Industry 4.0 in the mining industry: global trends and innovative development

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Abstract. The article shows that the implementation of Industry 4.0 will be implemented in many sectors of the global economy, including the coal industry. In Russia, "positive" experience has been accumulated in connection with the implementation of the Smart Mine and Smart Cut projects. The purpose of this article is to identify trends in the innovative development of the mining industry, as well as to systematize the basic elements of the Industry 4.0 project on basic mining processes. In the process of the study, the authors of the article prepared an enlarged systematization of technological solutions for the mining industry, which corresponds to the main directions of the global Industry-4.0 project and allows us to proceed with the formation of a technological platform that includes the need to implement the projects "Virtual Mine of the Future" and "Virtual Section of the Future".

1 Introduction

The mining industry plays an important role in the economic development of Russia and the countries of Central Asia, creating new qualified jobs, developing infrastructure and generating substantial foreign trade income. The share of the mining industry in the total industrial production of Kazakhstan is more than 60%, in Kyrgyzstan - 58%, in Tajikistan - 12.4%.

Russia is one of the leading world states in terms of both reserves and mineral resources; therefore, improving the mining industry is extremely important for the domestic economy. The leading mining territories are the Far North to Chukotka, territories from the Urals to the Kamchatka Peninsula, including Western and Eastern Siberia, Khabarovsk and Primorsky Krai [1].

Recently, innovative technologies have been actively introduced in the mining industry, which can significantly reduce production costs, increase production efficiency and successfully develop mining projects that have recently been economically unprofitable. Supported by ongoing global economic growth and infrastructure development, the mining sector is becoming increasingly attractive to international investors looking for long-term and profitable investment opportunities. Currently, active work is underway in Russia and

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other countries of Central Asia to create favorable conditions for stimulating exploration and efficient reproduction of the mineral resource base; enhanced control over the rational and integrated use of the subsoil; new high-tech and effective technologies of geological exploration, production and processing of mineral raw materials are introduced using automated control processes; systematization of data banks of geological information; intensively developing industry infrastructure; conditions are being created for training personnel corresponding to modern industry requirements.

Given the current realities, it is necessary to solve a whole range of issues that allow the mining industry to be brought to a qualitatively higher level in terms of efficiency, productivity and safety.

This requires the fulfillment of at least three conditions:

1. technical re-equipment of the industry, by introducing new, more efficient automated equipment;
2. development of the latest processing technologies for extracted raw materials and natural resources;
3. further training of personnel at mining enterprises at all levels.

World experience shows that the implementation of the above conditions is possible only with a close relationship between production and science. In other words, for more productive work of the mining industry, it is necessary to implement projects within the industry of innovative activities based on the fruitful integration of Russian science and production. The purpose of this article is to identify trends in the innovative development of the mining industry, as well as to systematize the basic elements of the Industry 4.0 project on basic mining processes.

2 Literature review

Currently, innovation is an active link in all spheres of society. It is impossible to imagine the modern world without innovations that have already taken place and which have become habitual, and without future ones that contribute to further evolution. Most scholars agree that innovation has become the main driving force behind economic and social development. In an environment where research and development excellence, a high level of mastering new knowledge and creating innovative products are key factors that determine the competitiveness of national economies and the effectiveness of national security strategies, education priorities are changing, and this creates new models [2]. The basis for the construction of these models, according to several researchers, are the following innovative processes: managerialism and performativity in Higher Education [3], automating the process of processing and researching data, but also in the intellectualization of information and organizational processes, the creation and implementation of effective methods and the intellectual and auxiliary decision-making technologies in oil companies [4], development optimization of investment portfolio of the oil and gas company [5], organization of a phase control system for the intensity of knowledge in accordance with established quantitative and qualitative criteria for achieving knowledge-based results (products, technologies, etc.) during the implementation of innovative projects [6]. Sayabek, Z., Ainur, M., Ulan, T., Gulvira, A., Aizhan, K., & Zhanar, T. [7] consider the role of human capital, knowledge and high technology in innovative development. Ziyadin, S. [8] examines the impact of the global global economic crisis on economic development and the need for innovative development.

According to Mutanov, G., Ziyadin, S., Shaikh, A. [9], recently, the intensity of digital technology and innovation has been largely reflected in the level of sustainable economic development. In the context of global competition, this can be seen in those countries that provide favorable economic conditions and the benefits associated with innovation. The

development of an innovative economy is an important prerequisite for increasing the country's competitiveness.

Ideally, to maintain competitiveness, mining aimed at long-term existence should be accompanied by a continuous search and implementation of innovative solutions. Although, often, innovations encounter certain difficulties of implementation, they are a source / reserve for a significant increase in the efficiency of mining operations and individual processes. This is especially necessary during periods of industrial crisis, when the optimization of production processes, cost reduction, increased sales efficiency due to the creation of new products, etc. take an important direction of development.

An analysis of recent studies and publications has shown that a number of works by domestic and foreign researchers are devoted to the study of innovation in the mining industry. Therefore, in the research of Lane, A., Guzek, J., & Van Antwerpen, W. [10] characterized some of the big, difficult decisions faced by the mining industry in the South African context, and discusses how these decisions could be approached in a fact-based and robust way. Sganzerla, C., Seixas, C., & Conti, A. [11] note the importance of the digital transformation of the mining industry. In their opinion, the possibilities for new operating models and new levels of optimization will create the next wave of differentiation in the industry. Ziyadin, S., Gulmira, Y. [12] note the need for diversification of industrial enterprises. Milanez, B., & de Oliveira, J. A. P. [13] argues that government funding and technical support dedicated to the development of mining clusters, i.e. working with small economic agents as a whole and not individually, could promote not only more economic development, but also effectively incorporate social and environmental issues, such as workers safety, water management and tailings recycling. In their studies, Shavina, E., & Kalenov [14] consider the innovative technological development of the Russian mining regions (on the example of the Kemerovo region). According to Kalenov, O., & Kukushkin, S. [15], technological parks should bridge the gaps and help the mining regions to integrate into the new economy. The authors consider the essence of techno-parks, the history of their establishment in Russia, and analyze the dynamics of the main indicators of their functioning. When considering techno-park structures of the Tomsk and Kemerovo regions, the most important problems inherent these regions are highlighted. The authors analyze in detail the results of the innovation territorial center "ITC Tomsk" and the Kuzbass Techno-park, determine the main activities for the integration of mining regions in the innovation economy and characterize the positive effect of the techno-park structures functioning. Dotsenko, E., & Ezdina, N. [16] note that the solution of the structural problems of economic development of mining region is connected with technological modernization of extractive industries and use of modern materials for the production of high-tech products. Kudrevatykh, N., Snegireva, T., & Tselischeva, A. [17] consider the innovative development of the economy as the most important factor in ensuring the financial security of the mining region. In their studies, Starikova, L., & Trapeznikova, I. [18] assess the environmental and economic trends in the development of the mining region (for example, Kuzbass). In the research paper of Martinez-Fernandez, C. [19] discusses the role of MTS firms in the transformation of the mining industry into the knowledge economy. Results from a study of Australian MTS and mining firms suggest that innovation results from the interaction of these firms through knowledge-intensive service activities. In the research paper of Phelps, N. A., Atienza, M., & Arias, M. [20] take an initial step in this direction, identifying analytical dimensions to the enclave and illustrating different manifestations of enclaves in the mining industry, drawing on the case of Chile. Research paper of Giurco, D., & Cooper, C. [21] applies the Mineral Resources Landscape to map stakeholder concerns for the case of deep-sea mining in Australia. It found that in exploring the future use of this technology to meet growing resource demand, the potential

role of dematerialization and recycling were overlooked. The paper concludes with reflections on the usefulness of the approach for citizens, companies and governments.

Despite the presence of scientific interest in the study as a whole, currently the unresolved part is the problem of matters of systematization of technological solutions for the mining industry of Russia, arising from implementation of the project "Industry-4.0". On this basis, there is a need for a more detailed study of the essence of Industry 4.0 in the mining industry and the identification of its main trends, since the lack of knowledge and lack of systematization of directions creates certain difficulties in the process of developing strategy.

3 Data and methodology

3.1 Data descriptions and analysis

For the world's Top 40 miners, 2017 was a remarkable year. Thanks in large measure to the continuing recovery in commodity prices, fuelled by general economic growth, revenues rose dramatically by 23 per cent. At the same time, the cost saving strategies of the past few years delivered, with margins and cash generating ability improved as well, leading to a sharp increase in profits (Figure 1).

Capital expenditures remained flat. With liquidity concerns that were still lingering in 2016 mostly resolved and balance sheets strengthened, companies have the flexibility to act. Across the board, a heightened focus on safety in operations, reducing advantage, and avoiding aggressive investments in new capacity indicates that management is proceeding in a measured and deliberate way.

3.2 Methodology

Use italics for variables (u) and bold ($\mathbf{u}$) for vectors. The order for brackets should be {[()]}, except where brackets have special significance.

4 Results and discussion

Based on the use of production cyber physical systems in the forecast period due to the implementation of the Industry 4.0 project and the planned breakthrough technologies, in the course of the study, we prepared an enlarged systematization of technological elements for the mining industry (Figure 1).

*Compiled by the authors.

Systematization (see Figure 1) covers such areas of mining as:

- exploration of reserves and planning of mining operations;
- coal mining;
- processing of coal and industrial waste;
- transportation of coal and other goods.

It should be noted that the two main elements of the Industry 4.0 project are flashing all the processes of mining: the Internet of Things, as well as automation and robotization of production processes. The systematization of the elements of the Industry 4.0 program presented in this article is not exhaustive; however, it gives an idea of the scale and possibilities of intensifying mining processes in the future conditions of the next industrial revolution. The technological solutions presented are the "basis" for creating an intellectual technological platform for the mining industry, taking into account the new achievements of the Industry 4.0 program and global digitalization, in which new technological solutions

are only captured. Unlike existing platforms, as part of its maintenance, research and development should be carried out to constantly support projects such as “Virtual Mine of the Future”, “Virtual Section of the Future”, aimed at optimizing the combination of promising technologies, organizational, economic and other solutions.

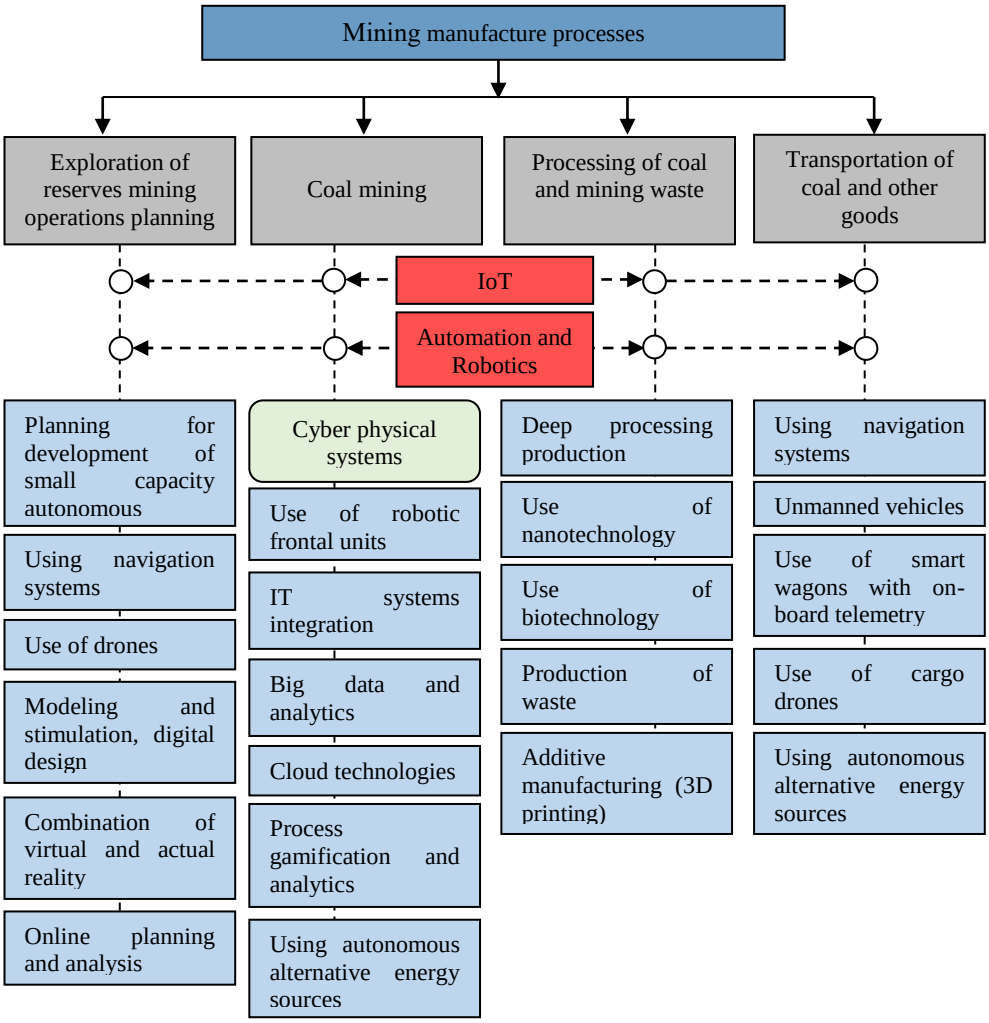

Fig. 1. Enhanced systematization of the basic elements of the project "Industry-4.0 on the basic processes of mining industry.

5 Conclusion

The Industry 4.0 Program, the fourth industrial revolution, is characterized by the use in industry of the so-called “Internet of things” capabilities and the use of “cyber physical systems” in production processes. The implementation of the Industry 4.0 project involves the creation of a smart industry that has evolved evolution from the use of integrated information and communication control systems to cyber physical systems.

The “Industry 4.0” and “Digital Economy” programs began to be implemented in many countries of the world - the USA, Germany, the Netherlands, Great Britain, South Korea, Japan, China, Sweden and others. The leader in the implementation of the “Industry 4.0” Program is Germany, in the economy, which the share of digital technologies by 2020 can be up to 90%.

Identified in the analysis of the problems of innovative development of Russian mining enterprises require an early solution in order to prevent technological lag from leading enterprises. To do this, the following steps are required:

- mining companies must overcome traditional conservative inclinations and make greater use of innovation in their operations. It is necessary not only to quickly respond to the emergence of new technologies and integrate into the innovative environment, but also to develop their own breakthrough technologies in this area;
- in order to ensure the maximum effect of technological and organizational innovations at the mining enterprises, constant work on training and advanced training of workers is necessary. In addition to formal training (training in educational institutions, obtaining official certificates), the role of training at the place of work (in-company training) and non-formal education (professionally oriented or general cultural education obtained with non-formal structures that are not part of the formal education system) are currently growing. It is necessary to develop a mechanism for planning intra-company education, as well as methods for its organization, taking into account industry affiliation and organizational and technological features of the enterprise;
- for the integration of scientific and production processes, it is necessary to form a sectoral innovation system that encompasses the processes of creation, dissemination and use of knowledge, which will ensure the intensification of innovative and technological processes, as well as ensure sustainable technology transfer chains [22,23]. To achieve the positive effects of the formation of innovative systems in the long term, it is necessary to strategically plan the system of government regulation measures, develop a set of measures combining elements of industrial and innovation policies that stimulate the innovative development of not only the mining industry, but also related sectors and industries.

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