The Choice of Explosion Parameters for Obtaining Specified Pre-Collapse of a Rock Mass

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Abstract. When performing Stripping operations, it is not rational to spend energy on re-grinding waste rock. in this case, it is sufficient to achieve a total value of the pre-destruction intensity coefficient equal to one. The explosion must be performed separately in each well with large decelerations. The study of the effect of the borehole grid showed that with an increase in the distance between the axes of wells from 4 to 8 m, the mass of the charge increases twice, and the number of wells on a block of 1000 m² decreases by 3.75 times. Due to the greater intensity of reducing the number of wells, the cost of charging explosives for the entire block with a large grid is reduced by 1.9 times, the cost of drilling operations is reduced, and the productivity of drilling and blasting operations is increased. In the case of mining a mineral, for example, iron ore, which is subsequently crushed during processing, it is rational to use the energy of the explosion for grinding, since the mechanical methods of crushing the ore by crushers and especially by mills are incomparably more energy-intensive. By increasing the power of the explosion (the radius of the zone of destruction of wells), you can significantly increase the pre-destruction of rocks, achieving a uniform set of grinding.

1. Introduction

The process of destruction of rocks by explosion was studied by many scientists [1, 2]. Considering the achieved effect of the explosion to the rock is considered as a brittle fracture of an elastic medium – a flat task which shall be notified to determine the required specific consumption of explosives [3].

Since the length of the charge exceeds its diameter by several orders of magnitude, and the displacements caused in the rock by the action of the borehole charge have axial symmetry, the nature of the charge action is proposed to be determined by solving a flat (two-dimensional) problem [4].

The stress wave extends beyond the boundaries of the explosive cavity, performing pre-destruction of the surrounding boreholes. The amount of deformation (pre-collapse) of the vicinity of these wells is determined by the formula

$$\varepsilon_i = \varepsilon_{us} \left(\frac{r}{R_i}\right)^2 = \varepsilon_{pr} K_{in},$$

where $\varepsilon_i$ is the value of destruction of the vicinity of the i-th well; $\varepsilon_{us}$ is the ultimate strain; $K_{in}$ is the coefficient of pre-destruction intensity, which takes into account the change in the value of deformation as it moves away from the axis of the exploding well; $r$ – radius of the zone of destruction of wells; $R_i$ – the distance from the axis $i$ of the well to explode. $K_i = \left(\frac{r}{R_i}\right)^2$ – the coefficient that N. G.
Shtukarin called the pre-collapse intensity coefficient [3], which takes into account the change in the amount of deformation as it moves away from the axis of the exploding well. The coefficient of \( K_{in} \) when the maximum deformation of the explosive cavity of the well is equal to one, i.e. the explosive cavity of the well is completely destroyed.

2. Methods
The amount of deformation of the rock mass of the exploding block when performing the passport of blasting operations must be pre-planned. When overburdening, it is not rational to spend energy on re-grinding waste rock. In this case, it is sufficient to achieve a total value of the pre-destruction intensity coefficient of \( K_{in} \) equal to one.

The largest size of the pieces of the exploded rock mass should ensure that they are scooped up by the bucket of the excavator. In the case of mining a mineral, for example, iron ore, which is subsequently crushed during processing, it is rational to use the energy of the explosion for grinding, since mechanical methods of crushing ore by crushers and especially by mills are incomparably more energy-intensive.

For example, let’s consider a diagonal explosion scheme. Let’s use a graphoanalytic method for determining the intensity of preliminary destruction of the vicinity of explosive wells [5, 6, 7]. Grid of blast wells \( a \times b = 4 \times 4 \, m \) (Fig. 1). Consider a cell of four adjacent explosive wells (1 - 2 - 3 - 5). An empty rock located at a point equidistant from these wells will receive the same pre-collapse from the explosion of each of the four wells, and the total value of the pre-collapse intensity coefficient \( K_{in} \) will be equal to one.

\[
\text{Distance } x \text{ from the well axis to point } A: x = \sqrt{(0.5a)^2 + (0.5b)^2}.
\]

When
\[
a = b \quad x = \sqrt{0.5a^2} = 0.707a.
\]

Coefficient of intensity of pre-collapse of the array at the radius of the well failure zone \( r = 1 \),
\[
K_{in} = \frac{r^2}{x^2},
\]
And when \( r = 1 \) m

\[
K_{in} = \frac{1^2}{2.83^2} = \frac{1}{8} = 0.125.
\]

But this is from the explosion of one well, and since there are four of them, the \( K_{in} = 0.5 \).

This shows that with the radius of the well failure zone \( r = 1 \) m, the preliminary failure is small. Such a small preliminary destruction of the array can be used to loosen the array while protecting it from freezing.

We determine the optimal power of the BB charge for the case when the coefficient of intensity of pre-destruction of the array at point A is equal to one. For the grid of blast wells \( a \times b = 4 \times 4 \) m in accordance with (3)

\[
0.25 = \frac{r^2}{2.83^2} \quad \text{and the radius of the well failure zone}
\]

\[
r = \sqrt{0.25 \cdot 8} = 1.41 \text{ m}.
\]

This explosion power is recommended when grinding waste rock with a grid of explosive wells of 4x4m.

A mandatory condition is post-well blasting with large decelerations (more than 150 MS).

With an increase in the radius of destruction of an explosive well, the pre-collapse of rock in the vicinity of other wells increases significantly. Let's determine how the parameters of blasting change at the same pre-failure with the coefficient \( K_{in} = 1 \) by changing the grid of wells.

Table 1 shows the values of the destruction radii of blast wells obtained at \( K_{in} = 1 \), calculated by the formulas (2) and (3), depending on the distance between the wells.

| Distance between wells \( b \), m | Distance \( x, \) m | \( x^2 \) | The optimal radius destruction, \( r \) |
|---|---|---|---|
| 4 | 2.83 | 8.0 | 1.41 |
| 5 | 3.535 | 12.5 | 1.768 |
| 6 | 4.242 | 17.0 | 2.12 |
| 7 | 4.95 | 24.5 | 2.474 |
| 8 | 5.656 | 31.0 | 2.83 |

For Fig. 2 shows the dependence of the radius of the fracture zone \( r \) on the distance between wells. The radius of the well failure zone indirectly determines the power of the explosion, from Fig. 2 it can be seen that when the well grid is increased from 4 to 8 m, the explosion energy needs to be doubled for the preliminary destruction of a block with a pre-collapse intensity coefficient \( K_{in} = 1 \).

Figure 2. Dependence of the radius of the destruction zone \( r \) from the distance between well.
3. Results
We will determine the effect of the charge power at a $K_{in}$ equal to one of the distance between wells on the consumption of explosives. Under certain conditions, it is experimentally established that at a distance between wells of 6 m and the diameter of the well (the diameter of the charge in the well) of 215 mm, $K_{in} = 1$ is achieved. In accordance with this in table. 2 shows the parameters of wells that provide the specified intensity of pre-failure.

Table 2. Parameters of blast wells that provide $K_{in} = 1$.

| Distance between wells, m | Radius of failure zone $r$, m | Diameter charge in the well, m | Cross-sectional area of the charge, m$^2$ | The volume of the charge in the well, m$^3$ | Specific charge consumption, kg / m |
|--------------------------|-------------------------------|-------------------------------|------------------------------------------|-----------------------------------------|----------------------------------|
| 4x4                      | 1,41                          | 0,14                          | 0,02                                     | 0,23                                    | 25,45                            |
| 5x5                      | 1,77                          | 0,177                         | 0,032                                    | 0,372                                   | 31,46                            |
| 6x6                      | 2,12                          | 0,215                         | 0,45                                     | 0,543                                   | 38,0                             |
| 7x7                      | 2,474                         | 0,25                          | 0,61                                     | 0,735                                   | 44,18                            |
| 8x8                      | 2,83                          | 0,285                         | 0,80                                     | 0,955                                   | 50,37                            |

For calculations, we assume that the height of the exploding ledge is 15 m. According to the existing technology of explosive loosening of overburden rocks, wells with a diameter of 215-245 mm are drilled with an overburden below the foot of the ledge by 2 m – up to 17 m.

When loosening rocks represented by Sandstone and siltstone, the well is proposed to drill a depth of 17 m, while charging at the bottom to produce an air cushion 2 m long. Industrial experimental explosions have shown that in an explosion with an air cushion, the rock is loosened to the entire depth of the well and the ledge is loosened to a depth of 17 m, and the explosive is consumed less by excluding it from the charge length by the length of the air cushion – 2 m. At the capacity of a well with a diameter of 215 mm, the specific consumption of explosives per one linear meter of the length of the well is 38 kg, for wells of other diameters, the specific consumption of explosives is shown in the table. 2 and Fig. 3.

As an explosive, we take Granulite m, made when charging wells with the MSZ-12-NP-K charging machine. The cost of Granulite m is accepted 17 thousand rubles per ton [8].
For comparison, let's assume that a block with an area of 1000 m\(^2\) explodes. When blasting boreholes with a 4x4 grid requires 5 rows of 12 wells, 60 wells; with a 5x5 grid of 6 rows of 8 wells for a total of 48; mesh 6x6 – 4 rows of 7 wells is only 28; when the grid 7x7 – 4 rows of 5 wells, 20; in an 8x8 grid – 4 rows of 4 wells, only 16.

Table 3 shows data for calculating the cost of explosives, and figure 4 shows the dependence of the mass of the explosive charge of one well and the number of wells in the area block. 1000 m\(^2\) of the well grid size, m.

**Table 3.** Data for calculating the cost of explosives.

| Distance between wells, m | Number of wells | The weight of one borehole, kg | Cost of a single charge, rubles | The cost of charging the block, rubles |
|---------------------------|-----------------|------------------------------|---------------------------------|---------------------------------------|
| 4x4                       | 60              | 382                          | 8404                            | 504240                                |
| 5x5                       | 40              | 472                          | 10384                           | 415360                                |
| 6x6                       | 28              | 570                          | 12540                           | 351120                                |
| 7x7                       | 20              | 662.7                        | 14580                           | 291600                                |
| 8x8                       | 16              | 755.6                        | 16623                           | 265968                                |

**Figure 4.** Dependences of the charge value of each explosive well and the number of wells on the block from the distance between wells when the intensity coefficient \(K_{in} = 1\).

Analysis of graphs shows that as the distance between explosive wells increases from 4 to 8 m, the mass of the explosive charge increases by \(755.6 / 382 = 1.98\) times, while the number of wells decreases by \(60/16=3.75\) times.

Next, you can calculate the cost of blasting a block of rocks under the condition of blasting at an intensity coefficient \(K_{in} = 1\) (Fig. 5).
Figure 5. Dependences of the charge cost of each explosive well and the cost of charging the entire block from the distance between wells when the intensity coefficient $K_{in} = 1$.

The graphs show that the cost of charging a single well with a grid of 8x8 is 1.98 times more than with a grid of 4x4, however, if we consider the cost of charging the entire block, then with a grid of 8x8 it is 1.89 times lower due to the fact that it is necessary to charge wells 3.75 times less.

Thus, it can be concluded that it is much cheaper to achieve pre-fracture of rock to the intensity coefficient $K_{in} = 1$ with a large grid of wells. Moreover, the calculations did not take into account a significant reduction in drilling costs and increased productivity.

When blasting with a coefficient of pre-destruction intensity $CI = 1$, the rock mass is crushed throughout the block fairly evenly, of the same size, but with a large grid of wells, the average size of the rock pieces is obtained more than with a smaller grid. Therefore, when choosing the distance between wells, you should take into account not only the physical and mechanical properties of the rock, but also the size of the bucket of the excavator, etc.

When extracting a mineral that is subsequently crushed during processing, it is rational to use the energy of the explosion for grinding, since mechanical methods of crushing ore by crushers and especially by mills are incomparably more energy-intensive. Moreover, the degree of preliminary destruction of the mineral depends on many factors (the strength of the mineral and the host rocks, fracturing, granularity, etc.), so the amount of deformation of the mineral mass of the exploding block must be pre-planned.

In Fig. 6 shows the dependence of the coefficient of the pre-fracture blasting block minerals depending on the radius of the zone of destruction of the wells, i.e. from the power of the explosion when the grid is 4x4.

By increasing the power of the explosion (the radius of the zone of destruction of wells), you can significantly increase the pre-destruction of rocks, achieving a uniform set of grinding. Each well should be blasted separately with great slowdowns.
The ratio of the intensity of the pre-destruction

Radius of the well failure zone r, m

Figure 6. Dependence of the value of the coefficient of preliminary destruction of the exploding block of a useful mineral depending on the radius of the zone of destruction of wells.

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4. Conclusions
When performing Stripping operations, it is not rational to spend energy on re-grinding waste rock. in this case, it is sufficient to achieve a total value of the pre-destruction intensity coefficient equal to one. The explosion must be performed separately in each well with large decelerations. The study of the effect of the borehole grid showed that with an increase in the distance between the axes of wells from 4 to 8 m, the mass of the charge increases twice, and the number of wells on a block of 1000 m² decreases by 3.75 times. Due to the greater intensity of reducing the number of wells, the cost of charging explosives for the entire block with a large grid is reduced by 1.9 times, the cost of drilling operations is reduced, and the productivity of drilling and blasting operations is increased. In the case of mining a mineral, for example, iron ore, which is subsequently crushed during processing, it is rational to use the energy of the explosion for grinding, since the mechanical methods of crushing the ore by crushers and especially by mills are incomparably more energy-intensive. By increasing the power of the explosion (the radius of the zone of destruction of wells), you can significantly increase the pre-destruction of rocks, achieving a uniform set of grinding.

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