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Research on the Low Detonation Velocity Explosives Containing Nitroesters

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Abstract: Some explosive mixtures detonating at low velocity were experimentally investigated. Detonation velocity and critical diameter were measured for mixtures, being different in composition and density. An attempt of physical and chemical interpretation of results obtained is also included.

Key words: detonation; nitroester; explosive
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1 Introduction

Explosives with low detonation velocity are used in mining industry, explosive welding and explosive processing. Many molecular explosives are characterised by high detonation parameters. They can be lowered by adding some inert substances with low bulk density[1,2]. Low detonation parameters are also typical for ammnonium nitrate explosives sensitised by a small amount of flaked aluminium and glass beads, urea-formaldehyde resin balloons, colloidal-sized silicon dioxide and lead oxides [3].

In this paper some explosive mixtures containing nitroesters, detonating at low velocity were experimentally investigated. Detonation velocity and critical diameter were measured for mixtures, being different in composition and density.

2 Experimental

The assumed aim to obtain explosives with low detonation velocity was achieved by explosion heat minimalization with a simultaneous reduction of gaseous explosion products. The above assumptions were realized by a proper choice of explosive ingredients:

① As a sensitizer the mixtures of nitroglycol (EGDN) and dinitrotoluene (DNT) (2 : 1) or nitrogliceryne (NG) (1 : 1) were used. From the preliminary study the sensitizer were used in the amount 6%, 9%, 10% and 12 %.

② Wood flour was used as the fuel and ingredient counteracting nitroglycol migration and was also a stabilizing factor of the explosive powder structure. The total amount of fuel in the explosive was regulated by the amount of wood flour.

③ As the oxidants potassium nitrate and ammonium nitrate were used. The potassium nitrate was used with regard to the endothermic characteristic of a decomposition reaction and the production of solid products of comparatively high specific heat during the explosion conversion, which reduce significantly the explosion conversion heat and the amount of gaseous explosion products. The amount of potassium nitrate was chosen in such a way as carbon included in fuels could be oxidized into carbon dioxide. Such an explosive design could provide positive oxygen balance and obtain solid products (carbonates) in the explosion conversion.

④ Supplementary to 100% (after the assumed amounts of sensitizers, wood flour and the calculated amount of potassium nitrate) the ion-exchange system KNO_3-NH_4Cl (the first group of explosives), equimolar mixture KNO_3-NaCl (the second group of explosives) or mixture NH_4NO_3-NaCl (the third group of explosives) were applied.

The explosives were mixed in 2 kg batches and cartridged into different paper shells. The charges were used

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to measure the detonation velocity and critical diameters. Both of the parameters can be used as a criterion of selection of explosives to specific blasting engineering. The mean values of detonation velocity were measured with short circuit sensors placed into charges. Conical and telescopic charges were employed to determine the critical diameters of detonation. The average error for every detonation datum was ±100 m·s^{-1}.

3 Results and discussion

Three groups of explosives including totally 30 explosives were designed and obtained. The composition of the tested and their density are given in Tables 1 ~ 3. The measurement results are given in Figures 1 ~ 3 and in Table 3.

Table 1 Ingredients and densities of explosives containing potassium nitrate and ammonium chloride (group 1)

Sample	KNO_3 /%	NH_4Cl /%	DNT /%	Wood flour /%	EGDN /%	Density /g·cm^{-3}
E 1/1	72.83	20.17	2.00	1.00	4.00	1.09
E 1/2	73.90	18.60	2.00	1.50	4.00	1.09
E 1/3	74.77	17.23	2.00	2.00	4.00	1.09
E 1/4	76.17	15.33	2.00	2.50	4.00	1.11
E 1/5	77.39	13.61	2.00	3.00	4.00	1.10
E 1/6	75.34	14.66	3.00	1.00	6.00	1.10
E 1/7	76.47	13.03	3.00	1.50	6.00	1.08
E 1/8	77.63	11.37	3.00	2.00	6.00	1.10
E 1/9	78.73	9.77	3.00	2.50	6.00	1.09
E 1/10	78.91	8.09	3.00	3.00	6.00	1.11

Table 2 Ingredients and densities of explosives containing potassium nitrate and sodium chloride (group 2)

Sample	KNO_3 /%	NaCl /%	DNT /%	Wood flour /%	EGDN /%	Density /g·cm^{-3}
E 2/1	71.63	21.37	2.00	1.00	4.00	1.10
E 2/2	72.80	19.70	2.00	1.50	4.00	1.08
E 2/3	73.85	18.25	2.00	2.00	4.00	1.09
E 2/4	75.26	16.24	2.00	2.50	4.00	1.11
E 2/5	76.59	14.41	2.00	3.00	4.00	1.10
E 2/6	74.47	15.53	3.00	1.00	6.00	1.09
E 2/7	75.70	13.80	3.00	1.50	6.00	1.08
E 2/8	76.86	12.04	3.00	2.00	6.00	1.11
E 2/9	78.16	10.38	3.00	2.50	6.00	1.09
E 2/10	79.43	8.57	3.00	3.00	6.00	1.10

Table 3 Ingredients, densities and detonation parameters of explosives containing ammonium nitrate and sodium chloride

Sample	NG /%	EGDN /%	NH_4NO_3 /%	NaCl /%	Density /g·cm^{-3}	Critical diameter /mm	Detonation velocity[1] /m·s^{-1}
E 3/1	5.00	5.00	10.00	80.00	0.98	10	650
E 3/2	5.00	5.00	20.00	70.00	0.98	10	810
E 3/3	5.00	5.00	40.00	50.00	0.98	8	1050
E 3/4	5.00	5.00	60.00	30.00	0.98	8	1380
E 3/5	5.00	5.00	80.00	10.00	0.95	8	1650
E 3/6	6.00	6.00	–	88.00	1.22	8	1170
E 3/7	6.00	6.00	20.00	68.00	1.20	8	1340
E 3/8	6.00	6.00	40.00	48.00	1.05	8	1430
E 3/9	6.00	6.00	60.00	28.00	1.01	8	1550
E 3/10	6.00	6.00	80.00	8.00	0.95	8	1750

Note: 1) cartridge diameter 18 mm.

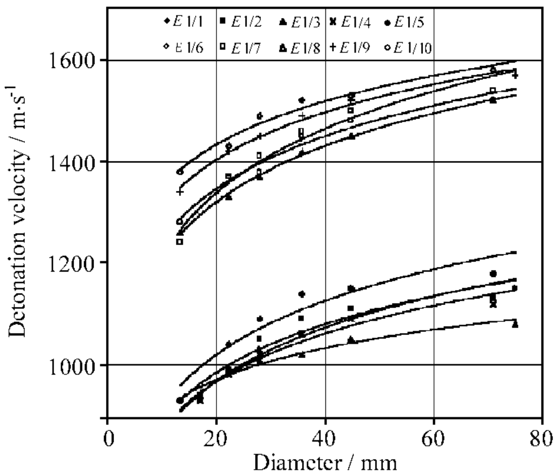

Fig. 1 Dependence of the cartridge diameter on detonation velocity for explosives (group 1)

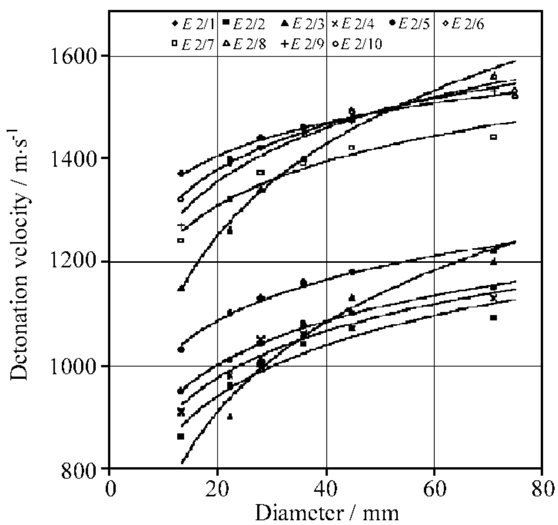

Fig. 2 Dependence of the cartridge diameter on detonation velocity for explosives (group 2)

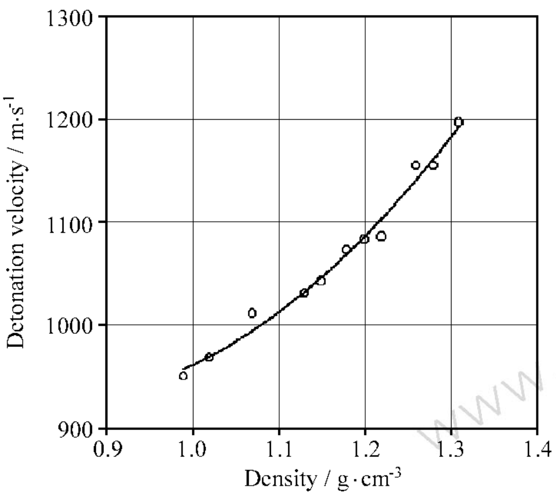

Fig. 3 Dependence of density (explosive E 1/3, diameter 35.8 mm) on detonation velocity

Depending on the cartridge diameter of explosives sensitized by nitroglycol (4 %), detonation velocities go up from 900 ~1 100 $m \cdot s^{-1}$ for the diameters 13.4 and 17.1 mm to 1 100 ~1 300 $m \cdot s^{-1}$ for the diameters 71.1 and 75.0 mm (bottom pencils of curves in Fig. 1 and 2). For the cartridges of bigger diameters, detonation depending on the cartridge diameter of the explosive sensitized velocities are practically stabilized within the range of 1 100 ~ 1 200 $m \cdot s^{-1}$. While by nitroglycol (6 %), detonation velocities rise from 1200 ~ 1400 $m \cdot s^{-1}$ for the diameters 13.4 and 17.1 mm to 1 400 ~ 1 600 $m \cdot s^{-1}$ for the diameters 71.1 and 75.0 mm (top pencils of curves in Fig. 1 and 2). In both groups of the worked out explosives similar dependencies were observed and the amount of nitroglycol was key factor for the detonation velocity.

Detonation velocity test was done for the explosive whose density equals 1.1 $g \cdot cm^{-3}$. For the smaller density the detonation velocity is also smaller. The dependence of detonation velocity of explosive E 1/3 on its density showed that, detonation velocity rise from 950 to 1 200 $m \cdot s^{-1}$ with the rise of density from 0.99 to 1.31 $g \cdot cm^{-3}$ (Fig. 3) In this range of densities the detonation velocity changes (exactly to 2 %) according to the dependence:

$$D = 212.15 + 735.23\rho_0$$

In the case of explosives sensitized by mixture of nitroesters, an increase of sodium chloride content results in decrease of detonation velocity. At high contents of the inorganic substance detonation velocities lower than 1 000 $m \cdot s^{-1}$ are obtained (Table 3, mixtures No. 1 and 2). From the comparison of detonation velocity data obtained for explosive mixtures containing 6 % nitroglycol or mixture EGDN-NG, it follows that value of detonation velocity not only depends on the amount of nitroesters but also is influenced by physico-chemical characteristics of other components. While the sodium chloride acts only as the substance which absorbs the energy from the detonation zone, other components can bring the positive contribution into energetic outcome of the explosive conversion. This concerns ammonium nitrate which at required circumstances can liberate heat well as it holds in the case of potassium nitrate mixtures with dinitrotoluene or wood flour. The substances react partially in the detonation zone, their transformation is initiated by decomposition of nitroesters.

Critical diameters of the explosives sensitised by nitroglycol equal from 8 to 14 mm. Where as, the explosives sensitised by the mixture EGDN -NG (1 : 1) changed from 8 to 10 mm (Table 3).

4 Summary

A wide variety of explosive mixtures have been worked out, especially containing mixtures. They are characterised by capability of stable detonation at low velocity (in small diameters) and therefore they can be used to clad steel with thin metal (also with lead) and to fix tubs in sieve bottoms of the heat exchangers.

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