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ANALYSIS OF RESEARCH ON BLASTING OPERATIONS IN THE PREPARATION OF WATER-FILLED OVERBURDEN BLOCKS IN OPEN-CUT MINES

Abstract. The article examines the problems of rock mass preparation during stripping operations in open-pit mines in conditions of waterlogging. It provides an overview of the basin's geological characteristics, regulatory and methodological documents for drilling and blasting operations, and actual consumption rates of explosives. The impact of waterlogging on slope stability, equipment productivity, and the economics of stripping operations is analyzed. Three groups of measures to reduce waterlogging are described : general quarry, local, and process; surface, underground, and combined drainage methods are considered. Particular attention is paid to preliminary contour blasting as a local method for creating drainage zones. A conclusion is drawn regarding the need for systematic research into the conditions for applying local and quarry measures to improve the efficiency and safety of blasting operations in waterlogged massifs.
Key words: *coal basin, water cut, drilling and blasting operations, contour blasting, drying machines, water-resistant explosives, drainage systems.*

Суланған аршу блоктарын дайындау кезінде жарылыс жұмыстарын жүргізу бойынша зерттеулерді талдау

Аңдатпа. Тау жыныстарының суланy жағдайында аршу жұмыстарын жүргізу кезінде тау-кен массасын дайындау мәселелері қарастырылды. Бассейннің геологиялық сипаттамасы, бұрғылау-жару жұмыстары бойынша нормативтік құжаттарға және жарылғыш заттарды тұтынудың нақты көрсеткіштеріне шолу берілген. Сулaнудың беткейлердің тұрақтылығына, техниканың өнімділігіне және аршу жұмыстарының экономикасына әсері талданды. Су тасқынын азайту жөніндегі іс-шаралардың үш тобы сипатталған: жалпы мансаптық, жергілікті және процестік; жер үсті, жерасты және аралас құрғату әдістері қарастырылған. Дренаждық аймақтарды құрудың жергілікті әдісі ретінде алдын-ала контурлық жарылысқа назар аударылды, су басқан массивтердегі жарылыс жұмыстарының тиімділігі мен қауіпсіздігін арттыру үшін жергілікті және мансаптық шараларды қолдану жағдайларын зерттеу қажеттілігі туралы қорытынды жасалды.
Түйінді сөздер: *көмір бассейні, сулану, бұрғылау-жару жұмыстары, контурлық жарылыс, құрғату машиналары, суға төзімді жарылғыш заттар, дренаж жүйелері.*

Анализ исследований по ведению взрывных работ при подготовке обводненных вскрышных блоков на разрезах

Аннотация. Рассмотрены проблемы подготовки горной массы при ведении вскрышных работ на разрезах в условиях обводненности пород. Приведен обзор геологической характеристики бассейна, нормативно-методических документов по буровзрывным работам и фактических показателей расхода взрывчатых веществ. Проанализировано влияние обводненности на устойчивость откосов, производительность техники и экономику вскрышных работ. Описаны три группы мероприятий по снижению обводненности: общекарьерные, локальные и процессные; рассмотрены поверхностный, подземный и комбинированный способы осушения. Особое внимание уделено предварительному контурному взрыванию как локальному методу создания дренажных зон, сделан вывод о необходимости системных исследований условий применения локальных и карьерных мероприятий для повышения эффективности и безопасности взрывных работ в обводненных массивах.
Ключевые слова: *угольный бассейн, обводненность, буровзрывные работы, контурное взрывание, осушающие машины, водоустойчивые взрывчатые вещества, дренажные системы.*

Introduction

The coal basin has long been the subject of research. Its geological structure has been studied in detail, and a stratigraphic division scheme has been developed. Seven geological-genetic rock complexes have been identified, ranging from Quaternary cover deposits to igneous rocks. Open-pit mining primarily targets rocks of the Kolchugin and Balakhon series. Jurassic rocks (the Tarbagan series) are present in small quantities. They are located primarily in the hypergenesis zone and have low resistance to fracture.

For open-pit mines, regulatory and methodological documents have been developed regulating the key parameters of drilling and blasting operations – specific explosive consumption and blasthole diameter. Analysis of these recommendations and actual drilling and blasting data shows that, in practice, the specific explosive consumption exceeds the recommended values (Table 1). One reason is the high water content of the blasted rocks, which requires a slight increase in the specific explosive consumption.

Currently, about 300 million m of overburden are blasted annually at the open-pit mines of the Management Company (Table 2).

Waterlogging of deposits reduces the stability of mine workings slopes, complicates and increases the cost of construction and maintenance of transport communications in the quarry, and reduces the productivity of the main mining and transport equipment [1].

Research methods

Measures aimed at reducing the negative impact of water cut on open-pit mining processes can be divided into three groups:

- *general quarry, aimed at reducing water content on the scale of the quarry as a whole or a separate section of it;*
- *local, covering some relatively small part of the mining front or a separate excavator block;*
- *process-related, associated with the adaptation of technological processes to the actually existing conditions of water content.*

General quarry drainage measures aim to lower groundwater levels by constructing special workings, such as trenches, a network of underground workings, and boreholes. Drainage methods should be selected based on the hydrogeological properties of the rock formations and the groundwater level.

There are three methods of dewatering a deposit:

- *surface drainage method – carried out using vertical water-absorbing and horizontal advanced drainage wells;*
- *underground drainage method – involves the construction of shafts and adits at a deposit or open-pit mine site with the*

Table 1

Values of specific consumption of explosives recommended by regulatory and reference documents and actually used in coal mines during their development by EKG type excavators

Кесте 1

Нормативтік-анықтамалық құжаттармен ұсынылған және ЭКГ типіндегі экскаваторлармен оларды әзірлеу кезінде көмір бөлімдерінде іс жүзінде қолданылатын ЖВ үлестік шығысының мәндері

Таблица 1

Значения удельного расхода ВВ, рекомендованные нормативно-справочными документами, и фактически применяемые на угольных разрезах при их разработке экскаваторами типа ЭКГ

Bucket, m^3	Parameters		Category of rocks by blockiness				
			I	II	III	IV	V
5	recom.	m	0.190-0.244	0.190-0.216	0.150-0.160	0.150-0.160	0.150-0.160
		kg/m^3	0.2-0.4	0.45-0.6	0.65-0.8	0.8-0.9	0.9-1.0
	fact.	m	0.216-0.244	0.216-0.244	0.216	0.216	0.216
		kg/m^3	0.3-0.4	0.5-0.6	0.6-0.7	0.8-0.9	0.95-1.05
10	recom.	m	0.244-0.269	0.244-0.269	0.190-0.216	0.150-0.160	0.150-0.160
		kg/m^3	0.2-0.35	0.4-0.55	0.6-0.75	0.75-0.85	0.85-0.95
	fact.	m	0.244-0.269	0.244-0.269	0.216-0.244	0.216	0.216
		kg/m^3	0.3-0.4	0.5-0.6	0.65-0.75	0.75-0.85	0.9-1.0
15	recom.	m	0.311-0.320	0.311-0.320	0.269-0.311	0.216-0.244	0.216-0.244
		kg/m^3	0.2-0.3	0.35-0.5	0.55-0.7	0.7-0.8	0.8-0.9
	fact.	m	0.269	0.269	0.269	0.244	0.244
		kg/m^3	0.3-0.4	0.5-0.6	0.7-0.8	0.8-0.9	0.95-1.05
20	recom.	m	0.311-0.320	0.311-0.320	0.269-0.311	0.216-0.244	0.216-0.244
		kg/m^3	0.2-0.3	0.35-0.45	0.45-0.65	0.65-0.75	0.75-0.85
	fact.	m	0.269	0.269	0.269	0.244	0.244
		kg/m^3	0.3-0.4	0.5-0.6	0.7-0.8	0.8-0.9	0.95-1.05

Table 2

Volume of blasted rock mass at KRU-Vzryvprom LLC from 2004 to 2009, cub. m

Кесте 2

2004 жылдан 2009 жылға дейін «КРУ-жарылыс» ЖШҚ бойынша жарылған тау массасының көлемі, куб. м

Таблица 2

Объем взорванной горной массы по ООО «КРУ-Взрывпром» с 2004 по 2009 год, куб. м

Branch of JSC «UK «KRU»	2004	2005	2006	2007	2008	2009
Kedrovsky	21953	23989	30922	38920	39,000	32320
Mokhovsky	12008	13012	14154	15845	15444	16407
Sartakinsky	8840	10073	8824	9987	10163	12857
Karakansky	5813	5525	5920	5216	5849	6016
Bachatsky	36858	38186	46129	46571	46990	38597
Krasnobrodsky	27183	31900	37085	44206	50568	37406
Vakhrushevsky	14432	14889	15640	17082	17542	17350
Tallinn	22540	23791	30760	34247	37250	42801
Taiga	3408	8019	12270	16714	18150	21040
Yerunakovsky	7569	9025	9348	9862	10130	12315
Kaltansky	7885	8902	10368	12336	13750	13097
Osinnikovsky	9416	10248	11336	11910	11499	10869
Total of JSC «UK «KRU»	177903	197559	232756	262896	276335	261075

calculation of drainage of the entire mineral deposit and the rocks overlying them within the technical boundaries of the quarries;

- combined method – combines the measures of surface and underground drainage methods.

When designing the deposits developed by the coal company (UK «KRU»), none of the deposit development plans included measures for dewatering the deposits using these methods. An exception is the «Bachatsky» open-pit mine, where, from 2000 to 2008, work was carried out on drilling horizontal drainage wells to ensure the stability of the quarry walls, following recommendations from VNIMI [2–4].

The creation of local drainage systems for individual blocks is possible through preliminary contour blasting, which creates a gap along the design contour of the bench, which acts as a kind of obstacle to the movement of groundwater flows.

The lowest cost for drilling and blasting operations corresponds to a bench height of H = 15 m. The use of contour blasting allowed for increased bench slopes and pit wall angles, significantly reducing the amount of overburden removal and positively impacting the economics of blasting and drilling operations. This ensures long-term pit wall stability and ensures safe mining operations.

A secondary effect is also noted: lowering the groundwater level, which reduces the proportion of water-resistant explosives in borehole charges. This, in turn, reduces the cost of high-explosive water-resistant explosives and reduces the share of drilling and blasting operations in the cost of ore extraction.

In the cited work, the decrease in water content of the massif is stated as a concomitant effect, which is not considered or studied from a systemic perspective positions.

The possibility of using preliminary blasting of some part of the boreholes with bottom charges to reduce the influx of surface and groundwater within a single drilling and blasting block is considered to varying degrees in the works of the Mining Institute of the Ministry of the Black Sea Fleet of the USSR (1970), as well as the scientific research, design and engineering and design institute UkrNIIproekt (1983).

The first of these projects is aimed at reducing waterlogging of the Kovdor Mining and Processing Plant quarry benches. The adopted quarry drainage plan included the following: minimizing the flow of groundwater from Quaternary deposits into the quarry, as well as the groundwater level associated with fractured rock formations; eliminating the possibility of ice formation on the bench work areas; and ensuring the removal of groundwater and atmospheric water entering the quarry.

These deposit features predetermined an effective method for draining bench work areas by creating directed zones of increased fracturing and permeability within the bench rock mass. Such a zone, as demonstrated by the authors, can be created by pre-blasting a series of boreholes with bottom charges. As a result, a zone of increased permeability is created along the line of bottom charges in the pre-blasted boreholes, which serves as a localized drainage system for the blasted block.

In our opinion, the use of preliminary contour blasting to reduce the water content of blast blocks is most fully reflected in the works of S.V. Grishin, as well as in our joint publications.

The results of this study are widely used at the coal company's open-pit mines during the preparation of high overburden blocks requiring the slope of the next bench along the mining front. The idea is that by incorporating a bottom charge of water-resistant explosives into the contour charge design , a zone of increased filtration can be created along the lower perimeter of the block; this zone, combined with the gap formed after blasting the contour borehole system, will act as a local drainage system for the block [5].

It should be noted once again that the cited results apply to high benches that require slopes to ensure safer equipment operation during coal seam mining (non-transport technology) or during the unloading of blasted rock mass immediately adjacent to the newly formed bench when the excavator is positioned at the lower working platform. The height of such open-pit benches is over 30 meters.

Results

The main directions of scientific research into the technology, engineering and organization of drilling and blasting operations during the preparation of rock mass in flooded conditions are as follows:

- development of new types of water-resistant explosives based on ammonium nitrate as a cheap and safe oxidizer in the composition of simple explosives, with the addition of various types of components as a combustible component, as well as means of technologically sufficient long-term protection from the effects of water [6, 7];

- justification of the parameters of drilling and blasting operations in waterlogged rocks;

- development of means for waterproofing charges of non-water-resistant explosives and the corresponding technology for loading wells;

- development of technical means for removing water from blastholes before charging them;

- reducing the water content of the blasted massif by creating quarry or local drainage systems.

The use of dewatering machines simplifies the borehole charging process, reduces labor intensity, and partially replaces water-resistant explosives with non-water-resistant ones. In open-pit mines, this process has been studied using both compressed air dewatering with foaming additives and simple water pumping [8]. Similar research and the development of recommendations on the technology, organization of blasting and drilling operations, and the range of explosives have also been conducted for quarries producing mining and chemical raw materials with complex hydrogeological conditions [9].

The first of these borehole dewatering methods was developed, in particular, by the branch of the Research Institute of Ore Mining and Mining in conjunction with the Kemerovo Coal Production Association, with the direct participation of I.B. Katanov. The feasibility of using foam-gel compositions stems from the ability to prepare them from readily available foam-gelling components using modernized dewatering machines available at open-pit mines. Thus, for dewatering blastholes, it was proposed to use the MO-1 dewatering machine, which operates by removing water from the boreholes using compressed air and a foaming agent. The unit is mounted on a MAZ-509 truck and is equipped with a compressor, a mechanism for raising and lowering the hose, and a sulfanol tank. The MO-1 dewatering machine is equipped with a reel for the dewatering hose and a console for aiming the water-removal device at the borehole. There is no water drainage.

For wells ranging in diameter from 150 to 311 mm and depths up to 30 m, the MO-1 dewatering machine can remove water from wells from 3 to 30 m deep with a capacity of 900 to 1200 l/min. Tests have shown that the machine's theoretical capacity, taking into account cycle time, including travel, maintenance breaks, and the installation of a water-diverting funnel at the wellhead, is up to 250 wells per shift.

The main disadvantages of the MO-1 are, firstly, a residual water column of 1–2 meters in the well after water removal; secondly, the rapid restoration of the well's water level due to the discharged water, which remains near the wellhead and immediately refills the well. After testing, the MO-1 unit was not widely used. This technology has not found practical application in open-pit mines.

In his review papers, B.N. Kutuzov proposed using well dewatering units, such as the UOS-250, developed by NIPIGormash, to remove water from boreholes with stagnant water immediately before loading. The operating principle is based on mechanical pumping of water from boreholes. The unit is mounted on a GAZ-66 vehicle and equipped with a pump, drive system, and a hose reel. The unit's capacity is 250 liters per minute. A major drawback of this unit is its limited well dewatering depth of 20 meters.

In open pit mines, water is present to some degree in every second blasthole. Its presence impedes the formation of proven borehole charge designs that ensure high-quality preparation of the rock mass for excavation. This applies to charge dispersal in the presence of water, their waterproofing when using non-water-resistant explosives, and the means and methods for stemming heavily watered boreholes.

Due to the predominant volume of stripping operations using motor vehicles, the majority of flooded wells are up to 30 m deep. However, the water column height is generally limited to 6 m.

In production conditions, the main technological directions for increasing the efficiency of blasting operations in flooded conditions are the improvement of the means and methods for forming borehole charges in flooded boreholes and the justified use of special methods for preparing for charging individual boreholes or a blasting block [10].

The second of these areas includes preliminary contour blasting as a special means of reducing the water content of the block and removing water from wells using dewatering machines.

Preliminary contour blasting is one means of reducing block water cut. Currently, well-founded recommendations for contour blast parameters are available for high benches – dual transport or non-transport benches – where water cut reduction is achieved simultaneously with backslope blasting to improve slope stability and ensure the safety of mining operations at the lower working platform. For predominantly transport overburden volumes, where backslope blasting is not mandatory, preliminary contour blasting to reduce water cut should be considered a special measure, the feasibility of which has not yet been studied and lacks scientific justification.

Removing water from boreholes using dewatering machines can, in some cases, lower the water level for a relatively short period of time. However, there are blasting blocks in which the water inflow into the boreholes is comparable to the pump capacity of the dewatering unit, which clearly predetermines the impracticality of using dewatering machines [11]. The conditions for using dewatering machines in relation to hydrogeological factors, their adaptability when used in conjunction with charging machines, and the relationship of this method to preliminary, contour blasting for reducing water cuts in the block as a whole are currently unresolved issues that require scientific research.

Conclusion

It follows from the above that the development and study of the effectiveness of technological means for forming charges in flooded boreholes, the study of the conditions for the feasibility of contour blasting as a special measure aimed only at reducing the water content of blast blocks, the establishment of conditions for the use of drying machines as an alternative to contour blasting, will make it possible to obtain the results necessary to increase the effectiveness of blasting operations not only in open-pit coal mines, but also in the open-pit mining of other minerals, where the preparation of the rock mass for excavation is carried out by blasting.

REFERENCES

1. *Burovzryvnye raboty na razrezakh Kuzbassa. Monografiya po vzryvnym rabotam na razrezakh Kuzbassa [Drilling and Blasting Operations in Kuzbass Open Pits. Monograph on Blasting Operations in Kuzbass Open Pits], V.I Kuznetsov et al. Moscow: Kemerovskoe knizhnoe izdatel'stvo. 1989. 92–98 pp. (in Russian)*
2. *Galim'yanov A.A., Sobolev A.A. Otsenka vliyaniya glubiny razrabotki ugol'nykh mestorozhdenii na osnovnye pokazateli burovzryvnykh rabot na predpriyatii «Urgalugol'» [Assessing the Impact of Coal Deposit Development Depth on the Key Performance Indicators of Drilling and Blasting Operations at the Urgalugol Enterprise], Gornyi informatsionno-analiticheskii byulleten' [Mining Information and Analytical Bulletin]. 2021. No. 12–1. 69–75 pp. (in Russian)*
3. *Kabidenova A.S. Sovershenstvovanie burovzryvnykh rabot na predel'nom konture kar'era [Improving drilling and blasting operations at the final contour of a quarry], Vestnik nauki [Science Bulletin]. 2021. No. 2 (35). 83–86 pp. (in Russian)*

4. *Blastability and ore grade assessment from drill monitoring for open pit applications / Navarro J. [et al.] // Rock Mechanics and Rock Engineering. 2021. V. 54. 3209–3228 pp. (in English)*
5. *Zdechlik R., Chudzik W. Open-pit mine dewatering based on water recirculation – case study with numerical modeling // Energies. 2021. No. 14 (15). 4576 p. (in English)*
6. *Zharikov S.N., Shemenev V., Kutuyev V. Ob osobennostyakh proizvodstva burovzryvnykh rabot v usloviyakh Severa [On the Features of Drilling and Blasting Operations in the North], Problemy nedropol'zovaniya [Problems of Subsoil Use]. 2017. No. 3. 1–7 pp. (in Russian)*
7. *Otsenka sovremennogo sostoyaniya burovzryvnykh rabot i neobkhodimost' osushchestvleniya perekhodnykh protsessov na nekotorykh krupnykh gornykh predpriyatiyakh Urala i Sibiri [Assessment of the Current State of Drilling and Blasting Operations and the Need to Implement Transitional Processes at Some Large Mining Enterprises in the Urals and Siberia], Regotunov A.S. [et al.], Problemy nedropol'zovaniya [Problems of Subsoil Use]. 2021. No. 2. 52–62 pp. (in Russian)*
8. *Martyanov V.L., Kolesnikov V.F., Lapaev M.N. Issledovanie parametrov burovzryvnykh rabot pri kombinirovannoi tekhnologii razrabotki naklonnykh mestorozhdenii [Study of the parameters of drilling and blasting operations in the combined technology of developing inclined deposits], Tekhnika i tekhnologiya gornogo dela [Engineering and Technology of Mining]. 2022. No. 3 (18). 53–78 pp. (in Russian)*
9. *Prediction and optimization of open-pit mine blasting based on intelligent algorithms / Guo J. [et al.] // Applied Sciences. 2024. No. 14 (13). 5609 p. (in English)*
10. *Wu X., Zhu D., Lu H., Li L. (July 10, 2024). Simulation research on blasting of an open pit mine slope considering elevation conditions and slope shape factors. Frontiers in Earth Science. https://doi.org/10.3389/feart.2024.1417895 (in English)*
11. *Tiwari A., Yadav R.K., Das B. Blasting impact on environment and their control measure techniques in open cast mining // Journal of Ecology and Natural Resources. 2022. No. 6 (2). 1–4 pp. (in English)*

ПАЙДАНЫЛҒАН ӘДЕБИЕТТЕР ТІЗІМІ

1. *Кузбасс кесінділеріндегі бұрғылау-жару жұмыстары. Кузбасс кесінділеріндегі жарылыс жұмыстары бойынша монография / В.И. Кузнецов [және т. б.]. Мәскеу: Кемерово кітап баспасы. 1989. Б. 92–98 (орыс тілінде)*
2. *Галимьянов А.А., Соболев А.А. Көмір кен орындарын игеру тереңдігінің «Ургалуголь» кәсіпорнындағы бұрғылау-жару жұмыстарының негізгі көрсеткіштеріне әсерін бағалау // Тау-кен ақпараттық-талдау бюллетені. 2021. № 12–1. Б. 69–75 (орыс тілінде)*
3. *Қабиденова А.С. Карьердің шекті контурында бұрғылау-жару жұмыстарын жетілдіру // Ғылым хабаршысы. 2021. № 2 (35). Б. 83–86 (орыс тілінде)*
4. *Ашық карьерлерде бұрғылау мониторингі деректері бойынша кеннің жарылыс қаупі мен сапасын бағалау / Наварро Дж. [және т. б.] // Тау жыныстарының механикасы және тау-кен дело. 2021. Т. 54. Б. 3209–3228 (ағылшын тілінде)*
5. *Здечлик Р., Чудзик В. Суды қайта өңдеуге негізделген карьерлерді дренаждау сандық модельдеудің мысалы болып табылады // Энергетика. 2021. № 14 (15). Б. 4576 (ағылшын тілінде)*
6. *Жариков С.Н., Шеменев В., Кутуев В. Солтүстік жағдайында бұрғылау-жару жұмыстарын жүргізудің ерекшеліктері туралы // Жер қойнауын пайдалану мәселелері. 2017. № 3. Б. 1–7 (орыс тілінде)*
7. *Бұрғылау-жару жұмыстарының қазіргі жай-күйін бағалау және Орал мен Сібірдің кейбір ірі тау-кен кәсіпорындарында өтпелі процестерді жүзеге асыру қажеттілігі / Реготунов А.С. [және т. б.] // Жер қойнауын пайдалану мәселелері. 2021. № 2. Б. 52–62 (орыс тілінде)*
8. *Мартьянов В.Л., Колесников В.Ф., Лапаев М.Н. Көлбеу кен орындарын игерудің аралас технологиясы кезіндегі бұрғылау-жару жұмыстарының параметрлерін зерттеу // Тау-кен техникасы және технологиясы. 2022. № 3 (18). Б. 53–78 (орыс тілінде)*
9. *Интеллектуалды алгоритмдер негізінде ашық Карьерлердегі жарылғыш жұмыстарды болжау және оңтайландыру / Го Дж. [және т. б.] // Қолданбалы ғылымдар. 2024. № 14 (13). Б. 5609 (ағылшын тілінде)*
10. *У С., Чжу Д., Лу Х., Ли Л. (2024 жылғы 10 шілде). Ашық карьердің еңісіндегі жарылыс жұмыстарын рельеф жағдайлары мен еңіс формасын ескере отырып модельдеу. Frontiers in Earth Science, 12, 1417895. https://doi.org/10.3389/feart.2024.1417895 (ағылшын тілінде)*
11. *Тивари А., Ядав Р.К., Дас Б. Жарылыс жұмыстарының қоршаған ортаға әсері және оларды ашық тау-кен жұмыстары кезінде бақылау әдістері // Экология және табиғи ресурстар журналы. 2022. № 6 (2). Б. 1–4 (ағылшын тілінде)*

СПИСОК ИСПОЛЬЗОВАННЫХ ИСТОЧНИКОВ

1. *Буровзрывные работы на разрезах Кузбасса. Монография по взрывным работам на разрезах Кузбасса / В.И. Кузнецов [и др.]. М.: Кемеровское книжное издательство. 1989. С. 92–98 (на русском языке)*
2. *Галимьянов А.А., Соболев А.А. Оценка влияния глубины разработки угольных месторождений на основные показатели буровзрывных работ на предприятии «Ургалуголь» // Горный информационно-аналитический бюллетень. 2021. № 12–1. С. 69–75 (на русском языке)*
3. *Кабиденова А.С. Совершенствование буровзрывных работ на предельном контуре карьера // Вестник науки. 2021. № 2 (35). С. 83–86 (на русском языке)*
4. *Оценка взрывоопасности и качества руды по данным мониторинга бурения на открытых карьерах / Наварро Дж. [и др.] // Механика горных пород и горное дело. 2021. Т. 54. С. 3209–3228 (на английском языке)*
5. *Здечлик Р., Чудзик В. Осушение карьеров на основе рециркуляции воды – пример с численным моделированием // Энергетика. 2021. № 14 (15). С. 4576 (на английском языке)*
6. *Жариков С.Н., Шеменев В., Кутуев В. Об особенностях производства буровзрывных работ в условиях Севера // Проблемы недропользования. 2017. № 3. С. 1–7 (на русском языке)*
7. *Оценка современного состояния буровзрывных работ и необходимость осуществления переходных процессов на некоторых крупных горных предприятиях Урала и Сибири / Реготунов А.С. [и др.] // Проблемы недропользования. 2021. № 2. С. 52–62 (на русском языке)*
8. *Мартьянов В.Л., Колесников В.Ф., Лапаев М.Н. Исследование параметров буровзрывных работ при комбинированной технологии разработки наклонных месторождений // Техника и технология горного дела. 2022. № 3 (18). С. 53–78 (на русском языке)*
9. *Прогнозирование и оптимизация взрывных работ на открытых карьерах на основе интеллектуальных алгоритмов / Го Дж. [и др.] // Прикладные науки. 2024. № 14 (13). С. 5609 (на английском языке)*
10. *У С., Чжу Д., Лу Х., Ли Л. (10 июля 2024 г.). Моделирование взрывных работ на откосе открытого карьера с учетом условий рельефа и формы откоса. Frontiers in Earth Science. https://doi.org/10.3389/feart.2024.1417895 (на английском языке)*
11. *Тивари А., Ядав Р.К., Дас Б. Влияние взрывных работ на окружающую среду и методы их контроля при открытых горных работах. Журнал экологии и природных ресурсов. 2022. № 6 (2). С. 1–4 (на английском языке)*

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