E3S Web of Conferences **174**, 01017 (2020) https://doi.org/10.1051/e3sconf/202017401017
V^th International Innovative Mining Symposium

Influence of the nature of the outflow of explosion products from blast holes and boreholes on the efficiency of rock destruction

Karina Yastrebova [1,*], *Dmitriy* Moldovan[1] , and *Vladimir* Chernobay[1]

[1]Saint-Petersburg Mining University, 199106, 2, 21st Line, St Petersburg, Russia

Summary. The problem of the quality of rock preparation before blasting for the further processing has been considered. The data that can solve the problem of keeping explosion products in the charging chamber, increasing productivity of mining companies have been presented. Based on field tests and further processing of the obtained data, conclusions on solving the relevant problem have been made.

1 Introduction

Currently, despite economic problems, both in the country and in the mining industry, the scope of mining is increasing significantly. Fierce economic competition dictates requirements for the efficiency of mining operations, as well as increased productivity of mining companies.

Despite the well-established rules for blasting, there are doubts about the need for stemming as one of the main factors for increasing the efficiency (efficiency factor) and increasing the blast hole efficiency ratio (BER). However, these disagreements arise due to technical and technological reasons.

The abolition of the stemming is often caused by economic reasons, namely specific conditions of a particular area where a mining company is located. But, there are also opinions, attempts to theoretically and practically prove the insignificant effectiveness of stemming [1, 2].

In practice, abandonment of the stemming leads to an increase in the consumption of explosive, number of boreholes (blast holes) and, as a consequence, cost of drilling, and lower BER [3].

2 Results

Despite all the arguments, the overwhelming number of detonators, both theorists and practitioners, are of the opinion that the use of stemming leads to:

*Corresponding author: dmitriy_moldovan@mail.ru

- maximum release of potential energy [3, 4, 5], prevention of energy loss during detonation and its completeness;
- higher initial gas pressure, as well as bigger effective length of the blast wave, which determines the value of the line of least resistance (LLR) according to the theory of rock destruction by a reflected wave [6];
- greater piston action of the explosion products (EP) on the walls of the explosive cavity and length of the radial cracks formed during the explosion.

Current theoretical and empirical relationships for determining the most optimal characteristics of the stemming often cannot take into account the following aspects [7, 8, 9]:
- the influence of the properties of the stemming materials on its ability to burst at the mouth of the blast hole (borehole), density change under the pressure, as well as the possible movement under the action of EP;
- EP delay time for various initiation methods;
- changes in pressure as EP come out of the explosive cavity at different design stemming, etc.

When an explosive detonates in a charging cavity (blast hole, bore hole, etc.), a blast wave arises, reflected from the walls and directed to the geometric center of the charge, this process is repeated several times. The wave amplitude decreases as the cycle is repeated; accordingly, the overpressure also decreases as the oscillations damp. This process depends on the volume of the explosive cavity, total cross-sectional area of the discharge openings (induced and natural cracks, openings in the stemming structure), as well as on the explosive itself and its energy release rate. Figure 1 shows overpressure on the walls of the explosive cavity as a function of EP outflow time [10, 11, 12].

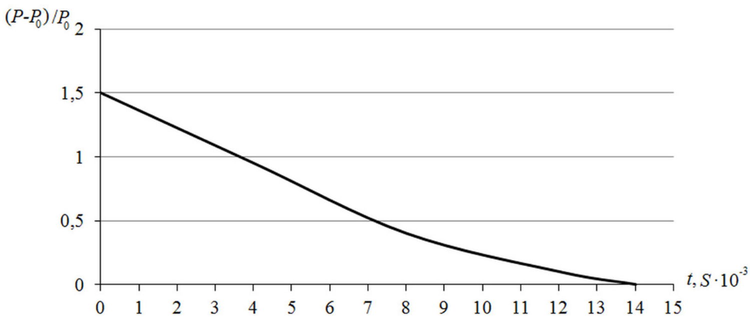

Fig. 1. Dependence of overpressure on the walls of the explosive cavity on EP outflow time (P_0 is the initial pressure in the explosive cavity, *P* is the pressure at a certain point in time).

A similar problem of the dependence of quasistatic pressure on time has been solved in the paper. As a result, the obtained formula in dimensionless quantities has the form:

$$ln\overline{P} = ln\overline{P}_1 - 2,13 ln\bar{\tau}, \quad (1)$$

where $\overline{P}$ and $\overline{P}_1$ - normalized pressure, Pa; $\bar{\tau}$ - dimensionless time of EP outflow from the explosive cavity;

$$\overline{P} = \frac{P(t)}{P_0},\ \overline{P}_1 = \frac{P_{кс} + P_0}{P_0}, \quad (2)$$

and $P_{кс}$ is quasistatic overpressure, Pa. Dimensionless time of EP outflow is then determined:

$$\bar{\tau} = \overline{A}\,\bar{t} = [\alpha_1 A_n V^{-2/3}][t a_0 V^{-1/3}] \quad (3)$$

In equation (3) α_1 is the ratio of the effective cross-sectional area to the inner surface area of the explosion chamber of the blast hole; A_n is area of the innermost surface, m^2; V is the volume of explosion chamber, m^3, t is time, sec; a_0 is time of sound in the air, m/sec. In [13], the appropriateness of using these parameters is expressed, thus, equation (1) will determine the total dimensionless time of the outflow of airflow, $\overline{\tau}_{\max}$:

$$\overline{\tau} = 0{,}4695 \ln \overline{P_1} \tag{4}$$

Comparison of the results presented in Figure 1, as well as the calculation formula (4) show the impossibility of determining the maximum quasistatic pressure, due to repeatedly repeated waves, both propagating and reflected.

3 Discussion

The experimental data obtained many times show that loading efficiency of EP rock largely depends on the ratio of the charge length and stemming length.

In the study of a variety of sources that describe constructive solutions for well shutoff, one can draw the following conclusions:

- length of stemming should be small and securely lock the explosion chamber, therefore, loose stemming does not meet such requirements, as they have a large length;
- effectiveness of water stemming is the same as in the previous ones, but their use is positive from the point of view of dust suppression;
- locking stemming also does not meet all the requirements, since the point of contact of the blades with the walls of the explosion chamber is not observed when exposed to EP;
- metal structures lock EP well enough for the required period of time, for sufficient crushing of the rock mass, however, high price is a negative drawback.

Based on the materials, it can be assumed that combined stemming will bring the greatest effect [14]. The locking device is held on top by loose stemming, as shown in Figure 2.

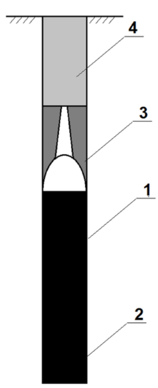

Fig. 2. Design of a blast hole charge with combined stemming (1 - borehole, 2 - explosive charge, 3 - locking device, 4 - loose stemming).

The advantage of this design is that the emitted EP do not produce an impact on the walls of the explosion chamber, they smoothly flow out through the outlet. The gas escape rate can be controlled by the diameter of the outlet of the device. This design is made of polymeric materials, and space between profile and walls can be filled with chemical reagents to reduce the emission of toxic gases or flame arrester.

Using this design, the following is achieved:

- provides sufficient retention time of EP in the explosion chamber, required for maximum use of the energy of the explosion;
- low production costs;
- simplified technology for installing the device in an explosion chamber.

The mechanism of high-quality crushing of the rock is achieved by locking the explosion products in the well. A comparative analysis of the time for stemming from the well shows that the new design is held three times longer in the explosion chamber [15, 16]. The shock wave interacts with the spread of the inner wall of the stemming device, while the internal material acts as a shock absorber and subsequently participates in the formation of plastic melt (Figure 3).

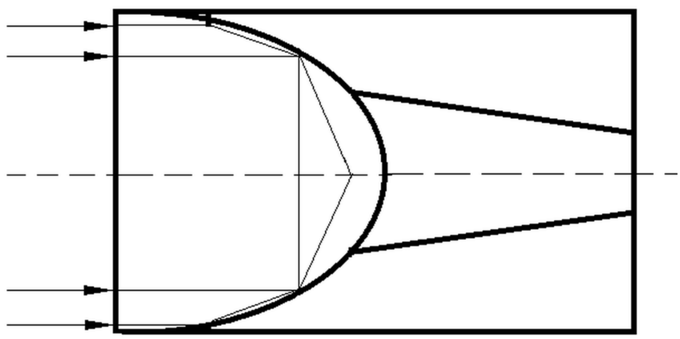

Fig. 3. Reflection of impact waves from stemming profile walls.

Further, detonation products smoothly emanate from the explosive cavity, reducing the blasting effect on the wells. The output of DP can be adjusted by the diameter of the outlet of the device. The measurements were performed on quarries of building materials. Two experimental blocks with the parameters shown in Table 1 have been exploded.

Table 1. Drilling and blasting parameters for blocks 14 and 15.

	14 block	**15 block**
Design volume, m^3	7000	7300
Number of boreholes, pcs	90	97
Diameter of boreholes, mm	115	115
Borehole grid a×b, m	3×3	3×3
In the first row a, m	2.5	2.5
The amount of sub-drilling, m	1.5	1.5
Borehole depth, m	9.0-9.5	9.0-10.5
Horizon, m	+18	+18
Stemming	standard (sand and gravel)	locking

The granulometric composition of the destroyed rock mass was estimated, according to results thereof a graph was built (Figure 4).

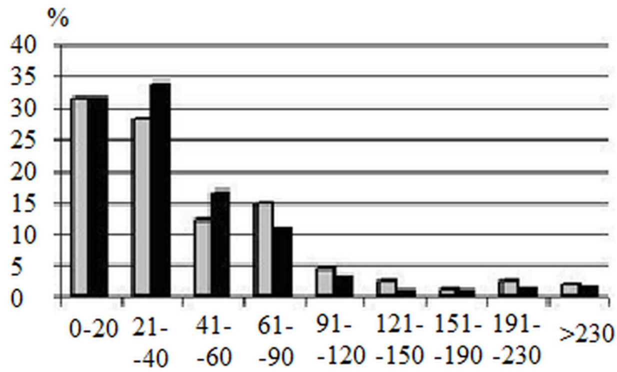

Fig. 4. Data on fractional composition for blocks 14 and 15.

The results presented in the graph (Figure 4) have been processed and a curve of the log-normal distribution of the fractional composition in the destroyed rock mass has been obtained.

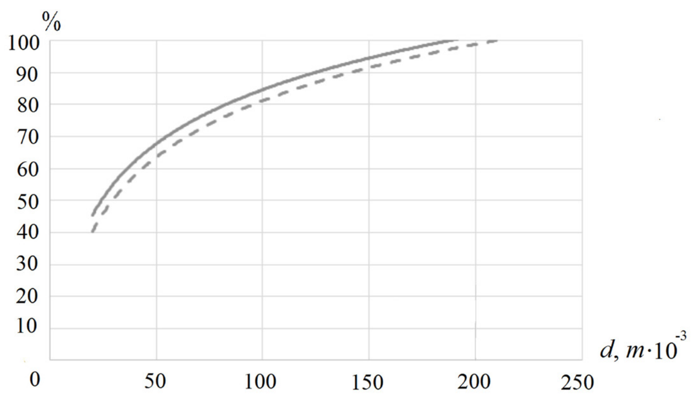

Fig. 4. The distribution of fractional composition in the destroyed rock mass (solid line - the explosion was performed without the use of profiled stemming; dashed line – the one with the use of stemming).

As can be seen from the graph, when blasting with conventional stemming, the average piece size is 325 mm, and with the use of a locking one, 270 mm. This result indicates a better study of the rock mass with a longer delay of EP in the charging cavity by 15-20%.

3 Conclusion

From the point of view of science and practice, the study of the mechanism of transfer of explosion energy into the environment using locking stemming of different designs is a relevant task.

On the basis of practical experiments and mathematical modeling, it was found that PD in the charging cavity when using locking stemming repeatedly affect the walls, therefore, this design of the charge brings an economic effect.

It was established that the borehole locking stemming device can hold PD in the charging cavity for 20 msec, while their smooth outflow through the axial channel occurs.

Therefore, to reduce the negative impact in the manufacture, you can change the diameter of the outlet.

The following studies on the effect of the charge structure, as well as other parameters of the explosive discharge on the quality of the destroyed rock mass and the formation of the shotpile itself are required in these areas.

4 References

1. A. P. Kazakov, Physical and technical problems of mining, **2**, 36-42 (1983)
2. A. P. Gospodarikov, Ya. N. Vykhodtsev, M. A. Zatsepin, Notes of the Mining Institute, **226**, 405-411 (2017)
3. G. Li, Y Wang, S Qi, J. Yang, Engineering Geology, **5,** 105460, China, (2020)
4. V. P. Marysyuk, G. V. Sabyanin, A. V. Trofimov, A. P. Kirkin, Mining Journal, **1,** 11 (2020) DOI:10.17580/gzh.2020.01.11
5. R. F. Favreau, D. Lilly, *The use of computer blast simulations to evaluate the effect of angled holes in cast blasting* (CUCCI, Morgantown, 1986)
6. H. Junqing, M. Yalong, H. Kelei, Z. Jianxun, *Analysis of Aperture Shape Changing Trend Base on the Shaped Charge Jet Penetration through the Steel Target, Asia Simulation* (Springer, Beijing, 2012)
7. D. S. Viktorov, S. Sharma, Min. Eng. J., **XXIII:4**, 17-21 (1984)
8. L. I. Baron, G. N. Sirotyuk, *Testing the applicability of the Rozin-Rammler equation for calculating the diameter of the middle piece during explosive breaking of rocks* (Nedra, Moscow, 1967)
9. N. A. Al-Shayea, Engineering Geology, **74:1-2,** 139-156 (2004) DOI: 10.1016/j.enggeo.2004.03.007
10. N. I. Aleksandrova, A. G. Chernikov, E. N. Sher, Physical and technical problems of mineral development, **3**, 46–55 (2005)
11. B. V. Rumyantsev, Technical Physics, **60:4**, 614-617 (2015)
12. X. P. Zhou, J. Bi, R. S. Deng, B. Li, Journal of Testing and Evaluation, 48:4, JTE20170595, (2020)
13. H. Yingguo, L. Wenbo, C. Ming, Y. Peng, Y. Jianhua, Rock Mechanics and Rock Engineering, **47:4**, 1307-1320 (2014)
14. G. G. Savenkov, B. K. Barakhtin, K. A. Rudometkin, Technical Physics, **60:1**, 96-101 (2015)
15. S. Ziaran, M. Musil, M. Cekan, O. Chlebo, International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering, **7:11**, 769-77, (2013)
16. W. Wittke, *Rock Mechanics Based on and Anisotropic Jointed Rock Model* (Wilhelm Ernst & Sohn, Berlin, 2014)