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Satbayev University

ХАБАРЛАРЫ

ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ НАУК
РЕСПУБЛИКИ КАЗАХСТАН
Satbayev University

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IMPROVING THE QUALITY OF BLASTING INDICATORS BY STUDYING THE NATURAL STRESS FIELD AND THE IMPACT OF THE BLAST FORCE ON THE ROCK MASS

Abstract: in the proposed article two different methods of blasting horizontal and inclined mine excavations are considered. The purpose of this article is to increase the stability of the contour rock mass and improve the quality of the blast by optimizing the parameters of drilling and blasting operations during the passage of underground mine excavations. When choosing the research method were used modern programs and methods for determining the zones of influence of the blasting force. On the basis of numerical modeling by the finite element method are determined the possible zones of destruction of law-shaped rocks under the influence of the blasting force. A comparative analysis of the excess cross-section coefficient of two different methods of blasting sinking excavations is performed. There are shown the advantages and disadvantages of the method of contour blasting of sinking excavations proposed by the authors. The design of the charge of contour holes and the explosives used in the proposed method of detonation are demonstrated. The actual results of experimental explosions are given. It is shown how much the quality indicators of blasting operations increase in comparison with the generally accepted methods of blasting sinking roadhead. By reducing the force of the blast on the sculptural rock mass, the surface of the uncovering contour of the excavations is more even, which allows to choose a lighter support to mine excavations in a stable state.

Key words: numerical simulation, finite element method, blast, contour blasting, perimeter rock mass, excavation, drilling and blasting, hole.

Introduction. Currently, the development of mineral deposits by underground method is characterized by large volumes of sinking operations. The speed and quality of sinking generally determine the efficiency of mine development and underground mining operations. One of the factors that reduces the rate of penetration when using drilling and blasting operations is the increased structural destruction of the rock mass, leading to falls and the formation of weakened zones, and ultimately, to increased costs for fixing and transporting the rock mass.

The analysis and generalization of the literature data [1, 2, 3, 4] allowed to estimate that more than 90% of rocks during mining are separated from the rock mass by blasting destruction, and despite the large volume of theoretical and experimental studies [5, 6], the effective control of the blasting action is not sufficiently studied, since there is currently no method for calculating the parameters of drilling and blasting operations taking into account the stress-strain state of the rock mass. Therefore, the problem of increasing the stability of the rock mass is very relevant, and its solution is based on improving the methods of controlling the energy of the blast, which are based on reliable physical representations of the processes of destruction of rocks by blast.

The destruction of continuous stressed media by blast and the identification of its regularities are the subject of research by many scientists. Adushkin V.V., Borovikov V.A., Zharikov I.F., Klochkov V.F., Kryukov G.M., Kutuzov B.N., Rodionov V.N., Menzhulin M.G., Fokin V.A., Shemyakin E.I., Khanukaev A.N., Andreev R.E., Brown C.J., Thomas G.O., Erion P., Algest A. and others made a significant contribution to the study of the processes of rock destruction, formation and propagation of stress waves in the rock mass during the blast of explosive charges.

Despite the large amount of work performed and the achievements in scientific research in assessing the impact of the stress state of the rock mass on the resulting effect of the blast, there are different opinions of researchers, so far there is no final scientifically-based approach to determining the rational parameters of drilling and blasting operations during excavation of workings [7].

Improving the efficiency of drilling and blasting operations, taking into account the stressed state of the rock mass, is an important task in practical and scientific terms, the solution of which will reduce the cost per unit of extracted mineral.

The aim of the study is to increase the stability of the contour rock by optimizing the parameters of drilling and blasting operations during the passage of underground mining excavation workings.

To achieve this goal, the following tasks are defined:

- to justify the feasibility of using contour blasting in strong rocks with increased fracturing;
- to develop passports for drilling and blasting and schemes for loading contour holes;
- to conduct pilot tests on the developed passports of drilling and blasting operations.

Materials and methods. Currently, the generally accepted method of drawing up passports of drilling and blasting operations is the calculation of the specific flow rate and charge parameters for the entire volume of the blasted rock in the face entirely, without considering, and even more so, calculating the features of the stress-strain state of the rock mass. In this regard, the seismic effect of the explosion on the contour array was studied by numerical modeling [8].

Experimental explosions were carried out at the underground mining excavation workings of the Akbakay mine. Rock strength indicators (RQD) were determined directly on the mine contour and a linear fracturing survey was performed, which in turn are the main indicators for determining the geological strength index GSI [9].

Based on the results of the survey of cracks, 3 systems of cracks were identified, the elements of occurrence of which are shown in Table 1.

Table 1 - Elements of occurrence of crack systems

System №	Average angle of incidence, deg.	The average azimuth of the fall, deg.	Characteristics of the crack system
1	50	345	stratification
2	65	159	longitudinally secant
3	43	256	transversely secant

The properties of the fractured massif are determined by the Hoek-Brown criterion [10] using the geological strength index GSI [11]. The geological strength index GSI is calculated using the formula:

$$GSI = \frac{52J_r/J_a}{(1+J_r/J_a)} + \frac{RQD}{2} \quad (1)$$

where J_r , J_a are the indicators of roughness and variation/filling of cracks according to N. Barton. For the conditions of the Akbakay field, J_r = 1,5; J_a = 2 is accepted.

Then, according to equation (1), the approximate value of the geological strength index GSI is 68.

For numerical modeling of the stability of a rock mass by the finite element method, it is necessary to process the physical and mechanical properties of rocks according to the Coulomb-Mohr or Hoek-Brown criteria in the RocLab program.

The program also takes into account the quality of the impact of the explosion on the contoured mass, that is, with identical properties of the rock mass, the quality of contouring depends on the brisance of the explosives. Table 2 shows the parameters of the physical and mechanical properties of rocks, which are the initial data for numerical modeling by the finite element method.

Table 2 – Processed physical and mechanical properties of rocks

Domain №	Initial data for computer simulation					
	Results of the processed physical and mechanical properties of rocks					
	Tensile strength (in the array) σ_p , MPa	Modulus of elasticity of the array E, MPa	Internal friction angle φ, deg.	Grip, G MPa	Poisson's ratio μ	Bulk weight γ , t/m^3
I	0,292	12550,8	48,15	2,614	0,3	2,69
II	0,746	16960	46	3,2	0,3	2,7

Results and discussion. According to the results of numerical modeling of the stress-strain state of the array, after man-made impact on it with the usual method of blasting (Figure 1, a), possible unstable zones in the roof of the workings can reach up to 0.2 m, and when using contour blasting (Figure 1, b), this indicator is halved (0.1 m), that is, the stability of the contour array increases. Based on the above, it can be argued that in strong rocks with increased fracturing, the use of contour blasting is advisable from the point of view of safety – by reducing possible collapse zones, and from the point of view of economy – by reducing the cost of secondary dilution and fixing during mining operations.

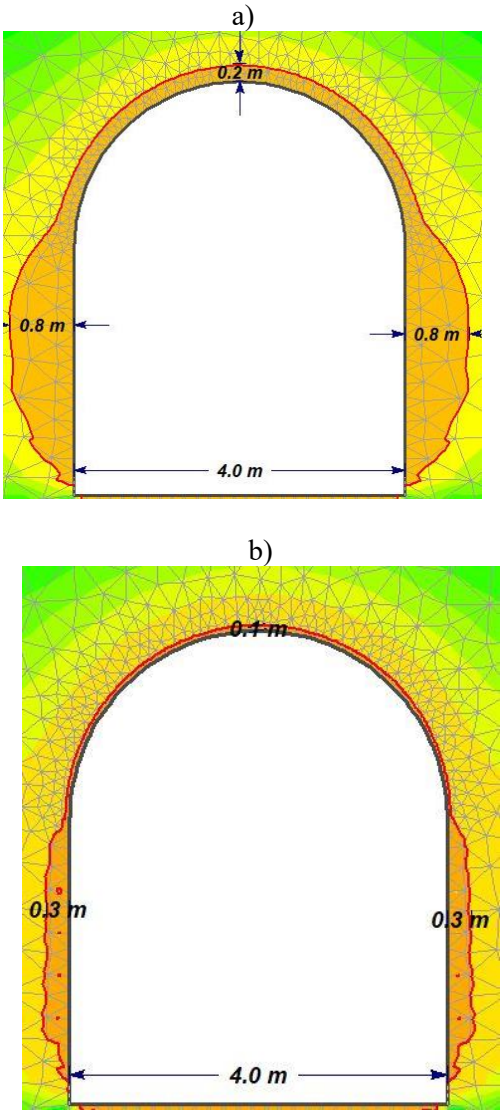

Figure 1 – Results of numerical analysis:
a - without taking into account contour blasting;
b - with allowance for contour blasting

The passport of drilling and blasting operations was developed for field horizontal workings according to the method of B.N. Kutuzov [12], and supplemented by the results of experimental explosions. In order to reduce the impact of the explosion on the structural array, it was decided to drill additional blank holes on the arch of the development in an experimental manner to distribute the force of the explosion. The layout of the holes is shown in Figure 2.

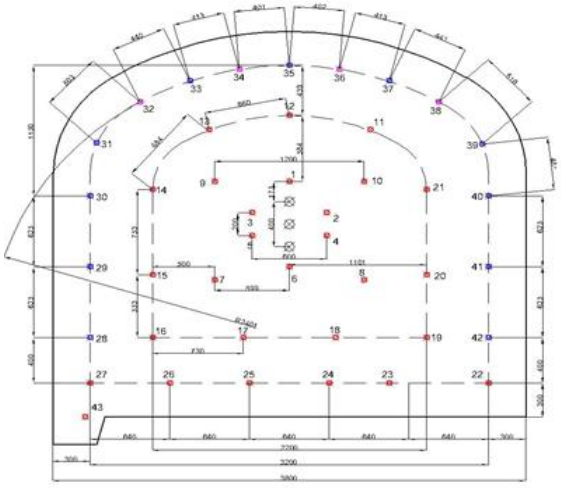

Figure 2 – Diagram of the location of the holes

To date, in foreign practice [13], the system of distribution of emulsion explosives with the help of a hose tap is widely used, which has shown a number of advantages, including increasing the efficiency of underground mining excavation, reducing the time of loading the face, as well as the need for labor resources. However, if we think from the point of view of economics, the cost of emulsion explosives is higher compared to the explosives proposed by the authors.

According to the new charging scheme proposed by the authors, contour holes are charged using ammonium nitrate, a detonating cord and a detonator capsule. This conventional method of loading contour holes achieves very effective results aimed at increasing the stability of the contour rock mass during blasting operations.

Figure 3 shows the actual mine surveying of the cross-sections of the workings with a total station meter in the usual method of blasting (a), and when loading contour holes in the way proposed by the authors of the work (b). In fact, the cross-sectional area of the workings in the conventional blasting method is 14.1 m^2, while the design cross-sectional area is 12.0 m^2. Based on Figure 3 (a), it can be argued that with the usual method of blasting, there are falls from the roof and sides of the workings, which often leads to an increase in the excess cross-section coefficient of at least 1,175. In the case of contour blasting (Figure 3, b), the average coefficient of excess cross-section does not exceed 1.05, respectively, the contour of the excavation is close to the design outline.

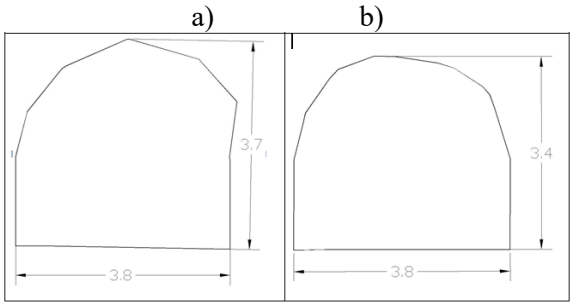

Figure 3 – Actual total station survey of the excavation contour: a - without taking into account contour blasting; b - with allowance for contour blasting

The analysis of the results of the pilot tests conducted in the workings of the Akbakay mine for 3 months showed a positive result. This is evidenced by the minimization of the formation of chips and cracks in the rock mass of the rock structure in comparison with the usual method of blasting. On the basis of the above, it can be argued that the reduction of the impact of the explosion on the legal rock mass has been achieved. Figures 4, 5, and 6 show the results of experimental explosions.

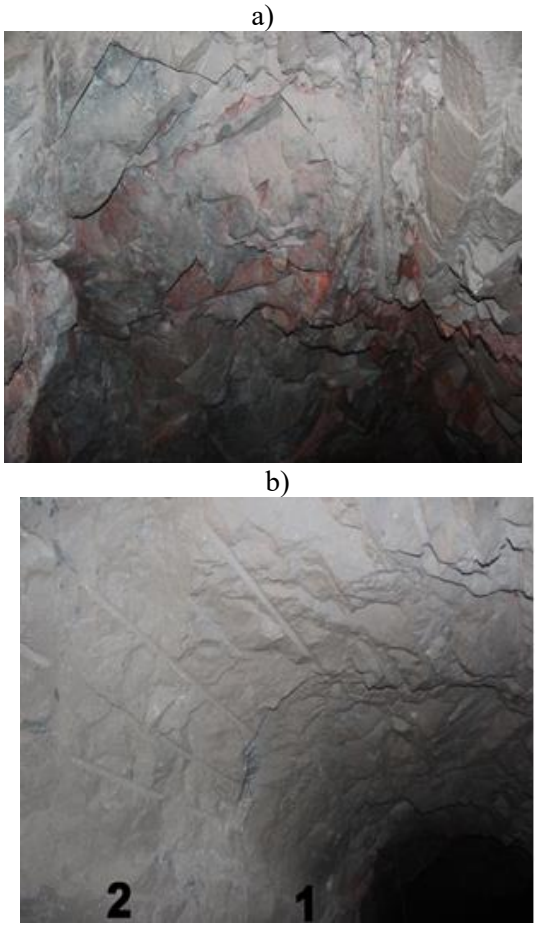

Figure 4 – Impact of the blast force on the roof of the excavations:
a - without taking into account contour blasting;
b - with allowance for contour blasting

Figure 5 – Results of the experimental blast

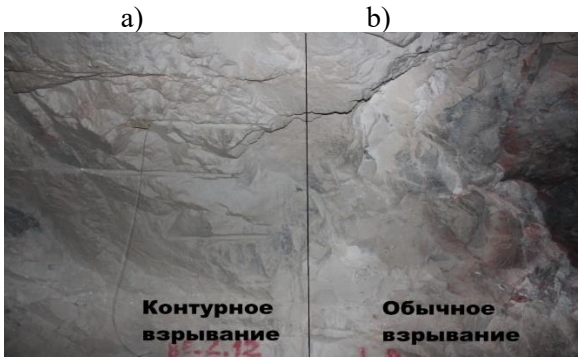

Figure 6 – The effect of the blasting force on the wall of the excavations:
a - with allowance for contour blasting; b - without taking into account contour blasting

Conclusion. The proposed method of contour blasting allows to solve the actual problem for underground mines of increasing the safety of the contour rock mass during mining operations by explosive method in strong rocks with intense fracturing. The main scientific results are as follows:

1. A scheme for charging contour charges is developed, taking into account the stress-strain state of the array in strong rocks with intense fracturing, which allows to increase the safety of the contour rock mass and the safety of mining operations.

2. As a result of the use of contour blasting, the surface of the contour of the outcrop of the mine is quite smooth, without chips and visible cracks. The remaining surface of the hole can be traced along the entire length of the hole, which indicates a reduction in the impact of the explosion on the contoured rocks.

3. It is established that when low-brisant explosives are detonated in contour holes, the radius of intensive crack formation is reduced by 30-40%, thereby reducing the search from the design parameters to a minimum.

4. The cost of explosives decreased by 7% when using contour blasting compared to the conventional method of blasting, and the cost of transporting the broken rock mass and the cost of fixing the mine excavations also decreased.

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ТАБИҒИ КЕРНЕУ ӨРІСІН ЖӘНЕ ЖАРЫЛЫС КҮШІНІҢ МАССИВКЕ ӘСЕРІН ЗЕРТТЕУ АРҚЫЛЫ ЖАРЫЛЫСТЫҢ САПАЛЫҚ КӨРСЕТКІШТЕРІН ЖАҚСАРТУ

Аннотация: мақалада жер асты тау-кен қазбаларын ұңғылау кезіндегі массивтің кернеулі-деформациялық күйін (КДК) ескере отырып, бұрғылау-жару жұмыстарының (БЖЖ) тиімділігін арттыру бойынша зерттеулердің нәтижелері келтірілген. Көлденең және көлбеу тау-кен қазбаларын жарудың екі түрлі әдісі қарастырылады. Зерттеу әдісін таңдау кезінде жарылыс күшінің әсер ету аймақтарын анықтаудың заманауи бағдарламалары мен әдістері қолданылды. Шекті элементтерді сандық модельдеу негізінде жарылыс күшінің әсерінен тоқтатылған тау жыныстарының ықтимал бұзылу аймақтары анықталды. Жарылыс ұңғымаларының екі түрлі әдісінің артық көлденең қимасының коэффициентіне салыстырмалы талдау жүргізілді. Авторлар ұсынған ұңғыма қазбаларын контурлық жару әдісінің артықшылықтары мен кемшіліктері көрсетілген.

Ұңғыманы жарудың екі түрлі әдісінің артық қимасының коэффициентіне салыстырмалы талдау жасалды, оның нәтижелері бойынша авторлар ұсынған контурлы жару әдісі жарылыстың контурлы жыныстарға әсерін кем дегенде екі есе азайтуға ықпал етті деп айту керек. Авторлар ұсынған ұңғыма қазбаларын контурлық жару әдісінің артықшылықтары мен кемшіліктері көрсетілген. Сондай-ақ контурлық теспелер зарядының құрылымы және қолданылатын жарылғыш заттар көрсетілген.

Контурлық зарядтарды зарядтау схемасы қарқынды жарықтығы бар қатты жыныстардағы массивтің КДК-сын ескере отырып жасалды, бұл контурлық массивтің қауіпсіздігін және тау-кен жұмыстарының қауіпсіздігін арттыруға мүмкіндік береді.

Контурлық теспелерде төмен байытылған жарылғыш заттарды жару кезінде қарқынды жарықшақтың пайда болу радиусы 30-40%-ға азаяды, осылайша жобалық параметрлерден аралықтар барынша азайтылады. ЖЗ-ға жұмсалатын шығындар контурлық жаруды пайдалану кезінде 7%-ға азайды, әдеттегі жару тәсілімен салыстырғанда, сынған тау-кен массасын тасымалдауға жұмсалатын шығындар және тау-кен қазбаларын бекітуге жұмсалатын шығындар да төмендеді.

Түйін сөздер: сандық модельдеу, шекті элементтер әдісі, жарылыс, контурлық жарылыс, контурлық массив, тау-кен өндірісі, бұрғылау-жару жұмыстары, теспе.

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УЛУЧШЕНИЕ КАЧЕСТВЕННЫХ ПОКАЗАТЕЛЕЙ ВЗРЫВА ЗА СЧЕТ ИССЛЕДОВАНИЙ ПРИРОДНОГО ПОЛЯ НАПРЯЖЕНИЙ И ВЛИЯНИЯ СИЛЫ ВЗРЫВА НА МАССИВ

Аннотация: в статье приведены результаты исследований по повышению эффективности буро-взрывных работ (БВР) с учетом напряженно-деформационного состояния (НДС) массива при проходке подземных горных выработок. Рассматриваются два разных способа взрывания горизонтальных и наклонных горнопроходческих выработок. При выборе метода исследования были использованы современные программы и методы определения зон влияния взрывной силы. На основе численного моделирования методом конечных элементов определены возможные зоны разрушения законсервированных горных пород под действием взрывной силы. Проведен сравнительный анализ коэффициента избыточного поперечного сечения двух различных методов взрывных проходческих выработок. Показаны преимущества и недостатки предложенного авторами метода контурного взрывания проходческих выработок.

Выполнен сравнительный анализ коэффициента излишки сечения двух разных методов взрывания проходческих выработок, по результатам которого следует утверждать что способ контурного взрывания, предлагаемый авторами, поспособствовал снижению воздействия взрыва на законтурные породы минимум в два раза. Показаны преимущества и недостатки предлагаемого

авторами способа контурного взрывания проходческих выработок. Также продемонстрирована конструкция заряда контурных шпуров и применямые взрывчатые вещества предлагаемого способа взрывания.

Разработана схема заряжания контурных зарядов с учетом НДС массива в крепких породах с интенсивной трещиноватостью, позволяющая повысить сохранность законтурного массива и безопасность ведения горных работ.

Установлено, что при взрыве низкобризантных взрывчатых веществ в контурных шпурах радиус интенсивного трещинообразования уменьшается на 30-40%, тем самым переборы от проектных параметров сводятся к минимуму. Расходы на ВВ уменьшились на 7% при использовании контурного взрывания, по сравнению с обычным способом взрывания, также снизились расходы на транспортировку отбитой горной массы и затраты на крепление горных выработок.

Ключевые слова: численное моделирование, метод конечных элементов, взрыв, контурное взрывание, законтурный массив, горная выработка, буровзрывные работы, шпур.

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