

Research on Intelligent Coal Mining

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Abstract

China's social and economic development is constantly moving forward, the industrial level is further developing, and the demand for energy production is constantly increasing. With the increasing scale of coal mine engineering, higher requirements are put forward for mining technology. Intelligent coal mining can not only improve the level of production management, but also increase coal production. This paper introduces the necessity of applying intelligent mining technology, then discusses the convenience brought by intelligent mining technology, discusses the specific technology, researches and discusses the limitations and development prospects. Only by analyzing the application of intelligent coal mining can we ensure the safe and sustainable development of mining engineering, so as to promote the development of our country's economy and promote the all-round development of society. In recent years, with the development of economy and the progress of science and technology, people's living needs have been continuously improved. Coal mining resources have a great impact on social life, the development of mining engineering in our country continues to move forward, in the field of technology and development management principles have made great progress, intelligent mining technology application ability and level further improved. In the future, while solving the problem of resource limitation, the application of intelligent coal mine provides the prerequisite for the development of mining engineering, and also provides the possibility for its further development. Therefore, the intelligent mining of coal mines is gradually bringing us convenience, which not only increases the efficient mining of coal, but also guarantees the life safety of workers.

Keywords

Intelligent Mining Technology, Automation, Big Data, 5G, Intelligent.

1. Introduction

(1) Background Introduction

To improve coal mining efficiency and safety, the state has issued a series of preferential policies for the intelligent development of coal mines. As a result, various types and modes of coal mines across the country have successively introduced or integrated intelligent and information-based technologies to reduce mining risks and ensure the life safety of workers.

Intelligent mining is a mining process characterized by digitalized mining environment, intelligent mining equipment, remote-controlled production process, networked information transmission and informatized operation management, aiming to achieve safety, high efficiency, economic benefits and environmental protection. Gu Desheng pointed out that the main tasks of implementing intelligent mining at present are to develop the mining software industry, research and develop intelligent mining equipment, build demonstration zones for intelligent mining, and cultivate new-type mining talents. Mine digitalization is the fundamental basis for realizing mine informatization and intelligence.

Intelligent mining technology includes manual remote control technology. Relevant operators can dynamically understand actual mining conditions and on-site problems through remote

operation, so as to adjust working modes in a timely manner and ensure overall operation effectiveness. In addition, during underground operation, high-definition cameras can be used to monitor fully mechanized mining in real time, monitor the operating status of shearers, conveyors and other equipment throughout the process, and accurately track the working positions of mechanical equipment through infrared sensors, creating favorable conditions for mining and reducing workload. Furthermore, with the application of straightness control technology, the working face of fully mechanized mining equipment can be kept straight, avoiding damage to conveyors and other equipment in the later operation stage. The digital intelligent mine system mainly consists of five parts: digital mining software system, production execution system, intelligent dispatching system, real-time grade analysis system and 3D management and control system [1].

(2) Research Significance

Driven by rapidly developing science and technology, intelligent mining technology adopts scientific and rational modern high and new technologies and uses machines to replace manual labor to meet the requirements of precise mining. While improving production efficiency, it provides scientific and intuitive guidance for mining engineering and represents a key development direction for the future of mining engineering. The application of unmanned equipment and intelligent systems in intelligent mining technology enables mining engineering to meet mechanization and automation requirements, while also realizing informatization and digitalization, optimizing production scheduling and management, thus ensuring safe and efficient mining, avoiding safety accidents and improving the economic benefits of enterprises. Intelligent coal mines serve as a key technological foundation for the high-quality development of the coal industry. The development and application of artificial intelligence, industrial Internet, cloud computing, big data, robotic intelligence and modern coal equipment are the major technological pillars for the coal industry to regain its peak in the future [2].

To further improve the application effect of intelligent mining technology, corresponding principles shall be followed in practical application to ensure the orderly progress of various tasks and bring higher economic benefits. Specifically: First, safety. During the application of intelligent mining technology, the safety of all operators shall be guaranteed. Technical personnel shall master the key points of relevant equipment and technology application and work in accordance with regulations. Second, intelligence. Various intelligent equipment, including intelligent spraying devices, infrared emitters, etc., shall be flexibly applied to continuously increase the output of fully mechanized top-coal caving faces.

2. Overview of Intelligent Mining

(1) Mine Automation

The mine integrated automation system enables the integration of various monitoring and automatic control technologies. It integrates on-site real-time monitoring data of personnel, equipment, environment and other elements with the intelligent video surveillance system, large-screen display system, intelligent disaster sensing system, alarm linkage system, disaster avoidance command system and other subsystems to form an integrated management and control platform, so as to realize the real-time collection, feedback and control of all-round information on the production site and build a highly sensitive production command center. The platform covers such business functions as basic functions, data integration and visualization, remote control, intelligent data fusion analysis, intelligent linkage, comprehensive intelligent disaster prevention and control, intelligent alarm, report statistics, diagnosis and auxiliary decision-making.

The intelligent mine automated mining technology is mainly developed to achieve the development goal of realizing the automation of underground fully-mechanized mining and

continuous heading faces as well as the integration of transportation operations [3]. By upgrading the collaboration mode among the shearer, hydraulic support cutting system and crusher, the automatic remote control of production equipment can be realized, and the core function construction of the intelligent platform, production control system and execution system can be completed. Furthermore, an intelligent mine automated mining system will be established, which features automatic information collection, high-degree data sharing, automatic statistical analysis, visualized business progress and real-time monitoring of equipment operation status, with the whole production process fully recorded.

(2) Mine informatization

The contemporary world is an era of rapid economic development and continuous technological innovation. The development of the coal mining industry cannot be separated from the support of modern information technology. It is imperative to take the advantage of this advanced productive force to effectively improve operational efficiency and continuously optimize and upgrade internal management. Specifically, it is reflected in the following aspects: Firstly, integrating modern high-tech information technology into traditional coal mining operations enables more accurate and meticulous deployment before operation as well as efficient implementation of specific mining tasks. Secondly, information technology can be adopted to acquire the internal working mechanisms and processes of major international coal mining enterprises, followed by necessary learning and reference, so as to improve its own internal automated management system. Thirdly, information technology is applied to guide the specific work of each employee, ensuring that staff can make full use of high-tech information technology in every work link, and effectively improve their work efficiency and operation precision. Fourthly, information technology helps enhance the professional quality and competence of workers, boost mining efficiency in practical operations, strive to ensure the safety of the working environment, and guarantee operation in a more sound working atmosphere.

(3) Mine intelligence

Mine intelligence represents the in-depth integration of artificial intelligence technology, big data technology, Internet of Things (IoT) technology with mine entities. It relies on intelligent communication, intelligent control and intelligent computing technologies to realize the computation and processing of digital mines, and further construct a digital twin mine. Through the intelligent interactive evolution between digital mines and physical mines, the safe, efficient and green production control of coal mines can be achieved.

With the development of artificial intelligence (AI) technology, researchers have explored the application of AI in various mine production systems. Given the broad research scope and long time span of AI technology, there are numerous integration points with coal mines. For instance, the combination of AI technology with mine disaster control enables the development of intelligent water hazard control platforms [4], intelligent gas drainage technology [5], intelligent rock burst monitoring and control technology [6], etc. Integrating AI with mining and tunneling technologies contributes to the establishment of intelligent coal-rock identification technology and intelligent fully-mechanized mining faces. When combined with relevant mine monitoring systems, AI can be applied to build intelligent drilling monitoring systems and intelligent surrounding rock monitoring system. Applied to communication networks, AI helps develop routing algorithms for intelligent underground wireless sensor networks. In addition, the integration of AI with management has given rise to an intelligent miner behavior management system based on miner action recognition.

Big Data Technology: As one of the core technologies of smart coal mines, big data mining and knowledge discovery play a pivotal role. The extensive application of numerous sensors is bound to generate massive volumes of data, and the scale effect of such data poses severe

challenges to data storage, management and analysis. It is imperative to make full use of big data processing technologies to explore the laws and knowledge behind the data, so as to provide timely and effective support for safety production, operation management and decision-making.

3. Application of Intelligent Mining

(1) Mineral resource exploration

Resource exploration and mining development are characterized by long investment cycles, high risks and high returns. In particular, geological exploration is not only a labor-intensive and technology-intensive industry, but also a capital-intensive industry. Geological exploration work is carried out step by step in a targeted manner, and its phased characteristics mainly reflect the general laws of mineral resource exploration: from area to point, from surface to interior, from shallow to deep, from sparse to dense, from near to far, and from the center to the periphery.

UAV aerial surveying and mapping technology is adopted to conduct orthophoto measurement, so as to obtain topographic and surface information of mining areas, improve work efficiency and quality, and reduce disturbances to surface vegetation at the same time. UAV surveys feature large coverage area, high data processing efficiency, flexible operation and high productivity. After orthorectification processing, the UAV-derived orthophotos contain rich information, which can visualize the scenes of the exploration area and ensure the content is abundant, accurate, reliable and complete. The orthophoto data can display detailed images of the mining area, helping exploration engineers understand the topography, vegetation, landscapes and other information of the mining area, and fully grasp the actual conditions of the site.

The implementation of green exploration technologies has led to the establishment of a mature green exploration technical system covering data collection and analysis, project site selection, preliminary investigation, application of new geophysical prospecting technologies, adoption of green drilling equipment, implementation of ecological exploration measures and technology integration. This system has been widely applied in various mine exploration projects, effectively guaranteeing resource supply and ecological environment protection during the exploration stage.

(2) Miner production process

As a vital supplier of essential social resources, mines have long played a pivotal role. However, with the advancement of society and the development of new energy sources, traditional mining methods can no longer meet current demands, and the mining industry is bound to stride toward a more efficient and eco-friendly future. The application of smart mines provides an unprecedented opportunity to achieve this goal.

The adoption of the MES (Manufacturing Execution System) integrated production management and control system in mines will assist production managers in scientifically and dynamically scheduling and managing production resources, optimizing and organizing production in a timely manner, ensuring smooth production flows and stable technological processes. Furthermore, it helps improve production efficiency, guarantee product quality, reduce consumption, lower costs and increase economic benefits, thereby enabling enterprises to realize the modern corporate goals of informatized production management, resource-oriented information processing, networked information transmission and scientific management.

(3) Miner safety and environmental protection

Countries around the world have begun to attach importance to sustainable development and the development of a green economy. In coal production, strengthening environmental protection and work safety measures, promoting clean production technologies and the construction of green mines can reduce energy consumption and resource waste, improve resource utilization efficiency, and boost sustainable development and the establishment of a green economy. At the same time, the development of the green economy has also provided new development opportunities and directions for the coal industry. Coal enterprises should strengthen technological innovation and industrial upgrading, actively explore green coal production modes, and achieve a win-win situation between sustainable development and economic benefits.

Environmental protection and work safety have an inseparable synergistic relationship in the coal mining industry. Coal mine safety production and environmental protection should promote each other to form a virtuous cycle. In addition, environmental protection and work safety require coordinated development. Coal enterprises should establish an integrated management mechanism for safety and environmental protection, integrate work safety and environmental protection into a unified management system, realize resource sharing, information sharing and supervision sharing, and promote the coordinated development of environmental protection and work safety. Finally, the construction of green mines is the common goal of environmental protection and work safety, as well as a necessary condition for the sustainable development of coal enterprises. By adopting clean production technologies, the discharge of pollutants and the generation of waste can be reduced, the recycling of resources can be realized, and energy consumption can be lowered, so as to promote environmental protection and work safety in coal mines.

4. Challenges and Prospects of Intelligent Mining Technology

(1) Inconsistent understanding and concepts of coal mine intelligence

Some regions and coal mining enterprises fail to attach sufficient importance to intelligent transformation. They cling to conservative mindsets and fail to recognize that intelligence is an inevitable trend in the development of the coal industry. They unilaterally emphasize the large investment, technical difficulties and high requirements of intelligent construction, and even regard it as a mere face-saving project. Failing to take a long-term perspective on economic benefits, work safety and people's livelihoods, they are afraid of both increased burdens affecting economic returns and undertaking risks of failure. With a fear of difficulties and negative attitudes, they take the initiative in promoting coal mine intelligence reluctantly, resulting in relatively lagging development of intelligent construction.

A distinctive feature of intelligent coal mines is the in-depth integration of modern information technology, artificial intelligence, control technology and mining technology. The construction of intelligent coal mines is a progressive and iterative process in which high-tech technologies are integrated into mining scenarios, representing a continuous improvement journey rather than a one-off achievement or a turnkey infrastructure project.

Mechanization, automation, informatization and digitalization constitute the foundation and connotation of intelligence. In essence, the inconsistent understanding and concepts of coal mine intelligence are not disputes over the definition of intelligence itself, but the incompatibility between rigid conservative thinking and technological transformation. Such divergences are natural in the initial stage of coal mine intelligence development, when relevant technologies and equipment are still immature and underdeveloped. Total negation and conceptual abuse are two typical manifestations of such divergences, which are similar to the situation at the initial stage of the development of comprehensive mechanization in coal mines.

(2) Unbalanced development of coal mine intelligence

Given the complex and diverse coal seam occurrence conditions in China, mines with different geological conditions vary greatly in the technical paths, difficulty levels and implementation effects of intelligent construction. At present, the development of coal mine intelligence in China is unbalanced, which is mainly reflected in the following aspects: Unbalanced foundation of intelligent construction among different mining areas; Unbalanced development level of intelligent construction across different regions; Unbalanced intelligent degree among different systems within coal mines; Mismatch between the demand for intelligent technologies and the current status of technological development; Disparity between the slow pace of software development and the massive investment in hardware; Unbalanced input-output ratio related to coal mine intelligent construction.

(3) Scarcity of 5G application scenarios and ecosystems in intelligent coal mines

As a new generation of information technology, 5G boasts remarkable advantages including large bandwidth, massive connections and low latency. Integrated with core technologies such as network slicing and edge computing, it can bring transformative application scenarios to vertical industries. Although the first phase of exploration and practice of 5G applications in coal mines has yielded abundant valuable experience, numerous practical problems have also been summarized and identified during this stage: the inconsistent architecture of 5G network systems from different manufacturers; the 5G application scenarios yet to be further explored; and the scarcity of 5G technologies and terminal ecosystems.

(4) Difficulties in compatibility and collaboration of the intelligent megasystem

An intelligent coal mine requires the construction of nearly a hundred subsystems, including basic application platforms, roadway heading systems, mining systems and others, constituting a complex megasystem. However, the performance of data compatibility, network compatibility, service compatibility and control compatibility among different systems is rather poor, making it difficult to realize intelligent collaborative operation between systems. The main manifestations are as follows: Unified data formats have not yet been achieved; Poor compatibility exists among network communication protocols; Service systems feature low compatibility with each other; Collaborative control compatibility between systems is insufficient.

(5) Insufficient management and talent reserve for intelligent coal mine

At present, the construction of intelligent coal mines still adopts traditional management models. Affected by factors such as population aging and labor shortage in China, there is a severe shortage of professional and technical talents for coal mine intelligence, which is mainly manifested in the following aspects: Traditional management models are difficult to adapt to the operation of intelligent coal mines; Coal mines lack specialized majors and functional departments for intelligent talent training; The overall technical level of employees in intelligent coal mines is low, and the training system is incomplete; There is a shortage of professional operation and maintenance (O&M) teams.

(6) Future development directions

In smart mines, Internet of Things (IoT) technology plays a crucial role. The intelligent layout of various sensors and monitoring equipment enables efficient interconnection and interoperability among mining equipment and facilities. By collecting key information such as real-time equipment operating status and environmental parameters, timely and accurate data can be provided for mine managers to help prevent and resolve potential problems. The application of intelligent monitoring systems has not only improved mine production efficiency but also reduced adverse impacts on the natural environment.

Unmanned mining trucks, automated exploration equipment and similar technologies have become the new normal in mine operations. This has not only improved operational efficiency and reduced labor costs but also lowered safety risks during operations. The introduction of

automation technologies has made mine operations more precise and controllable, laying a solid technical foundation for efficient mining.

Through big data analysis, mine managers can gain an in-depth understanding of the impacts of mine operations on the surrounding ecological environment and take timely measures for restoration. Intelligent environmental monitoring systems can monitor the discharge of wastewater, waste gas and other pollutants in real time, helping to reduce environmental pollution and realize the sustainable development of the mining industry.

5. Conclusion

With the continuous development of artificial intelligence technology, the mining industry has entered an era of intelligent management and control. Traditional mine management is often plagued by potential safety hazards and low efficiency, while the application of intelligent management and control systems has brought brand-new opportunities and challenges to mines.

The mine intelligent management and control system represents a major innovation in the mining industry. Its application has brought higher safety, greater efficiency and better sustainable development to mines. With continuous technological progress and wider application, mine intelligent management and control will play an even greater role in the future, leading the mining industry into a new era of intelligence, safety and sustainability.

References

- [1] Zhang Wenquan. Application of Digital Intelligent Mine System in Mining Technology of Open-pit Limestone Mines [J]. West-China Exploration Engineering, 2023, 35(11): 159-161+164.
- [2] Chen Jixun. Application of Digital Mine System and Intelligence in Mines [J]. Inner Mongolia Coal Economy, 2021, (15): 142-143.
- [3] Ma Xiaoping, Yang Xuemiao, Hu Yanjun, et al. Preliminary Study on Application of Artificial Intelligence Technology in Mine Intelligent Construction [J]. Industry and Mine Automation, 2020, 46(5): 8-14.
- [4] Wu Qiang, Xu Hua, Zhao Yingwang, et al. Mine Water Disaster Intelligent Emergency Rescue System Based on Cloud Platform and Its Application [J]. Journal of China Coal Society, 2018, 43(10): 2661-2667.
- [5] Zhou Fubao, Liu Chun, Xia Tongqiang, Liu Yingke, Sun Yuning. Theory and Regulation Strategy of Intelligent Gas Drainage in Coal Mines [J]. Journal of China Coal Society, 2019, 44(8): 2377-2387.
- [6] Pan Junfeng, Liu Shaohong, Ma Wentao, et al. Intelligent Prevention and Control Method and Development Path of Deep Rock Burst [J]. Industry and Mine Automation, 2019, 45(8): 19-24.