Discussion on coal mine safety production monitoring and communication technology

Zhenchun Ren

Lvliang City Comprehensive Emergency Rescue Detachment, Lvliang, 033000, Shanxi, China

Keywords: coal mine safety; Production monitoring; Communication technology

Abstract: Coal mine safety production monitoring and communication technology is the key to ensure the safe and efficient operation of coal mine. This paper first analyzes the importance of coal mine production safety monitoring, and points out its positive role in preventing accidents, protecting miners' life safety and improving production efficiency. Then, this paper summarizes the status quo of China's coal mine monitoring and communication technology, and finds that there are still problems such as imperfect technical standards, low degree of automation intelligence, and insufficient dynamic real-time monitoring ability. Finally, this paper looks forward to the future development direction of coal mine safety monitoring and communication technology, including accurate personnel positioning, the establishment of mining Internet of things and integrated communication system, the application of ground remote control and life detection technology, and the improvement of major disaster warning.

1. Introduction

Coal mining is a high-risk activity, with various accidents occurring frequently, which seriously threatens the life safety of miners. Perfect production safety monitoring and communication system is an important guarantee to prevent and control coal mine accidents. In recent years, with the development of modern information technology, coal mine safety monitoring and communication technology has made great progress, and has played a positive role in reducing the accident rate and reducing casualties. However, there are still many problems and deficiencies in China's coal mine safety monitoring and communication, and it is urgent to further strengthen the research and development of key technologies and system optimization and upgrading. On the basis of summarizing the current status of the existing technology, this paper analyzes the main problems and puts forward the future development direction, in order to provide references for promoting the progress of coal mine safety production monitoring and communication technology .

2. The importance of mine safety production monitoring

2.1 Prevent all kinds of accidents

Coal mine safety production monitoring system through real-time collection and analysis of all kinds of production data, timely warning and disposal of abnormal situations, can effectively prevent the occurrence of various accidents. For example, through real-time monitoring of key indicators such as gas concentration, ventilation conditions, and equipment operation parameters, potential dangerous factors can be found in time and corresponding measures can be taken to deal with them, thereby avoiding accidents. At the same time, the safety monitoring system can also mine and analyze historical accident data through big data analysis technology, identify the rules and characteristics of accidents, and provide decision support for accident prevention [1]. Advanced coal mine safety monitoring technologies, such as three-dimensional visualization and virtual reality, can realize the panoramic display and simulation of the coal mine production environment, help managers intuitively identify and evaluate various risks, and improve accident prevention and emergency response capabilities.

  DOI: 10.25236/icmmct.2024.007

2.2 Ensuring the life safety of miners

Miners are the main body of coal mine production, and their life safety is the core goal of coal mine safety management. The perfect production safety monitoring system can realize the real-time monitoring and management of the location, behavior and physiological state of miners, so as to ensure the personal safety of miners in the complex and changeable underground working environment. For example, the personnel positioning system based on RFID, UWB and other technologies can grasp the location information of each miner in real time, and warn and guide miners according to the preset danger area range to prevent miners from stranding into dangerous areas. At the same time, by monitoring the physiological parameters of the smart wearable devices worn by miners, such as heart rate, blood pressure, body temperature, etc., the physical abnormalities of miners can be found in time and rescue measures can be taken in time. In an emergency, the complete communication system and emergency broadcast system can ensure timely communication between miners and the ground dispatch center, and timely evacuation from the dangerous area according to the command, so as to maximize the safety of miners.

2.3 Improve coal mine production efficiency

Coal mine safety production monitoring system is not only a powerful tool for safety assurance, but also an important means to improve coal mine production efficiency. Through the real-time monitoring and optimal scheduling of mining equipment, transportation system, ventilation system and other production links, the efficient cooperation and stable operation of coal mine production system can be realized. For example, the industrial Internet and big data analysis technology are used to collect and analyze the operating parameters of shearer, boring machine, scraper conveyor and other equipment in real time, so as to improve the equipment utilization rate and production efficiency by optimizing the working state and running track of the equipment [2]. At the same time, through dynamic simulation and optimization of coal mine production scheduling process, such as optimization of mining area layout, roadway excavation sequence, production planning, etc., can realize the optimal operation of coal mine production system, improve coal mine production efficiency and economic benefits. Advanced automated control and remote monitoring technology can reduce manual intervention and unproductive labor, improve production efficiency and continuous operation level.

2.4 Reduce coal mine operating costs

A perfect mine safety production monitoring system can effectively reduce coal mine operating costs by optimizing the production process and improving the efficiency of resource utilization. For example, through intelligent control and optimization of coal mine ventilation system, real-time adjustment of air volume and wind direction according to production conditions and personnel distribution can ensure the working environment of miners, while reducing ventilation energy consumption and operating costs. For another example, through the comprehensive monitoring and energy efficiency management of the coal mine power supply system, the operation mode and load distribution of the transformer and distribution equipment are optimized, the energy utilization efficiency is improved, and the energy waste and loss are reduced. At the same time, the use of advanced equipment condition monitoring and fault diagnosis technology, the whole life cycle management of coal mine mechanical and electrical equipment, through condition overhaul and predictive maintenance, extend the service life of equipment, reduce equipment maintenance costs. Advanced coal mine safety monitoring system can also achieve system optimization and cost reduction by optimizing the production process and reducing leakage.

2.5 Promote the intelligent development of coal mines

Mine safety production monitoring system is the important foundation and support of mine intelligent construction. With the rapid development and deep application of new generation information technologies such as artificial intelligence, Internet of Things, and big data, the traditional coal mine safety monitoring model is being transformed and upgraded to an intelligent

and unmanned direction. By building an intelligent perception network covering the whole system of coal mining, transportation, ventilation and drainage, and using machine learning algorithms and knowledge models to conduct real-time analysis and intelligent decision-making on massive production data, adaptive optimization control and unattended control of coal mining process can be realized [3]. At the same time, based on virtual reality, augmented reality and other technologies, the coal mine digital twin model is constructed to realize the panoramic display and real-time simulation of the coal mine production process, and provide intuitive and efficient human-computer interaction for intelligent decision-making, prediction and early warning, emergency command, etc. The intelligent coal mine safety monitoring system can promote the transformation of coal mining from experience-driven to data-driven, from manual control to autonomous intelligence, and lead the coal mining industry to the intelligent development direction of high quality, high efficiency and high safety.

3. Current status of coal mine monitoring and communication technology in China

3.1 Technical standards are not perfect

At present, China's coal mine safety monitoring and communication technology has made great progress, but there are still many deficiencies in technical standards and specifications. On the one hand, the coverage of existing technical standards is not comprehensive enough, and there is a lack of unified and authoritative standards for some key technical fields, resulting in differences in technical specifications and interface protocols adopted by different coal mining enterprises, and it is difficult to interconnect and share information. On the other hand, the update speed of existing standards is relatively lagging, and it is difficult to adapt to the rapid development of new technologies and new applications. For example, in the emerging technology fields such as the Internet of Things, mobile communication and artificial intelligence for the coal mining industry, there is still a lack of mature and complete technical standards system, which restricts the large-scale application and industrial development of related technologies.

3.2 Low degree of automation and intelligence

At present, the automation and intelligence level of China's coal mine safety monitoring system is still generally low, the proportion of manual operation and experience judgment is large, and the systematization and integration degree of data collection, transmission, processing and application needs to be improved. In the data acquisition process, some sensors are not high in accuracy, reliability is not strong, easy to be disturbed by harsh environment, and the accuracy and continuity of data acquisition is difficult to ensure. In terms of data transmission, due to the complex and changeable underground environment of coal mines, the real-time, reliability and coverage of data transmission still face challenges [4]. In data processing and application, most coal mine safety monitoring systems are still mainly based on data collection and display, lack of intelligent data mining and auxiliary decision-making functions, and can not realize the adaptive optimization control of the production process. The uncertainty of manual analysis and judgment makes it difficult to guarantee the response speed and disposal effect of the system to the abnormal situation.

3.3 Dynamic monitoring and unattendance are not implemented

At present, most coal mine safety monitoring systems are still based on static monitoring at fixed time points, and it is difficult to realize real-time perception and continuous monitoring of dynamic changing environment. For example, in complex and changeable areas such as coal face and driving face, parameters and equipment status are constantly changing with the advancement of mining activities, and traditional static location monitoring is difficult to fully reflect the dynamic change process, and it is easy to appear monitoring blind areas and dead corners. At the same time, the behavior supervision of miners also mainly relies on manual inspection and spot checks, which is difficult to achieve all-weather and full coverage of continuous monitoring. In the complex

underground working environment, the dynamic monitoring of equipment operation status, miner location and behavior is very important to ensure the safety of production.

4. Future development of coal mine safety production monitoring and communication technology

4.1 Personnel accurate positioning technology

With the rapid development of the Internet of Things, mobile communication and other technologies, the precise positioning technology of coal mine personnel will continue to make breakthroughs, providing a more powerful guarantee for the safety of miners. The future positioning technology will comprehensively utilize a variety of wireless communication technologies such as UWB and 5G to build a three-dimensional, full-coverage underground positioning network. With the help of Internet of Things technologies such as sensors and intelligent terminals, real-time positioning and trajectory tracking of each well operator can be realized with an accuracy of up to meters or even higher [5]. At the same time, combined with the underground three-dimensional ore body model and virtual reality technology, the spatial position relationship between miners and roadway, goaf and danger sources can be visually presented, and miners can be warned and guided according to the preset safety distance, effectively preventing personnel from crossing the boundary and straying into dangerous areas. In an emergency, rescuers can quickly locate people in distress and combine optimal path planning to achieve accurate rescue. In addition, the behavior analysis and anomaly detection based on location big data can timely detect abnormal situations such as violations, lost, and retention of miners, and further improve the safety control effect.

4.2 Establishment of mining Internet of Things system

The development of Internet of Things technology provides a new way to realize the real-time perception and active prevention and control of all elements, the whole process and the full range of coal mines. In the future, the coal mine will establish a ubiquitous interconnection and intelligent sensing mining Internet of Things system to achieve real-time monitoring and data aggregation of all elements such as underground environmental parameters, equipment status, and personnel behavior. By deploying temperature and humidity, gas, carbon monoxide, wind speed and other sensors on a large scale in key areas such as mining faces, transportation tunnels, and ground structures, and integrating them with video monitoring, positioning systems, etc., a comprehensive and dynamic intelligent perception network is constructed. At the same time, by utilizing IoT identification technologies such as RFID and QR codes, we can achieve refined management of electromechanical equipment, material tools, safety equipment, etc., forming a visual control chain throughout the entire lifecycle. The application of emerging information technologies such as edge computing and artificial intelligence enables the real-time analysis and intelligent processing of massive iot data at the underground end, and realizes the "end-edge-cloud" collaborative calculation and closed-loop application of monitoring data. The establishment of the mining Internet of Things system is expected to fundamentally improve the intelligent and refined level of coal mine safety production monitoring.

4.3 Establish integrated communication technology and system in coal mine

A safe and efficient coal mine communication system is the key foundation for ensuring real-time transmission of monitoring data and emergency command and dispatch. In the future, coal mines will accelerate the construction of integrated communication systems that integrate wired, wireless, ground, and underground to meet the diverse communication needs of coal mine safety production and emergency rescue. On the one hand, by adopting wired communication technologies such as fiber optic and industrial Ethernet, a high-speed and reliable backbone communication network for mining is constructed, achieving broadband interconnection and data sharing both above and below the mine. On the other hand, by comprehensively utilizing wireless communication technologies such as 5G and WiFi6, a flexible and efficient mobile communication

network is constructed to ensure seamless connection and real-time communication between underground workers and mobile devices. At the same time, we are developing intrinsically safe communication terminals and intelligent communication equipment for mining to meet the special environmental requirements of coal mines, such as explosion-proof, waterproof, dustproof, and shock resistant. In addition, based on an integrated communication platform, establish unified voice, video, and data command. Scheduling system, achieving cross departmental and cross system collaborative operations and emergency linkage. Advanced integrated mining communication technology and systems will provide high-speed, reliable, and flexible information transmission and sharing channels for coal mine safety monitoring and production management, effectively supporting coal mine safety production and emergency rescue work.

4.4 Introduction of ground remote control technology

With the continuous progress of automation and information technology, the application prospect of ground remote control technology in coal mine field is increasingly broad. By building a centralized monitoring center on the ground and using technologies such as video transmission and data communication to achieve remote monitoring and control of underground mining equipment and transportation systems, the number of front-line operators can be minimized and personnel safety risks can be reduced. At the same time, the centralized monitoring center can gather and analyze massive data from various sensors and monitoring systems in the mine, and optimize decision-making and predictive maintenance of production equipment and process flow with the help of big data analysis, artificial intelligence and other technologies, so as to improve the level of production automation and intelligence [6]. In addition, in the emergency treatment of accidents, the ground rescue command center can rely on digital twins and other technologies to achieve real-time perception and situation analysis of the accident scene, and remote dispatch and command rescue equipment such as unmanned robots to carry out accurate and efficient rescue operations. The establishment of ground remote control and centralized monitoring mode will certainly promote the revolutionary change of coal mining mode and achieve the dual goals of reducing personnel and improving efficiency and intrinsic safety.

4.5 Improve life detection technology

At present, although the coal mine emergency rescue technology has been greatly developed, it is still faced with many technical problems to detect the vital signs of trapped people quickly and accurately in the accident rescue. In the future, with the continuous emergence of new technologies in the fields of the Internet of Things and biomedics, coal mine life detection technology is expected to make new breakthroughs. On the one hand, wireless sensor network technology can be used to develop portable life detection equipment with small size, long endurance and strong anti-interference ability, so as to achieve remote and continuous monitoring of vital signs such as heart rate and breathing of trapped personnel. On the other hand, by integrating various physical detection technologies such as sonar, electromagnetic, and infrared, a three-dimensional imaging and multi-sensor fusion technology is established to achieve precise positioning of trapped individuals in complex collapsed environments. At the same time, we will vigorously develop intelligent identification technology based on biometrics, and realize rapid and reliable identification through the collection and comparison of individual characteristics information such as faces, fingerprints and genes of trapped people. Advanced life detection technology can minimize the search and rescue time of trapped people, and win more opportunities for saving precious lives.

4.6 Application of major disaster warning technology

Major and major disasters are the biggest risks threatening the safety of coal mine production, and it is very important to do a good job in early warning and front-end prevention and control of disasters. In the future, with the continuous progress of monitoring means and the increasingly rich accumulation of data, major disaster early warning technology will develop in a more intelligent and accurate direction. Through large-scale deployment of iot sensors, a real-time dynamic monitoring network covering the entire mining area is built, and multi-source heterogeneous data

such as surrounding rock stress, gas content and hydrogeology are continuously obtained. On this basis, artificial intelligence technologies such as big data analysis and machine learning are comprehensively applied to establish physical models and knowledge maps of the occurrence and evolution of disasters, excavate the precursor information and evolution laws contained in historical disaster cases, and realize early identification and dynamic warning of disasters. At the same time, new generation information technologies such as cloud computing and edge computing are used to conduct hierarchical analysis and multi-scale correlation of massive monitoring data, forming a defense system in depth from single point monitoring, regional monitoring to global situational awareness. In addition, the application of new technologies such as virtual simulation and augmented reality can intuitively present the occurrence process and impact scope of disasters, providing intuitive and accurate data support for disaster early warning and emergency decision-making. The new model of early warning and prevention of major disasters will greatly enhance the initiative and foresight of coal mine disaster management.

5. Conclusion

Coal mine safety production monitoring and communication technology is the key support to ensure the safe and efficient operation of coal mine. China's coal mine safety situation is still grim, we must comprehensively strengthen the construction of safety production monitoring system, and continue to promote the innovation of monitoring and communication technology. In the future, efforts should be made to overcome key technologies such as personnel accurate positioning, mining Internet of things, integrated communication, ground remote control, life detection, and major disaster early warning, and establish a comprehensive three-dimensional intelligent security monitoring system. At the same time, it is necessary to speed up the construction of coal mine safety production informatization standard system to provide institutional guarantee for the promotion and application of new technologies.

References

[1] Yang Qingfeng. Analysis on coal mine safety monitoring and communication technology [J]. Inner Mongolia Coal Economy, 2023, (16): 91-93.

[2] Liu Ziyuan. Monitoring and Communication technology of Coal mine safety production [J]. Mining Equipment, 2023, (07): 22-23.

[3] Xu Xiaonan. Discussion on monitoring and communication technology of coal mine safety production [J]. Mining Equipment, 2022, (04): 163-165.

[4] Ding Yan. Analysis of safety monitoring and communication technology in coal mine [J]. Mining Equipment, 2021, (04): 182-183.

[5] Liu Xinying. Development of Coal mine safety monitoring and Communication Technology [J]. Electronic Test and Control, 2018, (Z1): 150-151.

[6] Jiang Rui. Study on Coal mine safety monitoring and communication technology [J]. Electronic World, 2017, (16): 17