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The scientific journal News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences has been indexed in the international abstract and citation database Scopus since 2016 and demonstrates stable bibliometric performance.

The journal is also included in the Emerging Sources Citation Index (ESCI) of the Web of Science platform (Clarivate Analytics, since 2018).

Indexing in ESCI confirms the journal's compliance with international standards of scientific peer review and editorial ethics and is considered by Clarivate Analytics as part of the evaluation process for potential inclusion in the Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI), and Arts & Humanities Citation Index (AHCI).

Indexing in Scopus and Web of Science ensures high international visibility of publications, promotes citation growth, and reflects the editorial board's commitment to publishing relevant, original, and scientifically significant research in the fields of geology and technical sciences.

«Қазақстан Республикасы Ұлттық ғылым академиясының Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналы 2016 жылдан бастап халықаралық реферативтік және ғылымиметриялық Scopus дерекқорында индекстеледі және тұрақты библиометриялық көрсеткіштерді көрсетіп келеді.

Сонымен қатар журнал Web of Science платформасының (Clarivate Analytics, 2018) халықаралық реферативтік және наукометриялық дерекқоры Emerging Sources Citation Index (ESCI) тізіміне енгізілген.

ESCI дерекқорында индекстелуі журналдың халықаралық ғылыми рецензиялау талаптары мен редакциялық этика стандарттарына сәйкестігін растайды, сондай-ақ Clarivate Analytics компаниясы тарапынан басылмды Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) және Arts & Humanities Citation Index (AHCI) дерекқорларына енгізу қарастырылуда.

Scopus және Web of Science дерекқорларында индекстелуі жарияланымдардың халықаралық деңгейде жоғары сұранысқа ие болуын қамтамасыз етеді, олардың дәйексөз алу көрсеткіштерінің артуына ықпал етеді және редакциялық алқаның геология мен техникалық ғылымдар саласындағы өзекті, бірегей және ғылыми тұрғыдан маңызды зерттеулерді жариялауға ұмтылысын айқындайды.

Научный журнал «News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences» с 2016 года индексируется в международной реферативной и наукометрической базе данных Scopus и демонстрирует стабильные библиометрические показатели.

Журнал также включён в международную реферативную и наукометрическую базу данных Emerging Sources Citation Index (ESCI) платформы Web of Science (Clarivate Analytics, 2018).

Индексирование в ESCI подтверждает соответствие журнала международным стандартам научного рецензирования и редакционной этики, а также рассматривается компанией Clarivate Analytics в рамках дальнейшего включения издания в Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) и Arts & Humanities Citation Index (AHCI).

Индексирование в Scopus и Web of Science обеспечивает высокую международную востребованность публикаций, способствует росту цитируемости и подтверждает стремление редакционной коллегии публиковать актуальные, оригинальные и научно значимые исследования в области геологии и технических наук.

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CONTENTS

Abdullaev A.U., Kamberov I.M.

Possibilities of mercury studies in seismic hazard assessment and earthquake forecasting.....8

Agzamova I.A., Abdurakhmanov B.M., Normatova N.R., Ermatova Ya.S., Agzamova N.Sh.

Forecast assessment of disturbances and fracturing during development of solid mineral deposits.....18

Arystanov M.B., Zhandiyar A.G., Kaipbayev Y.T., Sultanbekova A., Nikam B.R.

A geospatial approach to managing irrigation water resources of the big almaty canal.....32

Babii K., Kiriia R., Smirnov A., Kuttybayev A., Mishchenko T.

Justification of parameters of a steeply inclined tubular conveyor of cyclic-flow technology at a deep open pit in Kryvbas.....55

Bryukhanova N.N., Gladkikh V.A., Idigova L.M., Lepekhina Yu.A., Kondratiev V.V.

Engineering control of blast-induced seismicity and environmental safety in underground ore mining under complex geodynamic conditions.....74

Evsyukov D.Yu., Pchelintseva S.V., Vakhrusheva I.A., Ermolaeva O.S., Modina M.A.

Geophysical investigation of technogenically disturbed areas for environmental assessment in Southern Russia.....90

Galiyev S.Zh., Axanaliyev N.E., Sarsenbayev Y.Ye.

Justification of technological parameters and energy consumption of quarry excavators taking into account the quality of rock preparation for excavation.....109

Hryhoriev Y., Lutsenko S., Hryhoriev I., Kuttybayev A., Kuantayev N.

Adaptive modeling of mining schedule using genetic algorithm in a dynamic environment.....120

Ismailov V.A., Aktamov B.U., Yodgorov Sh.I., Yadigarov E.M., Avazov Sh.B.

Assessment of the possible seismic risk of residential buildings in the Samarkand region based on a scenario earthquake.....135

Ismayilov S.Z., Aliyev I.N., Karimov I.C.

Real-time monitoring and statistical analysis: optimizing sand detection in oil wells.....155

Kazakov A.N., Khakberdiyev M.R., Qurbonov H.A., Turgunov Sh.Sh., Obidov M.I.

Effect of rock mass discontinuities on underground mine stability (Uzbekistan).....170

Kukartsev V.V., Stupina A.A., Khudyakova E.V., Stepantsevich M.N., Matasova I.Yu.

Diagnostics of the structure of crystalline materials of rock formations by the method of thermally stimulated depolarization.....182

Medetov Sh.M., Zaidemova Zh.K., Suyungariyev G.E.

Oscillatory dynamics of rigging operations in the development of exploration wells.....196

Mustapayeva S., Nikolaeva S., Kabanov P., Omarova G., Assambayeva A. New ammonoid records and gamma-spectrometry in the stratotype of the Beleutian regional substage (Central Kazakhstan)	215
Nurpeissova M., Menayakov K., Aitkazinova Sh., Nukarbekova Zh., Bakyt N.K. Environmental and industrial safety of subsurface development near a nuclear power plant.....	231
Obeidat M.A., Shmoncheva Y.Y., Jabbarova G.V. Immiscible displacement of Herschel–Bulkley fluids in porous media: a modified Buckley–Leverett approach.....	247
Sakhmetova G.E., Uralov B.K., Brener A.M., Turymbetova G.D., Absamatova Z. System analysis of scaling problems while designing biogas plants in the context of energy.....	274
Salikhov T.K., Issayeva Zh.B., Onal H., Akhmetzhanov Zh.B., Atasoy E. Using GIS technologies and traditional ground-based methods to analyze the vegetation cover of ecosystems in the West Kazakhstan Region.....	286
Satybaldina D., Teshebayev N., Shmitov N., Kissikova N., Zakarina A. Methods for improving oil production efficiency using pumping units.....	303
Shalabaeva G.S., Abdimutalip N.A., Koishiyeva G.Zh., Ozler M.A., Toychibekova G.B. Study of hydrological and geostructural changes in the koskorgan reservoir due to climatic changes.....	318
Suiintayeva S.Ye., Bakhtybayev N.B., Imangazin M.K., Andagulov D.T., Atageldiyev K.T. Experience in the use of self-propelled drilling rigs to increase the efficiency of drilling and blasting operations with sublevel mining systems.....	332
Tolesh A.B., Mamitova A.D., Karlykhanov O.K., Tazhieva T.Ch., Kalmakhanova M.S. Flow regulation of the Syrdarya River at Shardara under energy releases.....	345
Torekhanova M.T., Tleuzhanova G.B., Yeserkegenova B.Zh., Kadyrov Zh.N., Kadyrova B.B. Innovative technical approaches to the development of automatic control systems for bitumen-chip spreading.....	362
Tynchenko V.S., Krasovskaya L.V., Ashmarina T.I., Kononenko R.V., Shtyrkhunova N.A. Geomechanical justification of underground mining technologies for ore deposits in complex rock massifs from the standpoint of nature and resource conservation.....	382
Zholtayev G.Zh., Rassadkin V.V., Umarbekova Z.T., Mashrapova M.A., Miniskul S.D. Formation and development prospects of placer gold deposits in Southern Junggar.....	396

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EXPERIENCE IN THE USE OF SELF-PROPELLED DRILLING RIGS TO INCREASE THE EFFICIENCY OF DRILLING AND BLASTING OPERATIONS WITH SUBLEVEL MINING SYSTEMS

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Abstract. Raise workings play a key role in the development of ore deposits by ensuring efficient ore transfer, drainage, block preparation, and ventilation. This paper examines the features of driving slot raises for the formation of a slot during drilling and blasting and stoping operations, which are essential for effective ore breakage. At mines in Kazakhstan, raise workings constitute a significant portion of underground excavations; however, traditional methods employing KPV-type raise complexes (Soviet-designed raise excavation systems) and Alimak systems

often require substantial time and labor inputs and create increased safety risks for miners.

The objective of this study is to assess and substantiate the efficiency of using self-propelled drilling rigs to improve the productivity and safety of drilling and blasting operations in sublevel mining systems.

This study presents a comparative techno-economic analysis of the efficiency of using the Sandvik DL210 electro-hydraulic self-propelled drilling rig and the Alimak system for the development of slot raises. The research methodology is based on analytical calculations, mathematical modeling, and comparison of key performance indicators, including drilling rate, equipment setup time, operating costs, number of sublevels, and volumes of mine development workings.

The results show that the application of the Sandvik DL210 drilling rig provides a significant increase in drilling rate and a reduction in equipment setup time compared with the Alimak system. It has been established that the efficiency of using the Sandvik DL210 is higher by 27 %, while increasing the sublevel height from 10 m to 20 m allows the volume of mine development workings to be reduced by approximately 50 %.

The practical significance of the obtained results lies in their applicability for selecting equipment for raise development at deep horizons of ore deposits, including the Akbakay deposit, with the aim of improving productivity, safety, and economic efficiency of underground mining operations.

Keywords: sublevel mining system, drill and blast operations, drilling rigs, raise, drilling, mine development work

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ҚАБАТТЫҚ ҚАЗУ ЖҮЙЕСІНДЕ БҰРҒЫ-ЖАРЫЛЫС ЖҰМЫСТАРЫНЫҢ ТИІМДІЛІГІН АРТТЫРУ ҮШІН ӨЗІЖҮРГІ БҰРҒЫЛАУ ҚОНДЫРҒЫЛАРЫН ҚОЛДАНУ ТӘЖІРИБЕСІ

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Аннотация. Өрлеме қазбалар кенді тиімді түсіру, дренаж, блоктарды даярлау және желдетумен қамтамасыз ете отырып, кенді кен орындарын қазу үдерісінде маңызды рөл атқарады. Бұл мақалада бұрғы-жарылыс және өндіру жұмыстары кезінде тілмелік саңылау қалыптастыруға арналған тілмелік өрлеме қазбаларды үңгілеудің ерекшеліктері қарастырылады, олар кенді уату үдерісін тікелей қамтамасыз етеді. Қазақстан кеніштерінде өрлемелер жерасты қазбаларының едәуір бөлігін құрайды, алайда КПВ және Alimak типті кешендерді қолданатын дәстүрлі үңгілеу әдістері көбінесе уақыт пен еңбек шығындарының көп болуын талап етеді және үңгілеушілердің қауіпсіздігіне қатысты тәуекелдердің артуына әкеледі.

Жұмыстың мақсаты – қабаттық қазу жүйелерінде бұрғы-жарылыс жұмыстарының өнімділігі мен қауіпсіздігін арттыру үшін өзіжүргі бұрғылау қондырғыларын қолдану тиімділігін бағалау және негіздеу.

Бұл жұмыста тілмелік өрлеме қазбаларды үңгілеу кезінде Sandvik DL210 электрогидравликалық өзіжүргі бұрғылау қондырғысы мен Alimak кешенін қолдану тиімділігіне салыстырмалы технико-экономикалық талдау жүргізілді. Зерттеу әдістемесі аналитикалық есептеулерге, математикалық модельдеуге

және негізгі көрсеткіштерді салыстыруға негізделген, оның ішінде бұрғылау жылдамдығы, жабдықты баптау уақыты, пайдалану шығындары, қабатаралықтар саны және кен қазбалардың көлемі қамтылды.

Зерттеу нәтижелері Sandvik DL210 бұрғылау қондырғысын қолдану Alimak кешенімен салыстырғанда бұрғылау жылдамдығының айтарлықтай артуын және жабдықты баптау уақытының қысқаруын қамтамасыз ететінін көрсетті. Sandvik DL210 бұрғылау қондырғысын қолдану тиімділігі 27 %-ға жоғары екені анықталды, ал қабатаралық биіктігін 10 м-ден 20 м-ге дейін арттыру кен қазбалардың көлемін шамамен 50 %-ға қысқартуға мүмкіндік береді.

Алынған нәтижелердің практикалық маңыздылығы оларды кен орындарының терең деңгейжиектерінде өрлеме қазбаларды үңгілеуге арналған жабдықты таңдауда, оның ішінде Ақбақай кен орнында, жерасты тау-кен жұмыстарының өнімділігін, қауіпсіздігін және экономикалық тиімділігін арттыру мақсатында қолдану мүмкіндігінде болып табылады.

Түйін сөздер: қабаттық қазу жүйесі, бұрғы-жарылыс жұмыстары, бұрғылау қондырғылар, өрлеме, бұрғылау, тау-кен үңгілеу жұмыстары

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ОПЫТ ПРИМЕНЕНИЯ САМОХОДНЫХ БУРОВЫХ УСТАНОВОК ДЛЯ ПОВЫШЕНИЯ ЭФФЕКТИВНОСТИ БУРОВЗРЫВНЫХ РАБОТ ПРИ ЭТАЖНЫХ СИСТЕМАХ РАЗРАБОТКИ

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Аннотация. Восстающие выработки играют ключевую роль в разработке рудных месторождений, обеспечивая спуск руды, дренаж, подготовку блоков и вентиляцию. В статье рассматриваются особенности проведения разрезных восстающих выработок для образования разрезной щели при выполнении буровзрывных и очистных работ, непосредственно обеспечивающих процесс отбойки руды. На рудниках Казахстана восстающие составляют значительную часть горных выработок, однако традиционные методы их проведения с применением комплексов типа КПВ и Alimak часто требуют значительных временных и трудовых затрат, а также сопровождаются повышенными рисками для безопасности проходчиков.

Цель работы – оценить и обосновать эффективность применения самоходных буровых установок для повышения производительности и безопасности буровзрывных работ при этажных системах разработки.

Выполнен сравнительный технико-экономический анализ эффективности применения электрогидравлической самоходной буровой установки Sandvik DL210 и комплекса Alimak при проведении разрезных восстающих выработок. В качестве методов исследования использованы аналитические расчёты, математическое моделирование и сопоставление ключевых показателей, включая скорость бурения, время настройки оборудования, эксплуатационные затраты, количество подэтажей и объёмы горнопроходческих работ.

Результаты показали, что применение буровой установки Sandvik DL210 обеспечивает существенный рост скорости бурения и сокращение времени настройки оборудования по сравнению с комплексом Alimak. Установлено, что эффективность использования Sandvik DL210 выше на 27 %, а увеличение высоты подэтажей с 10 до 20 м позволяет сократить объёмы горнопроходческих работ приблизительно на 50 %.

Практическая значимость полученных результатов заключается в возможности их использования при выборе оборудования для проведения восстающих выработок на глубоких горизонтах рудных месторождений, в том числе на месторождении Акбакай, с целью повышения производительности, безопасности и экономической эффективности подземных горных работ.

Ключевые слова: этажная система разработки, буровзрывные работы, буровые установки, восстающий, бурение, горнопроходческие работы

Introduction. Raise workings play a key role in the development of ore deposits, serving for ore transportation, block preparation, slot cutting, lifting of equipment and materials to stopes, drainage, and personnel movement. Raises are of particular importance for ventilation purposes due to the widespread use of self-propelled mining equipment with high-power diesel engines, as well as simplified blasting agents in modern underground mines (Ajdarova and Sudarikov, 2012).

The raises are driven at an angle of 60-90° to the horizontal plane. Their length depends on the height of the level and most often reaches 100 m. Some raises, especially in underground bunker workings, change direction along their length. The length of the raise is of great importance when choosing the driving

method. Driving raises with a height of 70-100 m is particularly challenging due to difficulties in ventilation, lifting materials and equipment, personnel movement, and other factors (Liu et al., 2019; Xu et al., 2021; An et al., 2024).

The methods of driving raises, based on the principle of separating rock from the massif, are divided into drill and blast methods and mechanical drilling (Belogorodtsev et al., 2016; Koltyshev, 2022).

Installations for sinking raises by drilling reduce the time for mining operations and make them safer. Using these machines is more effective in many situations than using traditional blasting technology. However, the high price of this type of equipment limits its demand in the domestic mining industry (Imangazin et al., 2024; Atageldiyev et al., 2025).

Currently, the driving of slot raises at most ore deposits in Kazakhstan is carried out using Soviet-era KPV systems or Western analogs like Alimak. Therefore, driving raises using KPV or Alimak complex requires significant time, labor, and is generally unsafe. In this regard, we consider it expedient to replace Alimak complex (and similar KPV-1, KPV-2, etc.) with self-propelled drilling rigs like Sandvik for driving slot raises, as they improve productivity and safety during drill-and-blast operations (Neverov et al., 2016; Khuangan et al., 2024).

The Sandvik DL 210 is a compact, maneuverable drilling rig designed for drilling in confined spaces of underground mine workings. Thanks to its high-precision control system and automated drilling process, it reduces labor costs, improves rock fragmentation quality, and allows for more efficient use of explosives. The implementation of this installation is especially important for mining enterprises where sublevel caving is carried out, since its use makes it possible to optimize drilling parameters and reduce the volume of oversized pieces, which greatly simplifies the process of subsequent mining (Brunton et al., 2010; Power and Campbell, 2016; Campbell and Power, 2017; Lapčević et al., 2024).

Materials and methods. Currently, a variety of equipment is used in the drilling industry, designed for different geological conditions and tasks (Changping et al., 2017; Changping et al., 2022).

In this work, we focus on comparing the efficiency of two different types of drilling rigs: the self-propelled Sandvik DL210 and the Alimak complex.

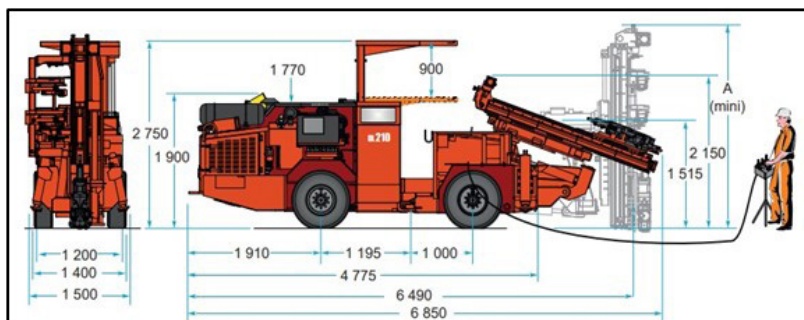


Figure 1 – Sandvik DL210 self-propelled drilling rig

The aim is to develop a mathematical model that will allow us to evaluate the efficiency of using the Sandvik DL210 drilling rig compared to the Alimak complex. This important study aims to identify the advantages and limitations of each equipment in order to provide decision makers with informed information to select the appropriate equipment based on the specific conditions of the mining project.

The model will take into account a number of key parameters, including, but not limited to, reducing the number of sublevels, drilling speed, setup time, operating cost, and other factors that are essential to determining equipment efficiency. The equations and dependencies between these variables will be determined taking into account the technical characteristics and data on the field, as well as data provided by manufacturers and equipment operators. The development of this mathematical model was carried out in the MathCAD and will allow for a more systematic and objective comparison of the two types of drilling rigs, which will ultimately help decision makers choose the best option depending on the specific requirements of the project.

To calculate the drilling rate (Rate of Penetration, ROP): The drilling rate model depends on various factors such as the capacity of drilling equipment, rock mass characteristics, drilling diameter, and others. We use the following equation:

$$ROP = C \cdot P^a \cdot D^b \cdot G^c \quad (1)$$

$$ROP_{DL210} = 1 \cdot 20 \text{ kW} \cdot 64 \text{ mm} \cdot 16 = 20480$$

$$ROP_{Alimak} = 1 \cdot 2.2 \text{ kW} \cdot 40 \text{ mm} \cdot 16 = 1408$$

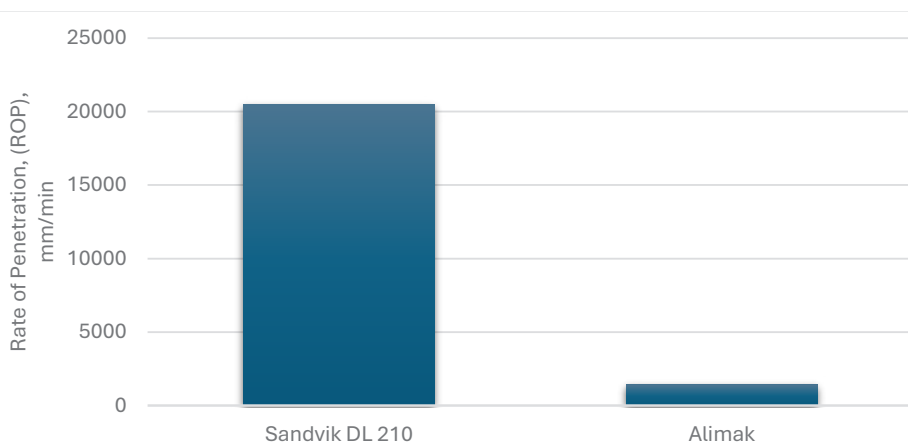


Figure 2 – Calculated rate of penetration (ROP) for the Sandvik DL210 drilling rig and the Alimak system

Where: ROP – drilling speed, C – coefficient, P – drilling rig capacity, D – drilling diameter, G – rock mass characteristics, and a, b, c – the coefficients to be determined based on data and analysis.

For calculating Setup Time: the setup time depends on various factors such as the complexity of the installation, the required preparatory work and the experience of the operator. The setup time model looks like this:

$$\text{Setup Time} = D \cdot E \cdot O \quad (2)$$

Where: Setup Time – setup time, D – installation complexity (where 10 – maximum complexity), E – operator's experience (where 1.0 – full experience, 0.0 – lack of experience), O – other factors affecting the setup time (where 1.0 – standard conditions),

$$\text{Setup Time}_{\text{DL210}} = 3 \cdot 0.8 \cdot 1.3 = 3.12$$

$$\text{Setup Time}_{\text{Alimak}} = 7 \cdot 0.8 \cdot 1.5 = 8.4$$

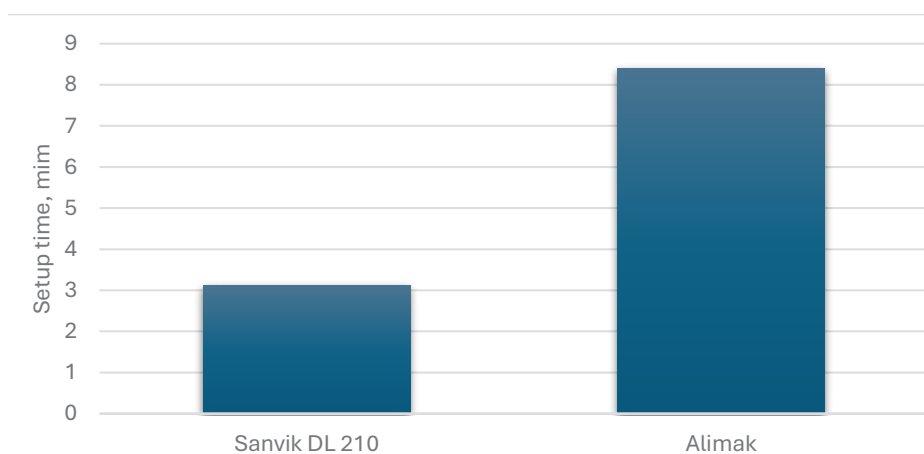


Figure 3 – Calculated equipment setup time for the Sandvik DL210 drilling rig and the Alimak system

To calculate the Operating Cost: the cost of operation depends on the cost of fuel, maintenance and other operating expenses. The cost of operation model is presented as follows:

$$\text{Operating Cost} = F \cdot (\text{FuelCost} + \text{MaintenanceCost}) \quad (3)$$

Where: OperatingCost – cost of operation, F – coefficient that takes into account other factors, FuelCost – fuel costs, MaintenanceCost – maintenance costs.

$$\text{Operating Cost}_{\text{DL210}} = 1.2 \cdot (5000 + 3000) = 1.2 \cdot 8000 = \$9600 \text{ USD}$$

$$\text{Operating Cost}_{\text{Alimak}} = 1.5 \cdot (6000 + 4000) = 1.5 \cdot 10000 = \$15000 \text{ USD}$$

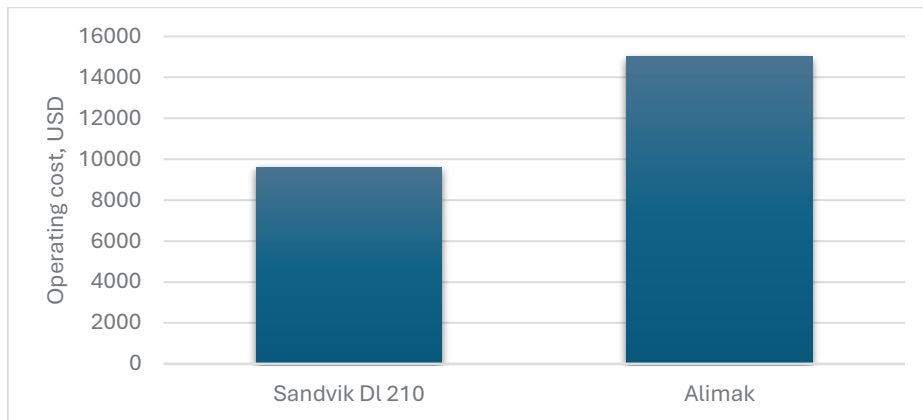


Figure 4 – Calculated operating cost of the Sandvik DL210 drilling rig and the Alimak system

To assess the comparative performance of the Sandvik DL210 self-propelled drilling rig relative to the Alimak system, a relative performance index based on the drilling rate and borehole diameter was applied:

$$\text{Relative performance index} = \frac{ROP_{DL210} \cdot D_{DL210}}{ROP_{Alimak} \cdot D_{Alimak}} \quad (4)$$

Substitution of the calculated values yields:

$$\text{Relative performance index} = \frac{20480_{DL210} \cdot 64_{DL210}}{1408_{Alimak} \cdot 40_{Alimak}} \approx 23.3$$

The obtained value represents a dimensionless comparative performance index and characterizes the relative performance advantage of the Sandvik DL210 drilling rig over the Alimak system in terms of drilling performance parameters.

To quantify the efficiency increase associated with the use of the Sandvik DL210 drilling rig, the following expression was employed:

$$\text{Efficiency increase} = \frac{(ROP_{DL210} \cdot D_{DL210} \cdot \text{Volume}) - (ROP_{Alimak} \cdot D_{Alimak} \cdot \text{Volume})}{ROP_{Alimak} \cdot D_{Alimak} \cdot \text{Volume}} \cdot 100 \quad (5)$$

$$\text{Efficiency increase} = \frac{(20480_{DL210} \cdot 64_{DL210} \cdot 34438) - (1408_{Alimak} \cdot 40_{Alimak} \cdot 34438)}{1408_{Alimak} \cdot 40_{Alimak} \cdot 34438} \cdot 100 = 27 \%$$

The depth of the Pologaya-1 vein is 520 meters; when using the Alimak complex, the distance between sublevel drifts (roof-soil) is 10 meters. By using the Sandvik DL210 self-propelled drilling rig, the distance between sublevel drifts can be increased to 20 meters, thereby reducing development work by 50 %.

For the Pologaya-1 vein, the use of the Sandvik DL210 can halve the number of sublevels.

To formulate an equation that takes into account the depth of the vein and the height of sublevels when using drilling rigs, the following data can be used: depth of the vein: $H = 520$ meters; height of sublevels for Alimak: $S_{\text{Alimak}} = 10$ meters; height of sublevels for Sandvik DL210: $S_{\text{DL210}} = 20$ meters; the number of sublevels is denoted as N .

Now we have two situations:

1. Alimak Complex

The depth of the vein is divided by the sublevel height for Alimak and Sandvik DL210:

$$N_{\text{Alimak}} = \frac{H}{S_{\text{Alimak}}} = \frac{520}{10} = 52 \quad (6)$$

2. Sandvik DL210

$$N_{\text{DL210}} = \frac{H}{S_{\text{DL210}}} = \frac{520}{20} = 26$$

$$\text{The decrease in mine development work is calculated as } = \frac{N_{\text{Alimak}} - N_{\text{DL210}}}{N_{\text{Alimak}}} \cdot 100 \\ = \frac{52 - 26}{52} \cdot 100 \approx 50 \, \%.$$

Results and discussions. Thus, the use of the Sandvik DL210 drilling rig instead of the Alimak complex leads to an approximate 50 % reduction in the number of sublevels, from 52 sublevels to 26.

If we assume the cost of 1 meter of mine development works to be \$3000 USD, then for the Pologaya-1 vein, the volume of development work amounts to 953 meters, resulting in $3000 \cdot 953 = \$2\,859\,000$ USD. When using the Sandvik DL210 drilling rig, the volume of development work is reduced by approximately 50 %, and in monetary terms, it decreases to \$1 429 500 USD.

Drilling speed (ROP): The drilling speed for the Sandvik DL210 drilling rig is 20480 mm/min, while for the Alimak complex it is 1408 mm/min. This indicates a noticeable superiority in the drilling speed of the Sandvik DL210 rig.

Setup time: the setup time for the Sandvik DL210 drilling rig is 3.12 minutes, whereas for the Alimak complex it is 8.4 minutes. This indicates a more efficient setup procedure for the Sandvik DL210 drilling rig.

Efficiency: The comparative analysis indicates that the Sandvik DL210 drilling rig demonstrates a substantially higher drilling performance than the Alimak system based on the calculated relative performance index. In addition, the integrated efficiency assessment shows that replacing the Alimak system with the Sandvik DL210 drilling rig results in an overall efficiency increase of approximately 27%, confirming the technical advantage of the Sandvik DL210 under the considered operating conditions.

In general, based on calculations, it can be argued that the Sandvik DL210

drilling rig has high productivity, shorter setup time and a significant increase in efficiency compared to the Alimak complex. These factors are crucial when choosing equipment for a particular mining project.

The application of the electro-hydraulic self-propelled Sandvik DL210 drilling rig at the Akbakay deposit is a vivid example of innovative technologies primarily focused on improving efficiency, accuracy, and environmental safety in the ore extraction process. Its unique characteristics make this equipment the optimal choice for enhancing production at deposits like Akbakay and represent a significant step towards more responsible and efficient extraction of natural resources (Zhakypbek et al., 2025).

The Sandvik DL210 electrohydraulic self-propelled drilling rig is not just a tool for mining, it is an innovative solution that defines the future of mining, taking into account high efficiency, precision and concern for the environment (Abdugaliyeva et al., 2024).

The application of the Sandvik DL210 electrohydraulic self-propelled drilling rig at the Akbakai deposit represents an important step in modern mining of ore resources (Imashev et al., 2021, Tulekov and Arystan, 2024).

Let's note a few key points.

- Efficiency and Productivity: the use of the Sandvik DL210 significantly improves production efficiency due to its accuracy, speed of operation and adaptability to the diverse geological conditions of the field;

- Environmental Safety: thanks to the advanced technology of electrohydraulic systems, this installation helps to reduce the impact on the environment and improves the environmental sustainability of mining processes.;

- Precision and Innovation: the Sandvik DL210 has high drilling accuracy, which significantly affects the quality and quantity of ore production, as well as the introduction of innovations in the mining industry;

- The future of Resource Extraction: the use of advanced technologies such as Sandvik DL210 in the Akbakai deposit indicates the evolution of the industry and the desire for more efficient, accurate and environmentally sustainable mining.

In general, the use of the Sandvik DL210 electrohydraulic self-propelled drilling rig at the Akbakai deposit opens up new horizons for the modern mining industry, emphasizing the importance of innovation and technological development to optimize resource extraction processes and promote the sustainable development of the industry.

Conclusion. The conducted research and the performed calculations lead to the following conclusions:

1. The calculated results show that replacing the Alimak system with the self-propelled Sandvik DL210 drilling rig provides an efficiency increase of approximately 27% under the considered operating conditions.

2. The application of the Sandvik DL210 drilling rig makes it possible to increase the spacing between sublevel drifts by up to 20 m, resulting in a reduction of mine development volumes by approximately 50 %. Overall, the obtained results

demonstrate the feasibility of applying self-propelled drilling rigs of this type in projects requiring high drilling efficiency and optimization of underground mining operations at various depths.

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