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## Development Status and Prospect of Intelligent Gas Extraction in Coal Mine

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**Abstract:** At the same time, in order to promote the development of intelligent gas extraction technology and improve the safety and security ability of coal mines, from the perspective of less manpower or unmanned gas extraction in the whole process of gas extraction, the five characteristics of intelligent gas extraction such as accurate perception, self-decision-making, self-execution, adaptive and self-learning are expounded, and the intelligent design of extraction drilling, drilling-penetration-sealing robot, intelligent regulation and control of extraction system, etc. The key supporting technologies of intelligent gas extraction were discussed in four aspects, including intelligent diagnosis of extraction system, the trend of key technologies developing in the direction of precision, efficiency and intelligence was analyzed, and solution strategies such as differentiated intelligent design of extraction drilling and multi-layer progressive dynamic evaluation of extraction standards were proposed, and typical application cases such as centralized control and collaborative operation of automatic drilling rigs such as "three people and five sets in a group" of Xieqiao Coal Mine were given, which were used to achieve "carbon peaking" and "carbon peaking" as soon as possible in the field of coal mine gas extraction. The "carbon neutrality" target provides a useful reference.

**Keywords:** "Carbon peaking", "carbon neutrality", intelligent extraction of coal mine gas, automatic and efficient

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### 1. Introduction

In September 2020, at the 75th session of the United Nations General Assembly, China put forward the goal of "carbon peak" by 2030 and "carbon neutrality" by 2060. This is a major strategic decision made by China based on its responsibility to promote the building of a community with a shared future for mankind and the inherent requirement of achieving sustainable development, so as to address global warming and accelerate global greenhouse gas emission reduction actions. In addition to the well-known carbon dioxide, greenhouse gases also include methane, nitrous oxide, sulfur hexafluoride, etc., the international community will collectively refer to them as non-carbon dioxide greenhouse gases, of which methane as the second largest greenhouse gas after carbon dioxide, its warming potential is 84 times that of carbon dioxide. For a long time, gas has been the main threat to the safety production of coal mines in China, and the main component of gas is the strong greenhouse gas methane. According to statistics, methane emissions in China's coal mining process account for about 40% of the country's total methane emissions. However, unlike other greenhouse gases, methane is also a new type of clean energy and high-quality chemical raw materials, reducing methane emissions not only has environmental benefits, but also can produce certain economic benefits. Therefore, strengthening coal mine gas extraction and utilization is not only the need of coal mine safety production, but also the need of the transformation and development of the coal industry under the goal of "double carbon".

Coal is China's basic energy and an important industrial raw material, and the Central Economic Work Conference held in December 2021 clearly pointed out: "We must base on the basic national conditions of coal,



and do a good job in clean and efficient use of coal." Although the proportion of coal in total energy consumption continues to decline, coal will still be the "ballast stone" and "stabilizer" of China's energy supply. In coal mine safety production, coal seam gas extraction is the fundamental measure to solve gas disasters and eliminate safety hazards, and vigorously promote the application of intelligent extraction and other precision gas extraction technology, which can not only ensure coal mine safety production but also meet the strategic goal of "carbon peak carbon neutrality".

With the vigorous development of the new generation of information technologies such as the Internet of Things, big data, cloud computing, industrial Internet, 5G and artificial intelligence, and their wide penetration in traditional fields, a mass technological revolution with intelligence as its main feature has been triggered, which is promoting the transformation and upgrading of traditional industries [1]. In the context of the current intelligent era, the intelligent coal mine represents the development direction of the advanced productivity of the coal industry, helps to speed up the solution of the contradictions and problems in the coal industry, promotes the transformation and upgrading of the coal industry, and is the core technical support for the high-quality development of the coal industry [2-3]. As a solution to gas disaster in coal mine, intelligent gas extraction will become the key technology to solve the problem of gas disaster prevention in deep mining, improve the safety level of coal mine production, and realize efficient extraction.

## **2. Research Status of Intelligent Gas Extraction**

At present, some scholars in our country have explored and studied the intelligent gas extraction technology in coal mine, and achieved certain results. For example, in terms of extraction pipeline and system control, Wang Chunguang [4-5] analyzed the development trend of coal mine gas extraction, proposed intelligent extraction ideas, and developed intelligent extraction and linkage devices. Zhou Fubao et al. [6] put forward the principle of intelligent gas extraction based on the principle of safety and efficiency, established the parameter optimization model of the extraction pipe network and the optimization strategy of the extraction system, developed the intelligent gas extraction system, and realized the automatic adjustment of pump station speed and pipeline valve opening. Zhu Zhao et al. [7] adopted the PLC intelligent control technology to realize the intelligent control of the electric control valve of the extraction pipeline. Li Jianwei et al. [8] developed an intelligent control system of unattended gas pumping pump station based on WinCC. In terms of intelligent drilling of extraction borehole, Shi Zhijun et al. [9] put forward the development approach of intelligent drilling on the basis of summarizing the status quo of coal mine drilling technology. Wang Qingfeng et al. [10] summarized the technical achievements and shortcomings of intelligent drilling for gas extraction, and proposed the development of intelligent drilling technology and equipment from the aspects of autonomous perception, intelligent control and autonomous navigation. The research institutions [11-12] represented by China Coal Science and Technology Group Chongqing Research Institute Co., LTD. (referred to as "Chongqing Research Institute") and China Coal Science and Technology Group Xi 'an Research Institute Co., LTD., have respectively developed automatic drilling equipment with the functions of automatic drilling pipe loading and unloading, automatic drilling, remote control and intelligent anti-stuck drilling, and achieved good field application results. In general, the research of intelligent gas extraction technology in China mainly focuses on the automatic drilling of extraction holes and the automatic control of extraction systems, and the whole is still in the initial stage.

## **3. Connotation And Characteristics of Intelligent Gas Extraction**

### **Connotation of intelligent gas extraction in coal mine**

Intelligent coal mine gas extraction is an important part of intelligent coal mine, which fully integrates information, automation and intelligent technology into coal mine gas extraction, and can independently complete the whole set of gas extraction operations from extraction drilling design to extraction standard evaluation in the case of little or no intervention, so as to achieve safe, efficient and economic gas extraction. The acquisition and application of information related to gas extraction, such as gas geology, drilling construction and extraction equipment working conditions, has reached an advanced level of knowledge, and modern information technologies such as mining Internet of Things, industrial Internet, big data, cloud computing and artificial intelligence are deeply integrated with gas extraction technology. The gas extraction



equipment is endowed with the ability of accurate perception, independent learning, independent correction, independent decision-making and independent control. In the case of no intervention, it can automatically adapt to the complex and changeable coal mine conditions and operating environment, and find the best solution and way, so as to complete the independent operation of the whole process of gas extraction.

#### **Early Warning of Mine Gas Disasters Based on Statistical Analysis**

The early warning of mine gas disasters based on statistical analysis [7] is to take whether the gas concentration data conforms to the normal distribution as an indicator of the early warning of gas disasters, and to analyze the abnormal eigenvalues of gas concentration by example. The early warning method first processes the 48 groups of gas concentration data monitored underground, and uses Matlab software for statistical analysis as the basis for statistical analysis, and adopts D inspection and W inspection for inspection. Using a 95% confidence interval, when the data is significantly level  $>0.05$ , accept the hypothesis and consider that the set of data conforms to the normal distribution. The results show that there are 46 data sets that conform to the normal distribution. The use of statistical analysis method to analyze the gas concentration is a reasonable and easy early warning method. When the monitoring data of the gas concentration on the work surface begins to deviate from the normal distribution, it may be a sign of abnormal gas gushing, and timely measures should be taken.

#### **4. Characteristics of Intelligent Gas Extraction in Coal Mine**

The intelligent characteristics of intelligent equipment are mainly reflected in the autonomous operation ability of the equipment [13], that is, it can accurately perceive the external environment information and its own operating state information, and form accurate judgments and optimized decisions through the analysis and understanding of the perceptual information, so that the decision can be effectively executed, so that it can automatically adapt to changes in environmental conditions and independently complete the scheduled tasks. Therefore, it is considered that intelligent gas extraction should have the following five characteristics: first, it has the ability to dynamically, sensitively and accurately perceive and acquire all kinds of information such as gas extraction conditions, underground working environment, equipment and system status; Second, it has the ability to analyze, process, understand and learn all kinds of perception information to form judgment conclusions, solutions or operational decisions related to gas extraction scenarios, such as the drilling layout scheme in the extraction drilling design scenario, the drilling rig operation decision in the drilling construction scenario, and the judgment conclusions on whether the extraction standard is reached or not in the evaluation scenario. Third, it has the ability to automatically implement plans and decisions, that is, it can effectively implement solutions and accurately make control actions according to operational decisions; Fourth, it has the ability of automatic coordination of various uncertain factors affecting gas extraction, and can automatically adapt to complex and changeable coal mine geological conditions and extraction operation environment. Fifth, it has the ability of self-learning and self-evolution, which can automatically optimize and iteratively update indicators, methods, models and knowledge, and constantly improve the analysis ability and decision-making level of gas extraction

#### **Key Technology and Prospect of Gas Extraction in Coal Mine**

##### **Intelligent design of extraction boreholes**

Borehole design is the main basis of drilling construction, and the scientificity and rationality of borehole design directly affect the difficulty of drilling construction and the size of the project, as well as the play of the extraction efficiency in the later stage. The design of extraction drilling hole must be comprehensively considered from various factors. It is a complex decision-making process that is limited by various factors such as coal seam gas geological elements, drilling construction environment, drilling tool performance, etc., and needs to balance various requirements such as gas extraction standard, drilling construction difficulty, drilling project size, etc., so that the drilling layout scheme can achieve overall optimization state.

At present, most coal mine gas extraction drilling design is mainly manual, in addition to the workload, time and effort, there are many problems: first, the drilling design basis is unreasonable, in addition to the gas geological conditions are not accurate enough, the effective extraction radius of the drilling and other key parameters are mainly determined by test or experience, there are static, inaccurate and other problems; Secondly, the drilling design is not fine enough, the entire extraction area is designed according to the same conditions, and the differences of coal seam gas geological conditions at different locations in the region, the connection of the



three parts of pumping, excavating and mining, and the length of gas pre-extraction time are not fully considered. The spacing of all drilling holes is the same, and the design of one hole is not achieved, which is easy to cause the layout of drilling holes to be too sparse or too dense. It leads to problems such as poor extraction effect, sub-standard extraction, increased drilling projects and tight mining replacement. Therefore, it is the development trend of intelligent design of gas extraction borehole to carry out research on differentiated intelligent design technology of gas extraction borehole, realize targeted automatic design of each borehole, make borehole layout reasonably match with extraction conditions and extraction needs, and improve the degree of refinement of drilling design.

### **Intelligent control of pumping system**

Coal mine production is a process of dynamic change, and the gas extraction capacity and pumping working conditions required at different times and places are different, so the gas extraction system needs to be dynamically regulated. Through the coordination of the gas extraction pump speed and the valve opening at different points of the extraction pipeline, The pumping capacity and working environment provided by the gas pumping system at each pumping site match with the actual demand, so as to pump gas economically, efficiently and safely.

After years of development, gas extraction systems have been established in almost all high gas and coal and gas outburst mines in our country. However, because the pumping system of some mines was not formally designed at the beginning, or the production conditions of coal mines have changed greatly for a long time, there is a mismatch between the capacity of pumping pump station and the demand of mine pumping, and there is insufficient or excess capacity of pumping station. In addition, the extraction management is not in place, and the drilling holes or pipelines with low concentration and small extraction volume are not closed in time, resulting in the waste of extraction capacity resources. The adjustment of pumping pipeline is not reasonable, and the negative pressure and flow rate are not reasonably matched, which can not meet the requirements of pumping conditions at various points. The gas extraction condition in the gob is unreasonable, the air pressure is not matched with the working face, and the negative pressure and flow are too large, which causes the spontaneous ignition in the gob. The unreasonable control of gas extraction system seriously affects the effect of gas extraction, leading to high energy consumption, low efficiency, poor effect and insecurity.

Water ring vacuum pump [14] is generally used in China's coal mine gas extraction system, its speed is fixed, and the amount of extraction depends on the extraction condition. In recent years, in order to meet the needs of pumping under different working conditions, the frequency converter has been gradually applied to pumping pump stations, and the valve of pumping pipeline has gradually realized automatic adjustment, laying a foundation for intelligent regulation of gas pumping system [15]. However, the gas extraction system is a complex fluid network system. At present, the accurate adjustment method of the complex pipe network pumping condition has not been effectively solved, and the evaluation method of the rationality of the gas extraction system operating condition also needs to be studied. Therefore, on the basis of frequency conversion regulation of extraction pump and automatic regulation of pipeline valves, technologies such as modal learning, pattern recognition and rule learning are fully adopted to break through technical problems such as determination of reasonable working conditions of gas extraction and precise regulation of complex pipe networks, so as to achieve independent and accurate regulation of pump speed and valve opening, and improve the rationality, economy and safety of the operation of the extraction system. It is the development trend of intelligent control technology of gas extraction.

In recent years, the research team represented by Chongqing Research Institute and China University of Mining and Technology has studied the automatic control technology of gas extraction system. Based on the gas extraction monitoring data, Chongqing Research Institute analyzed the operation status of the pipeline network through simulation, and remotely adjusted the opening of the pipeline valve. In Shanxi Holxinhe Coal Mine, the average volume fraction of gas extraction was increased from 25% to 45%, ensuring the safe and efficient operation of the extraction system. Zhou Fubao et al. [6] developed an intelligent regulation valve based on the Internet of Things, which continuously sensed pipeline gas temperature, methane concentration, negative pressure and other parameters, and uploaded it to the cloud storage, which could monitor and control gas extraction through computer web pages and mobile phone clients.



### Intelligent diagnosis of gas extraction system

The gas extraction system has the possibility of pump station failure, pipeline blockage or gas leakage during operation. The intelligent gas extraction system should have the ability of self-diagnosis, timely find the defects or hidden dangers of the extraction system itself, and automatically take measures to deal with them. At present, the on-line monitoring and fault diagnosis of pumping pump have been realized. Through the monitoring and analysis of the negative pressure, flow rate, water level, shaft temperature and vibration of pumping station, the fault of pumping station can be automatically alarmed. However, research progress is relatively slow in the automatic diagnosis of clogging, gas leakage and other faults in extraction lines. Based on the simulation and analysis of the operation state of the pumping pipe network, Chongqing Research Institute automatically identifies and alarms the pipeline faults according to the established fault identification model, but the accuracy needs to be improved. Therefore, it is necessary to develop automatic online fault diagnosis technology for extraction pipeline, fully integrate multi-source information such as extraction monitoring, inspection and status monitoring of extraction ancillary facilities, adopt big data analysis method to study the big data evolution characteristics of various faults, establish data-driven fault identification indicators and models, and develop intelligent diagnosis platform for extraction pipeline network. It is the development direction of fault diagnosis technology of extraction system to realize intelligent fault type determination and accurate fault location.

### 5. Conclusion

Under the background of China's "14th Five-Year Plan" and the construction of smart coal mine, intelligent gas extraction in coal mine will become the technical key to solve the problem of gas disaster prevention in deep mining and improve the safety level of coal mine production, and is an important part of smart coal mine. At present, the intelligent level of coal mine gas extraction technology and equipment is still very low, and the whole is in the initial stage. It is urgent to integrate modern information technology into the field of coal mine gas extraction, and gradually realize the information, automation and intelligence of gas extraction. Facing the application scenarios of coal mine gas extraction drilling design, drilling construction, coal seam anti-reflection, drilling sealing, extraction system control and maintenance, extraction standard evaluation, etc., the mining Internet of Things, big data, cloud computing, coal mine 5G, artificial intelligence and other technologies are fully adopted. Breaking through key technologies such as dynamic transparent gas geology, intelligent drilling design, drilling-sealing and pumping integrated robot, independent control and fault diagnosis of pumping pipe network, intelligent evaluation of pumping standards, etc., forming automation and intelligent equipment and systems with accurate perception, independent learning, independent decision-making, independent control and automatic adaptation capabilities. To realize the whole process of gas extraction less or even unmanned operation is the development direction of intelligent gas extraction, and it is also an important development direction for China to achieve the goal of "double carbon" in the field of coal mine gas extraction.

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