Research on detonation parameters of low density emulsion explosives modified by microballoons

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Introduction

Emulsion explosives were developed several decades ago [1÷3], but they are still the most modern mining explosives. Currently they are becoming the main blast means used in the Polish mining industry [4]. Their main advantages include low sensitivity to mechanical stimulus, which allows the mechanical loading of blast holes. Another very important advantage is the ability to regulate their density in a very wide range. Changing the density of emulsion explosives causes equivalent change in the energy density so its adaptation to the mechanical parameters of the rock mass as well.

Research on the detonation parameters is performed for several years in the Military University of Technology and the results are presented, among others, in publications [5÷14]. The results of recent experiments for the emulsion explosives of reduced density were included in this study.

Sensitization of emulsion explosives' matrix

Emulsion explosives' matrix has a density in the range of 1.4 – 1.5 g/cm^3 and is deprived of explosophores. In order to increase its ability to detonate, structural changes should be made which, after passage of the blast wave will be areas of higher temperature ("hot spots"). In these areas, energy caused by shock wave is sufficient to initiate chemical reactions. Sensitization of the matrix may be carried out by such factors as:

- addition of high-energy explosives
- addition of a substance with high hardness grains
- chemical or physical reduction of density.

Assuming obtaining the low density emulsion explosives, reducing the density of matrix by chemical aeration or addition of low bulk density substance will play an important role. Most of industrial emulsion explosives, and all loaded in loose to blast holes, are aerated chemically. However, in the laboratory scale it is much easier and more repeatable to enter into emulsion glass microspheres or microballoons made of plastic.

Experimental part

After detailed analysis of the methods of reducing the density of emulsion explosives, for test has been chosen the physical reduction of emulsion explosives' density using microballons made of plastic. Despite the lower cost of chemical reduction of the density of emulsion explosives this method was abandoned because of the complicated laboratory procedure and the difficulty in obtaining reproducible test results in laboratory scale.

This choice stems from a simple method of introducing these substances into the emulsion and reproducibility of test results of emulsion explosives detonation parameters. In the case of chemical aeration, arrangement and size of the gas intercalations is random and has a significant impact on detonation performance making it difficult to obtain reproducible and reliable results. Moreover, when chemically aerated, a time from the addition of the substance (or system of substances) secreting gas inclusions until the detonation of explosive, has a strong influence on sensitization and a reduction density of the emulsion explosive. This period should be the same for each of the sensitizer additives. This results from the progressive degradation of aerated substance, which releases additional gas microbubbles reducing the charge's density. This means that two charges which were at the same time introduced to the chemically reducing density additive, should be initiated at the same time, so measuring their density was reliable.

In contrast to the chemical, physical density reduction makes it possible to maintain a reduced density of emulsion explosives stable over time, which gives the possibility to obtain reproducible and reliable results of measurements of the detonation. This is a result of uniform distribution of microparticles (of known dimensions) reducing the density of the whole volume of emulsion explosive.

The study used a matrix produced by AUSTIN POWDER, Hydrox U, viscosity 120000 cPa and composition [%]: ammonium nitrate(V) – 64.4; sodium nitrate(V) – 14.6; organic phase – 6.0; water – 15.0. As a mean of reducing, the density used microballoons 092 DE 120 30.

To define the effect on reducing the density of the microballoons there were eight compositions of emulsion explosives prepared sensitized by microbaloons. Their density is presented in Table 1.

Table 1

Effect of addition of microballoons in water-in-oil emulsion explosives charge density

Content of microballoons, %wt	Density, g/cm^3
0.6	1.07 ± 0.01
1.0	0.86 ± 0.01
1.4	0.81 ± 0.01
1.8	0.73 ± 0.01
2.2	0.67 ± 0.01
2.6	0.60 ± 0.01
3.0	0.56 ± 0.01
3.4	0.55 ± 0.01

The largest decrease in density can be observed between the content of 0.6% and 1.0% of added microballoons, while after crossing the 3.0% of additive, density change is not so significant.

In order to determine parameters of obtained low density emulsion explosives there were tests carried out in order to appoint:

- detonation velocity
- the intensity of the air blast wave.

The measurement of detonation velocity was performed using short-circuit sensor, which were placed in the insulating covers within a distance of 15 mm, 55 mm, 95 mm and 135 mm from the bottom of charge. For each content of the microballoons made two charges which had a mass of 400 g and a diameter of 50 mm, while the height of charge was adapted to its density. Electrical detonators type ERG were used for all measurements of velocity of detonation (D). Appointed detonation velocity are shown in Figures 1 and 2. Figures

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also include for comparison the results of emulsion explosives detonation velocity measurements for containing microspheres 461 DE 20 d70 brand AkzoNobel.

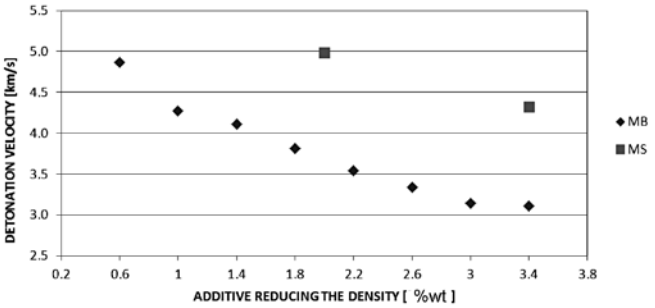

Fig.1. The dependence of detonation velocity of added microspheres (MS) and microballoons (MB)

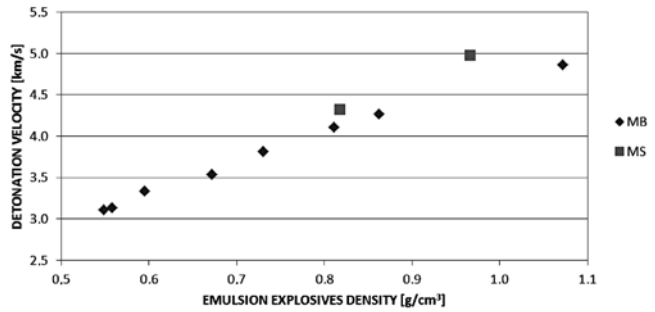

Fig. 2. The dependence of detonation velocity of water-in-oil emulsion explosives density

The intensity of the air blast wave.

Measurements of air overpressure accompanying the propagation of blast wave were made using emulsion explosives charges of constant weight of 400 g. They were placed in housings made of PVC, which diameter was 50 mm, hanging in the air at a distance of 2 m and 2.5 m from the piezoelectric pressure sensors. Made two measurements for each content of the microballoons. Examples of overpressure curve shapes for succeeding additives of microbaloons are shown in Figures 3 and 4, while magnitude of blast wave pulse and maximum overpressure on the individual sensors are shown in Figures 5 and 6.

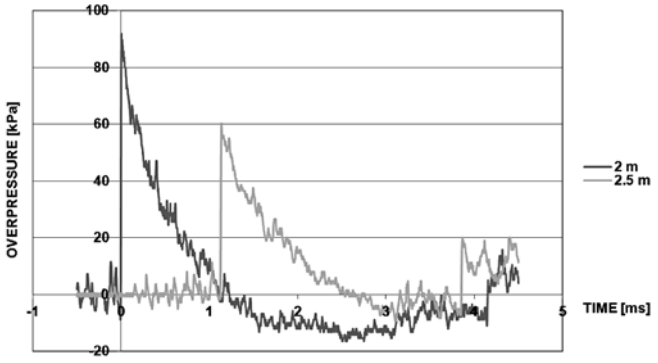

Fig. 3. Overpressure curve for 0.6 % of MB

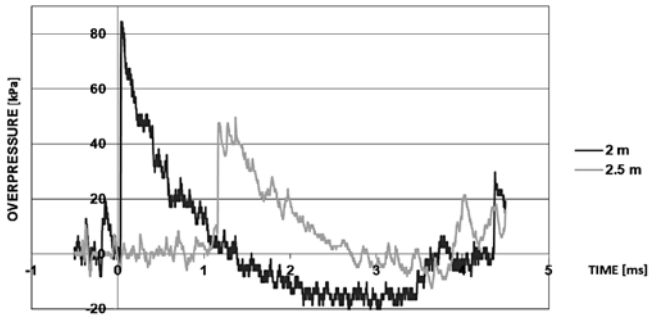

Fig. 4. Overpressure curve for 3.4 % of MB

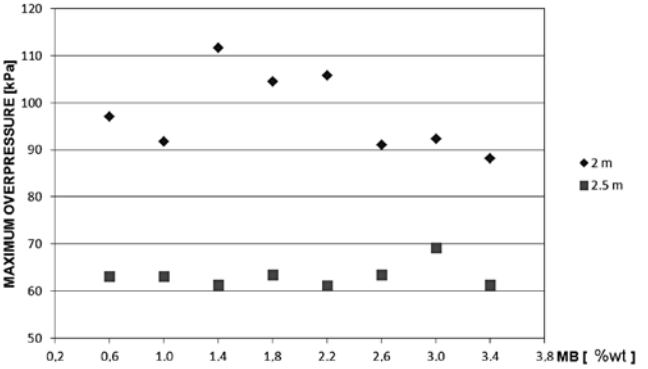

Fig. 5. Overpressure of the blast wave generated by the detonation water-in-oil emulsion explosives containing various amounts of MB

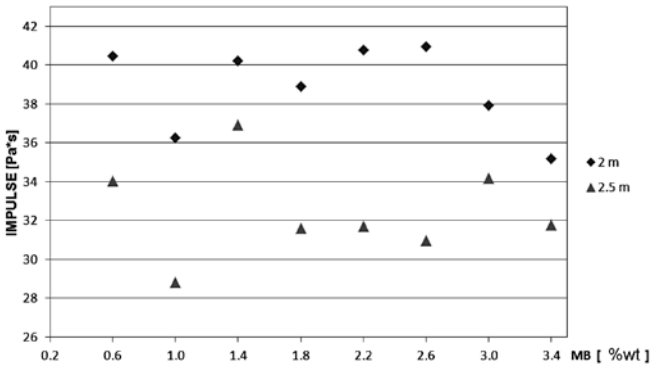

Fig. 6. Impulse of the blast wave generated by the detonation water-in-oil emulsion explosives containing various amounts of MB

Analysis of test results

Emulsion explosives density

In the first stage of the experiment the emulsion explosives' density was reduced by the addition of the microballoons and achieved the reduction level of the parameter in 48.87% of the initial emulsion explosive charge density. Further reduction of the density by using microballoons might cause difficulties in aspect of uniformity of charge. Even the addition of 3.0% of microballoons changed the texture of the material drastically. Originally the material was very sticky and ductile, with the structure of jelly, while with increasing additions of microballoons it became dry and agglomerating.

Emulsion explosives' detonation velocity

At first there was a significant decrease in velocity of detonation, but then it took on form of exponential. The results of detonation velocity changes are presented in the Table 2

Table 2

Statement of changes of detonation velocity for the test charges

Density reducing additive	Additive content, %wt	Detonation velocity, km/s	% the initial velocity of detonation
MB	0.6	4.87	100.00
	1.0	4.27	87.76
	1.4	4.11	84.49
	1.8	3.82	78.39
	2.2	3.54	73.78
	2.6	3.34	68.59
	3.0	3.14	64.52
	3.4	3.11	63.87
MS	2.0	4.98	100.00
	3.4	4.32	86.76

$$y = 5.1408\, e^{-0.16x} \quad (1)$$
$$y = 1.9665\, e^{-0.8767x} \quad (2)$$

Based on the above equation of the exponential function for the microballoons (1) detonation velocity can be achieved at the level of 2800 m/s for 3.8% of the microballoons in the emulsion. The calculated density of such explosive based on the equation (2) should oscillate within 0.40 g/cm^3.

Overpressure of blast waves

Despite the relatively large scatter of the results of maximum overpressure and blast wave pulse as a function of the amount of microballoons, these dependencies can be approximated by polynomial functions.

$$y = -6.6365x^2 + 22.99x + 84.99 \quad (3)$$
$$y = 0.2154x^2 - 0.2012x + 62.644 \quad (4)$$
$$y = -1.4759x^2 + 4.9298x + 35.829 \quad (5)$$
$$y = 0.1209x^2 - 0.6851x + 33.284 \quad (6)$$

Equations (3) and (4) concern the overpressure at a distance of 2 m and 2.5 m from the charge, while (5) and (6) describe a blast wave impulse in these distances. It can be noted that the input magnitudes are close to the output, and their ranges are given in Tables 3 and 4. This means that the addition of microballoons changes the overpressure impulse insignificantly.

Table 3

Overpressure range depending on the distance from the charge

Distance of the sensor from the charge, m	Minimum overpressure, kPa	Maximum overpressure, kPa
2	88.29	111.72
2.5	61.25	69.25

Table 4

Impulse of blast waves range depending on the distance from the charge

Distance of the sensor from the charge, m	Minimum overpressure pulse, Pa*s	Maximum overpressure pulse, Pa*s
2	35.18	40.96
2.5	28.83	36.91

Summary

As part of the work, emulsion explosive matrixes' density were reduced and detonation velocity and intensity of the air blast wave were measured for different amounts of mass aerating agent. The obtained experimental results show a decrease of velocity of detonation along with a reduction in the density of emulsion explosive. In contrast, changes in air blast wave's overpressure are slight. Therefore, it can also be assumed that the ability to perform the work by tested emulsion explosives varies in a small range.

By changing the charge's density you can modify the amount of it in the blast holes, depending on the strength properties of the rock mass. This allows to change blasting grid parameters in a wide range, starting from the same emulsion explosive matrix and changing only the extent of its aeration.

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Translation into English by the Author

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