Temporal parameters of co-operation of borehole charges and power characteristics of explosive destruction process

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Abstract
In this paper the ways of blasting operations efficiency increasing in the conditions of minerals opencast mining, namely the research and development of explosive energy control methods based on the interaction of explosives borehole charges, which explodes at one deceleration stage are studied.
Key words: BOREHOLE CHARGES, EXPLOSIVE, OPEN-CAST MINING, DESTRUCTION PROCESS

In the studies [1-3, 8-10], it is concluded that to achieve destruction of the medium at a given point, there must be a certain duration and the amount of stresses, and to establish the evaluation criterion of destruction. As such criterion the following ratio is taken

$$I \geq \sigma \cdot 1{,}5t, \tag{1}$$

where I – is the explosion impulse; σ_o – is the rupture stress; t – is the pulse load exposure.

It is known, that the critical crack length in the rock, which obtained by the explosion, is a function of the tensile strength of this rock

$$F = f(\sigma_o), \tag{2}$$

where σ – is the tensile strength.

Regulation of the rock destruction process can be achieved by changing the time parameters of explosive loading.

In the practice of drilling and blasting operations the methods of blast energy control based on the use of the interaction between borehole explosive charges, which are characterized in time by the following conditions are successfully used

$$t < (l / \upsilon_1) \tag{3}$$

$$t > (l / \upsilon + \tau), \tag{4}$$

where l – is the distance between charges; υ – is the sound speed in the rock; τ – is the interval of time, which is required for superposition of waves in a given phase; t – is the time between charges explosions. The inequality, which defines the opposing modes of interaction has the form

$$t_{1,2} = l / 2\upsilon, \tag{5}$$

where $t_{1,2}$ – is the wave propagation time from the first and second charges.

Under the condition (3) there is a symmetrical pattern of interaction. Inequality (4) is a necessary condition of the stress waves superposition. By denoting the rise time of pulse pressure by Δt the following options for interaction between charges can be determined. During deceleration, which is equal to

$$T = \frac{l}{\upsilon} + \Delta t, \tag{6}$$

the explosion of the second explosive charge occurs in the wave front of the first charge. Deceleration

$$T = \frac{l + x_o}{\upsilon} + \Delta t, \tag{7}$$

where x_o – is the coordinate of relative wave front in the positive phase of the wave from the first charge, which provides a further charge explosion during the passage of the wave positive phase from the first charge. During deceleration

$$T = \frac{x_1 + al}{\upsilon} + \Delta t, \tag{8}$$

where x_1 – is the coordinate of relative wave front at the end of positive phase, the propagating flows of the second actuated charge don't interact with a counter-moving flows of the first charge, there is flows superposition with positive and negative phase of waves. For condition

$$T = \frac{x_2 + l + x}{\upsilon} + \Delta t, \tag{9}$$

where x_2 – is the current coordinate of the negative waves phase propagation, the second charge will explode during the passage of the negative wave phase of the first charge.

In the limit, a second charge can be triggered after passage of the wave negative phase. For this case the delay interval is determined by the following expression

$$T = \frac{x_3 + l + x_2}{\upsilon} + \Delta t, \tag{10}$$

where x_3 - is the coordinate of relative wave front at the end of the first charge negative phase.

In this case, there may be no waves interaction and it can be assumed that there is a consecutive blasting of explosive charges. Consequently, the interaction of stress waves according to formulas (8) - (10) from two adjacent explosive charges is possible during deceleration, which satisfies the condition

$$t_1 \leq T \leq t_2, \tag{11}$$

where t_1 – is the passage time of stress wave from the explosion of the prior explosive charge to the location of the subsequent charge; t_2 – is the duration of the stress waves.

Time parameters of explosive charges interaction, according to many researchers [4-7], is advisable to base on amount of energy accumulated in the medium, which is a prerequisite for the occurrence of the rock massif destruction. In general form, total energy, which is accumulated in a given elementary volume under the action of two sources can be written as

$$E = \sum_{i=1}^{4} E_i, \tag{12}$$

where E_i – is the energy, which introduced by the flows by the action of direct I_1, I_2 and reflected I_3, I_4 waves.

Thus, the explosion energy distribution character in the rock massif and the intensity of its destruction, in its turn, depend on the degree of fracturing, which defined by the parameters and properties of cracks filler in each system. During the explosion energy propagation through the cracks system the flux density, which passing through them can be determined from the equation

$$I = K \cdot I_o, \qquad (13)$$

where I_o – is the energy flux density excluding cracks; K – is the coefficient of single crack energy conductivity.

The energy flow is determined from the following expression

$$I = \frac{P_o u (R_o + Ct)^3}{r_i^3} e^{-2\alpha(t \frac{r_i - R_o}{C})}, \qquad (14)$$

where u – is the radial mass moving speed of the particle; C – is the rate of cracks development; $\overline{r_i (i = 1,2,3,4)}$ - are the vectors, which are drawn from the stress waves sources to selected points; P_o – is the initial pressure of detonation products; R_o –radius of borehole charge; t - current time.

Energy accumulation in the elementary volume at the selected space point can be defined as

$$dI(r,t) = \left(\frac{\partial I}{\partial r} + \frac{I}{C} \cdot \frac{\partial I}{\partial t} \right) C \partial t, \qquad (15)$$

The formula for the total energy in a given volume takes the form

$$E = \frac{3P_o uC}{r^4} \left(\int_n^m (R_o + Ct)^3 e^{-2\alpha(t \frac{r - R_o}{C})} dt - 1{,}2 \int_n^m (R_o + Ct) e^{-2\alpha(t - \frac{r - R_0}{C})} dt \right) \qquad (16)$$

$$n = 2{,}5(r - R_o)C^{-1}; \; m = (r - R_o)C^{-1}.$$

Therefore, it can be concluded that rational from the standpoint of the most probable and intensive destruction of the massif under the action of two explosive charges, is their blasting with deceleration in the range of

$$(l / \upsilon) \le T \le (2l / \upsilon), \qquad (17)$$

where l – is the distance between the charges; υ – is the sound velocity in the rock.

Conclusion

It is obvious, that one of the ways of blasting operations efficiency increasing in open-cast mining is a research and development of methods of explosive energy control, based on the explosives borehole charges interaction, which explode at one deceleration stage. According to the obtained results blasting in the small decelerations mode is effective and rational in terms of energy pattern of rock massif destruction.

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