

Key technologies for intelligent mining of difficult-to-mine coal seams

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Abstract: Coal is still an important support for China's energy industry. The mining of difficult coal seams has become a major trend in the industry, and intelligent mining has become an important development direction. This paper expounds the definition and importance of intelligent mining of difficult-to-mining coal seams, emphasizes the connotation and technical characteristics, and proposes the key technical systems that need to be constructed for intelligent mining of difficult-to-mining coal seams, including risk identification, equipment scheduling and personnel management. It can also reduce the impact on the environment. Through refined operation control and the operation of automated equipment, it reduces pollutant emissions during the coal mine production process and achieves green and sustainable development; its promotion and application also promotes the industrial upgrading and development of the coal industry. Technological progress has promoted the development of related industrial chains and enhanced the competitiveness and innovation capabilities of the entire industry. Therefore, as the current coal mining environment and geological conditions gradually shift to deeper levels, combined with engineering experience and technical core, this paper focuses on the key technologies for intelligent coal mining under extremely complex conditions.

1. Introduction

China's resource and energy landscape determines that coal's status as the dominant energy source will be difficult to shake in the long term^[1-2]. Under the requirements of safe and efficient production in the new era, with the gradual improvement of mechanization and digitalization levels, new coal mining equipment and new technologies are emerging, and it is currently in the initial stage of coal mine intelligence^[3]. At present, great progress has been made in intelligent coal mining, and research on information monitoring, transmission and intelligent control has also made certain progress. Many domestic scholars and experts have made contributions to the top-level architecture of intelligent coal mines, various system design methods, monitoring indicators, etc. A lot of research has been done^[4], but there are still many issues that need further research in terms of intelligent mining in complex geological conditions.

90% of coal in my country is mined underground. After years of mining, shallow coal resources in many places have tended to shrink, and stopes have gradually moved to deep and complex conditions. Mining has become increasingly difficult and safety threatening. The biggest difference

between the coal industry and other industries is that safety risks always exist from the construction to the abandonment stage of the mine. With the advancement of technology, the update of coal production concepts and the improvement of processes, the production methods of coal mining enterprises have undergone significant changes [5]. Intelligent mining of coal seams with complex conditions has significant advantages in many aspects: it can effectively improve safety, and through real-time monitoring and intelligent control systems, timely detection and response to potential safety hazards such as geological disasters and gas explosions can reduce the risk of accidents. Risk; can significantly improve production efficiency. Through automated equipment and intelligent scheduling systems, mining efficiency and operation speed are improved, while labor costs are reduced and production output is increased. In addition, intelligent mining technology can also reduce costs. By optimizing resource utilization and controlling energy consumption, it effectively controls costs in the production process and improves the competitiveness of enterprises.

2. The connotation of intelligent mining of difficult-to-mine coal seams

In short, the intelligentization of difficult-to-mine coal seams means relying on intelligent technology construction on coal mine working surfaces with complex hydrogeological conditions and active structures, by fully sensing the geological conditions of coal mines and equipment operation information, and using data integration, cloud computing, Big data modeling, real-time identification and evaluation and other means can realize real-time monitoring of coal mine working faces under complex geological conditions, real-time reporting of safety production risks, and intelligent decision-making and early warning of big data platforms. Its goal is to ensure normal production of coal mines and provide timely warning of major disasters, such as gas outbursts, mine flooding and mine fires. The implementation of this system is based on accurate geological condition perception, comprehensive data platform construction and real-time cloud risk identification and assessment.

From the above definition, it can be seen that the intelligent architecture of difficult-to-mine coal seams is shown in Figure 1, which includes the following main levels: top-level coordination, cloud big data platform; risk level, accurate identification and early warning system of coal mine risks; management level, establishing new process reengineering coal mine safety management concept.

Coal mining in China is mainly based on underground mining. Due to the special geological characteristics, as the mining depth increases, the existence of coal seams and the mining environment are more complex, and it faces the threat of multiple disasters during the mining process, and various disasters interact with each other, seriously endangering the safe production of coal mines. Therefore, on the basis of accurate perception, data collection is conducted on major disasters such as gas, water, and fire in difficult-to-mine coal seams, and geological conditions, environmental factors, and equipment operating status information are evaluated. Through big data modeling, combined with Existing disaster occurrence mechanisms are subjected to cluster analysis and deep learning algorithm calculations to eliminate hazard sources in a timely manner and achieve early identification and warning of hidden dangers, major risks and other unsafe factors such as water, fire, and gas disasters in coal mines.

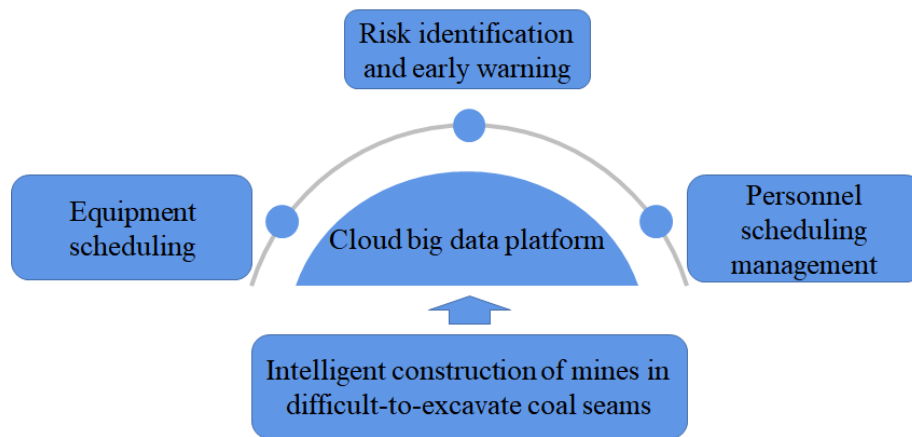


Figure 1: Intelligent architecture for difficult-to-mine coal seams.

At the same time, management should also be innovated accordingly, from human governance to data-oriented coal mine management concepts. Get rid of the existing traditional mine management experience, transfer the management center from labor-intensive to technology-intensive, and build an intelligent mining management experience for difficult-to-mine coal seams that is based on data, safety-oriented, and has the ultimate goal of reducing costs and increasing efficiency. Based on scientific management theory and on the basis of intelligent hardware, we give full play to the directional role of data to achieve active linkage between the difficult-to-mining coal seam perception system, risk identification and early warning system and management system, forming a deep integration of all links in the production process. Scientifically manage safety status. The core of smart safety management of difficult-to-mine coal seams lies in big data. The basic logic is to conduct safety risk assessment, intelligent adjustment, control and management of production factors that appear in each production link of the coal mine, so as to form a comprehensive data information and risk warning system. It is a new type of safety management system with characteristics such as modernization and intelligent management methods. This system is built on the basis of hardware and is highly implementable at the technical level.

The intelligentization of difficult-to-mine coal seams should reduce human intervention in operation links and reduce coal mine production costs. It no longer uses a large number of staff as the necessary communication medium for production equipment and production processes. The coal mine safety guarantee system under the information flow conditions of modern digital mines Intelligence is more prominent. During the production process of difficult-to-mine coal seams, timely information is transmitted to the mine data storage center. After processing through the big data platform, the estimated and early warning information is then transmitted back to the mine. Unmanned decisions are made on the safety hazards of the coal seams, and then the equipment associated with the entire system is contacted. Different situations will enter different states, and early warning judgment will not lag behind. It integrates dynamic information such as equipment, production personnel management, geological occurrence, risk identification and early warning, equipment linkage, etc., and is composed of three layers: perception layer, big data sharing platform, and operation center. Information perception mainly refers to the all-round and multi-dimensional perception of geology, hydrology, disaster indicator information, real-time status of production equipment, etc. that affect the enterprise's production process. It is the basis for data analysis and intelligent decision-making, equipment and personnel scheduling. The big data sharing platform mainly includes the storage and identification functions of a series of data generated during the production process. It screens and cleans massive information and then further processes it. It is the core of the safety assurance system for difficult-to-mine coal seams. It mainly analyzes the available data. Analysis, risk identification and real-time decision-making, etc. However, the corresponding

mine staff are still the main body and perform the overall operation and maintenance of the mine on the basis of high professional capabilities.

Because coal occurrence conditions vary widely, the main processes and technologies for intelligent construction in Shanxi, Shaanxi, Inner Mongolia and other regions are quite different. At the same time, as coal mining goes deeper, the amount of green coal resources available for mining in my country has become more Limited, the mining rate of difficult-to-mine coal seams will gradually increase. Depending on factors such as technical routes and equipment selection, the intelligence of coal mining enterprises shows the characteristics of a hundred flowers blooming, and the level of intelligence varies. Intelligent mining of difficult-to-mine coal seams should be based on "reducing costs and increasing efficiency" and gradually transitioning from the "few people" stage to the "unmanned" stage in coal mines over a long period of time. It should be divided into regions, levels, and levels according to local conditions. It will be promoted step by step in stages, and on the existing basis, intelligent mining solutions for difficult-to-mine coal seams with different characteristics will be truly realized, and ultimately the system will realize independent decision-making and zero risks and accidents in mine production.

3. Key technologies for intelligent mining of difficult-to-mine coal seams

It can be seen from the demand for difficult-to-mine coal seams in coal mines that risk identification and early warning are the absolute core of this system. Taking the "risk" of coal seams with extremely complex conditions as the core, a data-oriented closed-loop system is formed from multi-dimensional information perception to equipment and personnel management and dispatch. The construction of intelligent mining still needs a key technical system with information perception as the basic level, data storage and processing center as the carrier, risk identification and early warning as the core, and equipment scheduling and personnel management as the guarantee. By integrating various sensing devices, data analysis technologies and intelligent algorithms, intelligent management and optimization of the entire coal mining process can be achieved, thereby improving coal mining efficiency, reducing safety risks, and achieving safe and efficient coal mine production.

3.1. Risk identification and early warning

Risk identification and early warning of difficult-to-mine coal seams is a crucial part of coal mine safety management. When faced with difficult-to-mine coal seams with complex geological structures and high safety risks such as gas, timely and accurate risk identification and early warning can effectively reduce the possibility of accidents and ensure the safety of miners and the normal production of coal mines. Key technologies mainly include geological detection technology, gas monitoring and early warning technology, geological disaster early warning technology, and intelligent data analysis technology; geological detection technology uses geological radar, acoustic wave detectors and other equipment to detect the existence of underground rock formations, faults, and coal seams. Get geological information in real time. Combining geological exploration technology and three-dimensional geological modeling technology, the geological structure and rock formation changes of difficult-to-mine coal seams are accurately analyzed and simulated to provide a basis for risk identification; gas monitoring and early warning technology deploys gas sensors, gas drainage equipment, etc. Monitoring equipment can monitor gas concentration, gas emission and other indicators in real time, and conduct real-time monitoring of potential gas explosion risks. Based on sensor data collection and real-time data analysis, a gas explosion risk model is established, and artificial intelligence technology is used to predict and warn gas explosions; geological disaster early warning technology combines geological monitoring data and geological disaster historical data to establish a geological disaster early warning model and predict the roof Provide early warning for

geological disasters such as collapse and ground subsidence. Regular inspections of coal mine areas are carried out through remote sensing technology, drones and other means to promptly discover hidden dangers of geological disasters and improve the accuracy and timeliness of early warnings.

Intelligent data analysis technology is the core of the entire early warning system. Through big data technology and artificial intelligence algorithms, integrated analysis and comprehensive evaluation of monitoring data such as geology, gas, and geological disasters are performed to achieve fusion processing of multi-source data. The system is shown in Figure 2. Establish a risk assessment model to quantitatively assess and predict the risks of difficult-to-mine coal seams through the analysis of historical data and real-time monitoring data, improve the accuracy and reliability of risk identification, and ensure the safe production of miners.

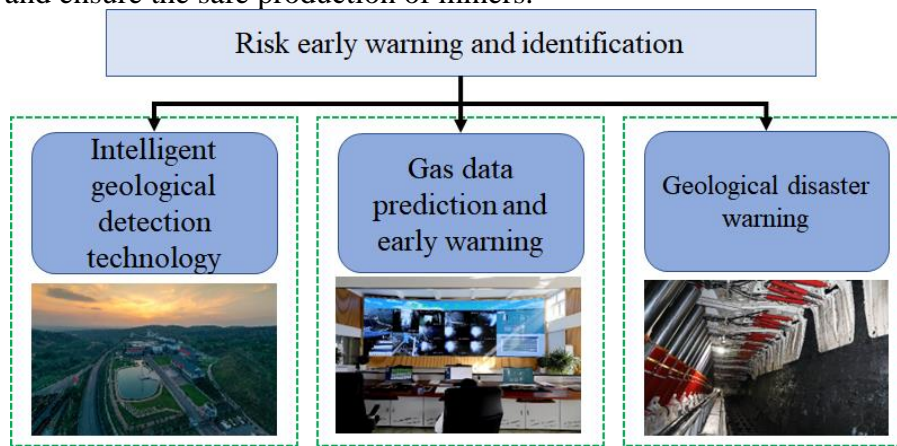


Figure 2: Risk identification and early warning technology architecture.

3.2. Equipment management and scheduling technology

Equipment management and scheduling technology for difficult-to-mine coal seams is a key link in coal mine production. By introducing advanced sensor monitoring equipment and intelligent algorithms, comprehensive management and optimal scheduling of various types of equipment in coal mining operations are achieved. The implementation of this technology includes many aspects: using advanced equipment such as geological radar, laser rangefinders, and cameras to conduct real-time monitoring and data collection of the geological conditions, coal seam thickness, coal seam structure, etc. of the coal mining face. These data are used by the equipment. Management and scheduling provide reliable basic information; with the help of intelligent algorithms and data analysis technology, a large amount of collected data is processed and analyzed to determine the optimal equipment operation path, working mode and parameter settings. By optimizing scheduling, we can improve coal mining efficiency, reduce energy consumption, and reduce waste generation, thereby maximizing the utilization of resources; real-time monitoring and maintenance of equipment status uses sensors to monitor various parameters during equipment operation to achieve real-time monitoring of equipment status. Monitor, diagnose and predict equipment failures and abnormalities through intelligent algorithms, and take maintenance measures in advance to reduce the impact of equipment failures on production and ensure the continuity and stability of production; through the establishment of a remote monitoring system, the monitoring of coal mining Remote monitoring and real-time data transmission of equipment use remote control technology to adjust and control the working status and parameters of the equipment anytime and anywhere, respond to changes in the production site in a timely manner, and ensure safe and efficient production, as shown in Figure 3.

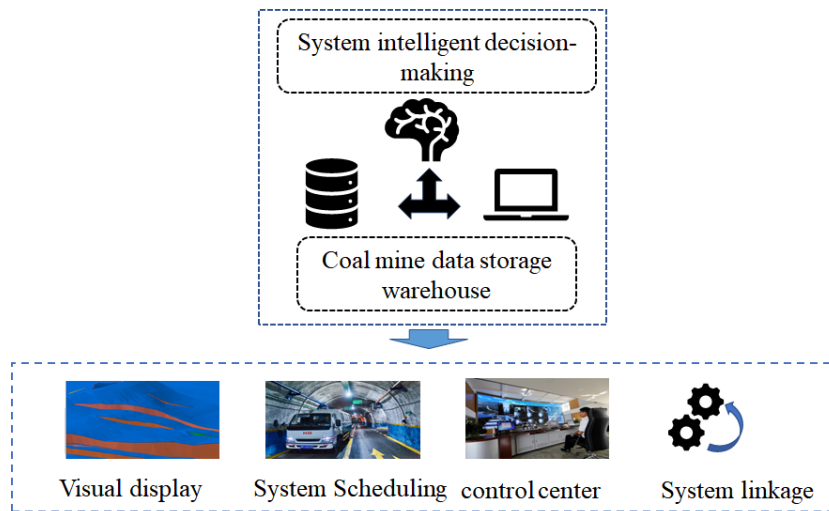


Figure 3: Equipment management and scheduling technology.

The information actions generated by correlating devices with each other through the big data platform, through unified data integration, classify different states. After the data analysis is returned, corresponding responses to different situations need to be made, and each subsystem is integrated. In the initial stage, the identified risks will be presented in the operation center for further verification by managers; with the further improvement of technology, the system can be adaptive and self-adjusting; the intelligent mine production command system of the entire mine will be necessary Control, realize the informatization and scientificization of data collection, production scheduling, decision-making and command of the whole mine, effectively prevent and promptly handle various sudden accidents and natural disasters, and provide effective means for managers to make choices. The traditional single work of each system is upgraded to collaborative scheduling control, and a three-dimensional display interface can be formed, passive query is transformed into active prompt, and efficient flat interaction is achieved. Improve work efficiency and effectively reduce the time wasted in communicating instructions. Equipment scheduling and management technology is an important guarantee for the intelligentization of difficult-to-mining coal seams.

3.3. People management strategy

In the process of moving from general mining and mechanization to intelligence, workers are still an indispensable main part in current mines. Personnel management strategies include establishing an intelligent personnel scheduling system, personnel positioning and safety monitoring, personnel training and skills management, data analysis and decision support, and knowledge management and collaboration. Based on the information returned by the big data platform, real-time monitoring and optimization of personnel scheduling and allocation are achieved, improving work efficiency and resource utilization, tracking and monitoring personnel's work trajectories, timely detecting abnormal situations and ensuring personnel safety; establishing a training system and skills assessment mechanism to improve the professional quality and coping capabilities of mine personnel. The data analysis and decision support system uses big data analysis and artificial intelligence technology to provide decision-makers with scientific basis and predictive capabilities, optimize personnel management strategies and production plans, and improve mine operations. The intelligent level of management enables efficient dispatching, safety monitoring, skill improvement, data analysis and collaborative cooperation to provide comprehensive support for mine safety.

4. Conclusions

(1) Intelligentization of difficult-to-mine coal seams is an indispensable part of mine construction. The connotation and technical characteristics of intelligence are comprehensively discussed. Emphasis is placed on its core elements, including real-time risk identification, equipment linkage, and personnel scheduling, to achieve digital, one-stop and intelligent closed-loop of coal mine risk identification, early warning, and processing.

(2) It expounds the key technical issues that need to be solved in the intelligent construction of difficult-to-mine coal seams, including coal mine risk assessment and early warning technology and smart coal mine system linkage technology, emphasizing the dominant position of workers in the construction and operation of mines.

(3) By elaborating on the key technologies for intelligent mining of difficult-to-mine coal seams, it provides a reference for projects under similar conditions and provides new solutions for subsequent intelligent mine construction.

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