

GEOETHICAL RESPONSIBILITY OF MINING ENTERPRISE MANAGERS IN ELIMINATING THE CAUSES OF INJURIES DURING BLASTING OPERATIONS BY INTRODUCING A METHOD OF NON-EXPLOSIVE DESTRUCTIVE MIXTURES

*RESPONSABILIDADE GEOÉTICA DOS GESTORES DE EMPRESAS DE
MINERAÇÃO NA ELIMINAÇÃO DAS CAUSAS DE LESÕES DURANTE OPERAÇÕES
DE DETONAÇÃO ATRAVÉS DA INTRODUÇÃO DE UM MÉTODO DE MISTURAS
DESTRUTIVAS NÃO EXPLOSIVAS*

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Abstract

The causes of injuries during blasting operations in the development of ore deposits are analyzed, and to ensure the safety of mining operations, instead of drilling and blasting operations, the use of non-explosive destructive mixtures is proposed, which depends on the human factor, geoethics and the responsibility of the managers of the mining enterprise.

Keywords: Trauma. Blasting Operations. Mining Enterprise. Geoethics. Non-Explosive Destructive Mixtures (NDM) Method.

Resumo

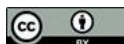
São analisadas as causas dos acidentes ocorridos durante as operações de detonação na exploração de jazidas minerais e, para garantir a segurança das operações de mineração, propõe-se, em substituição às operações de perfuração e detonação, o uso de misturas destrutivas não explosivas, o que depende do fator humano, da geoética e da responsabilidade dos gestores da empresa de mineração.

Palavras-chave: Traumatismo. Operações de detonação. Empresa de mineração. Geoética. Método de misturas destrutivas não explosivas (NDM).

1 THEORY

Currently, drilling and blasting, using explosive energy, is practically the only method for breaking hard rock during mineral deposit development. This method remains the leading method in terms of productivity and timeliness, and will remain so for the next 30-40 years, until new methods for breaking hard rock using higher power are invented.

An analysis of the causes and incidence of accidents conducted by Rosgortekhnadzor across all types of mining operations shows that blasting operations account for up to 6-8% of the total number. In recent years, mining companies have



experienced a number of accidents related to blasting operations. Blasting operations require constant attention to improve safety. As for the causes of accidents, analysis shows that they are mostly related to gross violations of the Uniform Safety Rules for Blasting Operations (USR), with many violations being repeated, indicating that there are typical work situations that lead to accidents. Such situations are primarily related to violations of blasting procedures, particularly in the destruction and transportation of explosive materials. This is due to the personal lack of discipline among blasters and inadequate supervision of their work by mining engineers and blasting supervisors. It's not uncommon for engineers to lack sufficient practical knowledge of blasting procedures from a safety perspective.

An analysis of the causes of accidents during blasting operations allows us to draw the following conclusions: 33% of accidents were due to violations of loading technology, 27% to inconsistency in personnel actions, 16% to violations of explosive material destruction regulations, 6% to violations of technology for the disposal of failed charges, and 6% to personnel being in a hazardous area; 20% of accidents occurred due to work at the location of failed charges.

The main disadvantages of the drilling and blasting method are the insufficient provision of complete safety during blasting operations, interruption of the rhythm of mining operations and downtime due to ventilation of blasting sites, a large volume of auxiliary work, insufficient use of the blast energy in fractured rocks of different strengths, the release of a huge amount of dust and toxic gaseous products, the danger of storing explosives (HE), etc.

These shortcomings necessitate the development of low-cost and promising methods for breaking hard rock formations with minimal impact on the surrounding rock mass. These explosive-based methods include contour blasting, or smooth blasting, which allows for directed cracking along the contour of boreholes. Contour blasting is used in mine workings where the drilling plan includes cut, break, and contour boreholes (Fig. 1).

Figure 1

View of a face with contour boreholes prepared for blasting



To reduce the seismic impact of the blast on the perimeter rock, the perimeter blastholes are first blasted, followed by the cut-hole blastholes, and then the breaker blastholes. The gap created by the perimeter blastholes initially protects the perimeter rock from destruction by the subsequent blast waves from the remaining blastholes (preliminary perimeter blasting). For smooth blasting, the perimeter blastholes are loaded with dispersed charges (garland-shaped cartridges) with a gap between the cartridges and the borehole walls, known as decoupling. Blasting is performed using detonating cords (DC), adjusting the decoupling and the distance between the cartridges to maintain the perimeter of the blasthole. However, to correctly direct crack development between the perimeter blastholes, the circular cross-section of the blastholes is modified to create an elongated elliptical cross-section by pre-blasting the DC on the borehole wall, i.e., the major axis of the ellipse is a stress concentrator on the contour of the borehole and in the direction of which the main crack is created [3].

However, even when carrying out contour blasting, the same disadvantages remain that were noted above, and therefore, a promising direction for solving this problem is the use of a static method of destroying various rocks using non-explosive destructive mixtures (NDM) [1,2].

Non-explosive destructive agents are substances (mixtures, compositions, compounds) whose chemical hydration reaction is accompanied by the generation of mechanical stresses in the host environment without combustion or detonation. Stresses in the rock arise and develop due to the expansion of the hydration product when NRS powder, suspended in water, is placed in the blasthole.

To date, more than 120 different NRS mixtures and compositions are known. Their main drawbacks include the complexity of their formulation, the use of rare and expensive additives, long breakup times (12-24 hours), limited operating temperatures, limited application conditions, and dependence on climatic and temperature conditions (for example, it does not work in winter). The technology for breaking rock using NRS is relatively simple. A mixture of a non-explosive breaker based on expanding cement and water is poured into drilled boreholes. During the hydration process, the cement expands, increasing by up to 30-50 MPa over time, resulting in cracks and the material breaking apart between the boreholes. The process is silent and lasts for several hours, ensuring safe rock breakup, unlike drilling and blasting operations in mines.

Such substances have been developed both abroad and in our country and are widely used in construction for the destruction of concrete and reinforced concrete structures, and in mining for the extraction of natural stones, precious stones, and rock. The technology for destruction using NRS is quite simple. A mixture of a non-explosive blasting agent based on expanding cement and water is poured into drilled boreholes. During the hydration process, the cement expands, increasing by up to 30-50 MPa over time. This results in cracks forming and the material being torn apart between the boreholes. The process occurs silently and lasts for several hours.

In most modern NRS, the main working substance is calcium oxide, the hydration of which is accompanied by an increase in volume [4]. Therefore, when the NRS is placed in a closed cavity, pressure is exerted on the walls of the cavity due to the expansion of the mixture.

The process of producing low-calcium oxide aggregates from local raw materials of a mining enterprise consists of the extraction of materials (limestone, dolomites, etc.), preparation of a raw mix (crushing, grinding, and homogenization of the composition), firing the mix (obtaining calcium oxide granules), and grinding clinker. Natural gypsum dihydrate is used as additives to increase the calcium oxide content in low-calcium oxide

aggregates, as well as industrial waste consisting of gypsum dihydrate ($\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) or their anhydrous calcium sulfate ($\text{CaSO}_4 \cdot 0.5\text{H}_2\text{O}$), or mixtures thereof – phosphogypsum, borogypsum, fluorogypsum, etc. Dolomitized limestones contain dolomite ($\text{CaCO}_3 + \text{MgCO}_3$) as an impurity.

The calcium oxide hydration reaction is exothermic and vigorous, making it difficult to prepare the working mixture, place it in the borehole, and ensure a stable reaction within the borehole to achieve the desired result. Therefore, to use calcium oxide in cementitious mortar, it is necessary to slow down the hydration reaction when mixing the cementitious mortar with water. This is achieved through passivation, which can be accomplished in various ways.

The first group of methods is based on the combined firing of raw materials (limestone, dolomite) with special additives at a temperature exceeding the decarbonation temperature of limestone (1200-1500 °C). The additives used are silicates, aluminates, ferrites, and aluminoferrites, as well as calcium sulfate, sulfoaluminate, and sulfoferrite (CaSO_4 , $\text{Ca}_4\text{B}_6\text{SO}_{10}$, $\text{Ca}_4\text{Fe}_6\text{SO}_{16}$). The passivation effect is achieved by encapsulating calcium oxide crystals within crystals or a solid solution of the phases of the additives listed above. During the hardening process of the HRC, calcium oxide hydration is limited by the hydration rate of the phase in which the calcium oxide crystals are distributed.

The second group of methods involves high-temperature (1300-1550 °C) calcination of limestone. At this temperature, calcium oxide recrystallizes: the larger and more regular the crystals, the slower the lime reacts with water, the lower the porosity, and the lower the water requirement during mixing. To simplify the production process and reduce the calcination temperature during lime sintering, appropriate additives are added, such as copper oxide and calcium fluoride.

2 CONCLUSIONS

In order to eliminate the causes of accidents, strict technological and organizational discipline of workers conducting blasting operations and a high level of geoethical standards of engineering and technical workers are necessary, allowing for the rational application of safer methods of conducting work on the destruction of rock mass.

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