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Demilitarized Double Base Propellants as Ingredients of Commercial Explosives

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Abstract: Demilitarized energetic materials such as explosives and propellants are a useful source of energy for civilian applications. The excess of military explosives and propellants can be reused as components in commercial explosives. The influence of double base propellants (DBP) on detonation characteristics of ANFO and emulsion explosives was investigated. Some physical characteristics of emulsion matrix and ammonium nitrate prills (densities, size distributions and structure examinations by scanning electron microscopy) were determined. Investigated explosive mixtures contained 20, 40 and 60% of the propellant. The velocity of detonation and intensity of blast waves (peak blast overpressures) generated by the explosion of the mixtures was measured. Positive phase impulses were also calculated. In the case of ANFO/DBP compositions their parameters increased along with the propellant content.

Keywords: emulsion explosives, ANFO, detonation velocity, overpressure, positive phase impulse

Introduction

The traditional way of disposing of demilitarized energetic materials was by open burning or open detonation. Known as OB/OD, this method consists of burning or exploding old ammunition in open sites designated for the purpose.

In recent years, however, OB/OD – which involves release of toxic fumes into the atmosphere – has come into conflict with environmental, health and safety regulations.

Demilitarized energetic materials such as explosives and propellants are a useful source of energy for other purposes [1-3]. In order to recycle the energetic materials, the munitions have to be disassembled to allow access to the energetic materials followed by a process of removing it from the munitions. The idea to use the excess military explosives and propellants in commercial explosives seems to be attractive. The propellant that consists basically of nitrocellulose can be removed relatively easily from the ammunition. A mixture of smokeless small-grained powder and ammonium nitrate, added for compensation of oxygen balance, is the simplest example of military explosive reuse [4]. Propellants can be used as sensitizer ingredients in watergel slurry explosives or water-in-oil emulsion explosives [5-7]. They usually contain 25-35% either single base or double base smokeless powder propellants. In Polish storage magazines there are a large number of double base propellants. Double base propellants contain nitrocellulose of various nitration levels, nitroglycerine and inert plasticizers to modify either the flame temperature or the physical properties of the propellant.

There are numerous commercial explosives suitable for double base propellants incorporation [8, 9]. They include ANFO and emulsion explosives. ANFO (ammonium nitrate-fuel oil) is a very popular and inexpensive explosive. It consists of ammonium nitrate prills sufficiently porous to take up the oil. Emulsion explosives, “water-in-oil” type, are the last generation of industrial explosives. Explosive emulsions consist of a dissolved oxidiser solution dispersed in the form of extremely small droplets in a continuous oil phase. The oil phase, along with the stabilizing surfactant, constitutes the fuel portion in the detonation process. Glass microspheres are used to achieve the desired sensitivity.

Materials and Methods

In the present work, studies have been carried out on the basic emulsion explosive and ANFO. The commercial emulsion matrix AN/SN type was examined. It consisted of inorganic oxidizers such as ammonium nitrate and sodium nitrate (83.6%), organic phase (7.0%) and water (9.4%) and its density was 1.45 g cm^{-3}. The structure of the matrix was examined by scanning electron microscopy (SEM) (Figure 1). The sample preparation was a standard procedure. Additionally emulsion matrixes were sensitized by glass microspheres. Size distribution of the microspheres is given in Figure 2. Most of them were between 10 and 50 μm.

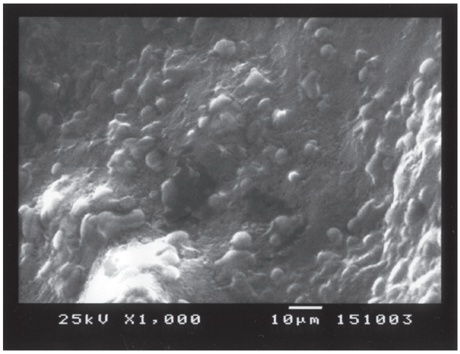

Figure 1. SEM micrograph on the emulsion matrix structure.

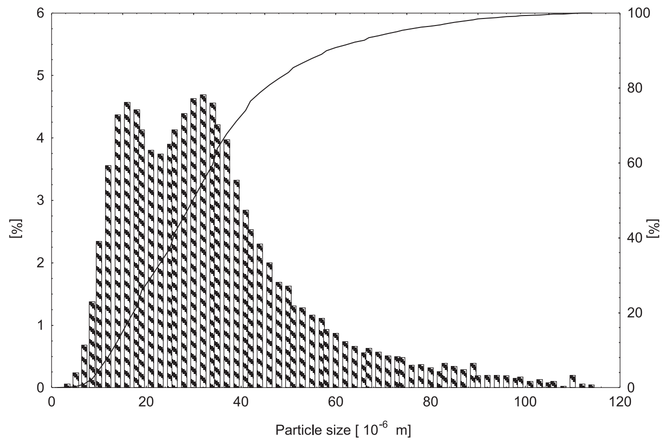

Figure 2. Size distribution of microspheres.

The some physical characteristics of commercial prilled ammonium nitrate (AN) was also determined. They included bulk density, apparent density, size distribution and oil absorption. The bulk density referred to the density of prills including pores and inter-prills spaces. The apparent density of AN prills was established by gas (helium) pycnometer – it was the mass of AN divided by its apparent volume (volume excluding open pores but including closed pores). The bulk density of investigated ANFO was 0.69 g cm^{-3} and its apparent density – 1.70 g cm^{-3}. The size distribution was determined by sorting the prills through sieves with various sizes. The prills were sifted in seven size ranges. The size distribution of AN prills is shown in Table 1. Method of oil absorption test involved measuring the quantity of fuel oil that could only be absorbed into the AN prills. For this test only prills over diameter of 1 mm were used. The value obtained in the test was 10.5 mL/100 g. The external and internal structure of AN prills was also examined by SEM (Figures 3, 4).

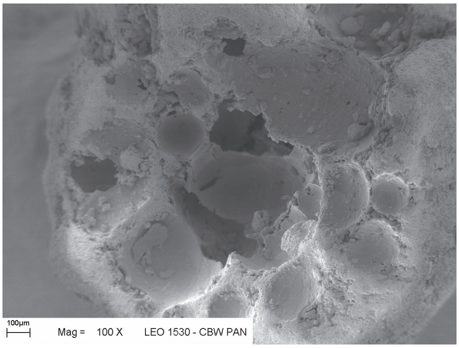

Figure 3. SEM micrograph on the cross-section of AN prill.

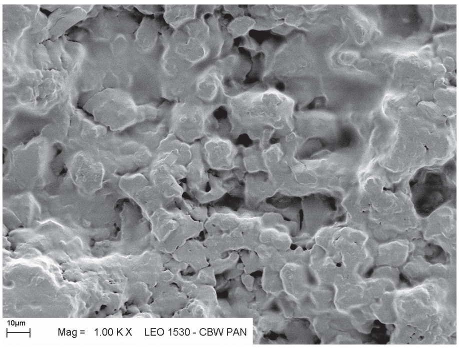

Figure 4. SEM micrograph on internal surface of AN prill.

Table 1. Size distribution of AN prills

Mass with prill diameter [%]						
>2.50	2.00-2.50	1.60-2.00	1.25-1.60	1.00-1.25	0.80-1.00	<0.80
1.1	7.3	75.8	8.6	4.9	1.4	0.9

Investigated explosives included ANFO and emulsion explosives containing demilitarized double base propellants (DBP). We used commercial ANFO, produced from tested AN prills, and emulsion explosive (EE) obtained by mixing commercial emulsion matrix with 3% of microspheres. Then double base propellant (DBP) containing 40% of nitroglycerine was added. The propellant was in the form of squares (2×2 mm), having a thickness of 0.42 mm. Detonation velocity of size-reduced propellant in the steel pipe was 4290 m s^{-1} at bulk density 0.74 g cm^3. Investigated explosives contained 20, 40 and 60% of the propellant.

We measured the intensity of blast waves generated by the explosion of EE/DBP and ANFO/DBP mixtures. Investigated mixtures were loaded into paper tubes having an inside diameter of 45 mm and an outer diameter of 50 mm. The weight of every explosive was 350 g. The explosives were initiated using boosters HT-14. Two PCB quartz pressure transducers were located: first one 2 m and the second one 3 m away from the centre of charges. The charges were hung 1.5 m above the ground. The gauges registered overpressure in the transient shock waves, sliding on the working surface of the device. A typical blast overpressure signal was presented in Figure 5.

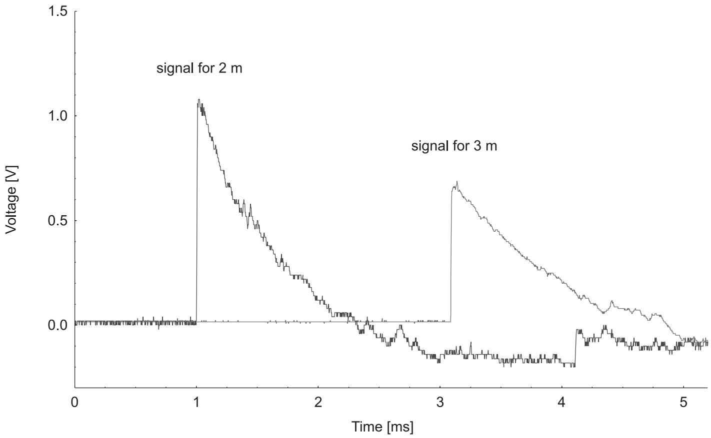

Figure 5. Peak blast overpressure signal recorded for EE/DBP explosive (composition **3**).

Simultaneously, detonation velocity tests were conducted. Four sensors were placed inside the explosive. Detonation velocity was determined by the measurement of the time needed for detonation wave transition through three sections; each of them was 40 mm long. Measurements of time were done by short circuit sensor method.

Results

Velocity of detonation

The results of detonation velocity measurements were presented in Table 2.

Table 2. The results of VOD measurements

Sample	Composition	Density [g cm^{-3}]	VOD [m s^{-1}]
1	EE/ DBP 80/20	1.24	5250
2	EE/ DBP 60/40	1.10	4330
3	EE/ DBP 40/60	1.17	3650
4	EE	1.18	5200
5	DBP	0.82	4080
6	ANFO/ DBP 80/20	0.771	1320
7	ANFO/ DBP 60/40	0.769	1680
8	ANFO/ DBP 40/60	0.764	2650

The detonation velocity value obtained for the size reduced double base propellant was rather low due to its density. The double base propellant that was added to the emulsion explosive caused the decrease of detonation velocities. In the case of the composition containing 20% of the propellant its detonation velocity was nearly the value determined for the emulsion. The higher propellant content the lower detonation velocity of the explosive.

On the contrary, the detonation velocities of compositions containing ANFO showed a growing tendency with the increase of DBP content. The VOD value for composition **8**, containing 60% of DBP, was twice the value determined for composition **6** (20% of DBP).

Peak blast overpressure

The results of peak blast overpressure measurements obtained for investigated explosives are shown in Figures 6 and 7.

As expected, peak blast overpressures of explosion products showed the same tendency as VOD values, slightly decreasing with the increase of DBP content for EE and significantly growing with the increase of DBP content for ANFO. Both values obtained at the first and the second transducer (2 m i 3 m) for compositions **2** and **3** (emulsion explosive containing 40% and 60% of DBP, respectively) were nearly the same. The increase in propellant content caused the significant growth in peak overpressure values for ANFO/DBP explosives, with the highest overpressure for 60% of DBP.

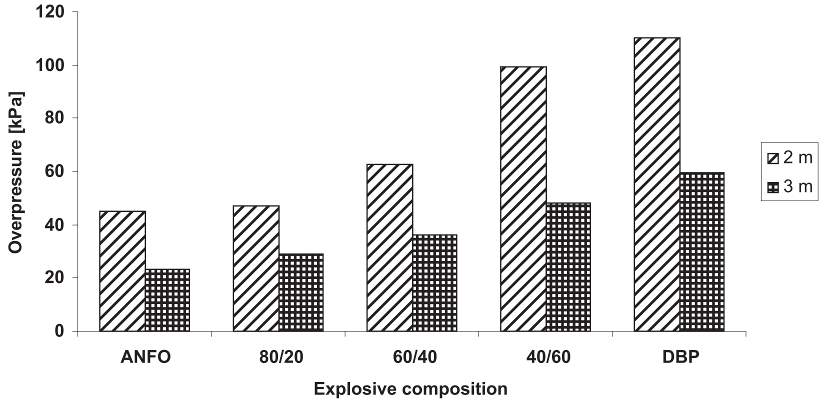

Figure 6. Peak blast overpressures for ANFO/DBP explosives.

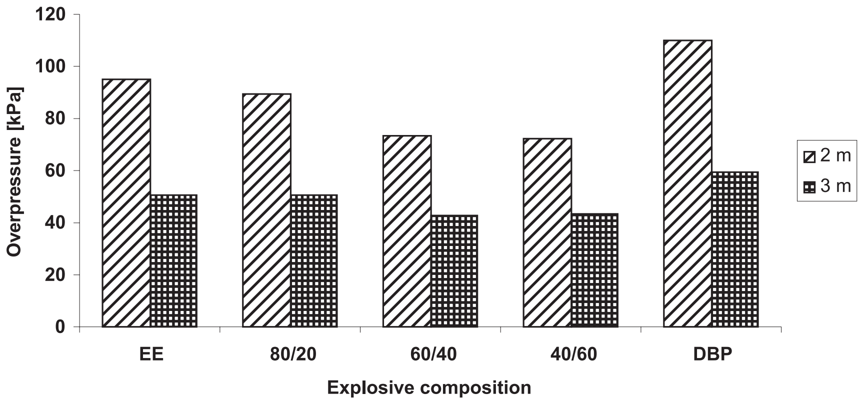

Figure 7. Peak blast overpressures for EE/DBP explosives.

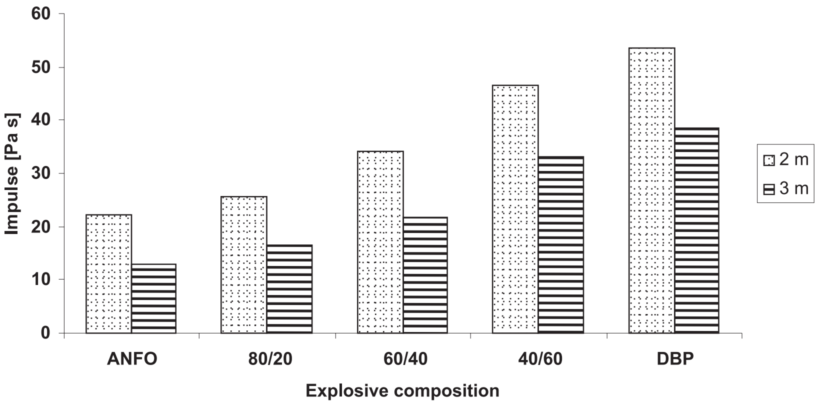

Figure 8. Positive phase impulses for ANFO/DBP propellants.

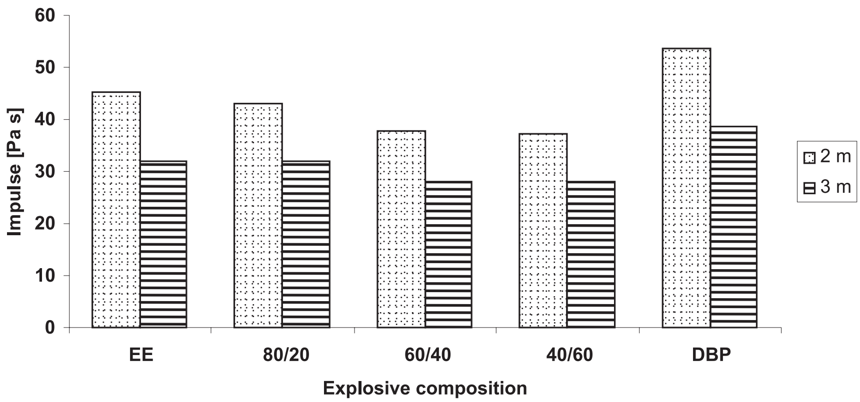

Figure 9. Positive phase impulses for EE/DBP explosives.

Positive phase impulse

The positive phase impulses were calculated by integrating the blast overpressure signals until a time when the pressure falls below atmospheric pressure. They were shown in Figures 8 and 9.

The impulses corresponded with overpressure values. The impulses for composition **2** and **3** were nearly the same, both at the distance of 2 and 3 m. The value calculated for composition **8** (ANFO/DBP 40/60) was close to the value obtained for the emulsion explosive and higher than for composition **3** (EE/DBP 40/60), though propellant content in composition **3** and **8** was the same.

Discussion

The chosen initial explosives were based on ammonium nitrate but they differed in their structure. ANFO are coarse-grained type explosives whereas emulsion explosives are of very fine structure. In the case of investigated mixtures the achievement and propagation of detonation is very complex. The large fraction of the total energy of the mixtures derives from reactions between components. In emulsion explosives there is not only a good intimacy of the mixture of the fuel and oxidizer but their density is much higher than ANFO. Their detonation characteristics and performance are the best among commercial explosives based on ammonium nitrate. Propellant grains are of the great size in comparison with emulsion particles and the additive disturbs emulsion explosive structure. The propellant added to the emulsion explosive caused the decrease of its detonation characteristics. Only the additive of 20% of DBP did not lower parameters of the initial emulsion explosive. But it is necessary to stress that all the charges were very lightly confined and their diameter was rather small (only 45 mm). The results are in agreement with that reported by Machacek and Eck [10, 11].

The propellant additive also influences emulsion rheology. The consistency of composition containing 60% of the propellant was not satisfactory and it could not be guaranteed that the propellant grains were entirely surrounded by the emulsion.

In the case of ANFO/DBP compositions their parameters (detonation velocities, peak blast overpressures and positive phase impulses) increased along with the propellant content. That means a factor determining detonation velocity in ANFO/DBP explosives is the amount of energy that generated in chemical reactions of the propellant in detonation wave. Blast wave parameters obtained for composition **8** (ANFO/DBP 40/60) resembled these determined for the emulsion explosive, however, measured detonation velocity of composition **8** was much lower.

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