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OPPORTUNITIES AND PROSPECTS OF DIGITALIZATION IN RUSSIAN COAL INDUSTRY

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Abstract

The article presents an analysis of the world experience in the use of digital technologies, including in the implementation of the "Industry-4.0" project, and highlights the key areas of use of "smart technologies" in the coal industry. The considered innovative scenario for the development of the digital transformation of the coal industry corresponds to the state's intention to make the transition from a resource-based economy to an intellectual innovation. Digitalization, cyber-physical production systems and the "Internet of things" systems will be key technologies in the coal industry's transformation. It was noted that it is necessary to create robotic mines to expand the area of coal production and production in a continuous mode, and coal processing based on the use of production cyber-physical systems, as well as the creation of an industrial Internet network in the coal industry. "Internet of things", automation and robotics of production processes will form the basis for the emergence of new production units - "Intelligent mine (section)", "Intelligent factory" and "Intelligent transport". The central element in the basic processes of mining production will be cyber-physical production systems in the extraction, preparation of reserves, processing and transportation of coal. It is emphasized that a full-fledged joint work of services and specialists in a single information space is necessary, which has difficulties in connection with finding the industry at the first level of "digital maturity". The research highlights the main promising technologies and areas of implementation of the "Industry-4.0" project in the coal industry.

Keywords: Coal industry, digitalization, technologies, Industry-4.0.

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1. Introduction

Despite the increasing use of alternative energy sources, the main trend in the development of the world economy is a significant increase in the consumption of fuel and energy resources. The fuel and energy complex forms a significant part of Russia's gross domestic product (GDP), has a significant impact on federal and regional budget revenues, the investment climate, the exchange rate, and other key parameters of Russia's economic development, and has been one of the key sectors of the economy for a long time period. Despite the decline in the share of coal in fuel and energy complex of the Russian Federation and several countries in the modern world, the coal industry continues to maintain a role as an important basic industry of FEC.

Production digitalization is an important direction in the work of large modern enterprises. Currently, GPS navigation systems are widely used in industrial transport, drones are used in mining areas, new technologies and software products are used in mine surveying, dispatching systems are used in production processes.

Analysis of the world experience in using digital technologies shows that the leading industrial countries have already started implementing the "Industry-4.0" project. Shvedina (2020) describes digitalization of the mining industry in the framework of this project:

"The digitalization of industrial enterprises means the use of the latest technologies: robotic or remotely controlled equipment, visualization of technological processes in inaccessible areas, remote centralized control rooms, high-precision positioning of drilling rigs and excavators, portable devices for monitoring the health status of personnel, electronic shift-based risk cards of workers, three-dimensional field models in design and management, predictive methods for analyzing geological and production data."

In the course of her study Shvedina (2020) defines digital mining enterprise as "is an integration of industrial-level automation systems with business applications". Shvedina (2020) also points that the technology can be used to create "a single cycle of planning, execution, accounting and analysis of the enterprise, thereby increasing the flexibility of the management system and radically reducing the time of reaction to changes in the external and internal environment" (p. 2).

As a result, digital transformation in the mining sector will not only improve production efficiency, but also create a qualitatively different platform, providing new tools for making management decisions.

2. Problem Statement

The mining industry is considered one of the most conservative industries: new technologies are rarely developed in this industry and are slowly being introduced. It is believed that a significant technological breakthrough in this area should not be expected in the near future, but, according to experts, it is possible to increase the profitability of field development through digitalization. The processes of digital transformation in coal companies have already passed a long way of development. Creating digital productions and enterprises is an objective necessity and reality. Currently, the coal industry is at a new stage of digital transformation. This stage is characterized by rapid development of technologies and means of telecommunications, high-precision navigation, computing technologies and robotics. The development of technical infrastructure is a necessary but not sufficient condition for the digital transformation of a coal

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mining company. A more complex stage in the digital transformation of a coal company is the restructuring of all organizational processes, the development of staff competencies, and the creation of trust in new digital technologies. Support from the state would help accelerate the progress of project work in the field of digital transformation in the coal industry. It is necessary to consolidate efforts to establish information exchange between participants in the digitalization of the coal industry and create a database of best practices in this area.

3. Research Questions

Over the past 150 years, mining has shown an increase in labor productivity, but in the 2000s it began to decline due, among other things, to the exhaustion of opportunities for extensive growth. In the world, the explosive growth of IT investment in the mining industry began at the end of the XX century. In Russia, digital technologies are widely used for solving management tasks, optimizing office and personnel work, but no more than 30 % of enterprises use them in process management. The introduction of digital technologies will reduce operating and capital costs, and provide an increase in underground and quarry coal production by 5–7 %. An important effect of the use of digital technologies is to increase the safety of work at coal mining enterprises. Digitalization of the industrial safety and labor protection system allows us to take it to a new level, optimize processes and increase efficiency. At the same time, the introduction of IT in the coal industry is possible at all stages, from exploration, design, construction of a mining and processing plant to operation and reclamation of the site.

4. Purpose of the Study

It is important to determine the possibilities of intensification of mining processes in the context of the next industrial revolution: digital technologies are the basis for creating an intelligent technological platform for the coal industry, taking into account the achievements of the "Industry-4.0" program and global digitalization, in which new technological solutions are only recorded.

Development in the Russian coal industry will follow two main directions: basic automation, which allows improving processes and preparing data arrays (Big Data), which will ensure the readiness of production and supporting functions for digital transformation (Digital Ready); digital transformation itself, including the development of expert systems, dispatch centers, end-to-end quality, scenario planning, and the development of digital mine technologies.

5. Research Methods

The methodological basis for the research was the use of a set of different methods, such as system analysis, synthesis, description, comparison and generalization. The theoretical basis consists of the works of Russian and foreign scientists in the field of digital technologies, including in the coal industry.

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6. Findings

Russian Federation has a large raw material base of coal which provides the country with the fourth place in the world after the United States, Australia and China. Russia's coal production is inferior not only to the main resource holders but also to a country with a comparable raw material base, in particular, India and even countries with significantly fewer resources, such as Indonesia which occupies the fourth position among the leading producers. Russian coal mining in 2018 it turned out to be more than 25 % less than in Indonesia and almost an order of magnitude lower than in China, providing almost half of the world's produced solid fuel. However, the quality indicators of the Russian raw material base of coal are not inferior to those of larger producers but also some of them are higher.

In recent years, coal production and exports have shown a clear upward trend. Over the period 2013-2018, the volume of export deliveries increased by one and a half times. Russia is a stable member of the top three countries that export coal, second only to Australia and Indonesia, and supplies it in both western and eastern directions. Coal consumption in Russia is significant and the country ranks fifth in this indicator, behind China, India, the United States and Japan. At the same time, the use of coal in the country is gradually decreasing due to competition from cheaper and more environmentally friendly fuel-natural gas.

105 coal mines and 216 mines were operated in Russia in 2018. A significant part of it is located in the Kuznetsk basin of the Kemerovo region which provides more than half of the domestic coal production (56 % in 2018). The role of other coal-producing regions is significant, but less: Kansk-Achinsk coal basin in the Krasnoyarsk region accounted for only 10 % of the extracted fuel, while production in Zabaikalsk region, in the Republic of Khakassia, in the Republic of Sakha (Yakutia), Irkutsk and Novosibirsk regions accounted for 3–6 % of the total figure (Yanovsky, 2019).The amount of coal produced in Russia annually increases, in 2018 it increased by 8 % compared to 2017, gross production (the total amount of coal produced, including waste rock) amounted to 432.7 million tons (Kiselev, 2019).

According to 2018 data, coal ranks fifth among basic products in the structure of Russian exports (after oil, petroleum products, gas and ferrous metals), with revenue from coal exports amounting to 17 billion dollars. At the same time, coal generation provides 50 % of electricity production in Siberia and the Far East. The industry's products account for 40 % of the rail freight turnover.

According to experts, due to an increase in energy consumption, a reduction in the growth rate of oil and petroleum products consumption, and the closure of nuclear power plants, a small increase in the share of coal in the energy consumption structure is predicted in a number of countries. According to the "Russian Energy Strategy until 2035", one of the directions of development of the Russian energy sector is to strengthen the role of coal and increase its production to 430 million tons by 2030. In the future the coal industry will remain significant both in Russia and in the world energy (Boyko, Chvileva, & Romasheva, 2019).

Russia is implementing the "Digital economy of the Russian Federation" program, which determines the development of economic sectors until 2024, including the coal industry. The program "Digital economy of the Russian Federation" was adopted by the Russian government (order No. 1632-R of July 28, 2017) and focuses on the "Strategy for the development of the Russian information society for 2017-2030" based on the fact that the digital economy is a business activity in which the key factor of production is data presented in digital form.

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Analysis of the world experience in using digital technologies shows that the leading industrial countries have already started implementing the "Industry-4.0" project. For example, in Germany, it is expected that the first enterprises operating on the principles of "Industry-4.0" will appear in 2021-2022, increasing labor productivity by an average of 18 % (Hiller, 2017). It is planned that by 2025 a large-scale industrial implementation of cyber-physical systems should be implemented in the country. As a result, Germany can become the main global supplier of these systems.

China is actively implementing the industrial concept of "Chinese production 2025", whose main goal is to pull the entire industry, including the coal industry, to the level corresponding to the third way ("Industry-3.0") and break through to the fourth industrial way ("Industry-4.0") by 2025.

The "digital twins" technology is being actively introduced in developed countries, combining the industrial "Internet of things" and digital modeling, at all stages of the product life cycle from development to operation. It is expected that the number of hardware failures will be reduced by an average of 30 % due to the introduction of "digital doubles" for modeling and evaluating various scenarios (Immerman, 2019).

The "Industry-4.0" program is based on the implementation of the following areas: industrial "Internet of things", augmented reality, big data, business analytics, "cloud technologies", autonomous robots, horizontal and vertical integration of systems, information security, additive manufacturing, digital modeling (Plakitkin & Plakitkina, 2017). In Russia the equivalent of the "Industry-4.0" program is the "TechNet" technology track of the national technology initiative (NTI), which is being formed by the government to serve the industrial revolution which is expected in 2025-2035.

Currently, the possibility of creating robotic mines is being expanded which allows to significantly expanding the area of coal mining, to carry out coal production in a continuous mode, and robots can be controlled from the surface, from places that are safe for people. Robotics eventually solves the problem of safety in mines, without requiring the constant presence of people underground. Robotic mines can produce methane, which is an energy carrier, in addition to coal, without using expensive reservoir degassing systems (Plakitkina, 2016).

Digitalization of the extractive industry is the integration of breakthrough technologies such as virtual modeling, the "Internet of things", robotics, artificial intelligence, big data, cloud and edge computing technologies, new communication standards and others. Digitalisation can be carried out in the system of managing production processes and product life cycle, as well as further maintenance. According to experts, the economic effect of the introduction of technologies of the "Internet of things" in industry by 2025. It may amount to about 1.2-3.7 trillion dollars in the world (McKinsey, 2015). However, with the significant success of many industrial companies in automating production processes and implementing distributed management and control systems, most enterprises do not fully realize the potential of big data analytics and decision-making algorithms based on artificial intelligence.

According to McKinsey company with experience in digital transformation of more than a hundred enterprises in different countries of the world, the efficiency of implementing digital technologies in mining and processing plants leads to an increase in production by 13 %, reducing costs by up to 15 %. The introduction of digital technologies in the mining industry in the world market is proceeding at different rates. The relevance of digital technology implementation is confirmed by market experts and Russian government agencies. The Ministry of energy of the Russian Federation has developed a departmental

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project "Digital energy" which affects the coal mining industry. The project assumes that the introduction of digital technologies will reduce operating and capital costs, as well as ensure an increase in underground and quarry coal production by 5–7 % by 2024. An important effect of the use of digital technologies is to increase the safety of work at coal mining enterprises.

The automated control system of the mining and technological complex ("ACS MTC") "Quarry", which is the basis for the construction of robotic mining production, has been implemented in large mining enterprises of the Russian Federation: JSC "SUEK", JSC "HC SDS-Ugol", JSC "Mechel-mining", JSC "Severstal-Resurs", JSC "Holding Sibuglemet", JSC "UK Kuzbassrazrezugol", etc.

In the coal industry of the Russian Federation, in accordance with the "Industry-4.0" project, it is possible to implement the following model of using technologies (Plakitkin & Plakitkina, 2018). "Smart coal seam" "informs" the executive body of the coal harvester of the current size and strength characteristics of the coal seam, the presence and value of non-solid inclusions in it, etc. Based on this information, the real-time mode automatically changes, for example, the slope of the cuts and other cutting parameters, the feed rate of the harvester's executive body and the vector of its movement along the cleaning plane. By "talking" to the transport system, the coal seam indicates which route and which vehicles should be used in order for the coal to be delivered to the desired point by the required time for the subsequent production cycle. All machines and equipment used at a mining enterprise as components of production cyber-physical systems can send signals about the wear of their individual parts and form orders for their manufacture, delivery and replacement by Internet. The level of autonomy of production systems in the long-term period will constantly grow and eventually such systems will be transformed into active production "cells" that can independently manage their production processes.

Until 2040, the development of the coal industry will be greatly influenced by the fourth industrial revolution currently underway in many countries of the world and the "Digital economy of the Russian Federation" program. The main directions of these projects are digitalization, the creation of an industrial Internet network in the coal industry and the development of unmanned robotic technologies for processing coal based on the use of production cyber-physical systems (Hiller, 2017; Plakitkin & Plakitkina, 2017; Plakitkin & Plakitkina, 2018).

Analysis of researches on the process and prospects of digital transformation of the mining industry allows us to identify two possible scenarios: innovative and conservative. When implementing the innovative scenario option, stabilization and systematic reduction of coal production volumes are provided (Plakitkin, Plakitkina, & Dyachenko, 2019). With the technological upgrade of the industry until 2040 it is expected that almost complete replacement of fixed assets with high-performance ones. As a result, the dynamics of the industry's capital return is expected to change in the direction of systemic growth. The conservative scenario is based on an increase in energy prices and a continued decline in the efficiency of capital investments and fixed assets. The innovative development scenario generally corresponds to the intentions of the state regulator to make the transition from a resource-based economy to an intellectual innovation economy.

According to the forecast dynamics up to 2040, the share of application of the technologies of the "Industry-4.0" project in the coal industry of the Russian Federation will be in the innovative version of the industry development: open coal mining in 2020 – 74, 2030 – 84, 2040 – 95; underground coal mining in

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2020 – 26, 2030 – 16, 2040 – 5. The conservative variant of development of coal industries: open mining of coal in 2020 – 74, 2030 – 75, 2040 – 76; prohibition coal production 2020 – 26, 2030 – 25, 2040 – 24. This dynamics in the open method of coal mining is due to the fact that it has a rapid adaptation to the basic technologies that are part of the "core" of the technological development of the coal industry. In the conservative version, the proportions of open-pit and closed-pit technologies are practically unchanged, and the "Industry-4.0" technologies have a "peripheral" character. The volume of application of new technologies in the coal industry of the Russian Federation in 5 years in the direction of "coal mining" can, according to experts, reach about 35–42 % and rise only to 57 % by 2030. This is due to the technologies of coal mining which are difficult for mines from the point of view of the introduction of robotization of production and unpopular organization of mining of coal reserves.

According to estimates of the research Center of coal industry of Russia and the world of energy research Institute, the rate of introduction of new technologies will be consistent with the programs of the 4th industrial revolution. About 85 % of coal production will be provided with new technologies by 2035. New digital technologies will occupy about 55 % of the coal processing volume by 2030 and by 2040 their volume will be about 75 %, which corresponds to the program milestones of the 4th industrial revolution (2030–2040). According to the conservative scenario, the rate of transformation will be approximately 7–10 years behind the innovative option.

The growth of labor productivity in the coal industry in our country will have a direct relationship with the scale of application of new technologies that are included in the "core" of the main processes of coal production, namely digitalization, the "Internet of things" and production cyber-physical systems (Plakitkin, Plakitkina, & Dyachenko, 2019). The basic technologies of the "Industry 4.0" project which form the "core" of the technological transformation of the coal industry are considered to be digitalization, the "Internet of things" and production cyber-physical systems (Plakitkin & Plakitkina, 2018).

One of the main elements of the "Industry-4.0" project is the "Internet of things", as well as automation and robotics of production processes which are included in all mining processes. These elements form the basis for the emergence of new production units, such as "Smart mine (section)"," Smart factory", "Smart transport". The central element for basic mining processes is the use of cyber-physical production systems in the production and preparation of reserves, as well as its processing and transportation of coal. The operation of these systems is based on the use of intelligent robotic systems in autonomous production units of low power. This allows you to increase the productivity of coal mining many times. Automation and robotization of mining operations makes it possible to create a new class of mining machines, the so-called geohods. The expansion of coal production without human use can be increased by using robotic systems for drilling and scraping coal. The processes of coal preparation and production must be accompanied by digital modeling of geomechanical processes implemented in the development of coal deposits.

Exploration of reserves, planning of mining operations and monitoring of the movement of the mining front must be carried out using temporary navigation tools. To assess the state of mining operations and monitor compliance with industrial safety requirements at the site, it is advisable to use industrial drones. They should also be used in solving problems of transportation and information and communication support of technological processes (Kutakhov & Plyaskota, 2017).

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The use of modern digital technologies provides new opportunities for conducting search and exploration operations. The use of the digital Internet in the interpretation of spatial and temporal data on objects represented in GIS is expanding. There is a possibility of active 3D-modeling of the geological environment during field exploration. Digital technologies can be actively used for remote sensing of the earth based on the use of satellite geodesy and laser scanning, for navigation and drones.

Implementation of IT in mining is possible at all stages, starting with geo-exploration (creating a digital model of the field), design and construction of the GOC (they are significantly accelerated due to the use of digital technologies) and ending with the operation and reclamation of the site. Creating a unified information landscape that integrates industrial-level systems with business applications allows you to create a single cycle of planning, execution, control, accounting, and analysis of industrial enterprise activities, as well as reduce the response time to internal and external changes. At the same time, a full-fledged joint work of various services and specialists in a single information space is necessary which currently has certain difficulties, since the Russian coal industry, according to experts, is still at the first level of "digital maturity", since companies use a lot of software products that are poorly connected to each other. Most of the IT projects implemented in mining are still aimed at improving security also. The result of digitalization should be deserted technologies. Currently, there are a huge number of sensors installed at mining enterprises that are designed to protect workers who register the methane content in the mine, disable equipment when they detect a person in its area of action, and measure the level of employee fatigue. The problem is that manufacturers of mining equipment use different technologies which are difficult to combine into a single system during operation. Industrial companies already collect and store a huge amount of data but use less than 1 % of this volume (Sanatina, 2019).

The world's largest coal producers are far advanced in the application of digital technologies. Integrated holdings that produce a wide range of minerals, including coal (Rio Tinto, BHP Billiton, Vale) are currently the leaders of digital transformation. In particular, Rio Tinto has a quarry fully equipped with robotic and remote-controlled equipment. Russian coal companies are still at the beginning of digitalization of technologies. "Severstal resource" which includes "Vorkutaugol" has successfully implemented a project to integrate the dispatching system of the mining and transport complex with the ERP-system. The use of digital technologies in the mining industry is not limited to optimizing production processes. The introduction of a system of unmanned aerial vehicles (drones) to automate surveying at the enterprises of the Raspadskaya coal company in the Kemerovo region led to a reduction in the downtime of quarry equipment and made it possible to take production and management actions more quickly (Stepanov, 2019). Mobile solutions for underground coal mining at coal mining enterprises allow for objective control of the gas content of mines, the state of workings and the operation of mining equipment.

Active implementation of "smart technologies" by Russian companies in the coal industry allows automating most processes increasing labor productivity and competitiveness of the industry, as well as reducing accidents and injuries at the production site.

Assessing the prospects for digitalization in the coal industry we can confidently say that the use of various tools and solutions based on information technologies allows industrial companies to optimize the management of production processes, industrial safety, labor resources and financial flows, and the use of

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electronic commerce services contributes to the realization of products online. Therefore, digital transformation will be carried out at a rapid pace in the near future.

7. Conclusion

The "Industry-4.0" and "Digital economy of the Russian Federation" programs can be the starting points of technological breakthroughs in the coal industry in the future. However, it is necessary to create an "Intelligent platform" that would take into account the main directions of the "Industry-4.0" project and digital technologies in the coal-mining sector of the economy.

The main promising technologies and areas of implementation of the "Industry-4.0" program in the coal industry in mining processes are:

Exploration of coal reserves: technologies for virtualizing exploration operations; remote sensing of the earth; geo-information systems based on 3D-modeling of the geological environment.

Coal mining and preparation of reserves: automation and robotics of mining operations and underground space formation; technologies of coal mining without the presence of people (deserted excavation); geo-information support based on digital modeling of mechanical processes; use of the "Internet of things" in the field of coal mining and participation in the formation of the "Intelligent mine" and "Intelligent section" complexes.

Processing of coal and waste: "Internet of things" for processing, processing of coal and waste, forming the complex "Intelligent processing plant"; technologies of coal chemistry to produce products with high added value; use of nanotechnologies and biotechnologies.

Transport: the use of automated vehicles; "Internet of things" which forms the "Intelligent transport and control center" complexes.

For the most complete disclosure of the potential of digital transformation of the coal sector and getting a systemic effect from the introduction of digital technologies for the entire industry, it is necessary to consolidate the efforts of business and government. The introduction of digital technologies opens up additional opportunities for the state and business. The state is given the opportunity to significantly improve the quality of management and strategic planning based on operational data. This allows businesses to improve the efficiency of production and business processes by optimizing assets and reducing the cost of the most expensive components. In practical terms, the technological renewal of the coal industry should be accompanied by the development and implementation of mechanisms for state assistance to technological re-equipment of enterprises based on the introduction of the "Internet of things" and cyber-physical systems into practice. The state regulator should also assist in the organization of production of waste equipment used in the production processes of coal mining and carried out by autonomous cyber-physical systems.

References

Boyko, N. A., Chvileva, T. A., & Romasheva, N. V. (2019). Influence of coal companies' activity on the socio-economic development of coal-producing regions and its assessment. *Coal, 8*, 48–49.

Hiller, B. (2017). “Industry-4.0”-smart manufacturing of the future. Experience of “digitalization” in Germany *VI Int. forum “Information modeling for infrastructure projects and business development in Greater Eurasia”*.

Immerman, D. (2019). Digital Twin Predictions: The Future Is Upon Us. *Industr. "Internet of things"-PTC*.

Kiselev, E. A. (2019). *On the state and use of mineral resources in 2018*. State report. Moscow: Ministry of natural resources and ecology of the Russ. Federation.

Kutakhov, V. P., & Plyaskota, S. I. (2017). *Information Interactions-Large-Scale Robotic Aviation Systems*. Moscow: V.A. Trapeznikov Institution.

McKinsey. (2015). *"Internet of things": displaying value beyond hype*. June 2015.

Plakitkin, Yu. A., & Plakitkina, L. S. (2017). Global innovation "Industry-4.0" project – application opportunities in the Russian coal industry. "Industry 4.0" program – new approaches and solutions. *Coal, 10*, 44–50.

Plakitkin, Yu. A., & Plakitkina, L. S. (2018). "Industry-4.0" and "Digital economy of the Russian Federation" programs – opportunities and prospects in the coal industry. *Mining, 1*, 22–28.

Plakitkin, Yu. A., Plakitkina, L. S., & Dyachenko, K. I. (2019). Forecasts of technological development of the Russian coal industry for the period up to 2040. Part. 1. Forecasts of production and prices of coal in accordance with the scenary levels of world oil prices for the period up to 2040. *Mining J., 7*, 55–59.

Plakitkin, Yu. A., Plakitkina, L. S., & Dyachenko, K. I. (2019). Forecasts of technological development of the Russian coal industry for the period up to 2040 Part. 2. Stages of technological development of the coal industry in Russia for the period up to 2040. *Mining Journal, 8*, 11–18.

Plakitkina, L. S. (2016). *Modern directions of innovative development in the Russian coal industry*. Moscow: INEI RAS.

Sanatina, Yu. (2019). Mines go into the clouds. *The Russ. newspaper-econ. of the Urals Fed. district, 262* (8009).

Shvedina, S. A. (2020). Digital transformation of mining enterprises contributes to the rational use of resources *IOP Conference Series: Earth and Environmental Science, 408,* 012064.

Stepanov, I. (2019). Digitalization of coal and metal. *Kommersant*, *9.* 25.09.2019.

Yanovsky, A. B. (2019). Results of structural adjustment and technological re-equipment of the Russian coal industry and tasks for future development. *Coal, 8*, 6–7.