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MILITARY TECHNICAL COLLEGE

CAIRO - EGYPT

1- # EXPLOSIVE AND DETONATION CHARACTERISTICS OF PBX'S

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4- ABSTRACT

Plastic bonded explosives (PBX) are known as the most modern types of explosives which posses excellent safety and mechanical characteristics in addition to their high energy values and long term thermal stability. PBX's are used in propulsion technology as linear cutting charges for separation between different stages of propulsion and for self-destruction during improper function of the propulsion unit. In this work , the explosive properties of PBXs including detonation velocity, detonatation heat, workability, brisance and sensitivity to different types of impulses were studied. Some of these properties were measured and calculated, moreover a comparison between the obtained results was made.

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1.INTRODUCTION

Castable plastic bonded explosives (PBXs) were developed in the seventies [1]. These formulations were basically RDX or HMX distributed in polyester or polyether prepolymers, they were of relatively low viscosity and were processable by conventional mixing. The main draw back of polyester and polyether PBXs is the brittle and friable nature of the fully polymerized products [2]. The introduction of polyurethanes as binders for these explosive components resulted in more rubbery, less shock sensitive explosives. These advantages will be apparent from the undertaken study which provides explosive compositions based on RDX as solid energetic ingredient, HTPB based binder, a diisocyanate curing agent, a chemically compatible surfactant and aluminium powder. In this investigation, the detonation heat, workability, brisance, sensitivity to different types of impulses and detonation velocity were measured. The detonation velocity is calculated using the modified Kamlet equation at different densities[3].

2.EXPERIMENTAL

The binder and composite sheets (150x150x3) were prepared according to the method described before [4], using a glass laboratory reactor equipped with counter rotating mixer. The materials used for making up the composite explosive compositions and their specifications are listed in Table 1. The detonation heat is determined using a calorimetric bomb. The sensitivity to impact is determined using Kast method. The sensitivity to friction is determined by Koenen & Ide friction apparatus, while sensitivity to heat is evaluated by ignition temperature and ignition delay. Workability is measured by Trauzel lead block test and the brisance is determined by Kast method.

3.RESULTS AND DISCUSSIONS

3.1.Detonation Velocity:

Different detonation velocity values for PBXs may be obtained as a result of varying the explosive type or proportion, the binder and / or additives. In general, we can say that the detonation rate of the composite is a function of both the amount and the properties of each ingredient. This may be understood on the basis of the fact that the detonation velocity of an explosive is a function of the chemical energy released, and the initial density of explosive [5].

3.1.1.Variation of the detonation velocity with density:

To study the effect of variation of the density on the detonation velocity, the detonation velocity values for hexogen and for a sample of PBX based on RDX were calculated at densities of 1, 1.1, 1.2, 1.3, 1.5, 1.6 and 1.7 g/cm , and also at the theoretical maximum density using the modified Kamlet equation.The results are plotted in Fig.1, from which we conclude that:

a- the increase of the density considerably increases the detonation velocity.

b- the detonation velocity of PBXs has reasonable values which are very near to those of the initial explosive (RDX).

3.1.2. Variation of the detonation velocity with additives:

To study the effect of additives on the detonation velocity, the latter was measured and calculated for a sample having the composition (RDX/ PPU : 80/20) as well as other samples containing Aluminium, Ammonium perchlorate, or Lead nitrate at the expense of RDX.

The data listed in Table 2. are the measured and calculated detonation velocity values. From which it is clear that all measured values are in the same range and close enough to the calculated values.

The effect of variation of percentage of the additive upon the detonation velocity is shown by calculating the detonation velocity values corresponding to percentage of the additive 1,2 .... up to 8% Al, AP or $Pb(NO_3)_2$. The results are plotted in Fig.2., from which one can see that the presence of Al, AP, $Pb(NO_3)_2$ in a PBX sample at the expense of RDX decreases the detonation velocity of the composite.

3.2.Detonation Heat:

The detonation heat (amount of heat liberated during the explosive conversion of unit mass of the explosive material in the absence of oxygen) was measured using a calorimetric bomb. Table 3. shows the effect of the composition of PBX on the detonation heat for various samples. From the listed data we can deduce the Following:

a- the heats of detonation based on RDX and plasticized polyurethane are slightly less than that of pure RDX. but still of reasonable value (higher than that of TNT).

b- the detonation heat decreases by increasing the binder (PPU proportion) and this is obviously due to the decrease in the energetic material.

c- the presence of aluminium in PBX samples increases considerably the value of the detonation heat for these composites.

d- by adjusting the composition of PBX , we can obtain different values of detonation heat. Table 3a,b. shows a wide range for detonation heat from 780 to 1295 Kcal/Kg.

3.3. Workability of PBXs:

The workability of PBXs was measured using Trauzel method. The increase in volume of the cavity of lead block is measured and compared to that of TNT. From the data listed in Table 4., one can say that, the workability of PBXs is in general higher than that of TNT but slightly less than that of RDX.

3.4.Brisance of PBXs:

The brisance, which is the ability of explosive to crush, during the explosion, the objects lying in its vicinity, was measured using Kast apparatus. The brisance is estimated from values recorded for copper cylinders compression. From the results shown in Table 4., it is clear that the brisance of PBX is slightly less than that for the original pure explosive (RDX) on which it is based, but still has reasonable values which is much higher than that for TNT (31% more than that of TNT).

3.5.Sensitivity of PBXs:

The sensitivity of PBXs to different impulses was determined and studied throughly.

3.5.1.Sensitivity to impact:

The sensitivity to impact was determined using Kast method. From the results shown in Fig.3. we can conclude that:

a- sensitivity of PBXs to impact decreases considerably by increasing the binder proportion at the expense of RDX.

b- plastic bonding of explosive materials is an excelant technique for desensitization of high explosives since they posses both merits of having better desensitization and reducing less energy.

3.5.2.Sensitivity to friction:

The sensitivity to friction was determined using the apparatus of Koenen & Ide. The experimental results are shown in Fig.4., from which we can see that, as in the case of the sensitivity to impact, the sensitivity of PBXs to friction decreases by increasing the binder proportion. It is also clear that the sensitivity of PBXs is much less than those of RDX and TNT, thus it is proved experimentally that PBXs are more powerful but less sensitive than TNT.

3.5.3. Sensitivity to heat:

The dependence of induction period of ignition on temperature was determined and thus the values of ignition temperature after a 5 seconds for PBX samples may be determined. These values of ignition temperatures are considered as a measure for the comparison of relative sensitivity to heat.

From the data recorded in Table 5., we can see that PBXs are thermally stable, and their sensitivity to heat is slightly different from the sensitivity of the parent explosives from which they were prepared. The slight decrease in the ignition temerature value is due to the presence of plasticized polyurethane.

We can also say that the presence of aluminium enhances stability to heat, and increases the temperature of ignition after 5 seconds delay. This may be attributed to the high melting points of Al and Al_2O_3, which are 660 °C and 2030 °C respectively.

3.6.Ignition Temperature:

The ignition temperature for PBXs were measured using classical method and thermogravimetric analysis. Table 6. shows the values obtained from the two methods. The presence of polymeric binder decreases slightly the ignition temperature.

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TABLE.1.
LIST OF MATERIALS

Material	Trade Name	Sources and Specifications
Hydroxyl terminated polybutadiene	HTPB	-Philips Petroleum Co. USA. -Hydroxyl value= 0.95 mg eq. OH/ g. -Viscosity= 110 poise at 20 C
1,2,6 Trihydroxy hexane	THH	-Aldrich Chem. Co., ENGLAND. - ρ=1.11 g/cm ^{3}
Diphenyl methane-4,4-di- isocyanate	MDI	-Merck GERMANY. -Isocyanate value= 7.9 mg eq.NCO/ g.
2,4- Toluene di-isocyanate	TDI	-Aldrich Chem. Co., ENGLAND. - =11.38 mg eq.NCO/g.
Ferric acetyl acetonate	$Fe(AAc)_3$	-Aldrich Chem. Co., - m.p.=182-185 C
Di-iso-octyl pthalate	DIOP	-BDH, ρ=0.98 g/cm^3
Hexogen	RDX	-RUMANIA, ρ=1.816 g/cm^3
2,4,6 Trinitro toluene	TNT	-SNPE, FRANCE - ρ =1.65 g/cm^3 -m.p.=82 C
Ammonium perchlorate	AP	-SNPE, FRANCE - ρ =1.952 g/cm^3
Lead nitrate	$Pb(NO_3)_2$	-Morgan,EGYPT
Aluminium	Al	_VEB,DDR.

Table (2)

Measured and Calculated Detonation Velocity Values for PBXs Containing Additives

Sample	Composition, wt. %	D, m/sec	
		Measured	Calculated
K_1	RDX / PPU 80 , 20	6950	7000
K_2	RDX / PPU / Al 79 , 20 , 1	6720	6750
K_3	RDX / PPU / Al 75 , 20 , 5	6175	6200
K_4	RDX / PPU / Al 72 , 20 , 8	6080	6100
K_5	RDX / PPU / AP 79 , 20 , 1	6490	6500
K_6	RDX / PPU / AP 75 , 20 , 5	5630	5650
K_7	RDX / PPU / AP 72 , 20 , 8	5480	5500
K_8	RDX / PPU / $Pb(NO_3)_2$ 79 , 20 , 1	5775	5800
K_9	RDX / PPU / $Pb(NO_3)_2$ 75 , 20 , 5	2980	3000
K_{10}	RDX / PPU / $Pb(NO_3)_2$ 72 , 20 , 8	2290	2300

Where: D = detonation velocity of explosive, m/sec.

Table 3 a

Measured and Calculated
Detonation Heats for PBXs

Sample	Explosive	Q, k cal/kg	
		Measured	Calculated
L_1	RDX	1255	1260
L_2	TNT	995	1005
L_3	RDX/PPU 83,17	1125	1140
L_6	RDX/PPU 75,25	828	840
L_8	RDX/PPU/TNT 83,16,1	1180	1195
L_{10}	RDX/PPU/TNT 83,14,3	1217	1235

Where:

Q = detonation heat, k cal/kg.

Table 3 b

Measured Detonation Heat for PBXs

Sample	Explosive	Q k cal/kg	Sample	Explosive	Q kcal/kg
L_1	RDX	1255	L_8	RDX/PPU/TNT 83,16,1	1180
L_2	TNT	995	L_9	RDX/PPU/TNT 83,15,2	1195
L_3	RDX/PPU 83,17	1125	L_{10}	RDX/PPU/TNT 83,14,3	1217
L_4	RDX/PPU 82,18	1080	L_{11}	RDX/PPU/Al 75,20,5	1025
L_5	RDX/PPU 81,19	1020	L_{12}	RDX/PPU/Al 75,17,8	1175
L_6	RDX/PPU 75,25	828	L_{13}	RDX/PPU/Al/TNT 75,15,8,2	1205
L_7	RDX/PPU 70,30	780	L_{14}	RDX/PPU/Al/TNT 75,14,8,3	1295

Where:

Q = measured heat of detonation, k cal./kg .

Table 4.

Workability and Brisance of Plastic Bonded Explosive

Composition, wt. %	RW	RB
RDX (Pure)	155	145
RDX (Flegmatized)	140	130
RDX, PPU:		
75 , 25	130	125
80 , 20	140	131
85 , 15	147	139
RDX , PPU , TNT :		
80 , 18 , 2	143	135
RDX , PFHC :		
90 , 10	149	142

Where

RW = relative workability, % TNT.

RB = relative brisance, % TNT.

Table 5

Explosion Temperatures After 5 Seconds Delay

No.	Explosive	T_5, °C
1	TNT	458
2	RDX	260
3	RDX / PPU	
	75 , 25	245
	80 , 20	250
	85 , 15	255
4	RDX / PPU / Al	
	75 , 20 , 5	277
	77 , 20 , 3	270
	79 , 20 , 1	261
5	RDX / PPU / TNT	
	77 , 20 , 3	259
	78 , 20 , 2	257
	79 , 20 , 1	253

Where:

T_5 = Explosion temperature after 5 seconds, °C

Table (6)

Ignition temperatures of some explosives
and explosive compositions

No.	Explosive Composition, wt.%	T_M	T_{TA}
1	RDX	220.0	215.0
2	TNT	300.0	296.0
3	RDX/PPU: 73,27	193.0	194.0
4	RDX/PPU: 85,15	203.0	205.0
5	RDX/PPU/Al: 80,15,5	202.0	204.0
6	RDX/PPU/AP: 80,15,5	200.0	201.0
7	RDX/PPU/TNT: 75,23,2	201.0	203.0
8	RDX/PFHC: 90,10	210.0	213.0

T_M = ignition temperature measured by using convetional method, °C.

T_{TA} = ignition temperature measured using TGA,°C.

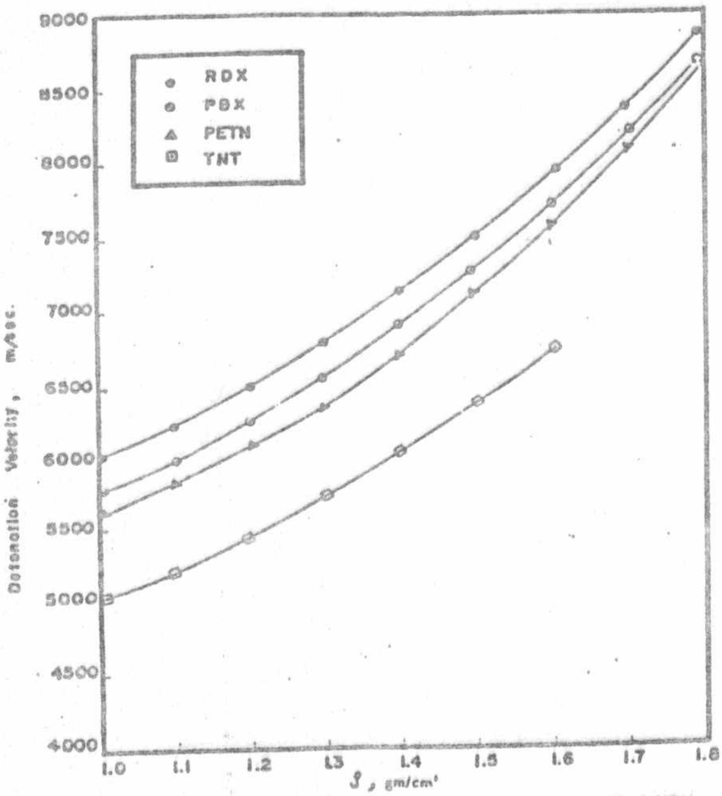

Fig.(1). EFFECT OF DENSITY ON DETONATION VELOCITY FOR DIFFERENT EXPLOSIVES

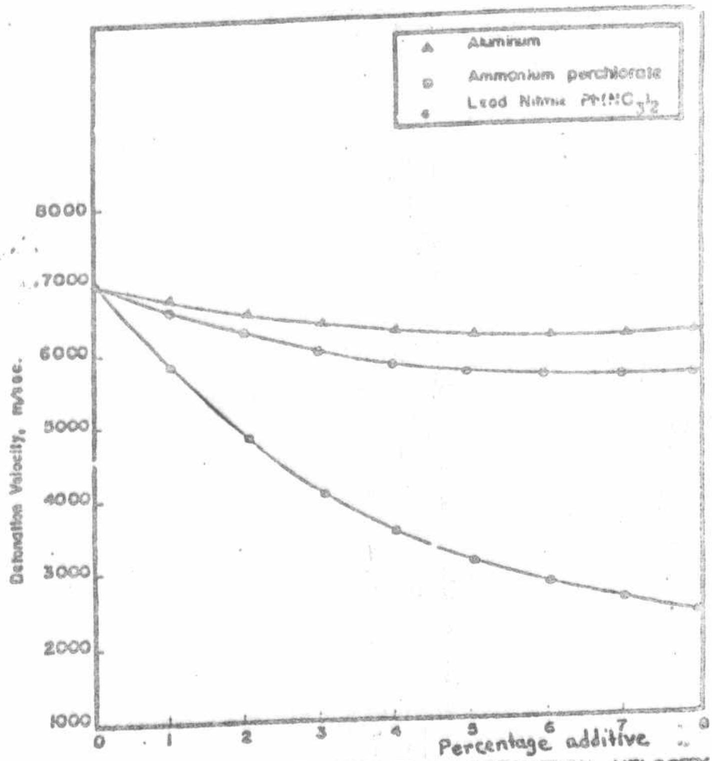

Fig.(2) EFFECT OF ADDITIVES ON DETONATION VELOCITY OF PBXS

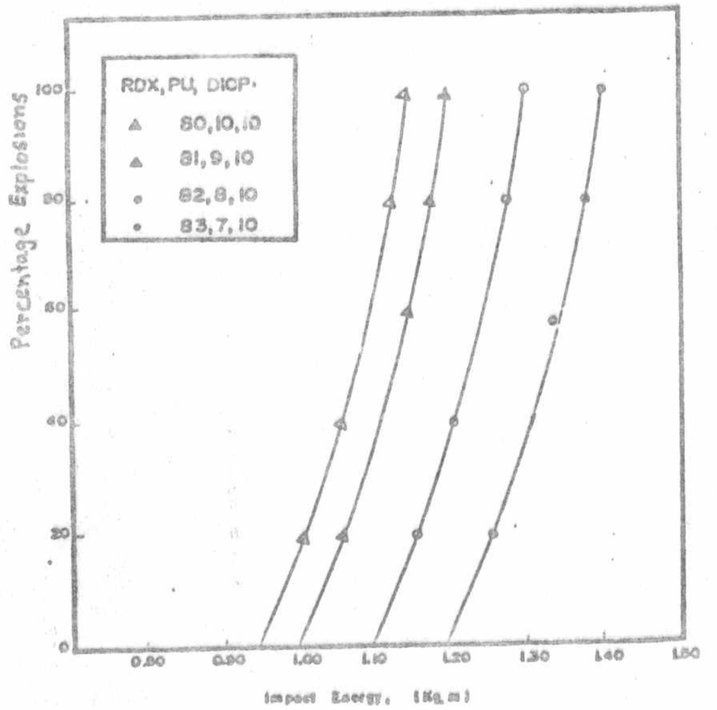

Fig.(3). RELATION BETWEEN IMPACT ENERGY AND PERCENTAGE EXPLOSIONS

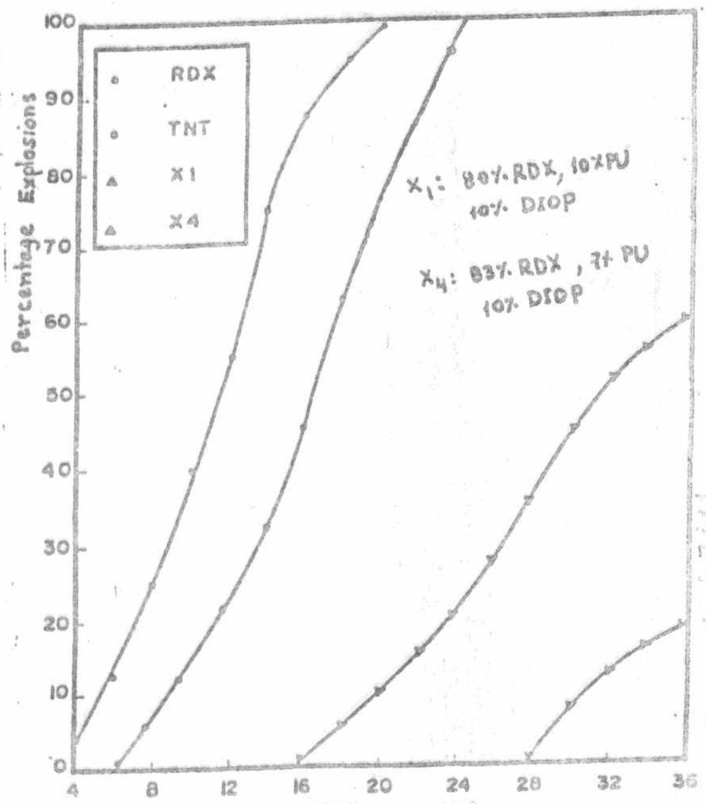

Fig.(4). SENSITIVITY OF PBXS TO FRICTION