Reducing dust pollution in the production of mass explosions in quarries

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Abstract. A method was developed to improve the efficiency of dust suppression and increasing of efficiency of energy of explosives in bulk blasting at quarries by using at the top of the borehole sealed shell filled soapstock (waste oil and fat plant) and water in the ratio 50:50. The intensification of the process of deposition of dust over the site of the explosion allows to reduce pollution the quarry site, which has a positive effect on the ecological situation in the region production and mining operations. It is established that with the passage of explosive gases through the shell with soapstock and water in the upper part of the borehole convective heat transfer from the gas shell and the loss of a fraction, the partial pressure on the borehole wall at the location of the shell. Due to the heat loss of the dust and gas cloud loses some of its energy, which leads to a decrease in the height of its ascent and, thus, prevents the removal of it beyond the open pit area.

1 Introduction

The main sources of harmful emissions during open-pit mining of mineral deposits are drilling and blasting operations, which account for up to 40% of the total mass of pollutants that have a negative impact on the environment. During a massive explosion, a dust cloud is ejected to a height of 150-300 m; in its development, it can reach a height of 16 km and spread in the direction of the wind over considerable distances.

In the process of explosive transformation of explosives with the release of huge amounts of heat, toxic gaseous products are formed. If we consider that the explosion of 1 kg of explosives produces on average 850-900 liters of gaseous products, then approximately 5-10% of them are toxic. Research shows that as a result of blasting operations at the Muruntau quarry of the JSC Navoi Mining and Metallurgical Combine (Republic of Uzbekistan), up to 913 tons of toxic gases are released into the atmosphere per year: carbon monoxide, nitrogen oxides, sulfur dioxide, hydrogen sulfide, mercury vapor, carbon dioxide, etc.

The maximum permissible content of carbon monoxide in the mine atmosphere during long-term stay of people should not exceed 0.02 mg/l (0.0016% by volume). The content of carbon monoxide in the atmosphere in the amount of 0.13% by volume has a dangerous effect on the human body when inhaled for 0.5-1 hour, and the content of carbon monoxide in the amount of 0.42% by volume is fatal, even with very short inhalation.

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Nitrogen oxides are gases even more dangerous than carbon monoxide. The content of nitrogen oxides in the atmosphere is only 0.02% lethal to humans even after short-term inhalation. The maximum permissible concentration of nitrogen oxides is 0.005 mg/l or 0.0001% by volume.

The content of 0.03% sulfur dioxide and 0.05% hydrogen sulfide in the atmosphere is dangerous to life. The maximum permissible concentration of sulfur dioxide in the atmosphere is 0.0007%, and hydrogen sulfide is 0.00066% by volume. The maximum permissible concentration of mercury vapor in the atmosphere is 0.00001 mg/l.

2 Method for increasing the efficiency of dust suppression during massive explosions in quarries

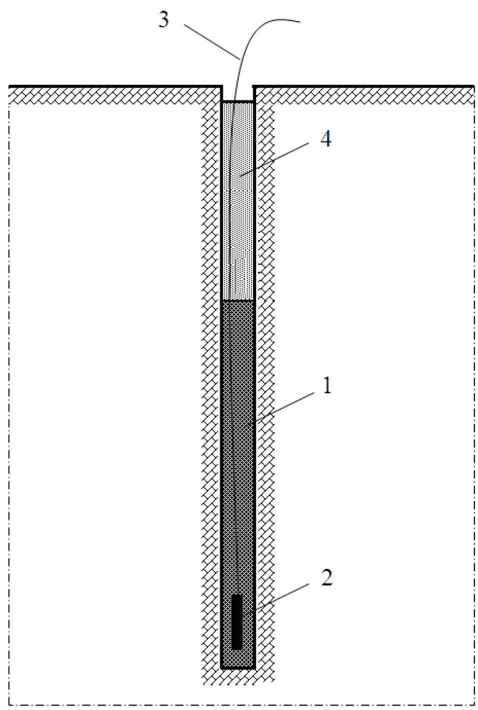
Currently, atmospheric air is constantly monitored for pollution at the border of the sanitary protection zone after each massive explosion in the quarries of Navoi Mining and Metallurgical Combine JSC. In addition, research is also being carried out to determine the specific emissions of dust and harmful gases after explosions, to calculate the parameters of dust and gas pollution of the atmosphere and to develop methods for reducing the concentration of dust and gas emissions.

Previously, studies were carried out in the quarries of the Kyzylkum region, the results of which are presented in works [1,2,3], but now they cannot be fully objective, because quarries deepened significantly, as a result of which the composition of rocks and the geological and hydrogeological characteristics of the deposits changed. In addition, new types of emulsion explosives have appeared, which are used with different specific costs, and new systems for initiating charges have been developed, which collectively changes the parameters of the dust and gas cloud.

As a result of the research, a method has been developed to increase the efficiency of dust suppression and increase the efficiency of explosive energy during massive explosions in quarries. Intensification of the dust deposition process above the explosion site makes it possible to reduce pollution of the area surrounding the quarry, which has a beneficial effect on the environmental situation in the mining region. This is achieved by the fact that in the developed method of dust suppression during massive explosions in quarries, each well is filled with an explosive charge according to the drilling and blasting passport for a given quarry and a sealed shell is placed in the bottom of the well, filled with soap stock (waste from an oil and fat plant) and water in a ratio of 50:50 (Figure 1).

The operation of the drilling rig consists of a diesel power plant and electric motors, a large amount of energy in the form of heat is released from the internal combustion engine of the diesel power plant and through the radiator of the cooling system, i.e. 55-65% of the fuel is released into the atmosphere in the form of heat.

In the process of drilling a well with flushing fluid, we have developed a device, a schematic view of which is presented in figure, for the useful utilization of heat generated from the internal combustion engine of drilling equipment [5-8].



1 – explosive; 2 – intermediate detonator; 3 – borehole shock wave tube of a non-electric initiation system; 4 – sealed shell with soap stock and water

Fig. 1. A method for increasing the efficiency of dust suppression during massive explosions in quarries.

Soapstock is released during the refining of vegetable oils. Its composition is variable and depends on the quality of the raw materials. The content of fats and saponified fatty acids in soap stocks is 50-70%. These acids are weaker collectors compared to oleic acid, but are much more selective and have good foaming properties. The composition of soap stock is given in Table 1.

Table 1. Soapstock composition.

1.	Fat content (total fat)	40-61%
2.	Incl. neutral fat	23-28%
3.	Non-fat substances (gossypol)	3-12,5%
4.	Unsaponifiables	2-2,7%
5.	Phosphorus-containing substances	0,8-1,0%
6.	Appearance and color	Brown pasty
7.	Acid number	71-100кг/KOH
8.	Solubility in acetone	80 %

Explosive detonation products destroy the rock mass, and at the same time, highly crushed rock is formed in the zone closest to the charge, which is subsequently carried out by gaseous detonation products from the well and forms the basis of the dust cloud. Under the pressure of the explosive detonation products in the well, instantaneous compression occurs and a corresponding increase in the temperature of the soap stock and water enclosed in a sealed shell occurs.

As a result of this process, soap stock with water transfers its share of partial pressure to the well walls at the location of the shell as a working fluid. This enhances the blocking effect on the path of explosive detonation products leaving the well and, consequently, a large proportion of the explosion energy is spent on the useful work of destroying the rock mass. As a result of coagulation from the dust cloud, in the developed method, enlarged dust particles fall out, interconnected by the surface forces of the wetting soap stock with water. A cloud freed from dust does not pollute the surrounding area. Simultaneously with the deposition of dust, an additional effect of neutralizing toxic gases generated during an explosion is achieved. Poisonous gases such as nitrogen oxides (NOx) and carbon monoxide (CO) react chemically with soap stock and water to form a liquid acid phase, which also precipitates at the site of the explosion. This prevents toxic gases from entering the surrounding atmosphere and eliminates acid rain [9].

The volume of gases formed during the explosion of 1 kg of explosives is recommended to be determined using the formula [2].

$$V_0 = \frac{22{,}42(n_1 + n_2 + \ldots + n_k)}{m_1 M_1 + m_2 M_2 + \ldots + m_n M_n}, m^3 / kg \tag{1}$$

here, n – number of moles of gaseous explosion products; m – number of moles of components, explosives; M - is the relative molecular weight of the explosive components.

At constant pressure and any gas temperature:

$$V_1 = v_0\left(1 + \frac{Tg}{273}\right), m^3 / kg \tag{2}$$

here, T_g – explosion gas temperature, °C.

The pressure of explosion gases in a well is determined by the expression

$$p = \frac{p_0 V_0 T}{273V}, MPa \tag{3}$$

here, p_0 and V–at zero temperature, respectively, atmospheric pressure equal to 0.1 MPa and the volume of explosive gases (m^3) at this pressure;

T – explosion temperature, counting from absolute zero, K; V – well volume, m^3; $T=T_C+273$ K (Tc – temperature of explosion gases in Celsius).

With an explosive charging density of 0.5-1.0 t/ m^3, covolume α plays a major role, taking into account the intrinsic volume of the molecules. In this regard, formula (3) will take the following form.

$$p = \frac{p_0 V_0 T}{273(V - \alpha)}, MPa \tag{4}$$

If the volume of the charging chamber is replaced by the explosive charging density (Δ=M/V), then at M=1 (unit mass), we obtain an equation for calculating the pressure of explosion gases.

$$p = \frac{p_0 V_0 T}{273(\frac{1}{\Delta} - \alpha)} = \frac{p_0 V_0 T \Delta}{273(V - \alpha\Delta)}, MPa \tag{5}$$

The temperature of the gases after passing through the shell with soap stock and water is determined by the formula [4]

$$Tg = Tg.f - (Tg.f - T_0)\exp(-\frac{3\alpha \cdot t}{r_o \rho_o C_o}), K \tag{6}$$

here $T_{g.f.}$ – temperature of the gas phase after the explosion, K; T_0 – temperature of the solid phase, K; α – heat transfer coefficient,Bt/(m^2•K); t – time of gas contact with the face,c; r_o – shell radius with soapstock and water,м; ρo – density of the solution of soap stock with water in the shell, kg/ m^3 C_o – heat capacity of soap stock with water in the shell, J/(kg•K).

Heat losses spent on heating the bottom of the well are determined by the formula.

$$Q_{T.\Pi.} = m_o C_o (T_g - T_0), Dj \tag{7}$$

here m_0 – weight of shell with soap stock and water, kg.

The mass of dust released from the block during the explosion of one well can be calculated using the formula

$$m_p = \rho_{g.n.} V_{bl} (1 - \frac{1}{k_r^2}) \frac{dp}{d_{sr}}, K \tag{8}$$

here $\rho_{g..n.}$ – rock density, kg/m³; V_{bl} – volume of the blasted block, m³; k_r – rock loosening coefficient; d_p – average size of dust particles, m; d_{sr} – average size of rock pieces in the blast block, m.

3 Conclusion

As a result of this process, soap stock with water transfers its share of partial pressure to the well walls at the location of the shell as a working fluid. This enhances the blocking effect on the path of explosive detonation products leaving the well. Consequently, a large proportion of the explosion energy is spent on useful work of destruction of the rock mass. As a result of coagulation from the dust cloud, in the proposed method, enlarged dust particles fall out, interconnected by the surface forces of the wetting soap stock with water. A cloud freed from dust does not pollute the surrounding area. Simultaneously with the deposition of dust, an additional effect of neutralizing toxic gases generated during an explosion is achieved. Thus, it has been established that when explosive gases pass through a shell with soap stock and water in the bottom of the well, convective heat transfer from the gas to the shell occurs and a loss of a fraction of the partial pressure on the walls of the well at the location of the shell occurs. Due to heat loss, the dust and gas cloud loses part of its energy. This leads to a decrease in the height of its rise. This prevents it from being carried outside the quarry space.

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