FORMATION OF LOAD PARAMETERS OF DESTROYED MASSIFE IN EXPLOSION OF MULTICHARGE COMPOSITION WITH SEPARATION OF ITS PARTS BY PROFILE INERT INTERVAL

G P Paramonov, A V Mysin, R S Babkin

Saint-Petersburg Mining University, 21 Line, 2, Saint Petersburg, 199106, Russia

E-mail: RuslanBabkin1992@yandex.ru

Abstract. The paper introduces construction of multicharge composition with separation of parts by the profile inert interval. On the basis of the previous researches, the pulse-forming process at explosion of the borehole multicharge taking into account the offered design is considered. The physical model for definition of reflected wavelet taking into account an increment of radius of cross section of a charging cavity and the expiration of detonation products is offered. A technique is developed for numerical modeling of gas-dynamic processes in a borehole with a change in the axial channel of a profile inert interval caused by a high-temperature flow of gaseous products of an explosion. The authors obtained the dependence of the change in mean pressure on the borehole wall on time for each of the parts of the multicharge. To blast a series of charges of the proposed design, taking into account optimization of the stress fields of neighboring charges, the delay interval is determined for a short-delayed explosion.

1. Introduction
Drilling and blasting precede other technological processes of development (ore drawing, excavation, transportation, etc.) and, to a large extent, determine the productivity of mining and conveyor equipment, labor safety and economy of operations in general. Therefore, at present, drilling is one of the most important technological process at enterprises.

Drilling and blasting entails periodic disruptions in the production cycle of mining operations because of the need to remove equipment, railroads, and energy lines outside the explosion zone. With open development of deposits, especially when using rail transport, it is very important to have a good work on the bottom of the ledge. Uneven bottomhole soil significantly complicates the excavation process, reduces productivity. The uneven platform of the ledge entails additional excavator and bulldozer work to equalize the profile of the route under the railway and road routes, increases the transportation costs due to the decrease in the useful weight of the trains.

2. Materials and methods
Department of Explosive Business of the Mining University developed a combined design of a well charge of an explosive with separation of parts by a profile inert interval for high-quality processing of the sole of the ledge (Fig. 1) [1]. As a profile inert interval, the use of the OGDU, developed by the
Department of Explosive Sciences of the St. Petersburg Mining University, is proposed. The principle of the design is the reflection of the shock wave toward the bottom of the charging cavity by the internal profile of the block when it expands [2].

Figure 1. The design of a combined downhole charge of explosives with separation of parts by a profile inert interval.

3. The study of the structure of the modified lead-tin-base bronze
   To confirm the effectiveness of the proposed design of the charge, it is necessary to carry out an analysis based on previous studies of the formation of a pulse in the explosion of charges of explosives. To do this, in order to have a complete picture of the action of the multicharge, conditionally the authors subdivide the proposed construction into two parts: the upper one to the profiled inert interval, the lower one which includes the explosive with a high concentration of energy
and the SGDU as an inert interval [3].

According to the theory of the explosion, when considering continuous borehole charges, the pressure at the front of the detonation wave is proportional to the density of the explosive and to the square of the detonation velocity [4]. Following the detonation wave, a rarefaction wave appears in the products of the explosion, which appears immediately after the completion of the decomposition reaction of the explosive. The pressure in the rarefaction wave can be determined from the formula:

$$P_2 = \frac{8}{27} P_1 \left( x \left( \frac{1}{Dt} + \frac{1}{2} \right) \right)^3,$$

(1)

where \(x\) – the distance from the initiating point to the test section, m; \(t\) – time of passage of the wave to the test section, p.

When in a charge of length \(L_3\), the detonation wave reaches a lower limit \(\frac{D}{2} \geq t \leq D\), wave velocity moves linearly \(x = Dt / 2\), and the pressure \(P\) changed in accordance with the power law from \(P_n\) at \(x = L_3\) to \(P_2 = \frac{8}{27} P_n\) at \(x = \frac{L_3}{2}\), and on the interval \(0 \leq x \leq \frac{D}{2}\), there is a pressure equalization over the entire length of the charge: \(P^2 = \frac{8}{27} P_n\). [5]

Let us consider the general physical model of the operation of the lower part of the proposed downhole charge design. The total momentum transferred by the explosion products to the rock mass during the time of expansion of the charging cavity to \(R_{max}\) can be determined by summing the pulses transmitted to the array by a series of reflection waves propagating the charge under the inertial profiled interval in the charge cavity. Let us consider the process of formation of a complete pulse upon initiation of the lower part of the multicharge of the explosive charged in the inert profiled interval. The detonation wave passing charge generates a pulse which is defined by the dependence:

$$L_3 = S_0 \int_0^{t_1} P_n dt,$$

(2)

where \(S_0\) – the surface area of the charging cavity; \(t_1\) – delay time of charge; \(P_n\) – pressure in the front of the detonation wave [6].

The shock wave penetrating into the conical entrance space of the locking device produces shock loading of the surface of the inert interval, as a result of which the device expands and locks the detonation products in the space of the charging cavity. According to the method of ME Deig, the shock wave is amplified as a result of three-impact Makhnov reflections to the value determined by the radius of the cross section (critical) [7]

$$P_{max} = (P_1 - P_n) R_k^{-0.4},$$

(3)

where \(P_1\) – the pressure of a normal shock wave, Pa; \(P_n\) – the pressure before a direct jump in the deviation (explosion pressure, amplified in oblique jumps) Pa; \(R_k\) – the radius of the critical section, m [8].

Based on the works of F.A. Baum and B.I.Stanyukovicha, the radius of maximum expansion of the cavity can be estimated on the basis of approximation dependence [3]:

$$\frac{4}{3} \pi \cdot R_{max} \rho_0 C_p^2 \rho \frac{E}{E} = 38 \left( \frac{\rho_0 C_p^2}{250 \sigma_c} \right)^{\frac{2}{3}},$$

(4)

where \(E\) – the energy of the explosion, J; \(\sigma_c\) – the limit of compressive strength, Pa.
Leakage of detonation products in time during $t_z$ is:

$$\Delta m = \rho_0 V_k S_k \left( \frac{2}{k+1} \right)^{\frac{3}{k-1}} \cdot t_z,$$  \hspace{1cm} (5)

where $S_k$ – the cross-sectional area of the neck of the diffuser, m$^2$, $k = 1,2$.

The increment of the radius of the cross section in the charging cavity:

$$\Delta R = \frac{R_{\text{max}} - R_0}{n},$$ \hspace{1cm} (6)

The momentum of the reflected wave over time $t_{n-1}$ is:

$$I_{n-1} = S_1 \int_{t_{n-1}}^{t_n} P_{a_{n-1}} \, dt.$$ \hspace{1cm} (7)

To obtain the desired result of the explosion action of multicharge with a profiled inert interval, it is necessary to specify the sequence of initiation of conditionally separated parts of the charge. In our case, the deceleration time of the lower block is 0 ms (instantaneous explosion). To define expedient time of delay of the top block it is necessary to calculate the speed of development of a crack in the massif [9]:

$$v_p = \frac{8800}{P} - 18.5 - \left( \frac{600}{P} - 1.287 \right) f f^2 (G - 887)$$

$$\left( 2.8 + 0.6 f \right) (0.123P - 0.000157P^2 - 22.28) r^{3.15 - 0.0007P}$$  \hspace{1cm} (8)

where $f$ - the coefficient of the fortress of rocks; $P$ – performance of explosives; $G$ - the heat of explosion; $r$ - distance from the explosion site to exposed surface.

Then, after determining the minimum distance to the exposed surface and calculating the speed of the development of the crack, one obtains the time before which a closed volume will form in the lower part of the charge. Using the results of tests conducted by ZGDU conducted by the Department of Explosives, one can state that the time for locking the explosion products with a profiled inert interval will be from 10 to 18 ms. Thus, one gets the time interval within which it is necessary to initiate the upper part of the charge.

Based on the above method, pressure plots were constructed (Fig. 2) on the walls of the well at times T1-T4 (the period of detonation of explosives along the lower part of the multicharge, the period of shock waves passing through the detonation products, the period of detonation of explosives along the upper part Multicharge, the moment of the beginning of the displacement movement and the release of the GPV).
Figure 2. Diagrams of pressure on the walls of the charging chamber during the explosion of the multicharge.

4. Conclusion
For the conditions of mining operations with high ledges in difficult mining and geological conditions (high rock strength, water cut, etc.), the problem of long-term maintenance of pressure inside the well until the complete destruction of the massif along the entire length of the charge is solved. This is achieved by using a multicharge with different energy characteristics of the parts separated by a profile inert interval, which initiates the upper part of the charge with a slowdown relative to the explosion of the lower part.

References
[1] Mysin A V, Paramonov G P, Mironov Y A 2016 Mine surveying Bulletin 6 18-21
[2] Paramonov G P, Menzhulin M G, Mironov Y A 1998 Blasting works 91/48 241-242
[3] Mironov Y A 1998 Development and investigation of well bore parameters for reduction of dust and gas emissions during explosion. Abstract. p 360
[4] Argimbaev K R, Alexandrovich I V 2016 Research Journal of Applied Sciences 11(5) 240-244
[5] Isheyskiy V A, Yakubovskiy M M 2016 Mining journal (12) 55-59
[6] Zhigalko Y F 1987 Dynamics of shock waves (Leningrad, LGU) p 142
[7] Deych M E 1974 Technical gasdynamic 44-56
[8] Baum F A, Snosaryan M S 1966 *Blasting works* 114-120
[9] Li Z F, Xue H J, Chen J, Liu K, He TY 2014 *Advanced Materials Research* **868** 335-338