

Research on Scientific Gas Extraction Technology Based on Engineering Thinking

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Abstract: Due to the complex and changing regional tectonics of the coal-bearing basins in China, it makes it more difficult of gas extraction; in addition, it seriously affects the gas governance effect of the single way of hole arrangement and other problems including the poor quality in hole drilling and sealing, hole collapse, downward hole ponding and air leakage of pipe network and so on. In view of this, it has proposed to establish spatial digital model by making use of the theory of transparent space geophysics to precisely identify and divide the regional tectonics. Based on engineering thinking, it depends on artificial intelligence, big data cloud computing technology and equipment in multi-factor identification method for scientific investigation of gas extraction radius, hole-drilling design, construction, management and extraction standard evaluation and other comprehensive control. It aims to realize scientific, procedural and precise packaged technology for gas extraction. This technology has filled the gap of scientific packaged gas extraction technology application in China.

Keywords: Artificial intelligence, Big data cloud computing, Dynamic extraction standard evaluation, Precise scientific gas extraction.

1. Introduction

For a long time, gas disaster has been one of the main reasons restricting coal mine safety production in China. Especially with the rapid development of the national economy and energy strategy deployment adjustment, coal mining is gradually shifting to the west and deep ground, which causes more serious gas disasters [1]. So far, it mainly depends on gas extraction in gas governance. With the development of scientific and technological progress, it has improved the packaged gas extraction technology and equipment, which has effectively controlled part of mine gas disasters. But there still remains a series of problems in many mine gas extraction designs and construction aspects: (1) unclear regional structure detection; (2) single hole-drilling method; (3) poor quality of hole sealing; (4) serious hole collapse of soft coal seam; (5) downward hole ponding; (6) air leakage of pipe network and other problems, which seriously affect the gas governance effect[2-6]. So far, the scientific and technological development in artificial intelligence is changing with each passing day, while the mine digitization is also improving benefited by the high-tech development. How to make use of artificial intelligence to establish precise scientific gas extraction will become a new trend in the future digital mine construction and realizing highly effective gas disaster governance.

2. Precise Scientific Packaged Gas Extraction Technology System

For the problems existed in the current gas extraction process, it has proposed scientific gas extraction technology system based on engineering thinking. Regional tectonics identification: based on the theory of transparent space geophysics, it can establish spatial digital model. By making use of the precise modern geological prospecting technology and equipment, it can precisely identify and divide the enormous mine geological structure information, coal seam

gas reserves and emission law features according to the overall form of the regional structure, regional sedimentary environment evolution and features, regional structure evolution and features, regional thermal evolution history and hydrocarbon generation history. Scientific gas extraction design: after full consideration of the dynamic influence of the disturbance factor in mining engineering to coal and gas outburst, it can depend on artificial intelligence technology and big data cloud computing in multi-factor identification method to establish intelligent management system for scientific gas extraction. With automatic fitting of gas extraction law and stepping-type computing of the coal seam gas extraction radius in gas extraction radius investigation, it can finally intelligently generate the optimization design for scientific gas extraction. Procedural control in hole-drilling construction: depending on highly effective “Two blockings and one pouring” pressure hole sealing technique and high-performance matching mining-use hole sealing materials, it can improve the hole sealing quality. By making use of modern online supervision equipment to precisely control the hole-drilling track and automatically identify the blank zones which can be patched and repaired to guarantee the hole-drilling quality.

Online evaluation for extraction standard: based on supervision data, it can timely extract the supervision data of gas extraction for intelligent analysis to automatically online evaluate the gas extraction effect in each section. Scientific, procedural and precise management technology system for gas extraction from precise identification and division of regional tectonics, gas reserves law and precise control of extraction radius, the optimal scientific gas extraction design automatically generated based on artificial intelligence technology and procedural control in hole-drilling construction to online intelligent evaluation of extraction standard can lay the foundation to realize safe and highly effective multi-resource precise coordination and safely continuous mining for the future digital sensing mines.

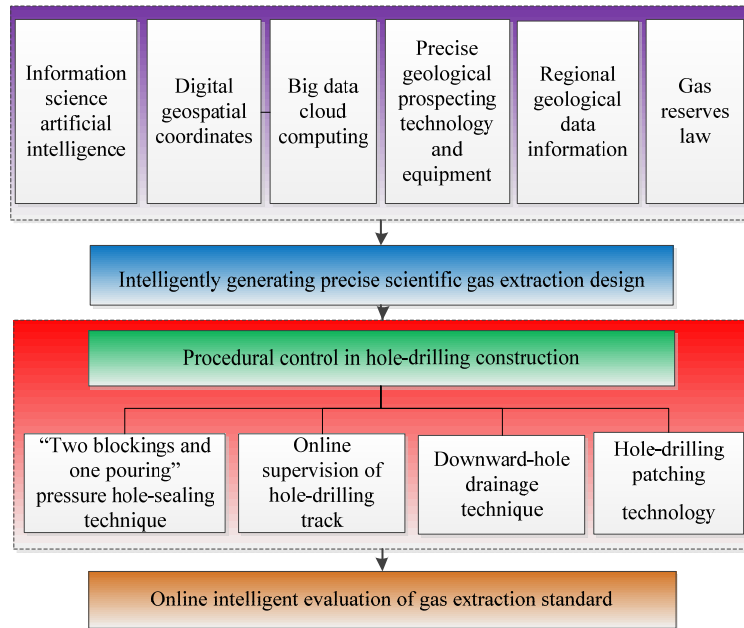


Figure 1. Precise Scientific Gas Extraction Technology System

3. Scientific Gas Extraction Design

3.1. Precise Identification and Division of Regional Tectonics

The history of coal mining development indicates: although amazing achievement has been made in geological prospecting, highly-effective coal mining, mining disaster warning and prevention theories, technologies and equipment and others, mining disasters, especially the mechanism of coal and gas outburst and unclear judgment of geological structure, unknown disaster threats and unsolved key technological problems and others, are the main reason for the accidents [7-10].

Further developing people’s cognition of the earth, the

technology of transparent space geophysics has also provided scientific basis for traditional coal mining toward precise and quantitative intelligent decision transformation. By integrating the geographic space service technology, Internet of Things+ and numerical simulation with advanced high-power radio wave perspective, seismic reflection probing technology and highly precise geological radar and other dynamic probing technologies and equipment, it can realize precise identification and division of regional tectonics to establish dynamic gas geological digital information platform with perspective function (as shown in Fig. 2). It can then realize simulation inversion method for coal seam and gas reserves to complete precise determination of disaster factors including fault, collapse column, wrinkle, coal seam and gas and others.

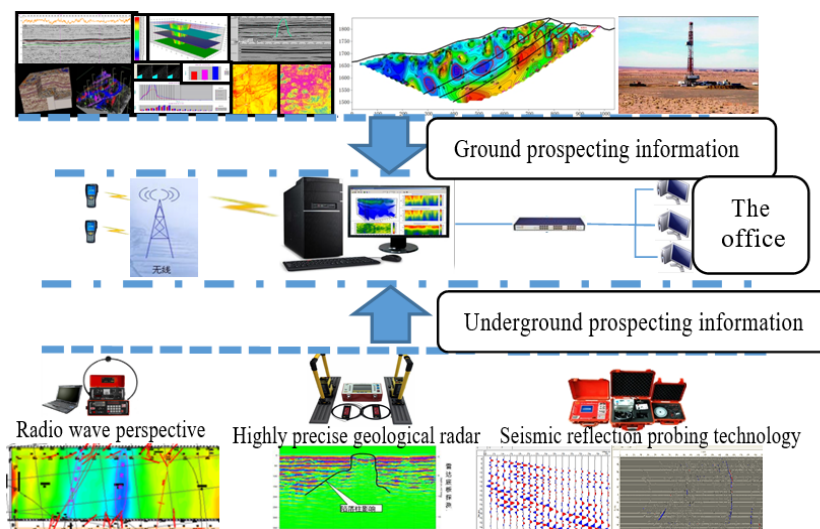


Figure 2. Regional Tectonics Big Data Platform

3.2. Investigation Method of Extraction Radius

Gas extraction radius investigation is the basis for mine gas extraction hole-drilling design. Traditional gas radius investigation methods include gas pressure drop method, gas content drop method or drillings gas desorption index K_1

measurement. These methods cannot precisely reflect the extraction law due to so many artificial and underground disturbance factors which result in great measurement differences. Based on this, it has proposed a new method according to the automatic fitting of gas extraction law and

stepping-type calculation of coal seam gas extraction radius. This method can rapidly, effectively and truly reflect the changing laws of gas extraction hole drilling in different regions with the time decay. The coupling model between the standard hole-drilling extraction radius R and the extraction time t is:

$$R = \sqrt{\frac{a \cdot t^2 + b \cdot t + c}{\pi \cdot \rho \cdot (W - W_0)}}$$

where a , b , and c are function fitting coefficients, W is the raw coal gas volume, ρ is the evaluation of regional coal bulk density.

With the above procedure, it can conclude the relation between the standard hole-drilling extraction radius of R and the extraction time of t to realize scientific gas extraction hole-drilling design.

3.3. Intelligent Precise Hole-drilling Design

Scientific gas extraction is established based on the precise control of the mine gas geological information. By integrating

complete gas extraction supervision data and cored with the research on gas extraction law, it can depend on comprehensive analysis of artificial intelligent technology to realize the optimal scientific design of highly-effective gas extraction. Through the above theoretical analysis, in combination with the underground mining conditions, the regional tectonics information and the gas extraction management and analysis system with basic coal seam gas data input, the system can intelligently generate the optimal scientific extraction hole-drilling design (as shown in Fig.3). It can innovatively intelligently generate modularizing gas governance method by section for the regional drilling holes in different length. It has proposed for the first time to make use of artificial intelligence and big data cloud computing technology in combination with the analysis of the geological structure distribution of each section of the working face and relevant information including the influencing region, gas reserves changing law and extraction influencing radius and others to intelligently automatically design gas extraction drilling holes in different sections to change the previous changeless hole-drilling arrangement technique.

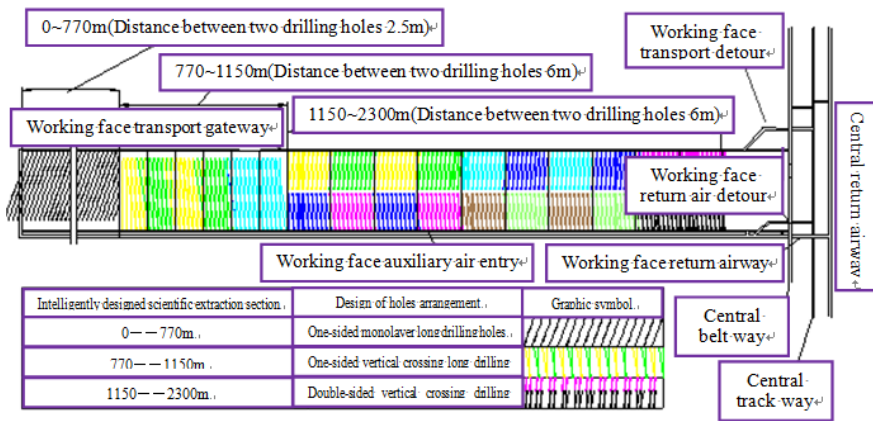


Figure 3. The Optimal Scientific Gas Extraction Design

4. Procedural Control in Hole-drilling Construction

4.1. Online Supervision of Hole-drilling Track

Online supervision analysis of hole-drilling track aims to realize 3D display of mine entities including the coal seam, roadway and drill sites and others and 3D effect analysis and visual demonstration of the hole-drilling form, geological structure and coal seam reserves based on hole-drilling construction and probing data, as shown in Fig.4. With

advanced hole-drilling track measurement technology in combination with virtual reality technology and entity/surface modeling technology, it can establish 3D visual application and a set of hole-drilling 3D effect display and analysis platform for online control of the gas extraction hole-drilling construction process in 3D display. This technological application can directly show the hole-drilling construction position in gas extraction and hole-drilling drifting distribution to provide technological guidance for scientific hole-drilling arrangement of the next similar regional gas extraction.

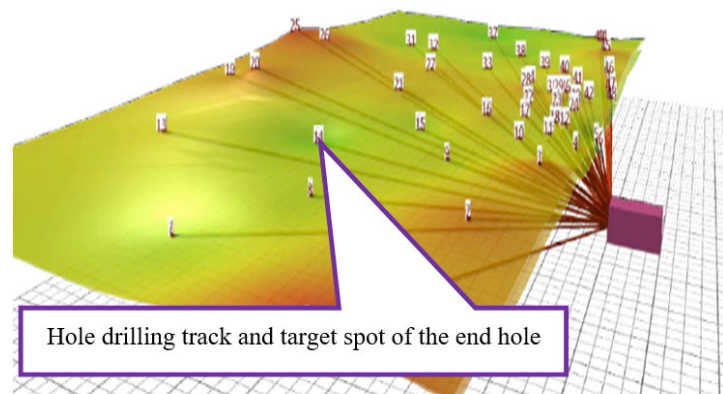


Figure 4. Hole-drilling Construction Diagram in 3D Display

4.2. Blank Zone Identification and Control

With automatic analysis of gas extraction law and intelligently identifying blank zones in hole-drilling construction (as shown in Fig.5) in combination with extraction supervision system, it can realize scientific hole-drilling arrangement of the minimum gas extraction and online dynamic evaluation of gas extraction effect for precise

judgment of the extraction standard of the working face to realize extraction standard online dynamic management. According to the identification result, it can directly show the blank hole-drilling zones and gas extraction hole-drilling drifting. Supplementation of gas extraction drilling holes in the hidden area can make full coverage of the coal seam of the working face.

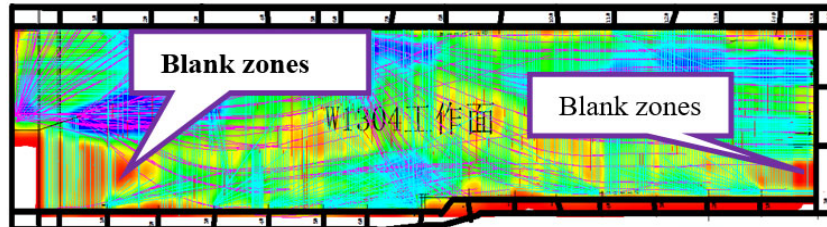


Figure 5. Blank Zone Identification in Hole-drilling Control

4.3. Highly Effective Hole-Sealing and Hole-Drilling Patching Technology

Single-hole gas extraction density is directly restricted by the hole-sealing quality, while traditional hole-sealing materials and technologies are universally faced with leakage phenomenon, seriously affecting the gas extraction effect [11,12]. As to this problem, with a new kind of inorganic chemical mining-use hole-sealing material in combination

with advanced “Two blockings and one pouring” highly-effective pressure hole-sealing technology (as shown in Fig.6), it can make sure that the hole-sealing material can enter the coal petrography fracture nearby the drilling holes under pressure so that the new hole-sealing material can keep certain pressure swelling and firm to fully block the drilling holes and nearby fracture. It can improve the hole-sealing quality. Not only the hole-sealing material is cheap, it is also easy and quick in construction.

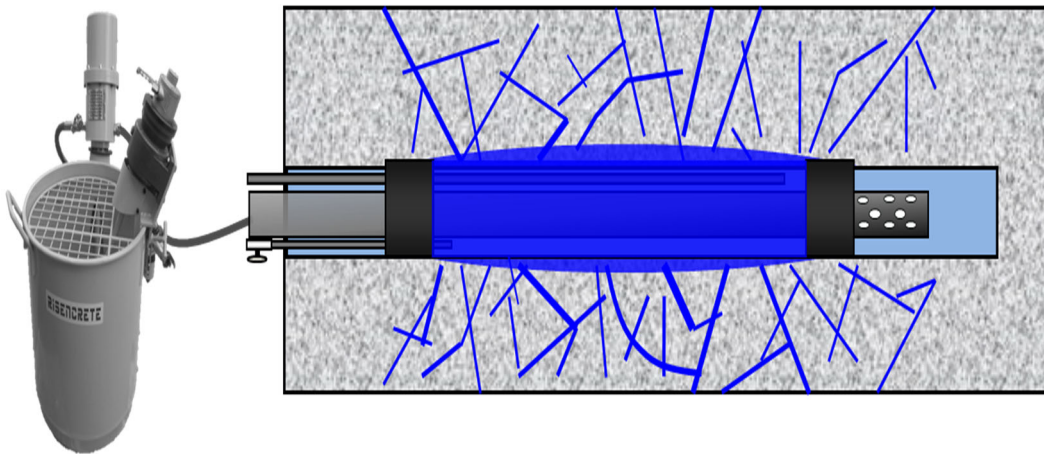


Figure 6. Highly-effective Pressure Hole-sealing Technology

In addition, part of drilling holes become unstable and collapse due to the unloading stress of nearby coal causing unbalancing of stresses; if the coal seam is rich in clay particles, it will swell to generate great transformation due to hydration when mixing with water, which will seriously shrink the hole diameter. As to the above hole collapse and hole diameter transformation, high-pressure water jet technology can be applied to ream holes. For long-hole sections, casing running technique can guarantee hole-drilling rate and effectively extend the hole-drilling life to increase the hole-drilling extraction rate.

4.4. Downward Hole Drainage Technique

As to the problem of downward hole ponding in hole-drilling construction and how to improve the downward hole extraction quality, it has proposed downward hole drainage

method based on compressed air ejection technology (as shown in Fig.7). With the function of compressed air, by fully making use of the current air-water separator and negative pressure water tank of the extraction pipe network, it can optimize and integrate the drainage technique to realize multi-hole parallel connection of the drainage system. The drainage technique and gas extraction can be simultaneously carried out without affecting each other. The drain pipe is plugged into the original extraction drilling hole, with the help of the improved “four in one” drainage device, to integrate the compressed air ejector and the drain pipe into the extraction pipe network to realize integrity of drainage and gas extraction. It can increase the service life of the downward drilling holes and guarantee highly effective extraction of downward holes.

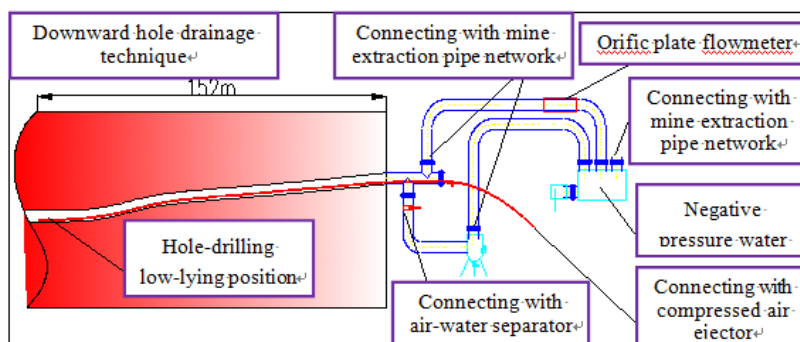


Figure 7. Downward Hole Drainage Technique

4.5. Online Leak Detection Technology of The Extraction Pipe Network

So far, there is still deficiency in the security technology of the underground pipe network, and there remains no research on underground conveying pipe network leakage, plugging technology and negative pressure automatic adjustment technology. But in oil and gas pipeline transportation, there has been certain development in leakage, plugging technology and positive pressure automatic adjustment technology [13-15]. With the development of the industrialization of coal bed gas and the attention to gas disasters, it increasingly requires the automation and control of the extraction system and its extraction effect. There are main routes including full-process automation and remote control of the extraction system pipe network, leakage and plugging technology and negative pressure automatic adjustment for the security of the underground extraction pipe

network. When there is leakage in the pipe network, the gas within the pipe will form turbulence near the leakage point to form sound wave in a certain frequency. It is so weak of the sound wave signal generated from the leakage point of the gas extraction pipe that it is hard to identify for people in the underground way. Accordingly, a new technology and device with highly precise and high-resolution ultrasonic wave is applied to accurately detect gas leakage (as shown in Fig.8). This technology can precisely detect the leakage source and it is also convenient to wear. It can automatically send alarming signal when discovering leakage points. With precise leakage detection and effective plugging, it can guarantee effective application of the negative pressure. For each link of the above hole-drilling construction: procedural management from hole sealing, hole-drilling track, hole-drilling patching, downward hole drainage and to online leakage detection of the pipe network can provide basic guarantee to realize scientific highly-effective gas extraction.

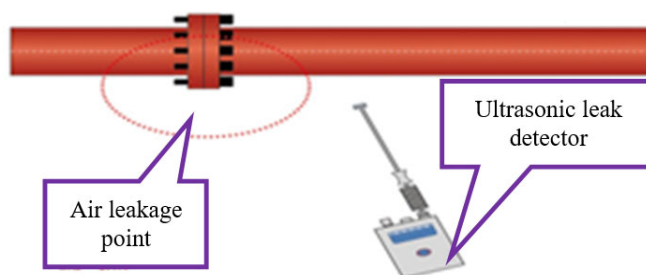


Figure 8. Online Leak Detection of the Extraction Pipe Network

5. Dynamic Intelligent Evaluation of The Extraction Standard

So far, no matter at home and abroad, the management and evaluation of gas extraction always depend on data collection by manual work. It is not only complex but also easy to make errors. Execution of measures requires management, while improper management will cause ineffective execution. The development of artificial intelligence has improved the information digital office level of the mining industry. But in application of gas extraction, there still remains blank at home and abroad. In consideration of this, it has resorted to automatic analysis on extraction law to optimize the hole-drilling arrangement. With extraction supervision network and big data cloud computing technology, artificial intelligence is applied to establish a set of complete scientific gas extraction technology system for intelligent analysis of

the supervision data of the gas extraction pipe network, manual record data, hole-drilling connecting time, actual hole-drilling construction project, gas extraction density, negative pressure, pure volume, actual hole-drilling control scope, wind speed of each working face and return air gas density and other information to realize dynamic online evaluation of gas extraction standard and procedural control of the extraction standard. With real-time acquisition of gas extraction data, it automatically makes it intelligent of the online evaluation of the gas extraction effect of each section to realize scientific, procedural and precise gas extraction. This technology has filled the blank of domestic scientific gas extraction application.

6. Conclusion

(1) It has proposed to establish space numerical-graphic model based on transparent space geophysics technology.

With modern highly-precise prospecting equipment, it has realized precise identification and division of mining regional tectonics. This technology has reflected the scientific technological advantage of information, precision and digitalization in the digital mining construction in the future sensing space and provided technical support for precise coordination and safely continuous mining of the coal resource and gas resource.

(2) It has proposed a new method of automatic fitting of the gas extraction law and stepping-type calculating of coal seam gas extraction radius. This method can rapidly, effectively and truly reflect the changing law of gas extraction hole drilling in different regions with the time decay. It has realized scientific design of gas extraction hole drilling, which can not only increase the safety, but also reduce the construction cost.

(3) Information time represented by artificial intelligence and big data cloud computing will gradually change the rough way of coal mining gas governance and will necessarily innovate the method of gas governance. With this opportunity, highly-effective hole-sealing technique has improved the hole-sealing quality; it has guaranteed full coverage of drilling holes by precisely controlling the hole-drilling track, supplementing the blank zones and repairing the hole collapse section; downward hole drainage technique has improved the gas extraction effect of downward holes; online leak detection technique of pipe network has increased the negative pressure operation efficiency; automatic online intelligence can evaluate the gas extraction standard by section. It can finally form a set of scientific gas extraction technology system based on engineering thinking.

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