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Replacement of Comp-B by Plastic Bonded Explosives In a Selected Warhead

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Abstract
A Plastic Bonded Explosives (type PU/RDX) was prepared and cured by casting technique. This aimed for producing a new generation of warheads with high performance and low sensitivity. The obtained PBXs were characterized by determination of melting point, and measurement of some explosive characteristics (Sensitivity to impact and ignition temperature). Properties of this explosive were compared with those of RDX and comp- B by using a computer program. An autodyne program was used to compare the terminal ballistic parameters of 122 mm warhead for different types of explosives (Inert PBXs, energetic PBXs, RDX, and Comp-B). Results show advantages of using energetic PBXs over the other explosives.

Key Words Plastic bonded explosives, PBXs, Composition B, RDX, Autodyne Program, 122mm Warhead, Natural Fragmentation**.**

NOMENCLATURE

BAMO	Poly-3-biazidomethyl-oxetane
BX	Styrene
DBS	Dibutyl sebacate
DOA	Diiso-octyl adiabate
DOS	Diiso- octyle sebacate
HDI	Hexamethylene diisocyanate
HTPB	hydroxy terminated polybutadiene
MAPO	Tri (2-methyl-1-aziridinyl) phosphine oxide
PU	Polyurethane
RDX	Cyclotrimethylenetrinitramine (Hexogen)
TDI	Tolyene diisocyanate
TNT	Trinitrotoluene

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1. Introduction

The design of weapon system requires the use of explosive and propellant formulations having enhanced performance (output energy) and reduced vulnerability during storage and transportation. The need for Insensitive Munitions has arisen from a number of accidents involving ordnance use and storage. Some of these accidents have been catastrophic with great loss of life, operational effectiveness and severe damage to expensive and important platforms and equipment **[1-4]**.

Plastic-bonded explosive (PBXs) is an explosive material in which explosive powder is bond together in a matrix using a synthetic polymer ("plastic"). PBXs are normally used for explosive materials which aren't easily melted able to cast or which are otherwise hard to form **[5-7].**

Insensitive munitions (IM) are those which reliably fulfill their performance, readiness and operational requirements on demand, but in which the violence of response to unplanned hazardous stimuli is restricted to an acceptable live. The main desired advantages of new energetic materials are: Low vulnerability, increase of energetic performance, increase thermal stability, improvement of mechanical properties, burning rate extension (rocket, gun propellants), Low signature, less environmental damage and Low cost **[7-9].**

The sensitivity of secondary explosives can be reduced by **[10]**:

(a) Reduction of the sensitiveness of the explosive components by changing their crystal properties (insensitive or reduced sensitivity RDX, I-RDX);

(b) Replacement of sensitive explosives by less sensitive (and unfortunately also less powerful) substances (insensitive high explosives IHE, e.g. TATB, NTO);

(c) Embedding of the explosive in an elastic binder matrix (PBXs);

(d) Low-cost melt-cast explosives with reduced sensitivity (e.g. TNT/NTO formulations).

1.1 AUTODYN

AUTODYN Century Dynamic, Inc. (2003), is a hydro-code program which is especially suited to the solution of interaction problems of different system of structure, liquid and gas together, as found in blast and ballistic applications. It has integrated pre-processor, post processor and analysis execution code together, which make it easy to use. AUTODYN allows different solvers (or processor), such as Lagrange and Euler to be used together in the same model [**11**].

2. Experimental

2.1 Raw Materials of Plastic-Bonded Explosive (PBXs):

The raw materials used are shown in Table (1).

2.2 Preparation of PBXs Based on RDX/PU by Casting Technique

The calculated amounts of HTPB as prepolymer, RDX and DOA as plasticizer were accurately weighed. HTPB was then placed in a mixing kettle and mixed with two thirds of DOA weight. RDX was then added in small portions during mixing for ½ hour. Through mixing was conducted for about 10 min after complete addition of RDX to ensure complete coating. The residual amount of DOA , MAPO as bonding agent and TDI as curing agent , calculated on basis of NCO/OH=1.1, were added to the mixture and mixing continued for about 15 minutes. The formed matrix (paste) was then pressed into the mold relevant to each test. The prepared compositions were cured for 7days at 55-60 ºC. Fig (1) show the Prepared PBXs (RDX-PU 88:12)

2.3 Characterization of the Prepared Products

(a) Determination of sensitivity to heat (Ignition temperature)

The ignition temperature was performed by using deflagration test apparatus under standard test conditions **[12].**Three samples of 0.2 g each were dried up and ground to suitable particle size then inserted into 3 test tubes which were placed vertically into the heating block and the temperature was uniformly increased (5 °C/min) until deflagration of the sample occurred. The ignition temperature was read digitally and the average temperature for the three samples was calculated.

(b) Determination of sensitivity to impact

Sensitivity to impact test was carried out by drop hammer test under the standard test conditions. The experiment was conducted using a weight of 5 kg and by changing the drop height. Six consecutive trials were performed for each drop height. The minimum height at which 100% initiation occurred was determined (the upper sensitivity limit); thus the energy required to initiate the explosive could be estimated.

2.4 Simulation by AUTODYN

An AUTODYN program was used to compare the terminal ballistic parameters of 122 mm warhead using Natural fragmentation. Figure (2) show the dimension of 122 mm warhead. Library material in autodyne was used for different types of explosives (RDX, Comp-B, Inert PBXs [RDX 92%, PU 8 %], and energetic PBXs-9407 [RDX 94%, FPC (461) 6%], FPC (461) Copolymer of Vinyl Chloride/ Cholorotri-Fluoroethylene 1.5:1]).

2.5 Computer Code

A computer program was written for calculation of the main explosive characteristics of various prepared plastic bonded explosive compositions. This program was prepared by using Q.BASIC programming language. This computer program can be used to calculate explosive characteristics for explosive formulations free of or containing aluminum and / or fluorine. It can also be employed for either negative or strongly negative oxygen balance explosives. The input data required to run the program are the summary formula of the explosive composition, density (ρ) and standard internal energy of formation (U_f at 298 ^oK) of this composition**[13]**.

3. Results And Discussion

3.1 Sensitivity to Heat

Sensitivity of the prepared PBXs (RDX-PU 88:12) explosive formulations to thermal impulses was examined by measuring the ignition temperature it was found as 210 ºC which is less than pure RDX (222ºC) and Comp B (239 ºC)**.**

3.2 Sensitivity to Impact

The impact Sensitivity of RDX/PU (88:12) explosive formulation (15 NM) was less than that of pure RDX (7.4 NM) and comp B (12.5 NM) **[14, 15]**.

3.3 Results of Thermo Chemical Calculations For PBXs Formulations

The characteristics of explosive formulations are very important for theory and practice, because they allow evaluation and comparison of explosives and are necessary to determine the explosive composition which gives the required high performance. Besides the composition of products of explosive conversion there are also the specific volumes of products, explosion heat, and explosion temperature, power of explosive and explosive pressure. Knowing the composition of products of explosive conversion make it possible to calculate the other characteristics of explosives. The explosive characteristics of PBXs, TNT, RDX, and Comp-B were calculated by using thermodynamic program and the results are shown in table (2).

It is obvious that PBXs close to Comp-B in all characteristic, except in explosion temperature in which value of Comp B is the higher.

3.4 Results from AUTODYN Software

Energetic PBXs shows the highest fragmentation, followed by RDX, Comp-B, and Inert PBXs respectively. Figure (3) shows the drawing of 122mm warhead in Autodyne program in 2 dimensions

4. Conclusions

The experimental work showed that the PBXs can successfully be prepared in laboratory. Theoretical calculations obtained from the computer program showed that the explosives characteristics of PBXs are closed to that of Comp-B, with an exception in explosion temperature.

From autodyne program it is obvious that energetic PBXs have the highest fragmentation performance, followed by RDX, Comp-B, and lastly Inert PBXs.

The Impact Sensitivity of RDX/PU (88:12) explosive formulation (15 NM) is less than that of pure RDX and comp-B

Sensitivity of the prepared PBXs (RDX-PU 88:12) to thermal impulses was examined by measuring the ignition temperature and it is found to be 210 ºC which is less than those of pure RDX and Comp-B.

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Table (1) Raw Materials Used In Experimental Work

No	Material	Percentage of Ingredients %	Function
1	DOS	2.4	Plasticizer
2	HTPB	8.96	Prepolymer
3	MAPO	0.01	Bonding agent
4	RDX 125 µm crystal size	88	Explosive
5	TDI	0.63	Curing agent
6	PX	-	Solvent

Table (2) Explosive Characteristics of TNT, RDX, Comp B and PBXs Explosives

Name	TNT	RDX	Comp B	PBX RDX/PU (88:12)
CO (mol)	13.541	10.056	14.114	10.42
CO_2 (mol)	2.923	3.443	2.513	1.67
H_2O (mol)	7.011	10.056	7.529	10.28
H_2 (mol)	3.908	3.443	4.970	8.01
N_2 (mol)	6.6	13.5	6.24	11.93
C (mol)	14.35	ZERO		8.14
Oxygen Balance O.B	-73.92	-21.6	-42.96	-55.52
Total no mol	34.064	40.5	34.367	42.31
Specific volume cm^3/g	763.054	908	792.235	947.75
Explosion heat k cal/kg	1068.64	1271.12	1115.307	1097.69
Explosion force J/g	1007.823	1452.40	1231.195	1215.01
Explosion Velocity m/s	7023.299	8553.38	7857.713	7578.21
Explosion Pressure kbar	203.966	332.87	270.128	241.2
Explosion Temperature K	3558.497	4309.59	4187.073	3454

Table (3) Main Technical Performance Parameters of 122mm Warheads

ITEM	VALUE
Total mass of warhead (kg)	20.8
Total length of warhead (mm)	689.5
Diameter of warhead (mm)	121
Mass center of warhead (mm)	310.5
Detonation charge type Mass of detonation charge	blunt RDX 0.1 kg

Table (4) Fragmentation Information of 122mm Warheads

material	Number of Fragment
Energetic PBXs	3870
RDX A-3	3687
Comp-B	3366
Inert PBXs	2879

Fig (1) Prepared PBXs (RDX-PU 88:12)

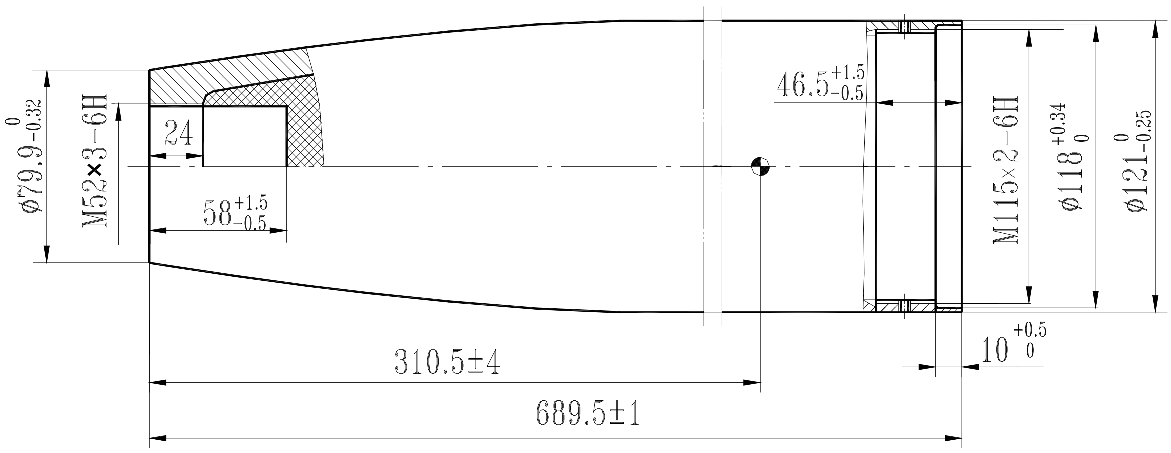

Fig (2) Dimension of 122mm Warhead

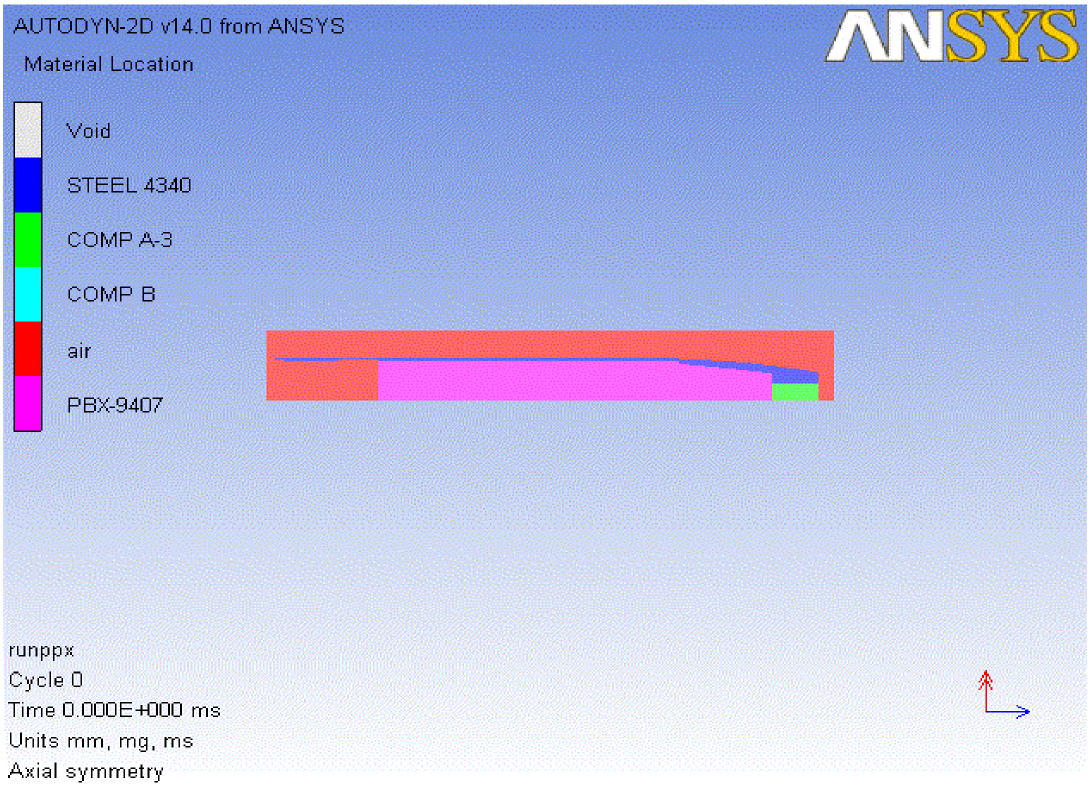

Fig (3) Drawing of 122mm Warhead in Autodyne Program in 2 Dimensions