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Testing of mining explosives with regard to the content of carbon oxides and nitrogen oxides in their detonation products

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ABSTRACT

Blasting operations are a risk to the lives of mining workers. Blasting gases are particularly dangerous factors – these are the products from detonations which come from applying explosives which contain toxic nitrogen oxides and carbon monoxide. The aim of this study was the experimental determination of the composition of the blasting gases from a variety of explosives currently being produced in Poland. On the basis of research results, analysis was carried out. To perform research of the composition of blasting gases, after the detonation of explosives, a laboratory test stand was used. The study involved the determination of gaseous products, i.e. nitrogen oxides and carbon oxides. Research was carried out in accordance with research methodology based on European Directive 93/15/EEC and the harmonized standard PN-EN 13631-16. These studies provided information on the amount of harmful gaseous products from mining explosives after detonation.

1. Introduction

During detonation, explosives used in mining undergo rapid decomposition due to high temperatures and large amounts of constantly evolving gases and heat. The more gases accompanying the decomposition of explosives, the higher the pressure of the gases in the blast hole. Therefore, the results of such blasting operations are greater. Additionally, gases that evolve during the detonation process contain gaseous products which are highly hazardous, such as: carbon monoxide CO, nitrogen monoxide NO and nitrogen dioxide NO_2 (their molecular formulae are marked as NO_x). In addition to these oxides, another significant impact of blasting techniques is the release of the non-toxic gas carbon dioxide CO_2, which is the product of the final explosive transformation of explosives (Mainiero, Harris, & Rowland, 2007).

During explosive transformation, alteration of the chemical structure of the explosive takes place. Decomposition of the initial molecular structure of the explosive leads to the creation of a non-equilibrium chemical system wherein reactions occur between atoms, radicals and products of the partial decomposition of materials. The primary source of energy from explosions, using an explosive that has a typical elemental composition $C_aH_bN_cO_d$, is the energy discharged during the formation of water molecules H_2O and carbon dioxide CO_2 (Maranda, Cudziło, Nowaczewski, & Papliński, 1997; Badgujar, Talawar, Asthana, & Mahulikar, 2008).

Toxic oxides are formed during basic explosive reactions between nitrogen, oxygen and carbon. These transformations

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relate closely to the oxygen balance, which is expressed as a percentage of the difference between the amount of oxygen contained in the explosive and the amount of oxygen that is essential to complete the oxidation of carbon to carbon dioxide and hydrogen to water (Urbański, 1985; Agrawal, 2010). The oxygen balance is indicated as positive, zero or negative when the oxygen content in the explosive is, respectively, bigger than, equal to or smaller than the amount of oxygen required to complete combustion of carbon and hydrogen to carbon dioxide and water.

The chemical reactions which lead to the formation of detonation products, including carbon monoxide CO and nitrogen oxides NO_x, were discussed in literature many years ago (Szepieliev & Kustov, 1974).

Taking into account that detonation products depend both on their chemical composition and the conditions in which detonation occurs, precise information as to the composition of blasting gases can be obtained from experimental tests.

This paper presents the research of selected cartridge explosives intended for use in underground mining. For these explosives there is a requirement to determine the composition of the blasting gases that are formed after their detonation. The explosives tested were produced by a leading Polish industrial explosive company.

Firing of the prepared charges were made for each explosive selected. During the firing of the explosives, the content of nitrogen monoxide NO and nitrogen dioxide NO_2 (referred to as NO_x), carbon monoxide CO (as toxic gases) and carbon dioxide CO_2 was determined. The research results concerning the composition of blasting gases for each explosive were obtained for several different batches of production. Their mean values were compared with the boundary values of the aforementioned oxides on the basis of criteria established in Poland and other European countries.

2. Methods and material

2.1. Explosive characteristics

The research subject matter consisted of materials which belong to two groups:

- Rock explosives (ammonites, dynamites, emulsion explosives) which do not correspond to the requirements concerning mixtures of methane and/or coal dust and air as defined in the Polish standard (PN, 1997) during safety tests, special methane explosives – permitted explosives (methanite) which correspond to the requirements defined in the standard above during safety tests with a mixture of methane and/or coal dust and air.
- Tested explosives i.e. ammonites (Ammonite 1, Ammonite 2) and one methanite (Methanite 1), according to Polish classifications due to their structure and chemical composition, belong to the subgroup of ammonium - nitre powdery explosives. Dynamites (Dynamite 1, Dynamite 2, Dynamite 3, Dynamite 4), on the other hand, belong to the subgroup of nitrate ester plastic explosives. All of the explosives mentioned are varieties of explosives devoid of carcinogenic nitro compounds i.e. dinitrotoluene and trinitrotoluene.

The emulsion explosives are the most recent variety of explosives used in mining. Their basic components include oxidizing agents. The most common of which is ammonium nitrate which is also in a mixture with either sodium nitrate or calcium nitrate. Other components include fuels, water, emulsifiers, allergenic and modifying agents. Tested emulsion explosives (MWE 1, MWE 2, MWE 3) belong to the group of rock explosives. Table 1 shows the summary and characteristic of the tested explosives.

The detonators which contained 0.6 g of penthrite as a secondary charge were used to initiate the detonation of the explosives highlighted.

2.2. The research method

The determination of the composition of blasting gases was carried out in accordance with the requirements of European standard (PN-EN, 2006). The above-mentioned standard is harmonized with the directive (93/15/EEC, 1993) which specifies the blasting gases research method. However, it does not include the requirements with regards to acceptable amounts of toxic carbon monoxide CO and nitrogen oxides NO_x for 1 kg of explosive detonated. Therefore, each country applies its own rules and normative requirements in this field.

In order to carry out the determination of the composition of blasting gases, the charges were made of explosives mentioned in Section 2.1 and initiators. Charges were detonated in a blast chamber as shown in Fig. 1. The chamber consisted of classic steel mortar. The detonation of the charges was carried out on the test bench designed for

Table 1 – The summary and characteristic of the tested explosives.

Explosive	Charges diameter [mm]/mass [g]	Charge shield	Explosive structure	Type of explosive	Oxygen balance
Ammonite 1	32/125	Paper	Powdery	Rock	+1.8
Ammonite 2	32/125	Paper	Powdery	Rock	+2.9
Dynamite 1	36/450	Polyethylene	Plastic	Rock	+4.2
Dynamite 2	32/300	Paper	Plastic	Rock	+3.3
Dynamite 3	40/1000	Polyethylene	Plastic	Rock	+2.6
Dynamite 4	50/500	Polyethylene	Plastic	Rock	+8.44
MWE 1	40/750	Polyethylene	Plastic	Rock	+8.7
MWE 2	32/300	Polyethylene	Plastic	Rock	+8.65
MWE 3	40/750	Polyethylene	Plastic	Rock	−2.38
Methanite 1	32/125	Paper	Powdery	Methanoic special	+4.4