

A study of the detonation parameters of nitrogen fertilisers and aluminium flake powder mixtures

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Introduction

Ammonium nitrate is an elementary component of mining explosives. The addition of flammable materials, i.e. coal dust or aluminium powder to an oxidiser, e.g. ammonium nitrate(V), considerably increases the heat of explosion of produced mixtures in comparison with pure ammonium nitrate(V). The flammable materials added to ammonium nitrate improve other explosive properties. Also higher detonation ability and higher demolishing and explosive effects are achieved [1 ÷ 7].

The explosives containing ammonium nitrate(V) were used in many bomb attacks that took place in Great Britain and Northern Ireland at the end of the 1970s and the beginning of the 1980s. In recent years, the attack launched in Oklahoma City in the USA on 19 April, 1995 and the one on the Bali Island on 12 October, 2002 illustrate the most spectacular terrorist attacks, in which ammonium nitrate(V) was used. The consequences of these attacks directed by organised terrorist groups were the introduction of stricter qualitative requirements for ammonium nitrate(V) (that is, reduced detonation ability) and the implementation of legal acts to restrict the placing on the market and the application of ammonium nitrate fertilisers that are easily available on the market. Only fertilisers containing considerable amounts of inert additives are allowed to circulate on the market.

The results of conducted studies are presented below. They allow the evaluation of possibilities and effects of using fertilisers in bomb attacks, that is, using them as precursors of explosive mixtures.

Experimental part

Determination of ammonium nitrate(V) content in tested nitrogen fertilisers

The total content of nitrogen in tested fertilisers was determined by the formaldehyde technique according to the standard PN-C-87054:2000. That analysis involved the addition of the standard formaldehyde solution to a neutralised sample solution. Then, the prepared sample was titrated with the standard solution of sodium hydroxide using the mixed indicator.

After averaging the results, the total content of nitrogen in nitro-chalk was 27.1 %; in salmag with sulphur - 27.3%; in salmag with boron - 27.5%; and in ammonium nitrate - 32.2%. The experimental results permitted calculating the content of ammonium nitrate (V) in analysed fertilisers. The obtained results are presented in Table I.

Table I

Ammonium nitrate(V) content in the tested nitrogen fertilisers

Component	Nitrogen fertiliser			
	Nitro-chalk	Salmag with sulphur	Salmag with boron	Ammonium saltpetre
Ammonium nitrate(V), %	77.43	77.97	78.60	92.10

The content of ammonium nitrate(V) in the determined fertilisers is comparable with the range provided by the manufacturer - Kędzierzyńskie Zakłady Azotowe.

The grinding degree of components in tested mixtures and the method for preparing samples

Two-component mixtures containing the analysed nitrogen fertilisers and aluminium flake powder were used to examine the detonation parameters. Aluminium flake powder was chosen due to its very high ability to sensitise ammonium nitrate(V). The samples of nitrogen fertilisers were mechanically grinded and passed through a sieve with 0.8 mm mesh size. Aluminium flake powder used in that experiment was produced in the Benda-Lutz company in Skawina. The powder was covered with 3% stearic acid. Aluminium content was 82.5%. The screen analysis of aluminium with IPS-U analyser was performed. The experimental results are illustrated in Figure 1.

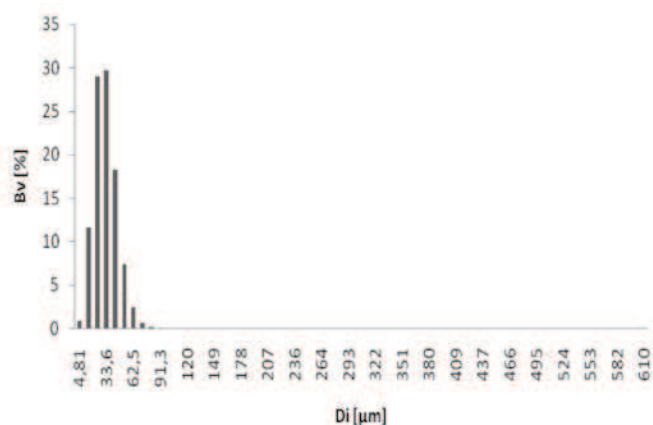


Fig. 1. Results of the aluminium flake powder screen analysis

Aluminium powder content in tested samples was changing in the range from 3% to 15%. Explosive mixtures were prepared by mechanical homogenisation of components.

Detonation ability of nitrogen fertilisers and aluminium flake powder mixtures

High energy conversion that occurs in explosives can be initiated either by different thermal and mechanical stimuli or by the detonation effect of another explosive. The detonation ability of explosives can be specified by determining the following: critical diameter, intensity of initiating blast wave, distance of detonation transfer or excitation by a detonator.

Critical diameter of detonation – it is the minimum diameter of an explosive charge for which detonation can propagate. This value is determined by the method of conical or telescopic charges. The critical diameter of detonation is connected with the load wave propagating from the outer layer of the charge towards the chemical reaction zone of the detonation wave. This phenomenon results in the

detonation pressure drop that influences the kinetics of the chemical reaction by reducing the quantity of released heat. Consequently, the parameters of the detonation wave are lowered. Energy losses that result from the temperature drop of the reacting explosive can exceed the energy released during the chemical reaction. As a result the detonation process can fade.

In the present paper, the critical diameter was determined by the conical charge method that can provide slightly lower value of a measured parameter than in case of the telescopic charge. The investigation was conducted for the mixtures of aluminium powder and three following fertilisers: nitro-chalk, salmag with sulphur and ammonium nitrate. The content of aluminium powder was 3% and 6%. The tested mixtures had bulk densities. In the first stage of the investigation, the conical charges with a diameter from 30 mm to 45 mm were used. A sheet of paper served as the charge shield. The charge was placed on a metal plate. After the detonation, the plate was marked with a trace to assess the charge diameter, at which the explosive process faded. Figure 2 illustrates typical results of such tests.



Fig. 2. Witness plates after detonation of nitro-chalk/aluminium powder mixtures in truncated cone 30÷45 mm: a – 97/3, b – 94/6

When the detonation of all the tested explosives reached the end of a charge in a 30÷45 mm truncated cone, next series of tests were performed in the truncated cones with a diameter range from 5 mm to 30 mm. Typical results of these tests are illustrated in Figure 3 and all the measurement results are presented in Table 2.

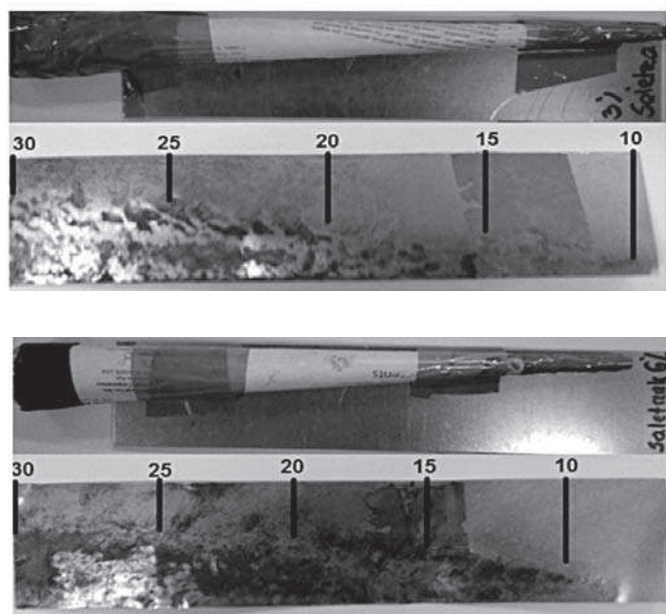


Fig. 3. Witness plates before (up) and after (down) detonation of nitro-chalk/aluminium powder mixtures in truncated cone 5÷30 mm: a – 97/3, b – 94/6

Table 2

Results of measurements of critical diameter nitrogen fertilisers and aluminium flake powder mixtures

Aluminium powder content, %	Type of nitrogen fertiliser	Density of explosive, g/cm ³	Critical diameter, mm
6	Nitro-chalk	0.79	7
3		0.73	10
6	Salmag with sulphur	0.86	7
3		0.81	10
6	Ammonium saltpetre	0.75	7
3		0.79	10

The measurement results have shown that the critical diameter was getting smaller as Al content in the mixture compositions was increasing. The propagation of the detonation process for the mixtures of fertilisers and 3% and 6% aluminium powder was observed for 10 mm and 7 mm diameters. The detonation ability of aluminised nitrogen fertilisers is similar to those of TNT (11 mm) and picric acid (9 mm).

Sensitivity to the blast wave. The explosive reaction of another charge can initiate the detonation of an explosive. Hot explosion products and blast wave are factors initiating this process.

The detonation ability under the impact of the blast wave is examined in the *Gap Test* – one of the most frequently used investigation methods. In this test, the charge of the tested explosive is excited by the blast wave generated in the inert barrier by the detonation of the charge of high energy hexogen. The thickness of the barrier, at which the detonation takes place or fails, is the result of the gap test. There are many variations of gap test sets. They differ in a type of the barrier material (aluminium, PMMA, resins, water), the diameter of individual elements of the set and a type of explosive generating the blast wave. The purpose of this paper was to conduct the research by the Trimborn technique (Fig. 4) using the layer of water as the inert barrier.

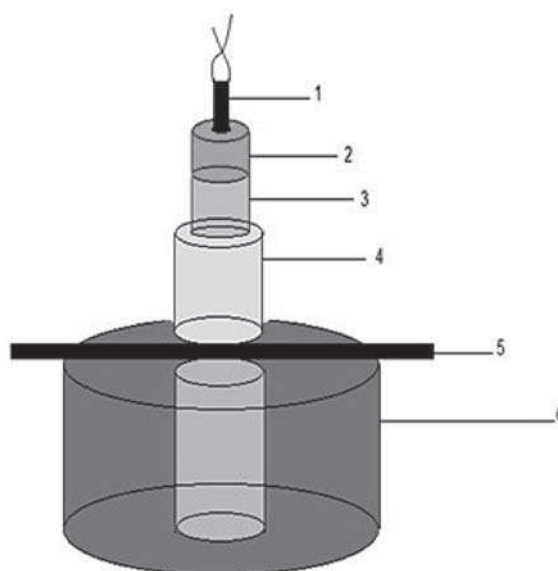


Fig. 4. Scheme of gap test: 1 – electric detonator, 2 – booster, 3 – water, 4 – tested explosives, 5 – steel plate, 6 – steel tube blank

The sensitivity to the blast wave was measured for mixtures of three nitrogen fertilisers: nitro-chalk, salmag with sulphur and ammonium nitrate with added aluminium flake powder. Phlegmatised hexogen with a diameter of 50 mm and height of 50 mm with a pressed opening for a detonator was used as the booster. The dimensions of

prepared charges were 28/50 mm. Water layer (inert barrier) of various thicknesses was placed between them. The test results are presented in Figure 4 and Table 3.

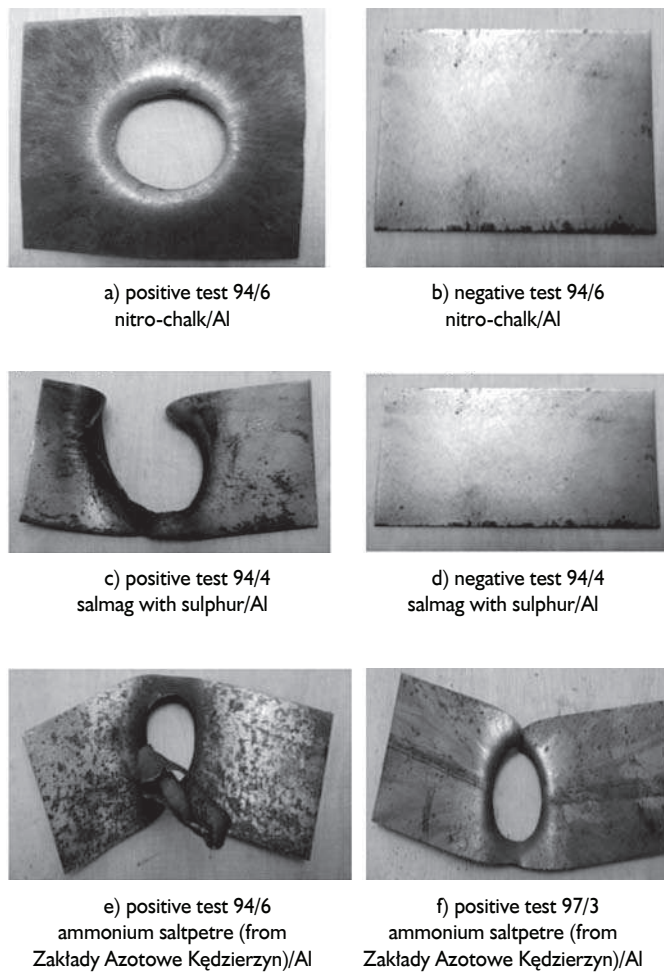


Fig. 4. Results of gap tests

Table 3

Results of gap tests

Explosive mixture	Mixture composition, %	Thickness of the inert barrier, mm	
		detonation	lack of detonation
Nitro-chalk/Al	94/6	34	35
Salmag with sulphur/Al	94/6	37	38
Ammonium saltpetre/Al	94/6	34	35
	97/3	33	34

The data from Table 3 show that the mixture of salmag with sulphur containing 6% of aluminium powder has the highest sensitivity to the blast wave, and ammonium saltpetre with 3% of aluminium powder has the lowest one. The conducted research indicates that the sensitivity of tested nitrogen fertilisers to the blast wave increases with the increased content of the flammable substance. The pulse amplitude from the blast wave reaching the tested material diminishes with the increase of the water layer thickness.

Determination of the detonation velocity of mixtures containing selected nitrogen fertilisers and aluminium powder

This paper involved the method of ionisation (electrocontacted) probes to measure the detonation velocity. The measurement was conducted inside the hardened PVC tubes with an internal diameter

of 36 mm and wall thickness of 3 mm. The charges were initiated with a booster made from phlegmatised hexogen of 10 g mass. Figure 5 illustrates the scheme of the charge for measuring the detonation velocity. Figures 6 and 7 present the dependence of the detonation velocity of aluminised mixtures of nitro-chalk and salmag with sulphur on the content of aluminium powder.

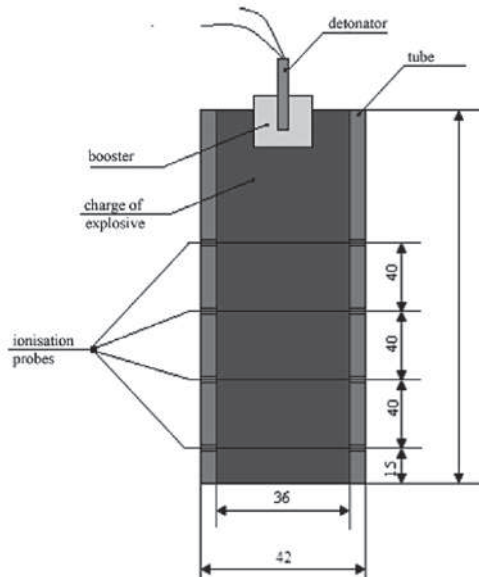


Fig. 5. Scheme of detonation velocity measurement set

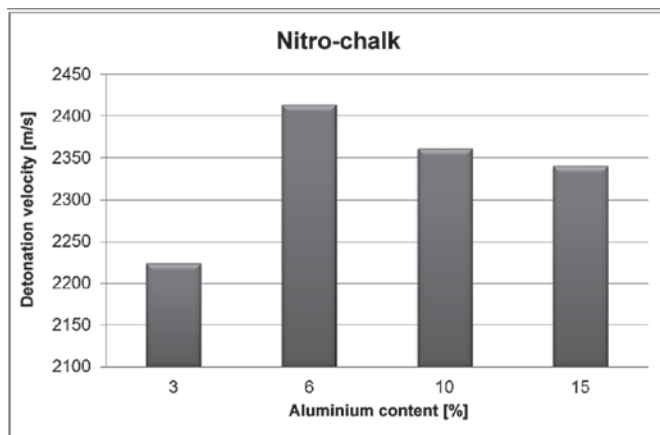


Fig. 6. Dependence of detonation velocity of nitro-chalk and aluminium powder mixtures on metallic component content

The presented results from the measurements (Fig. 6) reveal that nitro-chalk and aluminium powder mixture containing 6% of aluminium flake powder has the highest detonation velocity – 2410 m/s.

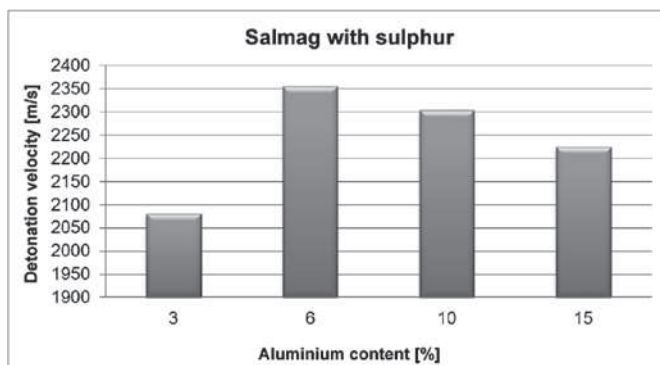


Fig. 7. Dependence of detonation velocity of salmag with sulphur and aluminium powder mixtures on metallic component content

In case of the explosive mixtures of salmag with sulphur and aluminium powder, the composition containing 6% of aluminium flake powder also has the highest detonation velocity – 2350 m/s. The similar

qualitative nature was observed for each established dependence of the detonation velocity on the content of aluminium powder in mixtures containing various types of nitrogen fertilisers.

Summary

The purpose of this work was to determine the possible applications of nitrogen fertilisers as precursors of explosive mixtures. These experimental studies involved three nitrogen fertilisers: nitro-chalk, salmag with sulphur and ammonium nitrate. The tested nitrogen fertilisers differed in the content of ammonium nitrate (V) and types of inert additives reducing the explosive properties. The conducted tests have revealed that the mixtures of tested nitrogen fertilisers and aluminium powder (NA – Al) have very high detonation ability. The following conclusions can be drawn on the basis of performed experiments:

1. The tested nitrogen fertilisers contain (78 ÷ 92) % of nitrogen ammonium (V).
2. The critical diameter of NA-Al mixtures in the tested range was getting smaller as the content of aluminium powder was increasing, and it ranges from 9 to 11 mm.
3. NA-Al sets containing salmag with sulphur are the most sensitive from all the tested samples to the impact of the blast wave.
4. NA-Al mixtures have the highest detonation velocity at 6% content of aluminium powder.
5. The detonation velocity of aluminised explosive mixtures containing nitro-chalk or salmag with sulphur is comparable with ammonium nitrate explosives, such as ammonal or ANFO.

The above properties indicate that the tested mixtures of nitrogen fertilisers and aluminium powder can be used by the terrorists to prepare improvised explosive charges. Regarding the availability of nitrogen fertilisers, the strict control on purchasing aluminium powder, and particularly its very grinded forms, should be implemented.

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Winners'2011 Young Researcher Award

MSc. Elżbieta Jędrych, Dr. Marcin Gronowski and Dr. Bartosz Kempisty are winners of the Scopus-Perspektywy Young Researcher Award for accomplished scholars below 30 with. The competition results were announced in late November in Warsaw. As a reward, young scientists will receive two thousand euros to cover cost of a trip to a scientific conference abroad. Microstructures will allow researchers to grow healthy or cancerous cell cultures, and then perform toxicity test on them. The researcher explained that the use of this tool can automate the testing, accelerate them and reduce their cost. In the future, it will allow for faster diagnosis and treatment of cancer.

Dr. Bartosz Kempisty from Poznań University of Medical Sciences has developed a microchip that helps in the analysis of farm animal embryos. His project will result in creating the world's first system capable of encoding cells. Scientists are developing a mathematical system, in which each cell is assigned the appropriate code number referring to its physical properties. Ready chips can be implanted to embryos of cattle and pigs.

The main theme of research of the third winner, Dr. Marcin Gronowski from the Institute of Physical Chemistry PAS, is the study of extraterrestrial molecules, for example, occurring in interstellar molecular clouds. The most important issue the winner investigates is the application of quantum chemistry in other fields of chemistry. So far, he successfully investigated the effects of light radiation on selected particles. In addition to three winners, the finalists of this year's competition also included: Dr. Piotr Trocha from Adam Mickiewicz University in Poznań, Dr. Andrew Ruth from AGH University of Technology in Kraków, MSc. Cezary Samojłowicz from the Institute of Organic Chemistry PAS in Warsaw, Julia Romanowska MA from the University of Warsaw, Dr. Magdalena Matusiak-Małek from the University of Wrocław, Dr. Jakub Growiec from the Warsaw School of Economics, MSc. Krzysztof Churski from the Institute of Physical Chemistry PAS in Warsaw. The competition- Scopus-Perspektywy Young Researcher Award is addressed to researchers below the age of 30, who have significant scientific achievements. Its organizers are "Perspektywy" Educational Foundation and Elsevier BV, publisher of the Internet database containing abstracts of articles and a bibliography of several thousand scientific journals devoted to various areas of science.

(<http://www.naukawpolsce.pap.pl>, 15.11.2011)