HIGH BLAST EXPLOSIVE COMPOSITION FOR ANNULAR THERMOBARIC AMMUNITIONS

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In the context of modern warfare, where the combatants need to engage targets in bunkers, caves, buildings and other semi-confined or enclosed spaces, the use of thermobaric or enhanced blast explosives is more suited due to their sustained overpressure and additional thermal effects.

In this study we propose a new high blast explosive composition, with low sensitivity, based on hexogen (RDX), aluminum (Al), magnesium (Mg) and an energetic organic binder, designed for annular thermobaric ammunitions.

By combining a polyol with an isocyanate and an energetic plasticizer we have attained an energetic binder that sustains the deflagration of the aluminum/magnesium mixture, hardens the thermobaric composition, and decreases the explosive sensitivity to mechanical stimulus.

Keywords: composite, energetic binder, explosive, RDX, thermobaric

1. Introduction

While the German army was the first one to use volumetric weapons in the World War II, Russia was the one to initiate the development of thermobaric weapon systems with a self-deflagrating mixture made of magnesium (Mg) and isopropyl nitrate (IPN).

Volumetric weapons are widely used, both outdoors and within protective structures. Nowadays, there is a high concern regarding the study and development of new weapons capable of generating a higher blast and higher impulse in order to destroy walls, to expand effectively in the corners and to collapse the reinforced targets [1, 2]. They include thermobaric and fuel-air

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explosives (FAE, aerosol bombs) characterized by the creation of a large fireball and good blast performance [3].

Thermobaric weapon systems effects and advantages were highlighted when Russia has employed this type of weaponry extensively in Afghanistan and Chechnya but did not receive extensive attention until U.S. Forces bombarded Gardez Mountains, in eastern Afghanistan, on March 3th, 2002 [4]. The pressure waves propagated through the Afghanistan caves and tunnels system, caused major damage within the subterranean mazes, proving thermobaric explosive has some considerable advantages in a modern battlefield, where the enemy forces are hiding in bunkers, caves, buildings and other semi-confined or enclosed spaces[3].

The thermobaric explosives (TBX) and enhanced blast explosives (EBX) are defined and categorized as liquid and solid mixtures, and advanced compositions including layer charges. Both in EBX and TBX, some anaerobic and aerobic reactions occur. In EBX formulations, the metallic fuel reacts mostly in the anaerobic stage without participation of the oxygen from air, thus resulting in an important energy liberation which participates in the process of sustaining the initial blast wave and impulse. In TBX formulations, the aerobic metallic reactions dominate, and the liberated combustion energy produced yields a moderate pressure and high temperature for a longer time in the last stage of the explosion after the detachment of the shock wave [3, 5].

Thermobaric explosive (TBX) consists of a certain central charge (called the core), which is usually a high explosive, and an external secondary charge (fuel-rich formulation). Therefore, the detonation of TBX consists of a dual action: (1) Firstly anaerobic action (without air oxygen) inside the conventional high explosive core occurs; (2) Then aerobic delayed burning action of the fuel mixture of the outer charge happens which depends mainly on the consumption of the surrounding air [6]. In a thermobaric weapon, the fuel consists of a monopropellant or secondary explosive designed to exploit the secondary combustion resulted from active metal particles they contain like Boron, Al, Silicium, Titanium, Zirconium and Carbon, mostly [7–10]. This metal combustion process raises the temperature of the gaseous product cloud as well, and meantime strengthens the shock wave. This phase is generally referred to as after burning or late-time impulse which can occur outside the detonation core and is able to add to the total impulse within fraction of a millisecond inside a building or up to one second within a tunnel [9, 10].

In confined spaces, if the solid fuel is ignited early in the dispersion process, transition to full detonation is not a requirement for enhanced blast occurrence because the efficacy of the thermobaric weapon is based on the effective utilization of the pressure effect. A series of reflective shock waves generated by the detonation leads the hot detonation gases and metal particles to be mixed and the metal particles are compressed at the same time [3]. Combustion in the immediate vicinity of a thermobaric explosion depletes the use of oxygen making it extremely dangerous for the subject to breathe.

The shock waves of conventional explosives are effective locally and substantially decrease while moving away from the explosion center. Thus, the conventional explosives have quite limited effects on combatants under the protection of fortified systems [1, 5].

In this context we propose the development of a high blast explosive composition, with low sensitivity, based on RDX explosive [11], Al, Mg and polyurethane, designed for annular thermobaric ammunitions.

The binder's nature directly influences the mechanical features of the composite material. A perfect binder should possess a low Tg (glass transition temperature), good traction/compression strength, good shock resistance, and a long shelf life [12]. Energetic binders/plasticizers are chemical compounds that poses energetic groups (like nitro, nitrate, azido) and can also contribute to the energetic output of the explosive mixture.

2. Experimental section

2.1. Materials

Aluminum (Al "I.D.F" Fair Pebtrade), magnesium (Mg "MPF-2", Fair Pebtrade), diphenylmethane-4,4′-diisocyanate (MDI, Fair Pebtrade), Sethatane D 1160 (Fair Pebtrade), phlegmatized hexogen (RDX, S. CARFIL S.A.) were used as received. Triethylene glycol dinitrate (TEGDN), an energetic plasticizer, was synthesized at MTA according to literature data [13].

2.2 Methods

Given the effect of a thermobaric composition, the long-term high temperature explosion using atmospheric oxygen, the process of making such a mixture is based on a solid ternary mixture, aluminum-magnesium-hexogen, which is added to a liquid prepolymer-curing agent-energetic plasticizer mixture.

After the complete homogenization of the composition, the resulted mixtures were wet pressed into cylindrical shapes, having 62 mm inner diameter × 108 mm inner height, with a central charge (core) to host the detonating system. The charge recipient was manufactured using an additive technology available in our research facility [14, 15]. The structure of the system is illustrated in Fig. 1. Based on the loading chamber, various parameters were determined by calculus or experimental trials: geometric characteristic (diameter, thickness, area, volume); physical characteristics of the energetic charge (loading density, pressing time, confinement); interactions between the thermobaric components and other elements of system, such as the ignition compound.

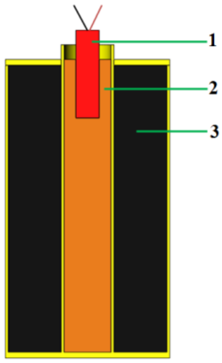

Fig. 1. System configuration
(1 – electric detonator, 2 – central charge, 3 – thermobaric mixture)

Table 1 shows the composition of the TBX formulations we used in the experiments.

Table 1

TBX formulations

Thermobaric mixture acronym	Compound proportion [%]					Experimental loading density [g/cm^3]
	Binder matrix		Al	Mg	RDX ph	
	BM 1	BM 2				
TBX A-20	20	-	35-55	15-25	10-20	1.31
TBX A-15	15	-	40-60	15-25	10-20	1.29
TBX A-10	10	-	45-65	15-25	10-20	1.29
TBX A-5	5	-	50-70	15-25	10-20	1.25
TBX B-20	-	20	35-55	15-25	10-20	1.30
TBX B-15	-	15	40-60	15-25	10-20	1.26
TBX B-10	-	10	45-65	15-25	10-20	1.27
TBX B-5	-	5	50-70	15-25	10-20	1.24

2.3. Characterization

The thermal behavior of thermobaric compositions was studied using an OZM 551 Ex Differential Thermal Analysis (DTA) apparatus. 2 tests were performed for each sample, where 30 mg were heated from 20 to 450 ° C with a heating rate of 5 ° C / min.

The friction sensitivity was evaluated using a BAM friction apparatus, where 30 tests were carried out for each sample with maximum loading force of 36 daN.

Pressure values were recorded in an open space test facility, by means of three piezoelectric transducers, PCB 102B06. The PCBs were mounted side-on at distances of 1 m, 2 m and 3 m from the central axis of the test system. Each sample was initiated from the top with the use of an electrical blast cap, as in Fig. 1. For data acquisition, a PicoScope® 6 - PC oscilloscope and a PHOTRON high speed camera, were used, for overpressure and dimensional measurements [16]. In Fig. 2, is depicted an overview of the experimental setup. The dimensions of the fireball was evaluated using a dedicated image processing software (Image Pro Plus).

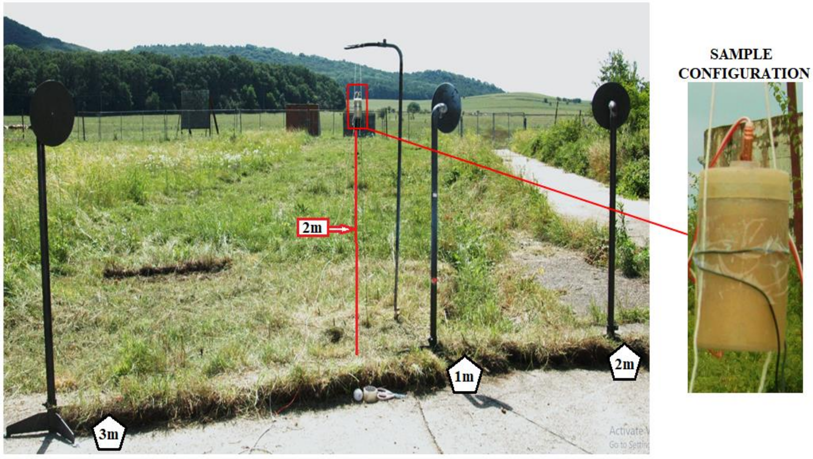

Fig. 2. Experimental setup, overview

3. Results and discussion

Thermal stability

Thermal analysis of TBX concluded that these types of mixtures are stable up to 170 °C, when the exothermic transformation occurs, due to the presence of phlegmatized RDX and TEGDN in the compound.

Although TBX specimens have RDX in their structure, on the basis of DTA it can be seen that no endothermic transformation occurs like in the case of RDX (due to melting). The main possible reason could be that the exothermic decomposition of TEGDN starts before the endothermic melting of RDX. Also, the difference between the proportions of RDX present in the sample tests is ensured by the heat flow variation. All the samples analyzed through DMA technique displayed similar behaviors, thus Fig. 3 is representative for all the samples tested.The DTA results are presented in Table 2.

Table 2

DTA results for TBX and RDX

Peak / Compound	P1			P2		
	Endotherm			Exotherm		
	Start	Onset	Top	Start	Onset	Top
TBX [°C]	-	-	-	172.75	200.81	220.06
RDX [°C]	198.79	204.96	210.14	211.63	215.08	215.82

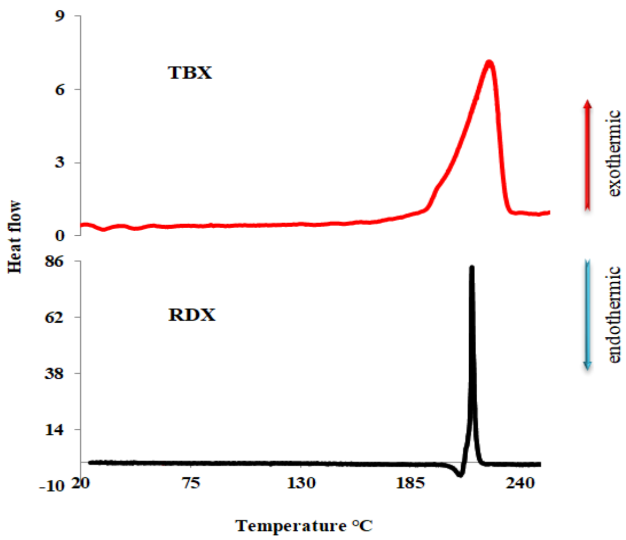

Fig. 3. DTA curves of TBX and RDX

Friction sensitivity

In terms of safety, based on friction analysis results, it can be concluded that these types of thermobaric mixture is completely insensitive to the mechanical friction stimulus, showing no reaction at the maximum load of 36 daN.

Overpressure evaluation

The overpressure evaluation was made in open field by live detonation. A typical example for TBX overpressure history recorded data is depicted in Fig. 4. For each TBX formulation, 2 tests were conducted, and 3 tests for TNT. The overpressure history obtained is depicted in Fig. 5. Experimental and theoretical data is presented in Table 3.

Table 3

Experimental and theoretical data resulted at the overpressure evaluation

Composition	Outer layer mass [g]	Central charge mass [g]	Pressure [bar]		
			1m	2m	3m
TBX A-20	297	39.31	3.822	0.535	0.229
TBX A-20	291	42.31	3.323	0.580	0.299
TBX B-20	295	39.13	2.899	0.901	0.251
TBX B-20	296	39.11	2.967	0.421	0.211
TBX A-15	303	42.10	2.498	0.568	0.306
TBX A-15	278	39.67	2.462	0.537	0.210
TBX B-15	280	38.94	2.659	0.574	0.289
TBX B-15	281	40.26	2.813	0.423	0.206
TBX A-10	297	39.26	2.276	0.614	0.216

Composition	Outer layer mass [g]	Central charge mass [g]	Pressure [bar]		
			1m	2m	3m
TBX A-10	280	40.78	2.374	0.435	0.359
TBX B-10	289	39.45	2.157	0.519	0.236
TBX B-10	284	40,10	1.968	0.485	0.222
TBX A-5	294	38.94	1.668	0.319	0.165
TBX A-5	290	39.17	1.512	0.345	0.153
TBX B-5	287	39.52	1.457	0.299	0.148
TBX B-5	288	42.12	1.536	0.302	0.150
TNT	300		3.975	0.829	0.602
TNT	300		4.829	0.856	0.429
TNT	300		4.557	0.424	0.403

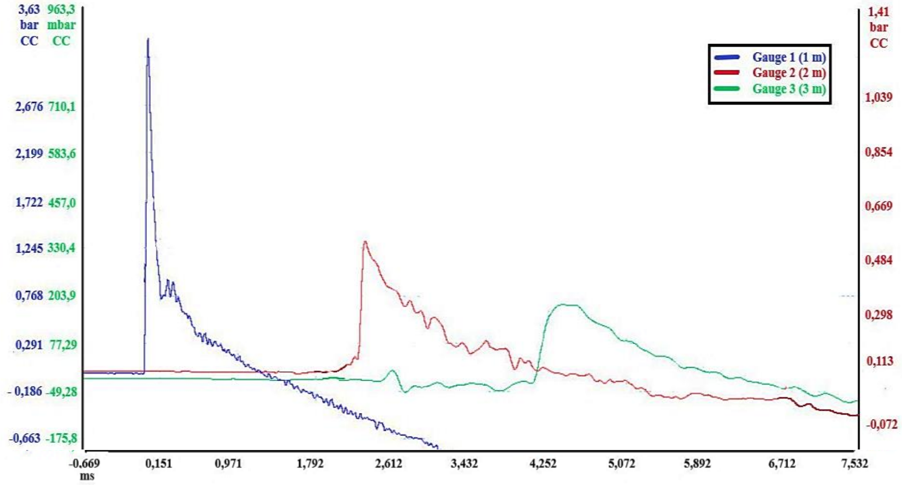

Fig. 4. Overpressure curves for TBX at specific distances

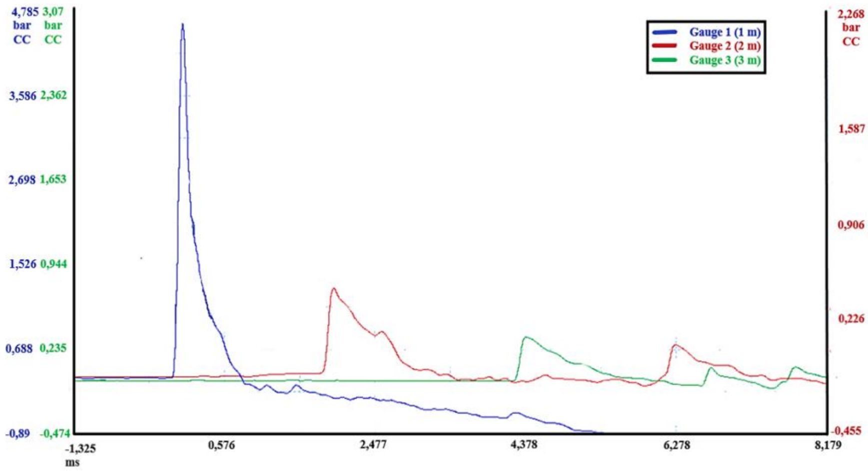

Fig. 5. Overpressure curves for TNT at specific distances

Overpressure experimental results for TBX formulations and TNT

The results show an increase in the overpressure maximum values, at all distances, with the increase in the energetic plasticizer content in the binder mass of the compound. This can be explained by the fact that the binder matrix contain an energetic plasticizer (TEGDN) having energetic groups (nitrate) which contribute to the energetic output of the explosive mixture.

Fire ball evaluation

Fire ball evolutions of TNT, TBX A-20 and TBX B-20 versus time are presented in Fig. 6, while the fire ball dimensions are depicted in Fig. 7.

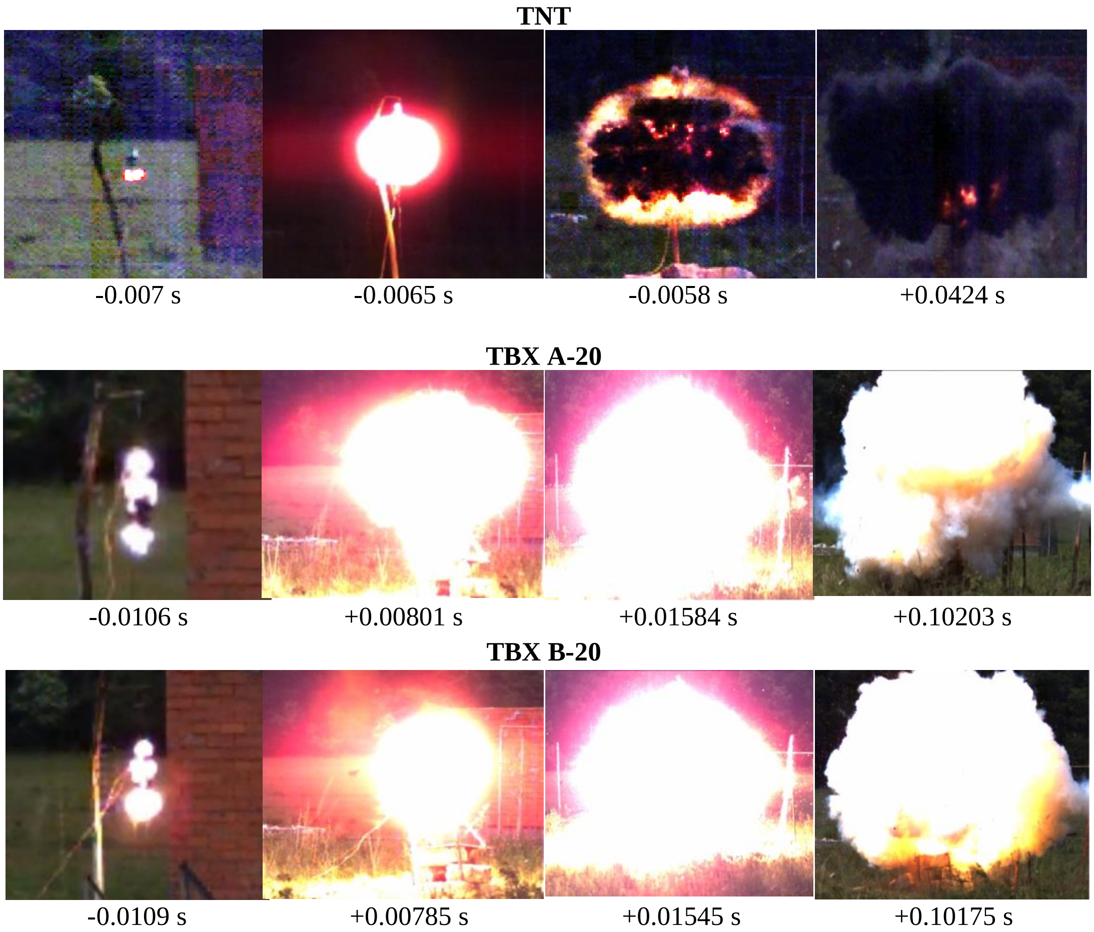

Fig. 6. Fire ball evolution for TNT, TBX A-20 and TBX B-20

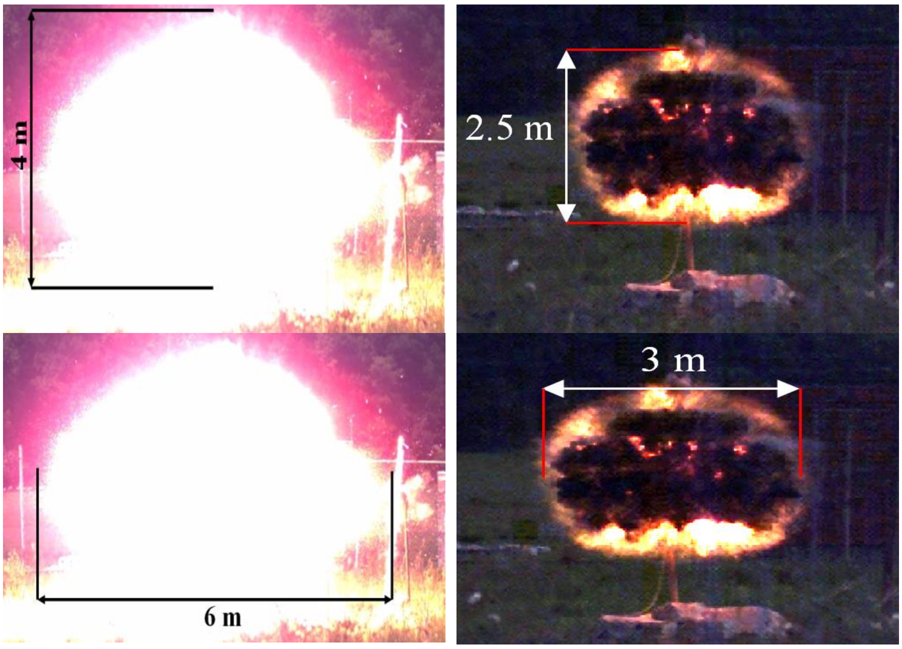

Fig. 7. Fire ball dimension for TBX B-20 and TNT

We can observe that for TBX formulations the overpressure duration and fire ball dimensions have improved compared with a classical secondary explosive. We can conclude that the energetic binder matrix we proposed sustains the aluminum/magnesium – oxygen deflagration and also contributes to the energetic output of the thermobaric charge.

4. Conclusions

In this study thermobaric composition formulations were analyzed in terms of safety and performance characteristics. It turned out that these types of energetic materials are rather sensitive to temperature and are not sensitive to mechanical stimulus. The energetic binder we proposed sustains the deflagration of the aluminum/magnesium mixture and hardens the thermobaric composition.

In terms of performance, comparing the values obtained from TBX formulations with TNT, we can conclude that:

- TBX overpressure duration is at least 2 times higher that TNT's;
- TBX overpressure reached 70% of TNT's;
- TBX fire ball volume is at least 3 times that TNT's;

The data obtained so far create a perfect background for more extensive research in order to demonstrate the safety and performance characteristics of these compositions.

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