Modification of PETN plastic explosive

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Abstract*– After long storage, a well-known problem related to missing the flexibility of the plastic explosives usually appeared. In this work, the reformulation of old PETN plastic explosives is presented. The plastic explosive was modified by adding a polymeric matrix based on a non-energetic thermoplastic binder plasticized by dibutyl phthalate (DBP). The crystal morphology after modification was studied by scanning electron microscope (SEM). The heat of combustion was determined experimentally. The compatibility of PETN plastic explosive with the polymeric matrix was studied by vacuum stability test. Sensitivity to impact and friction were determined. The detonation velocity was measured experimentally It was concluded that the old explosive is compatible with the polymeric matrix, and the sensitivity is close to that of the traditional plastic explosives. The detonation velocity is slightly lower than Semtex 1A.

Keywords-- Plastic Explosives, SEM, Compatibility, Sensitivity, Detonation.

I. INTRODUCTION

Several countries around the world manufacture plastic explosives with various explosive fillers bonded by various polymeric matrices. Many studies on the development of plastic explosives, including the preparation, sensitivity, and detonation characteristics of plastic explosives based on several interesting nitramines, have been published [1-7]. The thermal stability and decomposition kinetics of selected nitramines bonded by various polymeric matrices have been investigated using various techniques [9-15], and the low-temperature thermolytic behavior has been assessed using vacuum stability tests [16, 17]. Semtex 10 and Semtex 1A are plastic explosives manufactured by the Czech Republic's Explosia Company. They are used in demolition work and water blasting operations and contain Pentaerythritol tetranitrate (PETN) as an explosive filler bonded by a non-explosive plasticizer [18]. Formex P1 is a French plastic explosive that contains PETN that has been bonded by styrene-butadiene rubber and plasticized with an oily material [9, 16]. Sprängdeg m/46 is a plastic explosive from Sweden that contains PETN bonded by a highly viscous oily material [1, 7].

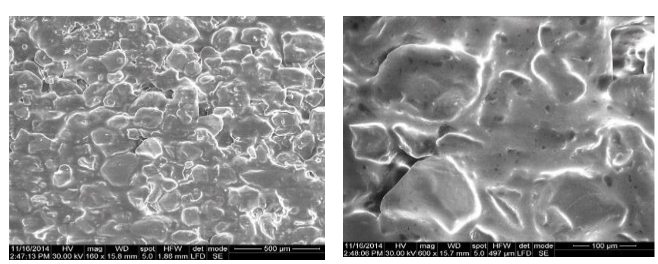
The prepared EPX-1's crystal morphology, sensitivity, and detonation velocity were investigated and discussed. In order to calculate the heat of formation of EPX-1, the heat of combustion and elemental analysis of the sample was determined. The EXPLO 5 thermodynamic code [19] was used to calculate the detonation parameters.

II. REFORMULATION OF PETN PLASTIC EXPLOSIVE

Heliopolis Company for Chemical Industries in Egypt prepared PETN plastic explosive. Jai Enterprises, Delhi, India, manufactures di-butyl phthalate. A non-energetic thermoplastic binder was prepared (unpublished details). The old plastic explosive is directly mixed with a polymeric matrix during the preparation process (binder swelled by dibutyl phthalate). Using a stainless-steel vertical mixer, the old plastic explosive (94% wt.) was mixed with the polymeric matrix (6% wt.) at 70 ^{o}C for 35 minutes under vacuum. The final product was prepared in the form of cylinders, each weighing 200 g. Plastic explosive cylinders in the shape of cylinders were prepared to measure the detonation velocity.

III. CRYSTAL MORPHOLOGY STUDY

The morphology of the coated explosives was studied using a scanning electron microscope (SEM) model Inspect S from the FEI company. SEM photographs of EPX-1 are shown in Fig. 2 to check the coating of the crystals. The polymeric matrix completely coated the PETN crystals, as shown in Fig 2 (a). There were no crystals visible outside of the polymeric matrix. To validate this result, Fig 2 (b) depicted a magnified resolution of EPX-1 with the surface of the crystals completely coated. These findings confirmed that the new polymeric matrix was capable of bonding the crystals and adequately coating their surfaces.



(a) (b)

Fig 2 SEM photos of the prepared EPX-1 explosive

IV. ELEMENTAL ANALYSIS

The Perkin Elmer 2400 CHNS/O elemental analyzer was used to detect the percentages of C, H, and N in the prepared samples, which were required for the theoretical calculation of the prepared sample's detonation parameters. The elemental analysis results were recalculated to match the N content to each individual explosive and are shown in table (1). The summary formula calculated in this manner was used to calculate the detonation parameters of EPX-1 as if it were an individual explosive.

Table 1.
The data required for the calculation of detonation characteristics

No	Explosive type	Formula	Mol. Weight ($g \cdot mol^{-1}$)	Heat of combustion ($J \cdot g^{-1}$)	Heat of formation ($kJ \cdot mol^{-1}$)
1	PETN [7]	$C_5H_8N_4O_{12}$	316.15	8182	-538.7
2	EPX-1	$C_{7.88}H_{12.36}N_4O_{12.59}$	364.58	11528	-666.5
3	Semtex 1A [7]	$C_{9.15}H_{14.85}N_4O_{11.42}$	362.22	14003	-660.2
4	Semtex 10 [7]	$C_{8.05}H_{12.64}N_4O_{12.37}$	363.38	11942	-646.8
5	Formex P1 [21]	$C_{8.26}\ H_{13.98}\ N_4\ O_{11.85}$	358.93	12943	-613.2
6	Sprängdeg m/46 [7]	$C_{8.10}H_{12.81}N_4O_{10.90}$	340.63	13179	-539.2

V. HEAT OF COMBUSTION

The heat of combustion of the samples was measured using an Automatic Combustion Calorimeter MS10A. The sample was prepared and placed in an oxygen-rich bomb [20], and the results of the measurements were reported in table (1). This information was used to calculate the heat of formation of the samples, which was then used to calculate the detonation parameters.

VI. COMPATIBILITY OF THE MATERIALS

The STABIL vacuum stability test, modernized apparatus STABIL 16-Ex [20] (manufactured by OZM Research; the original apparatus is described in Ref. [22]), was used to investigate the materials' compatibility. The polymeric matrix and PETN were combined to form a mass of 2 g. In addition, 4 g of prepared plastic explosive EPX-1 was prepared. Tests were performed at 100 °C for 48 hours under a vacuum at the desired temperature. The PETN result was 0.54 ml g^{-1} (slightly higher than the reference [23], while the polymeric matrix result was 1.32 ml g^{-1}. EPX-1 produced a gas volume of 0.79 ml g^{-1}. The sum of the gas evolved by PETN and the polymeric matrices separately was 0.71 ml g^{-1}, implying that EPX-1 has 0.07 ml g^{-1} more gas evolved than the sum of the gas evolved by the separate components (higher than 5 ml g^{-1} is considered being incompatible). The results show that PETN is compatible with EPX-1's polymeric matrix.

VII. SENSITIVITY MEASUREMENT

A. IMPACT SENSITIVITY MEASUREMENTS

A standard impact tester with an exchangeable anvil (Julius Peters [24]) and a 2 kg drop hammer was used, with the amount of substance tested being 50 mm^3. The probability levels for initiation were determined using probit analysis [25]. In this article, only the 50% probability of initiation was used, as shown in Table 2.

B. FRICTION SENSITIVITY MEASUREMENTS

The sensitivity to friction was determined using a BAM friction test apparatus under standard test conditions [24]. The sensitivity to friction was determined by spreading about 0.01g of the investigated explosive in the form of a thin layer on the surface of the porcelain plate. The normal force between the porcelain pistil and the plate was changed using different loads. Using the Probit analysis [25], the friction sensitivity is reported in Table 2 as the normal force at which 50% of initiations occurred.

Table 2.
The measured characteristics of the studied explosives

No	Explosive type	Impact sensitivity (J)	Friction sensitivity (N)	Density ($g \cdot cm^{-3}$)	Detonation velocity measured ($m \cdot s^{-1}$)
1	PETN [1]	2.9	44	1.70	8400
2	EPX-1	13.9	176	1.55	7636
3	Semtex 1A [1]	21.1	187	1.47	7264
4	Semtex 10 [3]	15.7	204	1.52	7486
5	Formex P1 [21]	13.5	194	1.53	7544
6	Sprängdeg-m/46 [1]	14.2	183	1.52	7520

Figure 3 shows a comparison of the results of impact and friction sensitivities. All of the investigated plastic explosives are based on PETN, and the comparison revealed that all of the polymeric matrices had a significant impact on decreasing the impact and friction sensitivities of PETN. In terms of friction sensitivity, all of the studied samples have friction forces ranging from 175 to 205 N, as shown in the figure, whereas PETN requires 44 N to initiate. The results show that the polymeric matrices used have nearly the same effect on decreasing PETN's friction sensitivity. In terms of impact sensitivity, all of the studied plastic explosives, with the exception of Semtex 1A, have an impact energy of initiation ranging between 13.5 and 15.7 J. Semtex 1A requires more impact energy (21.1 J) to initiate. This result could be attributed to the high wt% polymeric matrix in Semtex 1A (17 wt%). EPX-1 has the same sensitivity level as the other studied explosives, with the exception of Semtex 1A, which has lower impact sensitivity than the other studied plastic explosives.

VIII. Detonation velocity measurements

The detonation velocity of the prepared composition was measured using a KONTINITRO AG EXPLOMET-FO-2000. The composition tested was prepared in the shape of a cylinder with a diameter of 21 mm and a length of 300 mm. Each charge contained three optical sensors, the first of which was placed 100 mm from the surface containing the detonator. Each of the other two sensors was placed 80 mm apart from the previous one. Detonator no. 8 was used to set off the charges. The composition was measured three times, and the mean value (max. 68 m s^{-1}) is shown in Table 2. The results show that EPX-1 has the highest detonation velocity of any of the plastic explosives tested.

IX. Conclusion

This study concluded that EPX-1, a new plastic explosive, contains compatible ingredients. The polymeric matrix completely coats the PETN crystals in EPX-1. EPX-1's sensitivity to impact and friction is comparable to that of the majority of the plastic explosives studied. EPX-1 has the fastest detonation velocity of any plastic explosive studied. EPX-1's calculated detonation pressure and heat of detonation are on par with Semtex 10 and higher than the other plastic explosives studied. Some relationships were investigated and found to be in good agreement with the calculated detonation parameters by the EXPLO5 code and the measured parameters. EPX-1 is an intriguing plastic explosive that could be used in military applications.

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