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FORMATION OF CRUSHING ZONE AT THE LEVEL OF TAMPING IN THE CONDITIONS OF MASS EXPLOSIONS

The purpose *of the work is to study the sequence of formation of the fracture zone in the area of the array above the ends of the system of adjacent charges in connection with the technological parameters of their mutual location. The task of works is the analytically substantiate the dependence of the value of the undamaged area of the array at the level of the bottomhole on the parameters of the system of downhole charges, taking into account the phenomenon of the edge effect.*

Research results*. Data on the dimentions of the part of the massif in the lborewhole that does not participate in the mass deformation motion of the rock during the formation of adjacent downhole funnels are obtained. It is assumed that this area between adjacent charges is the source of the oversized fraction.*

Originality*. The process of formation of the destroyed zone in space above the end of the boreholeis considered step by step: generation of the shock wave front, the symmetry of which is close to spherical, formation of the loosenning funnel system in the second stage, which does not adjacent charges of the total front of the stress wave from the explosion of downhole charges detonated from their bottom. Behind him moves the deformation front of a complex structure. It is assumed that this front in the system of two adjacent charges acquires a shape similar to a vertical wedge inverted by the base towards the free surface. The expected result of such a step-by-step deformation process is the desired degree of crushing of the rock mass at the level of the tamping.*

Conclusions and practical implications*. Theoretically and calculatedly obtained and recommended rational parameters of the location of the system of well charges of limited length to reduce the size of the non-destructive region of the rock mass at the level of the tamping, which improves the design of mass explosions in mountain slopes.*

Keywords*: phenomena, energy loss, driving, adjacent charges, explosion phases, rational parameters, vertical cut.*

INTRODUCTION

The study of boundary phenomena in the explosion of a hole charge of limited size shows that under the condition of instantaneous initiation of the charge simultaneously on both its ends the axial symmetry of the force field degenerates into a central one [1] – [4]. This phenomenon is observed on segments of up to 50 charge radii and is accompanied by significant (up to 35-40%) energy losses of the explosion. The magnitude of the end part of the charge is determined only by the diameter of the charge. Therefore, when reducing its length in real blasting conditions, especially on mountain slopes, the mechanical effect of the explosion is largely associated with the destruction of the array by weakened end sections of the linear charge. When developing ways to control the mechanical effect of the explosion in the marginal areas of the borehole charge, it is necessary to take into account the peculiarities of the charge in the lower and upper parts. In the lower end part, responsible for the overburden zone, energy losses can be compensated by amplifying the charge with a powerful initiator (booster). As the upper end of the charge is detonated in the conditions of incomplete camouflage, its amplification threatens the growing scattering of individual pieces. Therefore, the methods of controlling the edge effect and the quality of shattering at the level of the tamping is not enough to study the edge effect of the explosion of a single charge. It is necessary to build control of mechanical effect of explosion on interaction of adjacent charges in groups by application of rational parameters of charges and their mutual arrangement.

The aim of the work is to study the mechanism of deformation of the upper layer of the rock mass at the level of the tamping to substantiate the rational parameters of mass explosions of hole charges of limited length**.**

The operating conditions of the vertical borehole charge during a mass explosion on the ledge differ significantly in height, as the resistance of the rock to destruction increases with depth. In the lower part of the hole or in the area of overburden, the charge works in conditions of full camouflage, the middle part of the charge - in conditions close to camouflage, the upper part - in conditions of attenuated discharge charge [5, 6].

Despite these significantly different horizontal conditions of block destruction, the vertical elongated charge must ensure uniform shattering of the array. A simple and affordable criterion for the quality of mass explosion is the percentage yield of oversized fraction in the broken-rock pile of the destroyed rock. In the middle part of the charge, the probability of oversize formation is minimal, because its destructive capabilities are taken into account by the appropriate calculation for the conditions of axial symmetry. Regarding the lower end part of the charge, its destructive capabilities are traditionally enhanced by the use of overburden, ie by increasing the mass of the charge in the lower part of the hole. The same goal is achieved by other design solutions [7] – [11].

In the known ideas about the peculiarities of the destruction of the rock mass in these areas of the landing block, the wave mechanism of destruction is most often preferred, in which a certain role is given to the waves reflected from the free surfaces. However, the role of both dynamic factors - stress waves and the piston action of the explosion - should not be ignored. The strength of the rock as an integral indicator of its resistance to destruction, determines the degree of participation of these factors in the mechanism of development of the deformation process. It is clear that in strong and fragile rocks wave phenomena prevail in the initial formation of cracks. We can assume that in the lower part of the borehole charge the role of wave phenomena in the general deformation process prevails. In the middle main part the two factors complement each other, in the upper part, the piston factor obviously begins to prevail, although some scientists [2] – [4] consider possible the predominant role of wave processes in the destruction of the weakened upper layer at the level of the packing.

The choice of the size of the tamping determines the further course of the process of deformation of the block by the explosion of the charge placed close enough to the surface. At the same time, he must take into account not only the quality of destruction (shaterings) of the rock, but also the ejection of a certain part of it over the charge on the surface of the ledge. This process is considered in the framework of the theory of the ejection funnel, started by MM Boreskov and improved by GI Pokrovsky, MV Melnikov, VM Rodionov. S.A. Davidov and other scientists [5, 6]. The theoretical regularities of these developments are based on the correspondence between the volume of the massif destroyed by the explosion, or the formation of new surfaces, the mass of the ejection charge. In the vast majority of cases, the basic solutions of the mechanics of continuous media must be adjusted to take into account the influence of the anisotropy of a real mountain massif.

Unfortunately, the techniques used in the lower part of the charge to amplify or concentrate its action in the desired direction are not relevant for the upper part. First of all, there are restrictions on the mass of the charge in the upper end part. They are associated with the danger of increased scattering of individual pieces of rock mass. This increases the probability of an increase in the content of the oversized fraction in the total volume of the broken-rock pile. The total yield of oversized fraction in each mass explosion characterizes its quality. However, it only averages the data on the quality of destruction, is an indicator that is not able to differentiate the distribution of oversize in the broken-rock pile by the height of the ledge. Attempts to determine the role of each of the dynamic mechanisms of fracture in the development of deformation processes in the array at the level of the tamping [3] are limited to wave and piston mechanisms. The mechanism associated with the phenomenon of counter-mass displacements of individual rock volumes (layers) with the inclusion of the mechanism of mass collision or collision was ignored. In connection with the above, the sequence of development of individual phases of the deformation process in the field of tamping is considered, taking into account the interaction of adjacent borehole charges.

MATERIALS AND METHODS

Based on the considered concept of the operation of the edge part of the hole charges in the subsurface layer of rocks in the mode of moderate lowering (n = 0.6), controlled shaterings is primarily possible due to the interaction of the lowering craters provided they overlap. Depending on the design distance between adjacent charges, these craters may partially or completely overlap or exist separately. It depends on what part of the array at the level of the tamping will be destroyed in the descent mode. The research is aimed at determining the size of the zone between charges at the level of the tamping, not affected by the interaction of adjacent loosening craters.

According to the scheme of Fig. 1 (source elaborated by authors), the total area between adjacent charges in the area of the tamping is denoted as $S = a h_{NAB}$, where *a* is the distance between the charges, h_{NAB} is the value of the tamping.

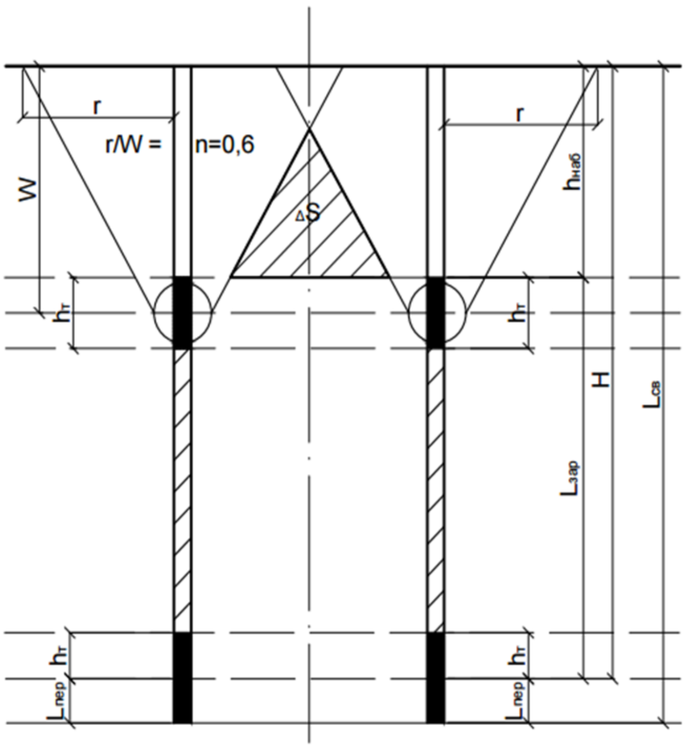

Figure 1 – Scheme of interaction of adjacent charges at the level of the tamping

The area of the rock block between adjacent charges, not affected by the craters of the descent, are indicated in table. 1 and in fig. 1 symbol ΔS (as the probable area of oversized output). Calculations of this value were performed for fixed initial parameters of blasting, namely, the height of the ledge in the range of 5, 7 and 10 m, charge diameter 105, 155 and 215 mm, 3 types of explosives, which differ significantly in physico-mechanical and detonation characteristics. In the table. 1 shows the absolute values of the desired area ΔS and its relative to the total area of the block S values in% (source elaborated by authors).

Table 1 - Area of elements of the borehole rock block at the level of the tamping

Output parameters		areas S / ΔS for different explosives m^2 and %%					
		Emulsion expl.		Gramomit 79/21		ANFO	
H, m	d_H, mm	m^2	%	m^2	%	m^2	%
10	105	12,63 6,37	100 50,4	10,86 5,46	100 50,27	9,32 4,62	100 49,55
	155	23,34 12,0	100 51,35	17,8 9,23	100 51,85	17,46 8,93	100 51,15
	215	37,22 19,4	100 52,12	18,72 10,0	100 53,22	26,4 13,71	100 52,0
7	105	10,88 5,55	100 51,0	9,7 4,93	100 50,8	8,19 4,13	100 50,48
	155	19,03 9,9	100 52,0	17,8 9,35	100 51,85	14,69 7,59	100 51,67
	215	28,2 15,0	100 53,0	25.6 13,46	100 52,54	22,65 11,9	100 52,6
5	105	9,05 4,67	100 51,63	8,03 4,13	100 51,43	7,18 3,58	100 49,73
	155	17,78 9,34	100 2,55	13,83 7,3	100 52,73	11,74 6,16	100 52,5
	215	23.3 12,41	100 53,3	18,72 9,96	100 53,22	17,42 9,45	100 54,2

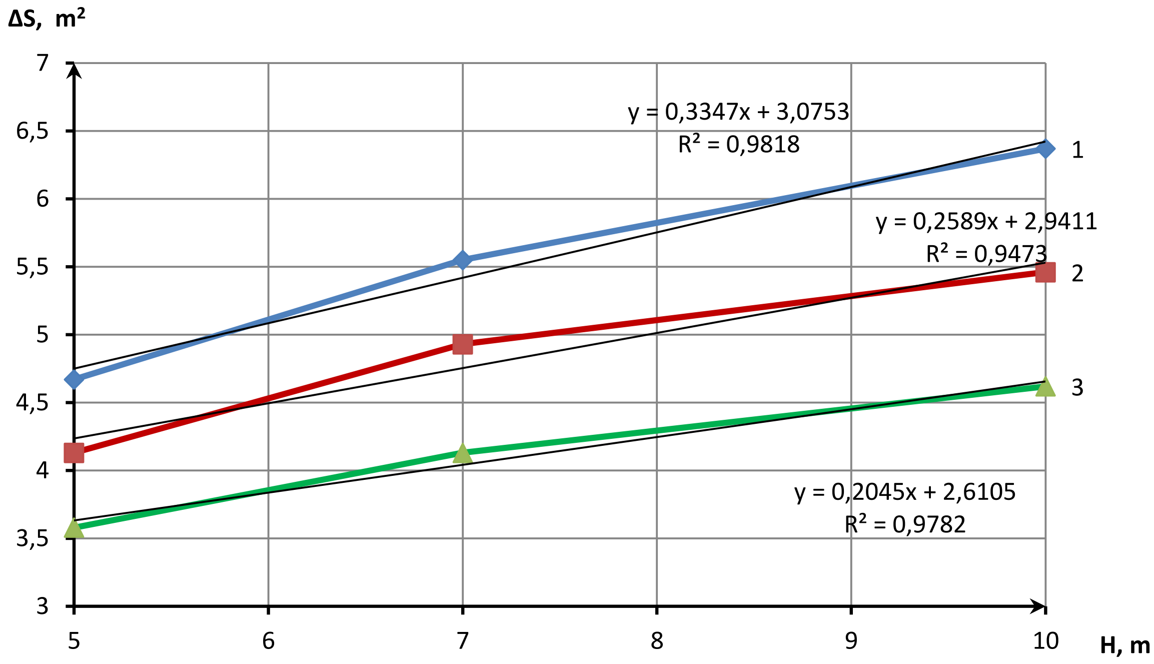

Figure 2 – The dependence of the area of the probable formation of the oversized fraction on the height of the ledge for charges with a diameter of 215 mm (1), 155 mm (2), 105 mm (3)

As can be seen from the analysis of the table. 1 and fig. 2 (source elaborated by authors), the relative area of the middle zone ΔS as a percentage depends almost little on the considered popular parameters of the mass explosion, including the height of the ledge, although some tendency of its growth with increasing charge diameter is observed. However, in absolute terms, the area of this zone is significantly reduced not only by reducing the diameter of the charge and the height of the ledge, but also due to the purpose of the type of explosives. This fact can be crucial for the choice of industrial explosive hole charge, namely - ANFO. The use of this simplest explosive minimizes (up to 3.58 m^2) the area of oversized fraction for a charge diameter of 105 mm against a maximum value of 6.37 m^2 when using emulsion explosives and a ledge height of 10 m, or more than 4.0 m2 when using EE or gramonite with the same diameter charge. This observation is based on the calculation of the degree of influence of edge effects at the level of the tamping on the total destructive effect of the explosion in the system of borehole charges. It is a strong argument for the appointment of i explosives based on ammonium nitrate - ANFO as an industrial explosive. This factor is always present, creating preconditions for the destruction of the array.

The dynamics of the development of the mechanical effect of the explosion at the level of the charge may be dominated by one of the following phases of the explosion:

radiation and propagation of the force front (wave phase),

formation of the explosive cavity or camouflage phase. accompanied by the emergence of a system of radial cracks,

mass shifts following a wave of stresses (quasi-static phase),

interaction of counter or successive different-velocity mass flows in the collision phase Fig. 3 (source elaborated by authors).

These phases in the dynamics of the general deformation process are present in each part of the charge, but their weight in each technological element can vary. From the most controversial and problematic areas of the hole charge, its upper end section was selected and the study was performed for it.

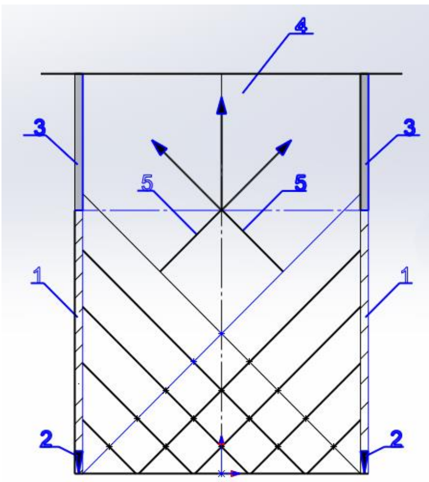

Figure 3 – The scheme of interaction of borehole charges of loosening in the conditions of simultaneous lower initiation: *1 - borehole charge, 2 intermediate action, 3 - tamping, 4 - overhead layer of rock, 5 - vectors of movement of interacting force and deformation fronts.*

The quality of shattering of the array in the interchanging zone at the level of the charge deteriorates due to the weak interaction of adjacent downflow craters over each of the charges, the middle zone is formed, which is one of the sources of oversized fractions. However, in reality, another mechanism of destruction is not excluded in this area. It is based on the phenomenon of pre-destruction under the influence of a system of counter power fronts generated by a simultaneous explosion of powerful boosters in the lower ends of adjacent charges according to the scheme shown in Fig. 3.

The total vector of these interacting fronts is directed towards the upper layer. Following each front, there is a displacement of rock masses that interact with each other in a mode similar to the traditional method of wedge or trapezoidal cutting in the technique of short-range blasting.

But unlike the traditional horizontal cut in the upper layer of the ledge at the level of the tamping, this cut is oriented vertically upwards. This implements the effect of a vertical wedge cut.

The above material assumes that adjacent charges are detonated simultaneously. However, the existing technique of blasting in the conditions of mass explosions with short decelerations between groups (rows) of charges in quarries does not provide for instantaneous detonation of adjacent charges. Therefore, the use of instantaneous blasting requires the development and justification of new combined circuit switching schemes. These schemes should coordinate the improvement of the quality of rock mass crushing with the limitation of the level of seismic oscillations, which are controlled by the method of short decelerations.

CONCLUSIONS

The total force field from an instantaneous explosion of adjacent borehole charges is formed with a loss of energy due to the degradation of the symmetry of the divergence of stress waves at its ends. Energy losses at the level of the lower ends of adjacent charges are compensated by the use of a powerful booster and the use of special design techniques that help change the orientation of oncoming power flows along the plane of the ledge sole. parameters of charges and their location in the system of mass explosion it is established that the type of explosives practically does not influence manifestations of boundary effect of the extended charge. It has been established that charges with a diameter of 105 mm should be preferred unambiguously, regardless of the length of the charge, in order to reduce energy losses due to edge effects, and for technical and economic reasons - ANFO charges in waterproof shells or sleeves.

It is theoretically and calculatedly proved that the energy of adjacent borehole charges is insufficient for complete shattering of the upper near-surface layer of rocks at the level of the tamping in camouflage and wave mode. Analysis of the calculated data shows that the size of the undamaged area of the array at the level of the tamping between adjacent craters does not depend on the height of the ledge, but is significantly reduced in absolute terms by reducing the charge diameter to 105 mm and using industrial explosives type ANFO.

When developing measures to control the mechanical effect of an explosion at the level of the tamping, it is not enough to limit the phase of formation and interaction of adjacent craters. It is necessary to consider the phenomenon of interaction of real force and deformation fronts. Under conditions of simultaneous detonation of adjacent charges, they provide counter-movement of local masses of rock, which in the process of contact form an additional zone of destruction in the rock layer at the level of the tamping.

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ФОРМУВАННЯ РУЙНОВАНОЇ ЗОНИ НА РІВНІ НАБІЙКИ В УМОВАХ МАСОВОГО ВИБУХУ

Мета та завдання. Метою роботи є вивчення послідовності формування зони руйнування в області масиву над торцями системи суміжних зарядів в зв’язку з технологічними параметрами їх взаємного розташування. Завдання. Аналітично обгрунтувати залежність величини неруйнованої області масиву на рівні набійки від параметрів системи свердловинних зарядів з урахуванням явища крайового ефекту.

Результати досліджень. Отримано дані про величину частини масиву в надсвердловинному цілику, яка не бере участі в масовому деформаційному рухові породи під час утворення суміжних воронок спушення. Припускається, що ця область масиву між сусідніми зарядами є джерелом надгабаритної фракції.

Наукова новизна. Розглянуто постадійно процес формування руйнованої зони в просторі над торцем свердловини: генерування фронту ударної хвилі, симетрія якого близька до сферичної, формування на другій стадії системи воронок спушення, яка повністю не охоплює область масиву над торцями суміжних зарядів, прихід в подальшому в середню область над сусідніми зарядами сумарного фронту хвилі напружень від вибуху свердловинних зарядів, детонованих з їх донної частини. За ним переміщується деформаційний фронт складної будови. Припускається, що цей фронт в системі двох суміжних зарядів набуває форми, подібної до вертикального клина, оберненого основою в бік вільної поверхні. Очікуваним результатом такого постадійного деформаційного процесу є бажаний ступінь подрібнення гірського масиву на рівні набійки.

Висновки та практичне значення. Теоретично та розрахунково отримано і рекомендовано раціональні параметри розташування системи свердловинних зарядів обмеженої довжини для зменшення величини неруйнівної області породного масиву на рівні набійки, що вдосконалює методику проектування масових вибухів в умовах гірських схилів.

Ключові слова*: подовжений заряд, негабарит, крайові явища, втрати енергії, забивка, суміжні заряди, фази вибуху, раціональні параметри, вертикальний вруб.*

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