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Combination of Fracturing Areas after Blasting Column Charges During Destruction of Rocks

Valentin Isheyskiy[1], Mikhail Marinin[2], Vadim Dolzhikov[3]

[1,2,3]*Ph.D., Associate Professor Blasting of Department, Saint-Petersburg Mining University, Russia.*

[1]*0000-0003-1007-6562,* [2]*0000-0002-5575-9343,* [3]*0000-0001-8851-2913*

Abstract

Rock fragmentation quality differently affects economics and performance of main mining enterprise processes. For example expectancy decrease of characteristic rock fragment size effects escalation of drilling and blasting cost but reduction of loading and hauling cost. And mining experience worldwide clearly shows that the maximum profit is corresponded to exact blast fragmentation distribution. The paper presents the results of modelling the explosion energy distribution in the rock mass for the combined areas of charges. It provides the calculations for staggered and square borehole patterns as well as numerical values of drilling and blasting parameters for both patterns, and estimations of the lumpiness of blasted rock mass. The formulation of the calculation of the explosion energy at various points of the rock mass and the correlation of energy values with the design parameters of mass explosions are described. The results were processed in the JK SimBlast software package. The paper gives guidelines for choosing the parameters of the drilling and blasting operations, which provide an improvement in the quality of crushing.

Keywords: granulometric composition, fragmentation, explosion energy distribution, borehole pattern, blasting destruction area.

I. INTRODUCTION

Being the initial step in the technological flow of mining and processing of minerals, drilling, and blasting operations, determine the efficiency of subsequent stages especially crushing and screening. In quarries producing the crushed stone, this dependency of stages results in the difficultly predicted yield of oversized fractions and the quality of preparation operations for blasting [1,2].

When using column borehole charges the effect of the explosion on the rock mass enables to identify areas of inefficient use of blasting energy [3,4]. The resulting oversized fraction and the average lump size present in the blasted rock mass indicate the presence or absence of such zones. Hence the engineering calculation based on the combination of blasting fractured area, ensuring the elimination of poorly fractured zones and improving the quality of blasting preparations, is an urgent scientific and practical task. The basis of this calculation is the principle of rational use of the subsoil. This approach allows solving many problems of drilling and blasting operations including their improvement [5,6,7].

The authors of this paper solved the following tasks:

- to analyze theoretical and experimental studies on blasting destruction of rocks;

- to determine the parameters of the blasting operations considering the combination of the radii of the fractured zones during the explosion of charges;

- to develop guidelines for choosing parameters depending on conditions of a quarry producing construction materials.

The analysis of papers on the selection and justification of rational parameters of the blasting operations will optimize the results of benching, which helps to reduce the oversize yield and improve preparation for blasting of the rock mass [8,9,10].

The main measures to improve the quality of crushing for the conditions of the target quarry [11,12], we suggested to use of a checkerboard pattern of boreholes, as well as the commissioning of a drilling rig for drilling small-diameter boreholes (165 mm). The borehole pattern is supposed to be staggered. Such allocation of wells will make it possible to minimize the volume of the zone of poorly fractured areas and to improve the quality of preparation operations. Fig. 1 presents the calculated poorly fractured zones. The crushing zones were calculated according to the method presented in [13, 14]. These measures will reduce the yield of oversized fractions and the size of the average lump in blasted rock mass.

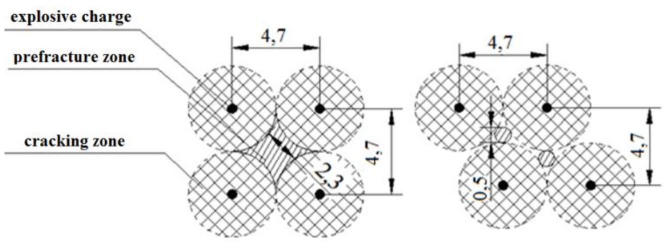


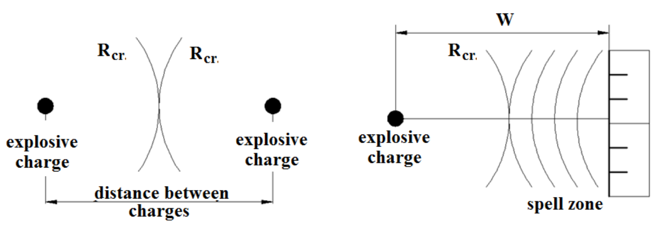
Fig. 1. Calculation of poorly fractured area soft he blasted rock mass.

This approach to the design parameters is based on the experiments simulated in the JK SimBlast software package, the results of which are presented in Figure 4.

When using the existing blasting pattern [13, 14] the oversize yield is 13%, which is a rather high indicator. Based on the analysis of particle size distribution, it was found that the average piece of blasted rock mass with a square pattern of boreholes (basic option) for the target quarry is 0.357 m.

II. MATERIALS AND METHODS

When knowing the energy loss, it is possible to determine the energy involved in the mechanical work [15], evaluate the radial and tangential components of stress waves, and on their basis calculate the fractured zones. Based on the combination of fractured zones (Figure 2,a) obtained during the explosion of two adjacent borehole charges, we can estimate the distance between them, as well as other parameters of drilling and blasting operations. The burden from the first row to the surface (bench surface) is determined by combining the fracturing and spell areas (Figure 2,b). The size and number of broken layers can be determined based on the paper [16].



a b

Fig. 2. Determining the distance between charges (a) and burden (b).

R_{cr}–fractured zone radius;

W–burden.

Also, fishweirs are formed from the side of the last row of wells, which decreases the efficiency of the explosion: the yield of oversized material increases and, thereby, the quality of crushing decreases. Fishweirs appear as a result of an increase in the width of the opening of natural cracks under the influence of an explosion, while there is a shift of the vertical layers of the massif towards the free surface (bench). To improve the quality of crushing in this zone, the face should be oriented concerning the vertical system of cracks at an angle close to perpendicular.

The authors of the paper carried out modeling of the blasting energy distribution in the three-dimensional space of the rock mass, the results of which are presented in Figure 4. The following describes the approach to modeling of the blasting energy distribution from adjacent charges.

The three-dimensional charge distribution does not take time into account and is determined by the algorithms of the 2DBanch software package according to the method developed by Klein. The traditional calculation of the specific consumption of explosives was further developed by considering the infinitesimal part of the charge and writing the equation for the final explosive concentration at point P of a sphere centered in that part of the charge. The general form of the equation is the following (see also Fig. 3):

$$\int_{L1}^{L2} \frac{1000\cdot p_e\cdot\pi(\frac{D}{2})^2}{p_r\frac{4}{3}\pi(h^2+l^2)^{\frac{2}{3}}}\, dl \qquad (1)$$

Equation (1) can be integrated and written in the following form:

$$P = 187.5\frac{p_e}{p_r}D^2\frac{1}{h^2}\left(\frac{L_2}{r_2}-\frac{L_1}{r_1}\right) \qquad (2)$$

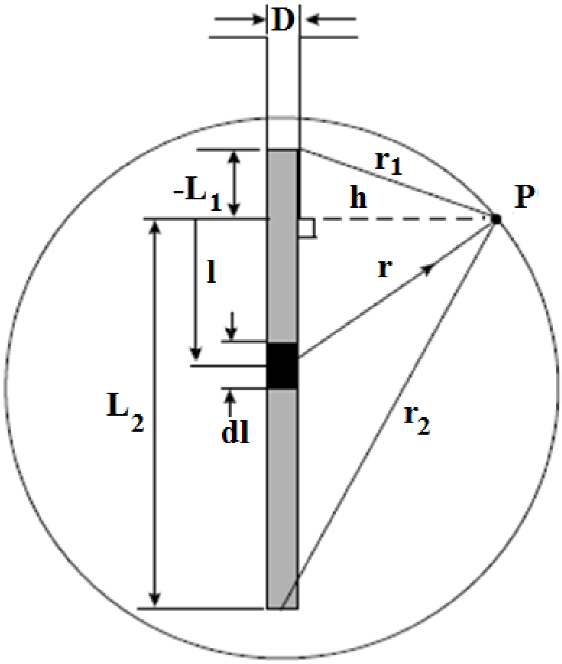
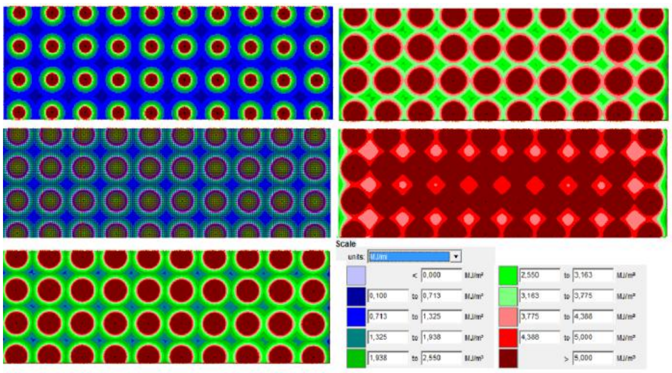


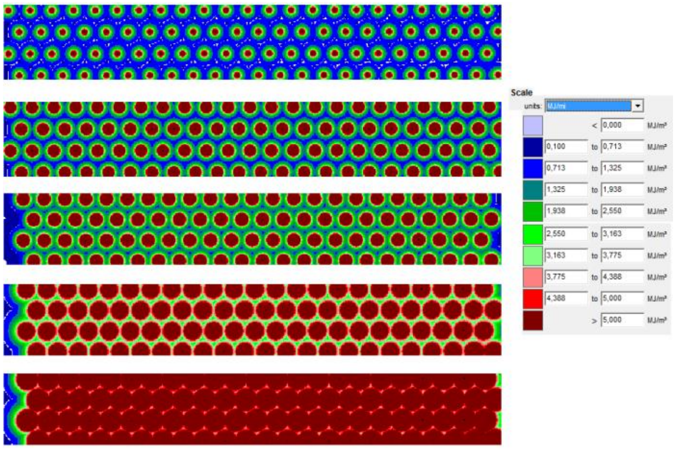
Fig. 3. Calculation of the concentration of blasting energy at point P in 3 - dimensional space, where: L- area leight (increment); r - radius to the point of calculation ; h - perpendicular height from calculation point; P - energy calculation point; dl - calculation area; D - Charge diameter.

IV. RESULT

On the graph of energy distribution, we see zones of poor fracturing with the basic drilling, and blasting parameters (Fig. 4,a). After modeling the results of the energy distribution in the rock mass according to the proposed option (the combination of blasting fractured zones), we observed a significant decrease in the size of poor fracturedzones (Fig. 4,b).



a - the basic version (without the combination of fractured zones);



b - the proposed borehole pattern (with the combination of fractured zones)

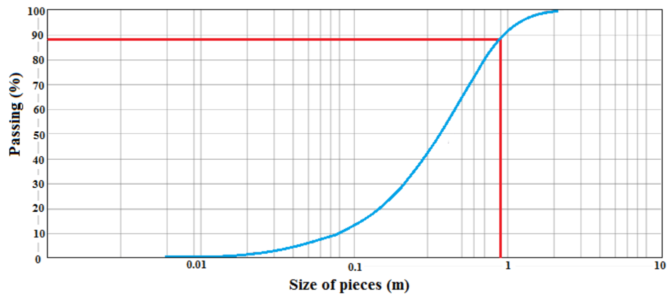
Fig. 4. Modeling the explosion energy distribution in rock mass.

V. DISCUSSION

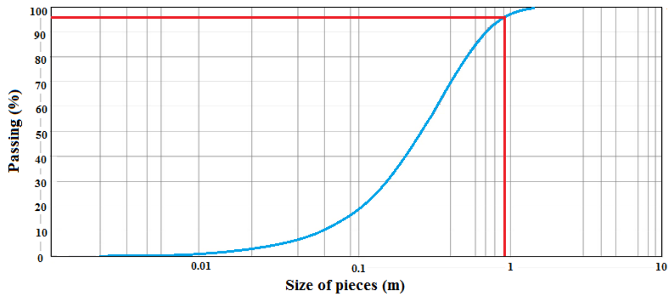
Fig. 4, a shows the sizes of the formed pre-fracture zones when combining various fractured areas using the square borehole pattern. It can be concluded that it is advisable to use a square pattern if the average size of the natural jointing of the rock mass is less than the maximum size of the size limit, otherwise an increased oversized yield will be observed in the prefracture zone. Also, to reduce the output of oversized pieces in this area, it is necessary to use, for example, diagonal, V-type patterns, which can increase the number of free surfaces and the blasting effect on the prefracture zone. It can be seen that at different times of detonation of adjacent charges, a zone of poor fracturing is formed. In the basic version, pink zones are clearly visible. This conclusion is confirmed by modelling the granulometric composition of the blasted rock mass.

If you pay attention to the proposed option with the combination of fracturing zones (Fig. 4,b), where the borehole pattern is located with an offset, you can see a reduction in the poorly fractured zones between adjacent charges.

To analyze the performance of blasting operations on the base and proposed options, the granulometric composition of the blasted rock mass was evaluated using the Powersieve by Orica software package and patented program [17]. The calculation results are presented in Figure 5.



a–basicoption (squarepattern)



b–proposed pattern (with combination of fractured zones)

- substandard fractions: *a* - 13 %; *b* - 5%

Fig. 5. Analysis of particle size distribution according to the basic option (a) (square pattern) and the proposed option (b) (with the combination of fractured zones).

VI. CONCLUSION

From the analysis of the graphs presented in Fig. 5, built on the basis of the proposed solutions, we can conclude that the predicted average lump in the blasted rock mass is 0.262 m versus 0.357 m for the basic option. The predicted oversized yield is reduced from 13% to 5%, which indicates economic benefits (reducing the cost of secondary crushing of substandard fractions (oversized). As a result of combining fractured zones, it seems possible to improve the quality of blasting preparation of rock mass.

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