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Pit wall stability and drilling-and-blasting

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Abstract. The author describes discipline of wall control blasting in open pit mining. The introduction procedure of the special drilling-and-blasting technology at ultimate pit limits includes analysis of blast effects on pit wall rock mass, finding of consistent patterns of wave processes in rocks, determination of introduction between charges in perimeter blasting depending on rock mass strength, semicommercial testing of cutback methods, staging of process blasting in critical areas as well as identification of drilling-and-blasting efficiency criteria. Analysis of seismic wave propagation in rocks under dynamic impact and initiation of stress waves allows setting parameters of destructive effect of explosions in production blocks. At the same time, determination of seismic stability in the zone of destructive effect of blasts makes it possible to select the most sound and moderate drilling-and-blasting regimes and to maintain pit wall slope stability.

1. Introduction

Increasing angles of pit wall slope decreases amount of wall control blasting and improves economic efficiency of open pit mining. On the other hand, there is a heightened risk of pit wall failure as a result of geodynamic movements due to rock pressure and under short-terms shock loads of explosions. Estimation of pit wall slope stability at a certain angle is based on measurements of rock mass displacements in different directions within a long period of time [1–7], and short-term deformations causing local block movements are disregarded in justification of stable slopes. In this regard, inaccurate wall blasting can violate stability of pit walls and result in disastrous earth sliding [8–13].

2. Methods and results of research

Miners have become very interested recently in wall control blasting at the stage of transmission to ultimate pit limit. Evidently, even rise in cost of wall control blasting at higher quality and adequate control results in increased safety of mining, stability of pit walls and, consequently, in higher economic efficiency of open pit mining in whole. For example, elimination of earth slide is connected with cessation of mining or, sometimes, total arrest of performance with corresponding damage and, sometimes, death. For this reason, improvement of mining efficiency is not only an item of cost but weighty contribution to progression, which largely governs future efficient performance of a mine.

The Institute of Mining, UB RAS, is engaged in R&D on introduction of special drilling-and-blasting technology at ultimate pit limits. In order to abate dynamic impact of blasting on pit wall slope stability, seismic stability of rock mass is comprehensively investigated. The related procedures are described in [14–23]. Based on the research findings on seismic stability of rocks, a special drilling-and-blasting technology is developed for the ultimate pit limit stage. The shielding parameters are determined for rock bands depending on characteristics explosives and diameters of the wall control blasting holes These characteristics are described in expressions (1)–(4), as well as in Figure 1 and Table 1.

The pressure on blast hole walls, P, MPa is:

$$P = \frac{r_{\text{charge}}^2}{2\, r_{\text{hole}}^2} P_d \,, \tag{1}$$

where r_{charge} and r_{hole} are the radii of explosive charge and blast hole, respectively.

The detonation wave pressure P_{d}, MPa:

$$P_d = \frac{\rho_{\text{expl}}\, D^2}{1+n} \,, \tag{2}$$

where ρ_{expl} is the explosive density, kg/m^3; D is the velocity of detonation, m/s; n is the index of explosion product expansion.

The fracturing radius, m:

$$R_{\text{frac}} = r_{\text{hole}} \sqrt[3]{(P / \sigma_{\text{dyn}})^2} \,, \tag{3}$$

where σ_{dyn} is the allowable dynamic ultimate strength of rocks, MPa.

The distance pressure in rocks after explosion of a cylindrical charge, P_R, MPa:

$$P_R = P \left(\frac{r_{\text{hole}}}{R} \right)^{1.5} \tag{4}$$

where R is the distance from the explosion, m.

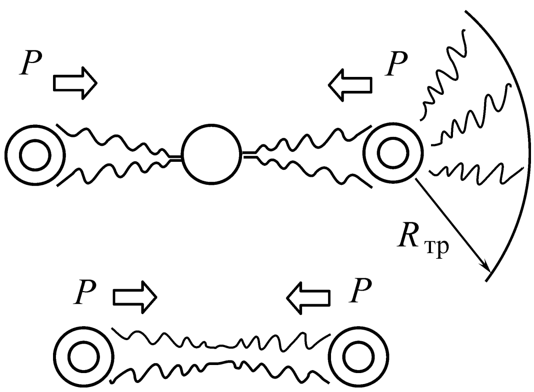

Figure 1. Analysis of pressures in determination of rational parameters of perimeter blasting.

The technological approaches are tested full scale in the framework of the program approved by management of a mine. The program describes implementation stages, lists necessary assets and dictates the control routine. After the program is implemented and the semicommercial tests are carried out, the results are analyzed, ad an in-house regulatory document on drilling-and-blasting at the ultimate pit limits is elaborated (production procedures). The expected results of this technology introduction include:

• Minimization of impact of drilling-and-blasting on pit wall stability;
• Increased safety of operation under high benches;
• Reduced cost of marketable products.

Table 1. Fragment of chart of spacing determination for blast holes in row using the table of values calculated from (1)–(4).

Rock	Tensile strength, MPa	Dynamic ultimate strength, MPa	Fracturing radius, m			
			Ammonite 6 ZHV			
			D_{hole}/d_{charge}			
			215/60	246/60	215/90	246/90
Carbon cataclasite	0.36	0.47	2.3	2.2	4.0	3.8
Carbon quart-carbonate rocks	0.56	0.73	1.7	1.7	3.0	2.8
Carbon metasiltstone	0.42	0.54	2.1	2.0	3.6	3.5
Metasomatite	0.53	0.69	1.8	1.7	3.1	3.0
Heavily damaged metasomatite	0.24	0.31	3.1	2.9	5.3	5.0
	Distance from charge, m		215/60	246/60	215/90	246/90
Perimeter blast pressure, MPa	1		1.66	1.56	3.75	3.50
	2		0.59	0.55	1.32	1.24
	3		0.32	0.30	0.72	0.67
	4		0.21	0.19	0.47	0.44
	5		0.15	0.14	0.33	0.31
	6		0.11	0.11	0.25	0.24
	7		0.09	0.08	0.20	0.19
	8		0.07	0.07	0.17	0.15

A key competitive advantage of this technology is its high efficiency when mining operations are very intensive. Safety is also increased due to the regulated operations at the ultimate pit limits. The application area of this technology is cycling open pit mining of steeply dipping mineral deposits.

The R&D involves investigation of seismic effect of explosions in order to correlate actual and calculated admissible vibrations in given rock mass based on the geological exploration documents, on the one hand. On the other hand, by deformations after blasting, properties of soil are approximately determined, and estimated zones of fracturing, inter-block displacements and residual strains are identified [24]. This information makes the background for selecting drilling-and-blasting patterns to be included in the semicommercial test program. Furthermore, depending on soil properties and explosive characteristics, parameters of charges in perimeter blasting meant for shielding are determined [25].

3. Conclusions

The introduction of the special drilling-and-blasting technology in wall control blasting is accompanied by investigation of wave processes in rocks, which governs the choice of the corresponding patterns. An important element of such investigations is refinement of properties of soil under short-term shock loading.

The technical approaches to seismic stability assessment of rocks include pre-calculation, comparison of the calculated data with the experimental measurement result, refinement of rock mass properties and identification of possible failure zones. Such scope of the research allows obtaining the broadest picture of wave propagation in specific rock mass and, consequently, enables rational control. For the first turn, this relates wall control blasting and subsequent process explosions.

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