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Influence of Cast Composite Thermobaric Explosive Compositions on Air Shock Wave Parameters

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This paper describes the effects of compositions on the detonation properties and the parameters of the air shock wave front on a lightweight model of cast thermobaric explosives, TBE (400 g). Within this investigation, 14 thermobaric explosive compositions have been analyzed. Depending on the content of explosive, binding and oxidation components, as well as on the content of Mg / Al as a fuel, the basic parameters of the shock wave speed, maximum pressure ($(P_{ut})_{max}$), overpressure (Δp) and TBE pressure impulse have been determined at different distances from the explosion center. The thermobaric effect examination was performed by the method of measuring overpressure in the shock wave front, using piezo-electric pressure transducers. The activation and the detonation of explosive charges as well as the expansion of detonation products were filmed by a Phantom V9.1 high speed camera.

Key words: **composite explosives, cast explosives, thermobaric explosives, air shock wave, pressure measurement, overpressure, pressure impulse, magnesium, aluminium.**

Abbreviations

TBE – Thermobaric explosives
FAE – Fuel Air Explosives
SFAE – Solid Fuel Air Explosives
PBX – Polimer Bonded eXplosives
HTPB – Hydroxyl terminated polybutadiene
DOA – Dioctyladipate
HMX – Cyclotetramethylenetetranitramine,Octogen
RDX – Cyclotrimethylenetrinitramine, Hexogen
FH-5 – Phlegmatized hexogen
ASWF– Air shock wave front

Introduction

THERMOBARIC explosives (TBE) are hybrid explosive compositions that, compared to conventional high explosives, have enhanced thermal and blast effects. As the name indicates, thermobaric weapons combine thermal (thermo – θερμός, Greek) and pressure (baric – βάρος, Greek) effects for the destruction of soft targets. They are highly effective against tunnels, bunkers, underground structures, buildings, field fabrications, etc. Shock waves generated by their detonation have substantially longer duration than shock waves generated by conventional high explosives, and they also have a greater lethal radius [1]. Thermobaric effects are obtained by long duration overpressure and heat due to the afterburning of detonation products with air. TBE compositions may be liquid or solid. Original Russian formulations were liquid, but more recent US formulations are solid [2]. This group of weapons is also called high-impulse thermobaric weapons - HITs, volumetric veapons, vacuum bombs, Fuel-Air Explosives - FAE or FAX, Solid Fuel Air Explosives - SFAE. As mixtures of crystalline high explosive and polymeric binder, they are actually a kind of *Plastic Bonded eXplosives* (PBX). They are prepared by the technology of casting and direct loading into corresponding weapons, where after curing at higher temperatures, they turn into a solid explosive charge with rubber-elastic characteristics [3].

Enhancement of the blast effect is achieved primarily by adding metal powder to the basic composition. The increase of the energetic level of their decomposition process is a result of adding specific amount of oxidant, which provides more appropriate conditions for the oxidation of metal powder and also for the release of larger quantities of heat, which determines the parametters of devastating effect. Fig. 1 shows typical pressure – time curves for a conventional high explosive and a thermobaric explosive observed as the expanding shock wave front moves outwards from the centre of explosion [2]:

- A dramatic increase in pressure is generated across the shock front developed at the interface between detonation products and the surrounding atmosphere (time t_1 on the graph), which has a crushing effect on objects in addition to an instantaneous lateral force.
- The peak overpressure is much higher for the high explosive detonation (P_2) than for the thermobaric detonation (P_1), but this pressure drops much more rapidly.
- The positive phase is followed by the negative phase below the atmospheric pressure. The negative phase results in a reversed-blast wind and causes human targets

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to be bodily lifted and thrown. This phase can be longer in a thermobaric detonation than a high explosive detonation, so despite the lower initial blast pressure, total imimpulse (the area under the curve) can be higher for thermobaric explosives than for high explosives.

Target effects are dependent on peak blast overpressure as well as on the duration (imimpulse).

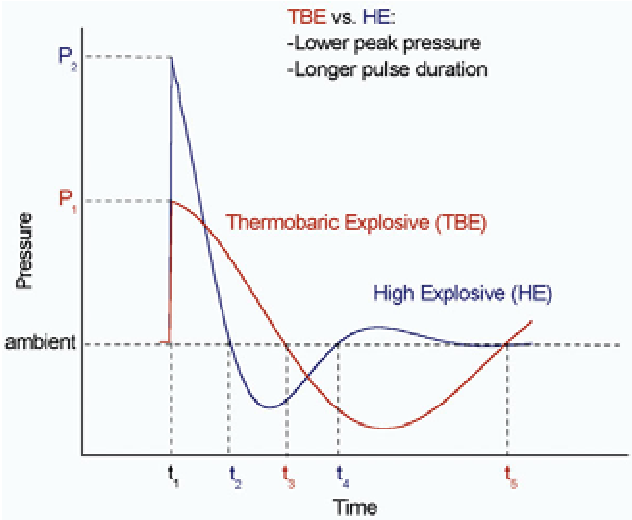

Figure 1. Pressure – time dependence of high explosive (HE) and thermobaric explosive (TBE) detonations

Typical cast composite thermobaric explosives consist of nitroamine as a crystal explosive component, a polymeric binder, an oxidizer and some metal powder as a fuel component. Aluminum has been used as the metal of choice, due to its high heat of combustion, cost and availability. However, combustion efficiency can be a problem, especially when the fuel content (often over 30 wt %) is high with respect to the total weight of explosive composition [4]. Poor combustion efficiency causes the severe ineffectiveness of the weapon. For proper combustion, alumunium requires a high ignition temperature, 2200 K. Burning of all the aluminium to completion requires maintaining the hot environment which can be maintained if it is supported chemically by the combustion of other oxidizers, such as ammoniumperchlorate (AP), much easier to ignite (AP has an ignition temperature of 250°C). The combustion of AP produces hot gases to support the burning of metal so that higher combustion efficiency can be obtained. Another way for further improvement of the metal combustion efficiency is to use a more easily combustible metal (as a part , or as an entire fuel component), to lower the ignition temperature. Nowadays, Al is used in mixtures with magnesium, for more complete combustion [4-5].

The goal of this investigation was to determine the parameters of the air shock wave front: speed, maximum pressure $(P_{ut})_{\max}$, overpressure (Δp) and pressure impulse on different distances from the center of the detonation of TBE charges in dependence on their composition.

Experiment

Within this investigation, 14 different explosive compositions were prepared. The labels and formulations for produced thermobaric explosives are given in Table 1. It was planned to prepare, as a reference, the TBE-1 composition because of its excellent properties which are the same as TBE-11, according to earlier studies [6-8]. As a standard (averaged) composition, TBE-12 was prepared with average mass concentrations of components for the compositions TBE-2 to TBE-9.

Table 1: Composition of the examined explosive charges

Explosive composition's labels	Mass concentrations of components (wt.%)				
	HMX	AP	Al	Mg	HTPB
TBE-1	50	0	30	0	20
TBE-2	45	10	27	3	15
TBE-3	45	10	21	9	15
TBE-4	41	10	27	3	19
TBE-5	41	10	21	9	19
TBE-6	35	20	27	3	15
TBE-7	35	20	21	9	15
TBE-8	31	20	27	3	19
TBE-9	31	20	21	9	19
TBE-11	40	20	25	0	15
TBE-12	38	15	24	6	17
TBE-1a	50	0	27	3	20
TBE-1b	50	0	21	9	20
TBE-1c	50	0	24	6	20

The following raw materials were used for the preparation of explosive charges:

- octogen (HMX, "DINO" - Norway, Class A/C) according to MIL-H-45444,
- aluminum of the average diameter of 5 µm, according to MIL-STD-129,
- magnesium of the average diameter of 65 µm (manufacturer ECKA GRANULES - Austria), according to MIL-DTL-382D,
- ammoniumperchlorate (AP), 7-10 µm, obtained by grinding 200 µm- AP on a vertical hammer mill ACM-10,
- polymeric binder, based on hydroxyterminated polybutadiene (HTPB) cured by isophorone-diisocyanate (IPDI) [9-10], including additives (plasticizer, antioxydant, and a bonding agent).

The quality of the chosen explosive compostitions was examined in a previous study [12] which has shown that they all have good processabillity, i.e. viscosity – time dependences, densities and porosities are favorable for this kind of explosives.

The experimental explosive compositions have been prepared according to [11], in a vertical planetary mixer under vacuum, at 50°C. The technological parameters of preparing all TBE compositions were the same (order of dosing components, stirring speed and time of homogenization, as well as the mixing time after adding the curing agent). After homogenization, explosive is directly poured into the previously prepared molds (diameter 50 mm, height 160-180 mm). After crosslinking and dismantling the molds, the experimental samples were obtained for testing the quality of PBX (density, velocity of detonation) and determining the parameters of the air shock wave front (Fig.2). The experimental models for measuring the detonation velocity and the shock wave parameters (Fig.3) consisted of:

- TBE charge (160-200 mm in height and 50 mm in diameter),
- boosters made of FH-5,
- detonating cap, DK N° 8,
- safety fuse.

Figure 2. Explosive charges

Figure 3. Experimental model

The detonation velocities for cast TBE charges were determined by the switching (electrocontact) probes/ gauges and an electronic counter Pendulum CNT-91. The tests were conducted in the zone of stable detonation in charge initiated by a detonating cap DK N8 and boosters made of FH-5.

The influence of TBE composition on the explosive air shock wave front parameters (ASWF) is defined by determining the following parameters:

- the value of the maximum overpressure $(P_{ut})_{max}$ in the air shock wave front at certain distances from the initiation of explosive charge,
- the time of the positive phase of pressure,
- total positive pressure impulse I_{ut} at certain distances from the center of initiation, and
- air shock wave velocity.

The ASWF parameters of the explosive charges were determined using the method of measuring overpressure by piezo-electric pressure transducers, ie. gauges. The reparation of the experiment, the charge activation, the detonation of TBE, as well as the expansion of explosion products, were filmed by a Phantom V9.1 high speed camera. The measurements were performed for 42 models in the form of a bare cylindrical charge, (14 explosive compositions of TBE, 3 experimental charges weighting 400 g each), in the examination fields of the Technical Test Center, in Nikinci. The measurement of the overpressure in ASWF was performed at defined distances from the center of initiation. The explosive charges were placed to the height of 1.5 meters above the ground using a tripod, so that their axis was parallel to the ground and perpendicular to the line of the set of probes. The initiation of the charges was done using DK Nº 8 and boosters made of FH-5, 30 mm in diameter. The schematic view of the experiment is illustrated in Fig.4.

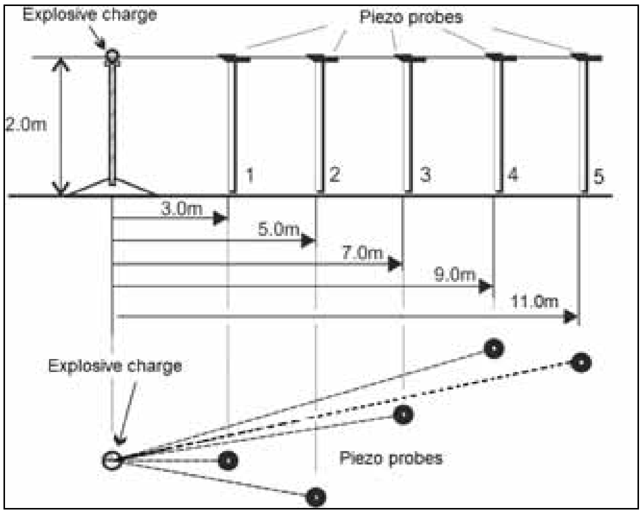

Figure 4. Scheme of the experimental determination of the ASWF parameters

To record the time dependence of the overpressure, the piezoelectric probes /transducer was applied. The probes were placed at distances: 3, 5, 7, 9 and 11 m from the explosive charge, at the height of 2 m above the ground. The receiving surface of the probe was placed perpendicularly to the direction of the propagation of the shock wave front, thus avoiding the reflection of waves on the inverter surface. The measured data were digitalized using an analog-to-digital converter. The results of measuring the ASWF overpressure - time (p-t diagrams) were obtained by processing the recorded signals on a computer. Based on these records, the basic parameters of the air shock wave were determined: $(P_{ut})_{max}$, the time of the positive overpressure phase effect τ_+, the impulse pressure (I_{ut}) and the velocity of the air shock wave in the defined ranges.

Results and discussion

Density and detonation velocity of TBE

The measured densities are very close to the theoretical values (Table 2). The porosities of the examined explosives are low, which is good quality for this kind of explosives. The results of detonation velocity measurements for selected TBE compositions are given in Table 2. From the obtained results, general conclusions can be drawn regarding the effect of composition on the detonation velocity. By increasing the content of oxidants or decreasing the share of the explosive component, detonation velocity decreases. By reducing the binder content in the composite explosive, the value of the detonation velocity increases. Composition TBE-3 stands out with even a higher detonation velocity than the one measured for the reference-charge TBE-1 and than that of TNT (D_{TNT} = 6767.00 m/s).

Table 2. Theoretical and experimental densities and porosities of TBE charges, and detonation velocities

Explosive composition's labels	ρ_e (g/cm^3)	ρ_T (g/cm^3)	v (%)	D (m/s)
TBE-1	1.705	1.670	2.03	7090.00
TBE-2	1.773	1.753	1.11	5806.20
TBE-3	1.734	1.702	1.83	7154.33
TBE-4	1.706	1.689	0.97	/
TBE-5	1.669	1.578	5.48	/
TBE-6	1.776	1.730	2.59	/
TBE-7	1.737	1.664	4.20	/
TBE-8	1.709	1.697	0.68	6124.97
TBE-9	1.672	1.663	0.57	6058.95
TBE-11	1.771	1.750	1.18	/
TBE-12	1.721	1.584	7.97	/
TBE-1a	1.686	1.666	1.21	/
TBE-1b	1.651	1.635	0.98	/
TBE-1c	1.669	1.651	1.06	/

The parameters of the TBE air shock wave front

Air shock wave overpressure

For all the tested explosives diagrams, $\Delta p = f(t)$ are similar - after a sharp peak at the beginning, the maximum overpressure decreases rapidly (the biggest drop was registered in the area near the blast center, 3 - 5 m), followed by the area in which this decrease is more moderate (7 - 11 m). An illustrative example of the obtained overpressure - time diagram (for TBE-2, at the points 3 m, 5 m and 7 m), is shown in Fig.5. The reflected shock wave is registered. The occurrence of secondary and tertiary waves caused by reflection, prolongs τ_+, and thus affects the value of the total impulse.

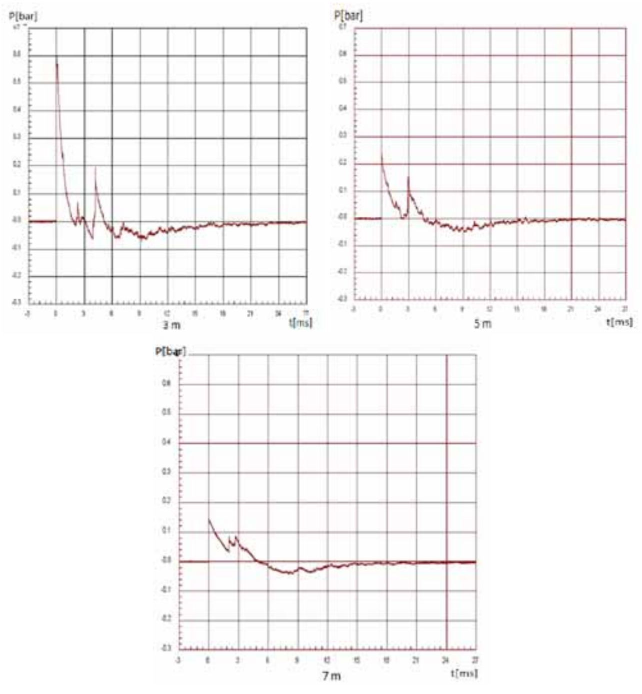

Figure 5. Dependence $\Delta p = f(t)$ for TBE-2 at distances 3, 5 and 7 m, respectively

In previous studies [8], it was noted that the reflected wave does not affect the maximum overpressure value of the primary wave at any measuring point, but substantially affects the value of overpressure impulses over long distances. Piezo-electric pressure transducers were placed 2 meters above the ground, but placing them on an even higher position could eliminate the effect of the reflected wave, since the higher the transducers are placed, the larger the delay of the reflected wave is. On the $\Delta p = f(t)$ diagrams, the values of the maximum overpressure, P_{max} are determined. Their average values are given in Table 3, and Fig.16 graphically shows the changes in the function of the distance from the explosion.

Table 3. Maximum overpressure, P_{max}, of the examined explosive compositions

TBE label / Distance of the measuring point	Overpressure, mbar				
	3m	5m	7m	9m	11m
TBE-1	533.67	225.00	136.00	89.00	/
TBE-2	600.33	239.33	147.67	100.33	/
TBE-3	662.67	258.33	157.33	104.67	/
TBE-4	558.67	227.33	140.33	94.67	/
TBE-5	536.33	227.33	146.00	95.67	80.33
TBE-6	554.33	230.00	147.67	95.67	78.00
TBE-7	628.33	246.67	153.67	99.33	82.33
TBE-8	581.67	224.00	138.67	92.33	72.33
TBE-9	572.33	224.00	141.33	94.67	75.67
TBE11	593.67	226.33	145.33	95.00	/
TBE12	597.67	238.33	150.00	102.00	/
1a	571.33	224.33	138.67	86.00	70.67
1b	601.67	232.00	144.67	95.67	74.00
1c	619.00	222.50	135.00	89.00	67.50

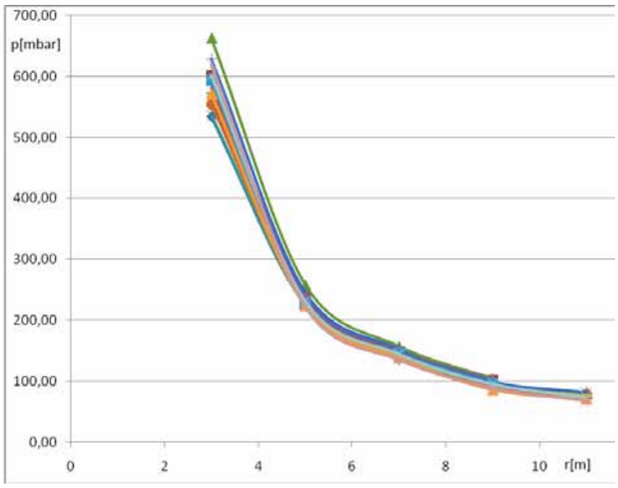

Figure 6. Dependences $\Delta p_{max} = f(r)$ of the examined explosive compositions

At further distances (9 – 11 m), there are small differences between the values of the maximum overpressure, so one can say that the influence of TBE composition on the values P_{max} is most pronounced in the area near the detonation site (measuring point 3m). The greatest overpressure values at all measuring points are obtained with TBE-3, and the lowest with TBE-1.

The influence of the mass concentration of individual components is more obvious on separate diagrams given in Figures 7 and 8, where the new compositions are also compared to the standard charge.

Fig.7 indicates a stronger thermobaric effect of the compositions with a higher content of magnesium (TBE-3 and TBE-5) at all measuring points. When speaking about the maximum overpressure, all new bands are more advanced than the standard charge, especially TBE-3.

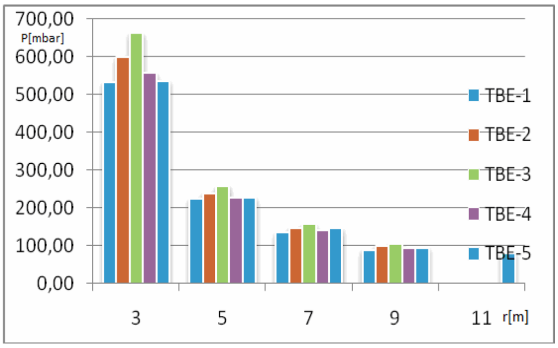

Figure 7. Dependence $\Delta p_{max} = f(r)$ for TBE-1 – TBE-5

Fig.8 shows a comparison of four compositions without AP, with the same proportion of HMX and HTPB, and with different ratios of Al/Mg, in order to single out the effect of Mg. All compositions containing magnesium have higher values of overpressure compared to the standard charge. In the area near the center of the explosion (measuring point 3 m), the composition that stands out is TBE-1c, and at further distances, the TBE-1b composition has better performance.

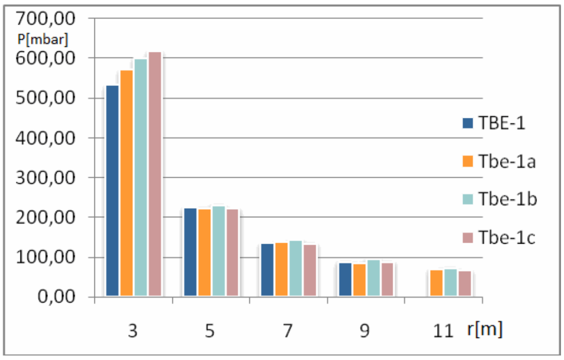

Figure 8. Dependence $\Delta p_{max} = f(r)$ for TBE-1 , -1a, –1b and TBE-1c

Comparing the results for TBE-1 and TBE-2 with those for TBE-8 and TBE - 9, it can be concluded that the increased share of AP at the expense of reducing the share of HMX does not increase the thermobaric effect, but sustains it at greater distances. Earlier research has led to similar conclusions [8].

Velocity of the air shock wave

The average values of the air shock wave velocities for the examined explosive compositions are given in Table 4, calculated by measuring the time between the registration of the front edge of the signal at the previous (2 m ahead) and the current measuring point. The values obtained for all compositions show an increase in the ASW velocity from the measuring point of 5 m to the measuring point of 7m, and then a drop at the measuring site of 9 m, and again an increase at the measurement point of 11 m. The compositions TBE-3, TBE-7 and TBE-1a have the highest values of the ASWF velocity. The differences in the velocity of ASWF become more noticeable with increasing the distance of the measuring point from the explosion centre.

Table 4. Velocity of the air shock wave

TBE label	Velocity of the air shock wave, m/s			
	5m	7m	9m	11m
TBE-1	403.67	418.00	360.00	/
TBE-2	408.33	420.67	361.33	/
TBE-3	415.00	424.00	364.33	/
TBE-4	410.67	420.33	361.33	/
TBE-5	404.00	423.67	330.33	409.33
TBE-6	407.33	425.33	332.00	410.00
TBE-7	413.67	426.67	333.00	411.67
TBE-8	407.33	421.33	328.00	406.33
TBE-9	408.00	421.67	328.67	407.00
TBE-11	406.67	419.67	361.33	/
TBE-12	405.33	420.00	362.33	/
TBE-1a	415.00	425.00	331.00	408.33
TBE-1b	380.33	418.67	354.67	350.33
TBE-1c	385.00	418.00	354.00	348.50

Pressure impulse

Due to the reflected wave, the reliability of determining the duration of the positive phase of pressure (τ_+) is significantly reduced, and so is the calculating imimpulse - I_{ut} [1], in particular at the measurement points away from the explosion center. The results of measuring the overpressure (curve Δp-t) were analyzed using data processing program (a developed version of the FTM program), which determines the positive phase of the shock wave within the boundaries where the pressure is greater than one percent of the maximum value before and after the maximum pressure. In this range, the pressure impulse is calculated as an integral, the area under the curve. In the cases where the reflected wave arrived during the positive phase, approximately correct values of the pressure impulse are calculated in the points before registering reflection, by interpolating a straight line to the intersection with the zero and the integral is obtained along this line. The obtained values of τ_+ and I_{ut} are given in Table 5.

Table 5. Duration of the positive phase of the pressure (τ_+)

TBE label/ measuring point	Duration of the positive phase of the pressure, τ_+ (ms)					Pressure impulse, I_{ut} [mbar·ms]				
	3m	5m	7m	9m	11m	3m	5m	7m	9m	11m
TBE-1	1.29	1.82	4.58	4.61	/	308.67	140.03	247.33	179.00	/
TBE-2	1.32	2.06	4.46	4.52	/	346.67	196.67	284.33	201.00	/
TBE-3	1.27	2.03	4.39	4.33	/	371.67	209.00	296.67	207.67	/
TBE-4	1.32	2.00	4.45	4.39	/	323.67	177.33	254.67	175.00	/
TBE-5	1.45	2.13	4.45	4.31	/	349.00	199.33	285.67	193.33	192.33
TBE-6	1.46	2.13	4.49	4.29	4.54	343.00	198.00	288.67	192.00	195.33
TBE-7	1.33	2.10	4.46	4.29	4.53	361.67	208.67	293.00	196.00	198.00
TBE-8	1.33	2.07	4.50	4.28	4.59	329.33	185.67	255.33	169.33	173.67
TBE-9	1.68	2.08	4.45	4.30	4.54	339.67	188.67	268.00	179.00	182.00
TBE-11	1.30	2.08	4.46	4.33	/	338.67	192.00	269.67	191.33	/
TBE-12	1.40	2.09	4.45	4.49	/	355.00	205.00	290.67	211.67	/
TBE-1a	1.27	2.08	4.47	4.29	4.51	320.33	175.67	253.00	168.33	173.33
TBE-1b	1.34	2.08	4.57	4.45	4.67	357.33	192.33	268.33	184.00	179.67
TBE-1c	1.22	2.02	4.59	4.41	4.52	353.50	178.50	263.50	178.50	173.50

The change of the pressure impulse at a distance of 3 m and 5 m (where the error of determining the duration of the positive phase of pressure is small [1]) is plotted in Fig.19.

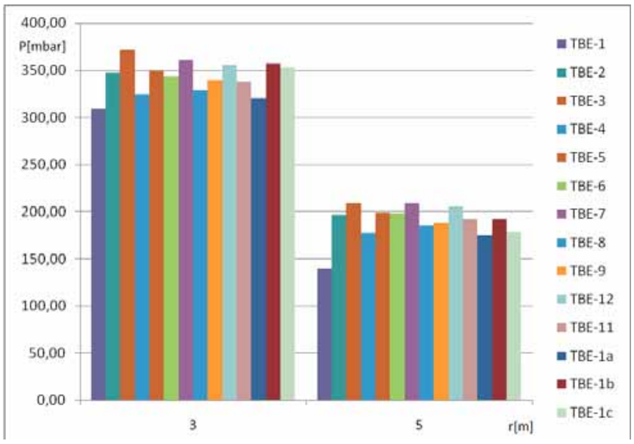

Figure 9. Pressure impulse at 3 m (1) and 5 m (2)

It can be concluded that all new compositions have a higher pressure impulse than the standard charge. The impact of the individual components can clearly be seen on separate diagrams for certain compositions in Figures 10 and 11. Among these, TBE-3, TBE-7, TBE-12 and TVE-12-1b are outstanding, containing a higher proportion of explosive components, combined with a greater share of magnesium.

When comparing TBE-2 and TBE-3 compositions to TBE-8 and TBE-9 ones (where the proportion of AP is increased at the expense of the reduction of HMX), there is a slight decrease in the pressure impulse, while its values are greater for the compositions containing a higher share of Mg. These 4 compositions, as well as TBE-12, have a smaller share of HMX than the standard composition, but a clearly higher pressure impulse, due to the combination of oxidant and fuel components.

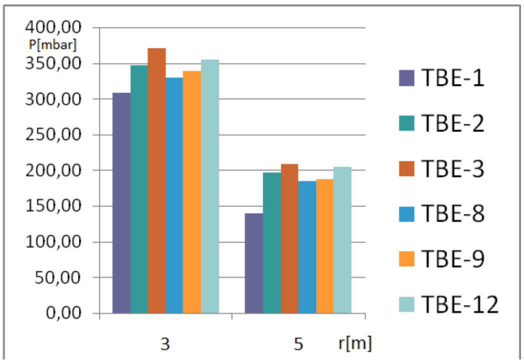

Figure 10. Pressure impulse at 3 m and 5 m for TBE-1, -2, -3, -8, -9 and TBE-12

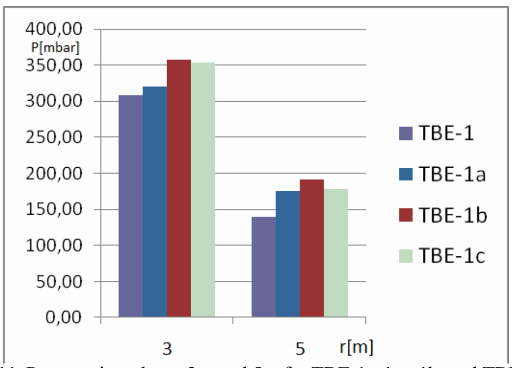

Figure 11. Pressure impulse at 3m and 5m for TBE-1, -1a, -1b, and TBE-1c

When analyzing the compositions that do not contain AP, but contain the same amount of the explosive and the binding component with just a different ratio of Al / Mg, as well as when analyzing the maximum overpressure, the impact of the Mg share can be isolated (Fig.11). TBE-1b composition is leading, having the greatest value of the pressure impulse, confirming the positive effects of Mg.

Conclusion

New compositions of cast composite thermobaric explosives (TBE) are developed for the needs of investigation of the effects of composition on the detonation properties and the parameters of the air shock wave front, having the mass fraction of components: 31-50% of HMX, 15-20% of HTPB - based binder, 21-30% of Al, 0-9% of Mg and 0-20% of AP. For the 14 experimental TBE compositions, the influence of the compositions and the ratio between the components on the detonation properties and the parameters of the air shock wave was examined, on light-weight experimental models ~ 400g. The test results are compared to the parameters of the standard charge (HMX/Al/HTPB = 50/30/20).

The maximum overpressure values at all measuring points are achieved with TBE-3, and the lowest ones with TBE-1. At greater distances from the explosion center, small differences in the values of the maximum overpressure were registered, which indicates that the influence of the composition on P_{max} values is most pronounced in the area near the detonation site. All compositions containing magnesium have higher values of overpressure compared to the standard charge.

All new compositions have higher pressure impulses than the standard charge. Among these, TBE-3, TBE-7, TBE-12 and TBE-1b are outstanding, having a higher content of the explosive component, combined with a greater share of magnesium. The TBE-3 composition has the most favorable characteristics of thermobaric explosive: in comparison to the other investigated compositions, it has higher detonation velocity, higher overpressure and pressure impulse, and can be recommended as the composition of choice for further research.

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Uticaj sastava livenih kompozitnih termobaričnih eksploziva na parametre u vazduhu udarnog talasa

U radu su prikazani rezultati ispitivanja uticaja sastava na detonaciona svojstva i na parametre fronta vazdušnog udarnog talasa livenih termobaričnih eksploziva (TBE), modela male mase (400 g). Analizirano je 14 termobaričnih eksplozivnih sastava, za koje su, u zavisnosti od sadržaja eksplozivne, vezivne, oksidacione komponente, i sadržaja Mg/Al kao goriva, određeni osnovni parametri udarnog talasa: brzina, maksimalni pritisak $(P_{ut})_{max}$, nadpritisak (Δp) i impuls pritiska TBE punjenja na različitim rastojanjima od centra eksplozije. Ispitivanje termobaričnog efekta TBE vršeno je primenom metode merenja nadpritiska u frontu udarnog talasa piezo-električnim davačima pritiska. Aktiviranje i detonacija punjenja, kao i širenje produkata detonacije, snimani su ultrabrzom kamerom Phantom V9.1

Key words: **kompozitni eksplozivi, liveni eksplozivi, termobarični eksplozivi, udarni talas, merenje pritiska, nadpritisak, impuls pritiska, magnezijum, aluminijum.**

Влияние состава литых композитных термобарических взрывчатых веществ на параметры воздушной ударной волны

Эта статья описывает эффекты испытаний влияния состава на детонационные свойства и параметры фронта воздушной ударной волны литых термобарических взрывчатых веществ, лёгкой модели (400 г). Мы анализировали 14 термобарических взрывчатых составов, для которых, в зависимости от содержания взрывчатого вещества, связанной и окисленой составляющих и содержания Mg / Al в качестве топлива, определены основные параметры ударной волны: скорость, максимальное давление $(P_{ut})_{max}$, избыточное давление (Δp) и импульс давления зарядки КЭ на разных расстояниях от центра взрыва. Тестирование термобарического эффекта КЭ было выполнено с использованием метода измерения избыточного давления на фронте ударной волны пьезоэлектрическими датчиками давления. Активация и взрыв наполнения и расширение продуктов детонации, были сняты в сверхбыструю камеру Phantom V9.1.

Ключевые слова: **композитные взрывчатые вещества, литые взрывчатые вещества, термобарические взрывчатые вещества, ударные волны, измерение давления, избыточное давление, импульс давления, магний, алюминий.**

Influence de la composition des explosifs composites thermobarics coulés sur les paramètres de l’onde de choc aérien

Les résultats des recherches de l’effet de la composition sur les propriétés de détonation et sur les paramètres du front de l’onde de choc aérien chez les explosifs coulés thermobarics , modèle léger (400 g) ont été présentés dans ce papier. On a analysé 14 compositions d’explosifs thermobarics pour lesquelles on a déterminé, en fonction du contenu explosif, les composantes de liaison et d’oxydation ainsi que le contenu de Mg / Al comme carburant combustible, certains paramètres basiques de l’onde de choc: vitesse, pression maximale, surpression (Δp) et impulsion de pression TBE de charge à différentes distances du centre de l’explosion. L’examen de l’effet thermobaicr TBE a été effectué par la méthode de mesurage de surpression dans le front de l’onde de choc au moyen de capteurs de pression piézoélectriques. L’activation et la détonation de la charge ainsi que la propagation des produits de détonation ont été filmé par la caméra ultra rapide Phantom V9.1.

Mots clés: **explosifs composites, explosifs coulés, explosifs thermobarics, onde de choc, mesurage de pression, surpression, impulsion de pression,magnésium, aluminium.**