivity of the Estane/eutectic system used for PBX 9501 was not known as a function of concentration. The sensitivity of the system was of special interest when the energy was matched to PBX 9502. The behavior of PBX 9502 like systems is interesting because their unique mechanical properties, such as high strain to failure, might be designed into a useful formulation usable as a substitute for PBX 9502.

Desensitizing high-energy PBXs was another reason for undertaking this work. One of the most important mechanisms for the initiation of explosives is believed to be hot spots caused by voids or other density discontinuities. High energy PBXs, such as PBX 9501, typically can be pressed to 98% of theoretical density (TMD). This means that the explosive composites have about 2 vol% voids that may serve as hot spot locations. It appears that removal of the voids is the logical starting place to desensitize a PBX.

EXPERIMENTAL

The experiments used in this study were the large scale gap test and the plate dent test described by Gibbs and Popolato[1]. The plate dent test is a measure of the energy delivered by an explosive to a calibrated steel plate. It has been found experimentally that this delivered energy can be closely related to the CJ pressure of the explosive being tested. A theoretical basis may be found for this relationship in such works as Fickett and Davis[2]. For this reason it is customary to calibrate the plate dent test to accepted CJ pressures and to report the results as CJ pressure. Because this pressure is a measure of the delivered energy we will refer to the results of the plate dent test as the energy of the explosive.

A low-void material was formulated to investigate the effect of the removal of voids from a PBX. The material to be tested was a formulation with HMX and the Estane/eutectic binder used in PBX 9501 (X 0242 92 01 04 92/8 wt% HMX/binder).

This formulation was chosen to provide more than ample binder to fill all the voids in the composite. To assure elimination of all voids, the PBX was pressed at unusually high pressure (30,000 psi), at maximum permissible temperature (100°C), with maximum vacuum on the powder before pressing, and with five intensifications. The resulting PBX had a density of 99.7% TMD. The CJ pressure and gap sensitivity were measured for this material; the results were CJ pressure of 366 kbar and a gap sensitivity of 47 mm. This compares with values of 360 kbar and 55.6 mm for PBX 9501.[1] These data are included in Table 1. It is possible to formulate a PBX with less sensitivity than PBX 9501 at no loss in energy, perhaps even a small gain.

The pressing conditions used to obtain the void free samples of X 0242 92 01 04 were rather extreme. A pressing evaluation was conducted to evaluate which of the measures used in processing

TABLE 1. PERFORMANCE AND SENSITIVITY OF HIGH-BINDER PBXS

Material	Composition	Gap (mm)	CJ (kbar)	TMD
PBX 9501	95/2.5/2.5 HMX/Estane/eutectic	55.6	363	98.0
X-0242-94-01-03.	94/3/3 HMX/Estane/eutectic	55.1	363	99.1
X-0242-93-01-03.5	93/3.5/3.5 HMX/Estane/eutectic	53.3	364	99.4
X-0242-92-01-04	92/4/4 HMX/Estane/eutectic	47.58	366	99.7
X-0242-91-01-04.5	91/4.5/4.5 HMX/Estane/eutectic	48.46	360	99.6
X-0242-90-01-05	90/5/5 HMX/Estane/eutectic	48.26	355	[illegible]
X-2444	88/6/6 HMX/Estane/eutectic	46	340	99.8
X-2438	80.5/[illegible].5/9.5/[illegible].5 HMX/Estane/eutectic/stearate	47.1	334	95.1
X-2430	88/6/6 HMX/Kraton/Sulfur [illegible]	46	[illegible]	[illegible]

this PBX were responsible for the improved performance. All the variables used in the processing of X-0242-92-01-04 were varied from normal to extreme in an experimental design, and the density of the sample at these conditions was measured. The concentration of the binder and, to a lesser extent, the number of pressing intensifications were found to be the only variables that significantly influenced the densities of the pressed samples. The CJ pressure and the gap sensitivity were redetermined for one sample of X-0242-92-01-04 pressed under nominal pressing conditions. The results reproduced those of the formulation pressed under more extreme conditions. Improved sensitivity in a PBX can be obtained by simply increasing the fraction of binder in the composite while using three intensifications.

To investigate in detail the behavior of the HMX/Estane/eutectic system, a number of formulations were made with HMX compositions varying from 80.5 to 94 wt%. These materials were pressed, the detonation pressures were determined with plate-dent experiments, and the gap sensitivity was measured. These data are listed in Table 1, with the literature values for PBX 9501 included for reference.

All the HMX/Estane/eutectic materials listed in Table 1 made satisfactory pressings with the exception of the 80.5 wt% formulation. This material was extremely "gummy" and tended to extrude around the seals in the press. We were not able to obtain the desired density for this formulation. The properties of this material are interesting even though they are not directly comparable with the other formulations.

The first observation made from the data in Table 1 is that the gap sensitivity falls off dramatically as the HMX in the formulation is decreased, reaching a plateau at about 46 or 47 mm (Figure 1). The second observation is that the energy of the system remains relatively constant as the HMX in the formulation is decreased until the mixture is approximately 92 wt% HMX (Figure 2). This result does not seem too surprising, if one realizes that voids of zero energy are being replaced with an energetic binder. Looking at the results presented in Figures 1 and 2, one concludes that an improved version of PBX 9501 can be obtained by decreasing the HMX content to 92 wt%. The gap sensitivity will be decreased while the energy will remain constant.

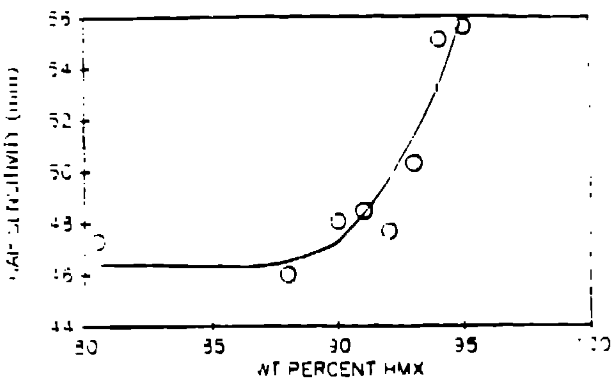

FIGURE 1. GAP SENSITIVITY AS A FUNCTION OF HMX CONCENTRATION.

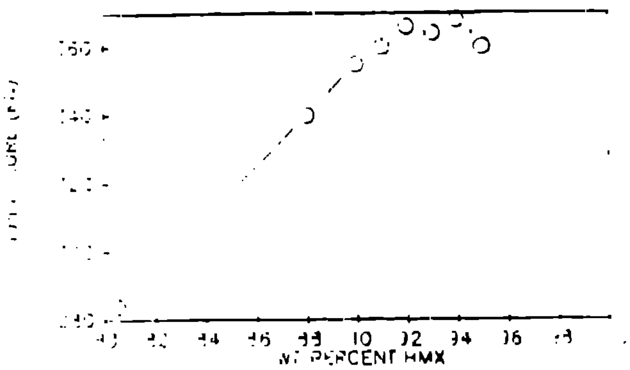

FIGURE 2. CJ PRESSURE AS A FUNCTION OF HMX CONCENTRATION.

Additional insight into the behavior of the HMX/Estane/eutectic system can be obtained by examining the data in Table 1. The per cent TMD is seen to be a function of the binder loading in the system, with the per cent TMD decreasing rapidly as the HMX fraction is increased (Figure 3). There does, however, appear to be a reasonable amount of scatter in the system, which indicates that variables other than binder loading are probably important when trying t

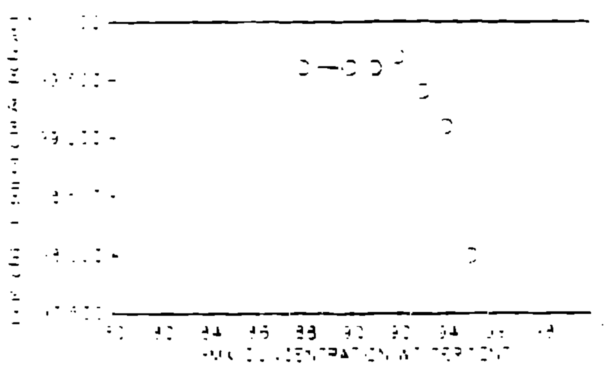

FIGURE 3. PER CENT OF THEORETICAL DENSITY AS A FUNCTION OF HMX CONCENTRATION.

reach very high per cent TMDs. The importance of reaching very high per cent TMDs is seen in Figure 4, where the gap sensitivity is plotted as a function of per cent TMD. It is apparent that a PBX should be at the maximum possible per cent TMD. To obtain the best sensitivity in a HMX/Estane/eutectic formulation, it will be necessary to determine what controls the relatively small differences in pressing densities.

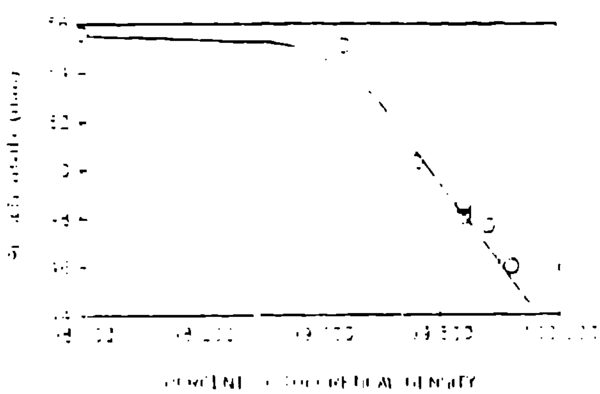

FIGURE 4. GAP SENSITIVITY AS A FUNCTION OF PERCENT OF THEORETICAL DENSITY.

When Figures 1 through 4 are examined, it appears that PBX 9501 may be anomalous. The PBX 9501 data were taken from the literature and may not be consistent with the other data in Table I. Additional experiments are planned to verify the behavior of PBX 9501.

The behavior of binder systems other than the Estane/eutectic is also of interest. A PBX with 88 wt% HMX, 6 wt% Kraton, and 6 wt% Tufflo oil was formulated (X-0430) for this reason. The gap sensitivity and CJ pressure were determined and are reported in Table I. Interestingly, the gap sensitivity is the same as for the high-binder Estane/eutectic formulations. Based on very limited evidence, the gap sensitivity of a high-binder formulation does not appear extremely dependent on the binder material.

One of the purposes for this study was to investigate the properties of HMX-based PBXs with energies similar to PBX 9502's. Two of the formulations discussed above, X-0430 and X-0438, were designed to have the energy of PBX 9502. The energy of these two formulations was indeed very near to that of PBX 9502. The X-0430 performed very much as expected; the HMX coated well and no major problems were encountered in pressing. The X-0438, however, was another problem because the Estane/eutectic is a very soft, rubbery material that flows much too easily and sticks to the metal parts in the press. Excessive amounts of this binder make the samples very hard to press and creates problems in uniformity of material, and produces a pressing that is not dimensionally stable. Additional experiments are planned to investigate the properties of Estane/eutectic binder formulations with decreased amounts of the eutectic. This will provide a stiffer material and perhaps overcome some of the problems of X-0438. The amount of HMX will need to be increased in these experiments to maintain the desired energy level.

CONCLUSIONS

In conclusion, a series of PBXs has been formulated with more binder than is normally used in high energy explosives. It was determined that adding a relatively small amount of binder to a material such as PBX 9501 will improve the gap sensitivity without degrading the energy of the explosive. It appears that the best compromise for a PBX 9501 type material is about 92 wt% HMX. Adding additional binder does not continue to improve the gap sensitivity of the formulation. However, the energy of the PBX decreases as expected. The high binder formulations are of potential use because of the possibility of formulating a PBX with energy similar to PBX 9502's but with a much higher strain to failure and other desirable advantages.

REFERENCES

1. Gibbs, T. and Popolato, A., LASL Explosives Data, University of California Press, Berkeley, 1980, pp 425, 288, 105-119.

2. Fickett, W. and Davis, W., Detonation, University of California Press, Berkeley, 1979.