DIGITALISATION OF THE INDUSTRY AS A KEY TO RISK REDUCTION AT A MINING ENTERPRISE

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ABSTRACT. Nowadays, mining enterprises are characterised by many risks. They concern not only financial and economic risks typical for any modern company but also many hazards related to safety. In modern conditions mining enterprises are forced to operate in complicated mining and geological conditions which result in many dangerous events, especially possible in case of underground mining. It leads to many negative consequences which damage not only the company and its image, but also pose a threat to company employees. The article describes the current situation at mining enterprises, highlights particular risks caused by modern working conditions and suggests a new problem solving method based on the use of a state-of-the-art technology of digitalisation.
Key words: mining company, risk, risk management, digitalisation, digital twin.

ДИГИТАЛИЗИРАНЕ НА ПРОМИШЛЕНОСТТА КАТО ОСНОВА НА НАМАЛЯВАНЕТО НА РИСКА НА МИННО ПРЕДПРИЯТИЕ

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РЕЗЮМЕ. Днес минните предприятия се характеризират с много рискове. Те се отнасят не само за финансовите и икономическите рискове, характерни за всяка съвременна компания, но и за редица опасности, свързани с безопасността. В съвременните условия рудодобивните предприятия са принудени да работят в сложни минни и геоложки условия, които водят до много опасни събития, особено в случай на подземен добив. Това води до много негативни последици, които увреждат не само компанията и нейния имидж, но и представляват заплаха за служителите на компанията. Статията описва настоящата ситуация в минните предприятия, подчертава специфични рискове, причинени от съвременните условия на работа, и предлага нов метод за решаване на проблеми, основан на използването на съвременна технология на цифровизация.

Ключови думи: минна компания, риск, управление на риска, дигитализиране, цифров близнак.

Current state of the mining industry

The extraction of natural resources is a challenging process which includes many various operations from deposit evaluation to transportation of beneficiated ore to end customers. All these stages require experienced workforce, modern equipment and use of up-to-date technologies. Only in this case a mining company will remain competitive and efficient in current economic environment.

Today, compared with the period of a decade ago, mining operations are characterised by increased complexity. For example, one of the current trends is an increase in the depth of mining, characteristic of both open-pit and underground mines.

As an example, a list of the deepest careers in the world (Table 1) can be given (Melnikov, 2013). Underground mining has reached a much greater depth − the maximum depth of South African gold mines reaches 3800 m.

Increasing the depth of mining complicates the mining and geological conditions of extraction, for example:

1) the ore decreases and the thickness of the ore bodies also decreases, as can be clearly seen at the Khibiny apatite-nepheline deposits and the Kovdor baddeleyite-apatite-magnetite ore deposit, as well as most iron ore deposits;

2) an increase in the depth of the open pits leads to an increase in the waste-to-ore ratio and an increase in the distance of transportation of the rock mass for both open-pit and underground mining;

3) an increase in the depth of the open pits worsens their ventilation, and an increase in the depth and length of underground mine workings increases the cost of ventilation;

4) an increase in the depth of mining operations leads to the need to work in conditions of high rock pressure, which is fraught with its manifestations in the form of rock bursts and technogeneous earthquakes.

Table 1. *Deep open-pit mines*

Name	Location	Depth, m	Dimensions, km×km	Extracted mineral
Kennecott Bingham Canyon Mine	the USA	1200	4×3.8	Copper, molybdenum, gold
Chuquicamata	Chile	850	4.3×3.0	Copper, gold, silver, rhenium, selenium
Palabora	South Africa	700	1.9×1.7	Copper
Udachny	Russia	640	1.7×1.3	Diamonds
Escondida	Chile	620	3.8×2.7	Copper, gold, silver

Muruntau	Uzbekistan	600	3.5×2.5	Gold
Sibay	Russia	600	2.0×2.0	Copper, Zinc, Sulphur
Batu Hijau	Indonesia	550	2.5×2.2	Gold, copper
Escondida Notre	Chile	500	1.6×1.4	Copper, gold, silver
Kovdorskiy	Russia	500	2.3×1.6	Iron ore, apatite, baddeleyite

Increasing the depth of work leads to a variety of negative consequences, such as the complication of conditions for the maintenance and repair of equipment, reduced productivity of the enterprise, loss of life. As an example can be cited a partial collapse of the open-pit side at the Bingham Canyon open-pit (USA) in April 2013, where the volume of the collapsed rock amounted to 165 million tons. For comparison, the open-pit's mining productivity was 50 million tons/year. It should be noted that the monitoring system of the state of the open-pit sides, which was in operation at the open-pit, made it possible to avoid loss of human life and to minimise the loss of equipment.

Risks of mining companies

Today, it can be said with absolute precision that mining companies belong to high-risk enterprises, but this is caused not only by the deterioration of mining and geological conditions.

An important role is played by significant capital intensity of the mining production, due to the use of expensive equipment for the extraction, processing and transportation of raw materials, as well as the construction of above-ground and underground buildings and structures. In addition, environmental requirements for industrial enterprises, which have been growing in recent years, determine the growth of investments in modern equipment, reducing the company's load on the environment, and the need to increase the cost of developing new technologies for conducting works that have a sparing impact on the environment.

Another factor of increased risk of enterprises of the mineral-resource complex is the long term of construction of the enterprise, namely the length of the period from the beginning of construction to the moment of receiving the first cash flows from the sale of products. According to experts (Peshkova, 2002), such a period can be 5-8 years or more, which is a special risk, since during this period the demand for raw materials and prices for it can change significantly under the influence of various factors, such as the discovery of new deposits, the transition to a green economy and the use of alternative energy sources, the instability of the political situation in the world, and especially in mining production countries. All this can lead the company to significant losses and shortfalls in the originally projected profit.

Thus, the risk in the mining industry is an important factor for making management decisions and can determine the policy of an enterprise in the direction of its economic activity.

In addition to all types of risks, such as financial, marketing, transport, insurance, etc., special attention should be paid to the specific risk that is characteristic only for enterprises of the mineral-resource complex. This is the so-called mining risk, which is a combination of all factors affecting the conduct of work on the extraction of raw materials.

The main one is geological, which reflects the likelihood of non-confirmation of explored mineral reserves. This includes such criteria as the accuracy of estimates of the boundaries of the ore bodies, the deviation of the amount of reserves from their projected volumes and the expected quality. The content of the concept of "geological risk", as well as its scope is variable and changes as work progresses. At the very first stage, the stage of prospecting, the risk is associated with the failure to detect a deposit due to the lack and low reliability of information. At the stage of geological and economic assessment of a deposit, geological risk is characterised by the possibility of not confirming the discovered and forecasted reserves. At the next stage − the stage of a feasibility study of a field − the geological risk means the possibility of not confirming the profitability of an estimated field. During operational exploration, the geological risk is manifested when comparing data obtained during exploration and development of a field. Thus, if we talk about the assessment of geological risk in monetary terms, in the case of a negative outcome of geological exploration, the risk is estimated by the sum of the costs of the work carried out.

The next important component is the geotechnical risk. It means the change in the properties of rocks in the process of conducting work underground. The influence of various factors, both natural and anthropogenic, leads to the loss of the original physical and mechanical properties of the enclosing rock taken into account during the development of project documentation. This leads to an increase in the possibility of rock collapse due to their volatility to loads and breakthroughs of the groundwater in the mine workings, therefore, in the case of assessing geotechnical risk, it is not only about material losses, but also about the occurrence of accidents harmful to human health and leading to their death.

Mining risks can also include the risk of growth in reserves, reflecting the availability of potential resources that can be assessed, transferred to reserves and mined in the future.

Mining risk not only predetermines the choice of equipment and technology of work, but also represents an important circumstance on the basis of which are made decisions to increase or decrease production volumes or stop it completely. Working conditions at mining enterprises are especially dangerous; therefore, the identification of the mining risk and its analysis are the key tasks of the management of a modern company in the mineral resource complex.

Identification of risks and their analysis allows the management of the company to make balanced and informed decisions both short term and of strategic importance. In particular, competent risk management allows the company to reduce financial losses, increase safety at an industrial facility and strengthen its attractiveness in the eyes of potential investors.

That is why, the risk management process is so relevant nowadays. However, despite the importance of this topic, today there is no clear and definite mechanism that would help not only to predict the occurrence of adverse situations, but also to calculate the possible damage and minimise it. Therefore, this paper proposes the use of digitalisation processes, which has been gaining popularity recently.

Digitalisation of the industry

The digitalisation process today covers not only the IT sphere. It strengthens its position in other industries, including the process of the extraction of mineral resources.

Taking into consideration the complexity of the whole production chain, it can be stated that during all the years of their history mining companies have been technology innovators and leaders in some aspects, and followers in others. As for adoption of new technologies, mining enterprises have always been slow due to different reasons. For example, mining companies are characterised by big scale of manufacturing; all the operations carried out during extraction are risk-related, and costs that accompany any process of change are high.

Today, when other production branches already face the digital revolution, the extractive sector has just begun to recognise the potential of innovations that could bring significant changes and invigorate the industry. However, in comparison with other branches, especially customer-facing ones, the mining production is considered to have lower levels of utilisation of digital technologies. This is being confirmed by numerous reports of international consulting companies like Earnst & Young or Deloitte.

Mining operations have always been divided into isolated steps, with insignificant interaction between such processes as extraction, processing and transportation of extracted resources. The chance to bring these components all together presents not only the good scope for change but also the strong chance to improve the efficiency of a mining company.

Implementation of digitisation allows a mining company to have an aggregate picture of the existing supply chain and prove a holistic view of the full process of extraction of mineral resources. Information received thanks to digitisation can be studied and used by managers afterwards. For instance, it can help in production problems identification, quality management, production tracking, and costs understanding.

Even if the realisation and the implementation of a fully automated supply chain are hardly probable in the short term, it seems to be the logical end point in a series of technology transformations that have already been launched by mining companies.

New technologies in general and digitisation in particular provide employees quick access to key statistical data and necessary technical knowledge. The presence of such information accelerates decision-making and performance efficiency.

Digitisation also improves collaboration between workers and attracts new staff by increasing job appeal. A growth of number of training, testing and process simulations with the use of life-like 3D environments contributes to the employees' skill improvement as these new methods are not only safer but also more engaging than existing traditional on-site ones. Remote operations, in conjunction with the above-stated opportunities result in fewer people in hands-on operational roles. It must improve productivity and safety, and also cut down total expenses. These advantages are impossible to resist for any company which is going to face future and remain competitive in new market conditions.

So, it cannot be doubted that digitisation is one of the main features of mining industry of tomorrow. Mining companies must become more agile and able to face the future. It means they should be prepared for the adoption of new technologies that will continue to transform the industry in the next years.

Digital twins

One of the manifestations of the digitalisation process in the mining industry is the creation of the so-called digital twins.

The introduction of "digital twins" is the result of the development of the concept of "digital production" and the Industrial Internet of Things.

Currently, many industries are collecting equipment performance data. In recent years, digital transformation has been able not only to fully process the collected information using advanced analytics, but also to make informed decisions to optimise operations in various industries. Similarly, new modelling technologies provide manufacturers with the ability to use digital twins in their products and processes. A digital twin can be defined as a developing digital profile of the historical and current behaviour of a physical object or process. New projects can be tested in the virtual world, saving time, money and resources. The digital twin can enable companies to solve physical problems faster, discovering them with a much higher degree of accuracy, design and create better products, and ultimately optimise business performance. With this type of intelligent architectural design, companies can obtain value and benefits iteratively and faster than ever before (Michael, 2014).

The digital twin is based on big data that comes in real time through a variety of measurements. These measurements can create an evolving profile of an object or process in the digital world, which can provide important information about system performance, leading to decisions in the physical world, such as changes in product development, and in the production process.

The digital twin is different from the traditional computer-aided design (CAD) system and is not just another solution with support for the Internet of Things (IoT) sensors. The digital twin is much more than any CAD system that is completely encapsulated in a computer environment that has demonstrated success in modelling complex environments. It can also be a more complex system than IoT systems that measure such things as position and diagnostics for the entire component, but not the interactions between the components and processes of the full product life cycle [5].

Despite the fact that the mining industry uses the concept of digital twins, today it does not go beyond the limits of modelling the operation of any equipment or the processes taking place in a mine or an open-pit. In this case, the virtual production process creates different scenarios and shows what happens in different situations. This allows the company to develop the most effective methods of work, but does not solve the abovementioned problem of risk reduction, which is so relevant today.

Therefore, to manage risks in the process of the extraction of minerals the digital twin of the system can be used, which is a virtual model of the entire system (for example, a field). These digital twins collect huge amounts of operational data produced by devices and products in the system, get an idea and create new business opportunities to optimise all processes. In the mining industry, this consists in creating a

complete model of the field throughout the entire life cycle of an enterprise: from exploration to the final stages of production.

First of all, the benefit of such models lies in the fact that they accumulate not only information about individual processes occurring during production, but a full range of data about the field, which allows the company not only to have information about current processes, but also to predict the development of future ones.

Thus, the advantages of using digital twins of the system in the development of mineral deposits are as follows:

1) Reducing production costs;

As a rule, the procedure for the field mining undergoes various adjustments in the course of work, which is associated with the non-confirmation of mineral reserves, changes in water inflows, increased rock pressure and the danger of rock collapse, etc. These changes are very expensive because they require a significant investment of time and money. Digital twins allow engineers to perform all tests and simulations in a virtual environment, which reduces the likelihood of unforeseen situations during actual production. It is much easier, cheaper and faster to repair defects in the digital world than in the real one.

2) Predictable diagnostic maintenance.

Another important advantage of the technology "digital twin" is that it can solve many problems in advance. Virtual copies provide permanent remote control of their physical prototypes, collecting various information about them. Analysis of the collected data allows us to predict possible accidents and breakdowns (Rosen et. al. 2015).

3) The possibility of reuse and sale of the digital twin.

As the field is developed, the amount and reliability of information increases, reducing the cost of the digital model. However, the decline does not occur to zero, since the collected and processed information can be used in the development of other fields similar in certain parameters. Thus, it will allow mining companies to sell this intangible asset after its full use for its own purposes and to receive additional profits.

Thus, the introduction of the digital twin will allow companies to:

1) predict, with a significantly higher degree of reliability, the state of the field, possible emergency situations, respond promptly to them, reducing threats to safety, human health and the environment;

2) increase the depth of understanding of the processes occurring in production, by obtaining advanced statistics on the "virtual" operation of the facility;

3) more accurately calculate the economic performance of the project and manage them;

4) identify weak links and improve the engineering aspects of production;

5) reduce the time to implement the necessary changes.

Conclusion

The mining industry covers a wide range of operations from the exploration activities and deposit evaluation to the beneficiation and transportation of the product to the end user, therefore it is characterised by complexity and increased risk. The use of modern technology and the involvement of highly qualified personnel ensure the efficiency of the mining enterprise. However, today in modern market conditions, this may not be enough to ensure the competitiveness of the company. Given the increasing complexity of mining and geological conditions, increase of risk of production and the need to process information in large volumes, the so-called digitalisation of mining production comes to the fore.

Especially important is that in addition to such advantages as process automation and cost management improvement, digitalisation contributes to production safety increase. For instance, this concerns the use of robots in particularly dangerous areas in order to reduce the use of manual labour and the need for the physical presence of people underground. In addition, the use of modern technologies allows mining companies to process large amount of data needed to predict accidents and simulate risk events in order to minimise them.

In order words, today more and more enterprises around the words understand the feasibility of introducing information technologies at all stages of mining. Digitalisation allows companies to remain profitable, while maintaining a high level of safety for people and equipment.

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