Quality preparation improvement of mined rock for mining extraction considering spatial temporary formation of field strain

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Abstract. The analysis of blasting works production shows the necessity of quality preparation improvement of rock mass for the subsequent processing. Blast operations make up 20% to 30% of the general and end products cost. The crushing of mined rock strongly depends on an action of an explosion wave direction. The investigation results of the wave field strain at explosion of the system of borehole charges have been presented in this paper. The model and method of calculation of the wave field strain have been provided. The influence of an interval delay between a borehole set and the ignition direction on wave tension has been established. Results of the pilot tests scheme of ignition for the pit of the construction materials "Prudyansky" located in Leningrad region of Russia have been demonstrated.

1. Introduction
Modern production technologies of drilling-and-blasting operations at pits provide the breaking of rocks mainly with borehole charges. Nowadays the short delay blast method (SDBM) is widely applied to blasting of borehole charges [9].

The SDBM is one the most effective progressive methods of the drilling-and-blasting operation. There are a number of the hypotheses explaining its nature. However, despite broad application of SDBM there are no still current views on physical essence of the SDBM process [2, 4]. Now there are empirical formulas of calculation which are usually specified experimentally.

Now the investigation of the influence of the delay intervals on the parameters of waves strain is an urgent task in the scientific and practical terms [10, 11].

2. Materials and methods
Comparative analysis and reviewing the domestic [3, 5, 6] and foreign [7, 12] research in the field of blasting, the integrated use of theoretical and experimental methods in laboratory and production conditions, the application of numerical simulation on a computer of wave strain on a rock mass by a system of explosive charges have been provided.

For the calculation of the main strain, a special program based on Pascal language program was developed. It takes into account the location of the ignition points, the ignition sequence, the delay interval between the charges, an unlimited number of wells, various explosives, and charge structures in different points in the plane. To visualize the results of calculating the field stress, the MathCad program was also used.

3. Scheme and model calculation of the wave field stress

To calculate the parameters of the wave field strain, the physical model which was developed by the authors has been applied [1, 8]. Calculations were carried out for the conditions of the building materials quarry "Prudyansky", located in the Leningrad region of Russia. The rocks are characterized by the following physical and mechanical properties: density (ρ = 2.74 kg / m^3), the propagation velocity of longitudinal (C_P = 5 km / s) and transverse waves (C_S = 3.5 km / s).

The borehole charge is divided into a number of concentrated elementary charges as it is shown in Fig.1 and initiated sequentially through time intervals Δt. The value of Δt is the propagation time of the detonation wave from the center of the detonated elementary charge to the center of the next one. It should be assumed that the elementary charges are equal to each other, although another partition is possible.

The shape of the concentrated elementary charge is assumed to be spherical, since at present, both in the theoretical and in the experimental plan, the stress field caused by the blasting of spherical charges is the most investigated. The mass of a spherical elementary charge is assumed to be equal to the mass of the corresponding cylindrical charge. The wave strain created by each concentrated elementary charge is conventionally taken as a short wave, which includes the compression phase and the rarefaction phase, and is damping and changing in shape as the distance from the center of the explosion increases.

The strain field at some point A (R, 0, Z) is determined by summing the stress waves generated by each concentrated elementary charge, taking into account the arrival time of these waves t_{pri}, the angles θ_i formed by the radius r_i to the observation point A (Figure 1), and the total waves forms and shapes.

We take the height of the elementary charge equal to the diameter of the charge in the borehole. A smaller breakdown of the borehole charge into elementary charges is of no great importance, because first of all, we are not interested in the shape of the wave front, but in the field of the main strain.

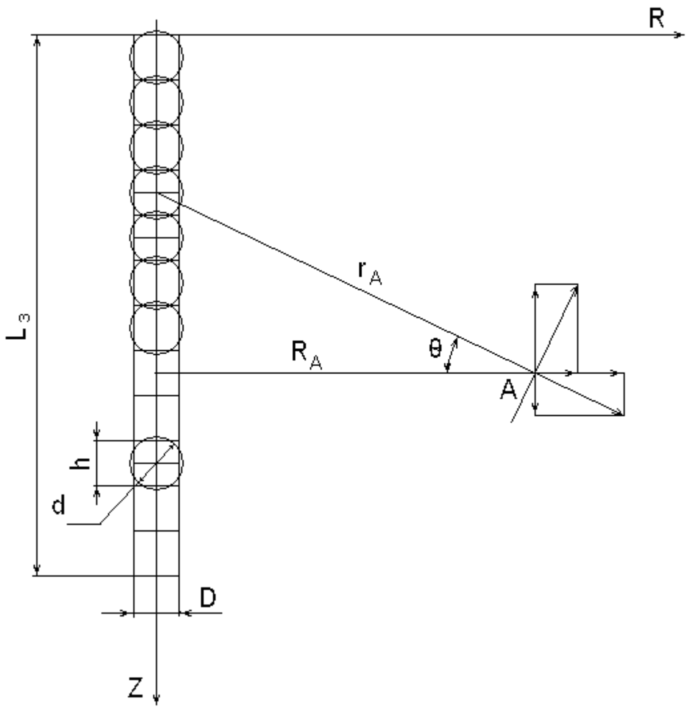

Figure 1. Scheme of calculation of strain field, by means of the borehole charge blast

In this case, the formulas for calculating the components of the total strain wave at the observation point are:

$$\begin{cases} \sigma_x(r,t) = \sum_{i=1}^{n}\left[\sigma_{xi}(r_i,z,t)\cos^2\theta_i + \sigma_{zj}(r_i,z,t)\sin^2\theta_i\right]; \\ \sigma_y(r,t) = \sum_{i=1}^{n}\sigma_{yi}(r_i,z,t). \\ \sigma_z(r,t) = \sum_{i=1}^{n}\left[\sigma_{xi}(r_i,z,t)\sin^2\theta_i + \sigma_{zi}(r_i,z,t)\cos^2\theta_i\right]; \end{cases} \quad (1)$$

$$\begin{cases} \sigma_x(r,t) = \sum_{i=1}^{n}\left[\sigma_{xj}(r_j,y,t)\cos^2\alpha_j + \sigma_{yj}(r_j,y,t)\sin^2\alpha_j\right]; \\ \sigma_y(r,t) = \sum_{i=1}^{n}\left[\sigma_{xj}(r_i,y,t)\sin^2\alpha_j + \sigma_{yj}(r_j,y,t)\cos^2\alpha_j\right]; \\ \sigma_z(r,t) = \sum_{i=1}^{n}\sigma_{zj}(r_i,z,t). \end{cases} \quad (2)$$

Figure 2 shows the model adopted to calculate the voltage field from the explosion of borehole charges system, taking into account the delay interval and the ignition direction.

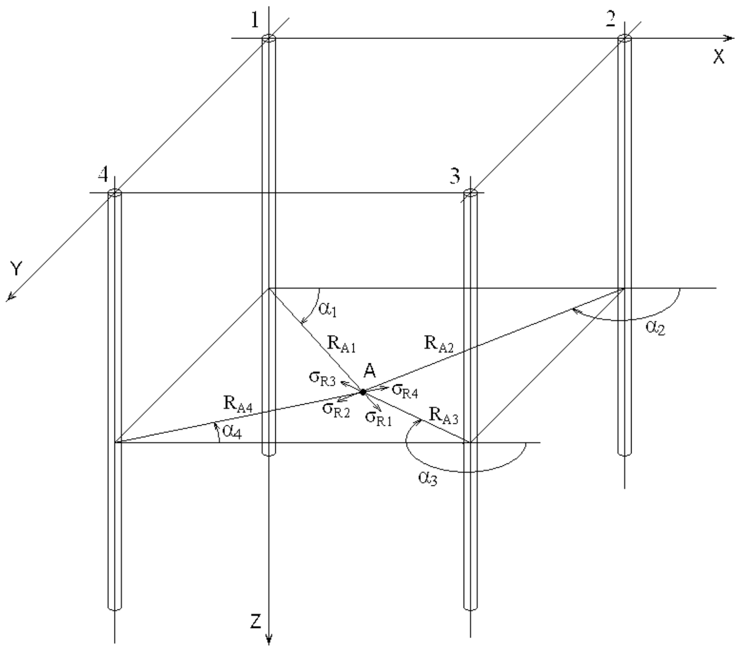

Figure 2. The model for calculating the stress field from the system of borehole charges, taking into account the delay interval and the specified direction of ignition.

The developed program allows varying the following blasting operations parameters: borehole depth, borehole diameter, stemming length, ignition points, delay intervals, observation points and explosives type.

4. Results

Figures 3 and 4 show graphically the numerical calculations of the wave field strain in the explosion of borehole charges:

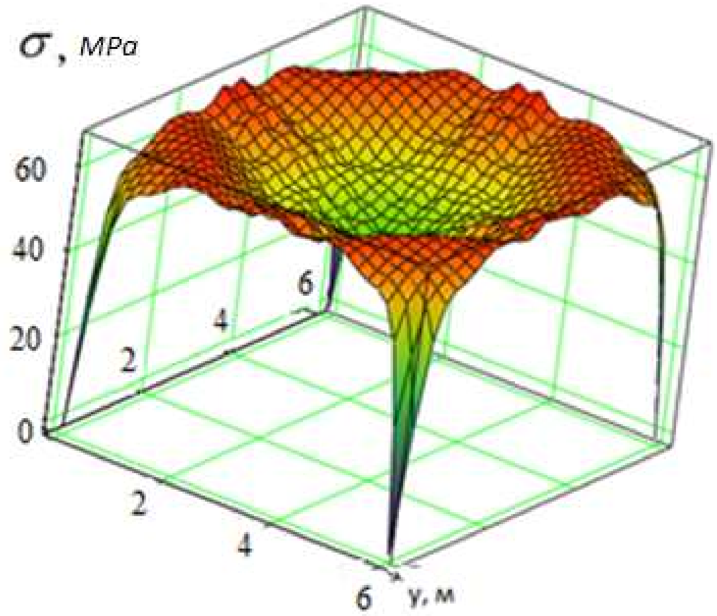

Figure 3. The wave field strain in the explosion of borehole charges without slowing down (simultaneously).

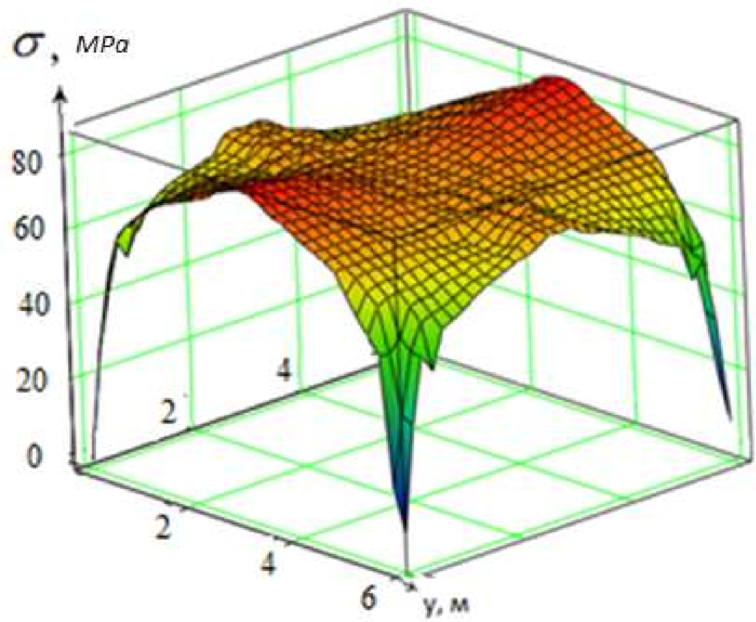

Figure 4. The wave field strain in the explosion of borehole charges at t = 2 ms.

5. Conclusion

Thus, the theoretical results obtained in the calculation of the wave field strain during the blasting of borehole charges show that control of the wave strain parameters can be achieved by changing the delay intervals between charges in the row and between the rows.

The direction of the wave factor of the explosion is determined by the ignition scheme, which allows us to justify its choice for the specific conditions of the blast block. In the production of drilling and blasting operations, the following ignition schemes are used: row order, cutting, trapezoidal, diagonal, diagonal-cutting schemes, and etc.

The above theoretical studies were tested during the production of mass explosions at the "Prudyanskiy" quarry of building materials. The results of the experimental explosions show that, for the "Prudyansky" quarryб the most optimal blasting is the diagonal scheme with a delay interval of 25 ms, which ensures the qualitative crushing of the rock mass.

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