WEP Warwick Evans Publishing

International Journal of Natural Resources and Environmental Studies

ISSN: 3006-2012 (Print), ISSN: 3006-0834 (Online) | Volume 2, Number 3, Year 2024
DOI: https://doi.org/10.62051/ijnres.v2n3.02
Journal homepage: https://wepub.org/index.php/IJNRES/index

Status and Development of Coal Mine Gas Extraction Technology

Liuyang Li

College of Resources and Environment, Henan University of Science and Technology, Jiaozuo, Henan 454003, China

ABSTRACT

Most of the coal seams in China are geologically old, well closed, with high gas content and high pressure, which are prone to coal and gas protrusion accidents. Coal mine gas extraction technology has been developed for a long period of time, and some extraction pressurization technologies have appeared in improving the effect of gas extraction. And in the research process of low permeability coal seam pressurization technology, hydraulic pressurization technology is gradually applied. In order to solve the problems encountered in the actual production, the development trend of gas extraction technology will be the up-and-down joint extraction, “three-area linkage” three-dimensional extraction, and coal and gas co-mining technology. However, there are some problems in gas extraction, such as theoretical research, extraction technology and popularization and application of technology and equipment, etc., and the research directions are also various.

KEYWORDS

Coal bed methane; extraction technology; equipment application.

1. CURRENT STATUS OF GAS EXTRACTION TECHNOLOGY

China's coal mine gas extraction technology has experienced a long period of development, in the 1950s in Fushun high permeability thick coal seams for the first time in the underground drilling pre-extraction of gas, to solve the problem of preventing gas accidents in the deep part of the mine; since then Yangquan area through the layer of drilling extraction of neighboring seams of gas, to solve the problem of the first mining face in the group of seams, a large amount of gas out of the problem, in the 1960s, the adjacent layer In the 1960s, the gas extraction and depressurization technology of adjacent seams was widely promoted; in China, there are a large number of high-rupture coal seams with poor permeability, and it is difficult to solve the problem by pre-pumping of holes, so the methods of loose blasting, hydraulic fracturing, cross-bored holes, and large-diameter holes have been applied to the extraction of low-permeability seams in order to increase the amount of gas extraction; since then, with the application of large-scale mechanization of coal mining, the efficiency of the mining advancement has increased dramatically, which has also led to the absolute increase of the amount of gas outflows. In order to solve the problem of high-yield and high-efficiency working face gas, high and low negative pressure gas extraction systems were gradually established and combined with various extraction methods to realize comprehensive gas extraction; the current surface well mining technology has made great progress, and the ground vertical well drilling technology has been successful in many different geologic basins of China, and the successful promotion and application of the test of multi-branched horizontal well technology has greatly pushed forward the progress and innovation of gas mining technology in coal mines. Gas mining technology progress and innovation [1].

2. EXTRACTION EFFICIENCY TECHNOLOGIES

China's gas mines are characterized by the mining of most of the coal strata of the Carboniferous-Diabase system, the geological age of the coal seams, good closure, high gas content, high pressure, and many periods of tectonic movement, so that the coal seams are subjected to serious extrusion and rubbing damage, the coal seams are unstable, the structure of the soft and broken, and the geological structure is complex. In terms of improving the effect of gas extraction, the main technical ways are to improve the parameters of the drilling and extraction process and to increase the permeability of the coal seam. In recent years, there are some new advances in the research of extraction effect, which have achieved good results in engineering applications and have been widely promoted[2].

Unloading mining gas extraction theory[3]: through the mining of the protective layer, the formation of rock movement, coal seam expansion and unloading, in the top plate ring fissure area, the top and bottom plate is unloaded coal seam expansion and deformation area to form a fissure field, increase the permeability of the coal seam, so that adsorption of gas into the free state of gas, according to the mine gas overburden, mining layout, mining procedures, and the mining geological conditions of the mine to choose the appropriate extraction methods, drilling construction techniques and sealing technology methods, a large number of desorption of gas, and the extraction of gas, the mining process is very effective, and widely promoted. According to the mining arrangement and mining procedure as well as the mining geological conditions, suitable extraction methods, drilling techniques and hole sealing techniques are selected, and a large amount of desorbed gas flows in the radial direction in the unpressurized tensile fissure under the action of negative pressure of extraction, and the unpressurized extraction of gas is realized through the extraction holes.

Soft coal seam sieve pipe protection technology [4, 5]: soft coal seam due to the poor stability of the coal seam bare hole wall, the hole wall will be destabilized and collapsed within a short period of time after drilling, resulting in local or overall blockage of the hole, and making the hole fail. The sieve pipe protection technology can avoid the failure caused by the collapse of the drill hole, and greatly improve the reliability of the pre-pumping of gas in the drill hole. The application in Huainan mine shows that the success of the lower sieve pipe is high, and the depth of the lower sieve pipe is high, and the volume fraction of the extracted gas can be increased by about 120%, which is a remarkable effect.

Medium air pressure air-stabilized foam composite drilling technology[6]: the use of compressed air and stabilized foam two kinds of gas-based fluids as a drilling flushing medium, the two alternately injected into the holes in a composite way to circulate the drilling, to solve the soft coal seam downgradient gas extraction drilling into shallow depth, the problem of low pore formation rate.

Dense drilling technology: Increase the diameter of drilling holes, reduce the spacing of drilling holes, and reasonably set the negative pressure of gas extraction to improve the effect of gas extraction. Due to the limitation of the underground environment and the complexity of the technology, it is difficult to widely promote the application of some newly developed technologies to improve the permeability of coal seams, but the intensive drilling technology is favored by coal mines due to its simple technology. The intensive drilling technology is widely used in the down-grade drilling of the coal seam in Huainan Mine, Anhui Province, to extract the gas from this seam, and it has obtained a very successful effect on the gas extraction of this seam.

3. ENHANCED PUMPING HYDRAULIC PENETRATION TECHNOLOGY PRINCIPLES AND APPLICATIONS

In the research process of low permeability coal seam penetration enhancement technology, hydraulic penetration enhancement technology is gradually applied. This technology takes water as the medium, pressurizes the water through high-pressure pump, makes it act on the coal seam, under the strong

water pressure, cracks are produced inside the coal seam, these cracks communicate with each other, forming a multi-fracture connecting network within a certain range, increasing the permeability of the coal seam, improving the flow of gas inside the coal seam, so as to obtain a better effect of gas extraction from the coal seam. A large number of domestic enhanced pumping hydraulic penetration technology has been applied with good results. At present, enhanced pumping hydraulic penetration technology mainly includes hydraulic fracturing penetration technology and high-pressure water jet slit penetration technology[7].

3.1. Hydraulic fracturing for penetration enhancement

Hydraulic fracturing penetration enhancement technology is to inject liquid into the coal seam through drilling, when the liquid is pressed in at a rate far exceeding the natural water absorption capacity of the coal seam, due to the increase of flow resistance, the liquid pressure into the coal seam will gradually rise, when it exceeds the pressure of the rock above the coal seam, the original closed fissures within the coal seam will be pressed open and extended, forming a new coal seam gas flow network, the permeability of the coal seam will increase, and the pressed open The pressure-opened fissures create favorable conditions for the flow of coal seam gas[8].

3.2. High-pressure Water Jet (HWJ) Seam Penetration Enhancement Technology

High-pressure water jet seam cutting and penetration enhancement technology takes water as medium, injects it into the coal seam after pressurization by high-pressure water pump, and then sprays it out from the nozzle of automatic switching seam cutter downhole to form high-pressure jet with strong penetrating ability, which cuts and breaks the coal seam. This technology is mainly aimed at cutting seams in the borehole of the extraction drilling for coal seams with poor permeability and high gas content. The high-pressure water jet cuts the coal seam along the hole in the coal seam borehole, forming a flat slit groove with a certain depth and width on both sides of the borehole, while the water flow will utilize its own energy to discharge the cut coal out of the hole [9]. Under the action of stratum pressure, the coal seam will produce uneven deformation and damage, so that the drill holes are connected to each other, improving the permeability of the coal seam and providing a channel for the desorption and flow of gas. The high-pressure water jet cuts slits and grooves in the coal seam while also causing strong displacement and expansion of the surrounding coal seam, increasing the fissures in the coal seam, changing the original stress and fissure conditions in the coal seam, and changing the flow state of the gas while improving the permeability of the coal seam to improve the efficiency of gas extraction from the coal seam.

4. DEVELOPMENT TREND OF GAS EXTRACTION TECHNOLOGY

Currently, the main methods of coal seam gas extraction include underground drilling and ground extraction. Underground drilling is low-cost, highly reliable and mature after years of development, and it is the main technology for gas extraction in most mines. However, in some mines, direct extraction alone cannot solve the problem of large gas outflow, so it is necessary to use the ground extraction technology and underground drilling extraction technology to solve the problems encountered in actual production.

4.1. Combined uphole and downhole extraction technology

Currently, the main technologies of surface extraction include vertical well gas extraction technology and horizontal well gas extraction technology; and downhole drilling extraction technology includes extraction of the coal seam, extraction of neighboring seams and extraction of the air-sealed area. The up-and-down joint extraction technology utilizes vertical wells on the ground and long horizontal boreholes downhole, which makes the coal seams near the mining face and in the mining influence

area produce stress release, expansion of the original cracks and generation of new cracks, increasing the permeability of the coal seams and reducing the difficulty of extraction. Yuan Liang et al [10] pointed out that due to the low permeability, low reservoir pressure, low saturation and other characteristics of China's coal seams, it is necessary to adopt the method of joint extraction above and below the well to solve the related extraction problems. In a mine in Henan Province, the 4301 back-mining face was subjected to up-and-down joint extraction, with coal seam gas pre-extraction in the underground and pumping and releasing with a water ring vacuum pump on the ground. After the ground construction, the concentration in the upper corner of the working face was significantly reduced, which effectively solved the problem of gas management in the mining airspace of the layered comprehensive mining face.

As a new technology, there are many problems to be solved, especially in the process of ground drilling, which is restricted by geological conditions, borehole stability and other factors, which brings troubles for the implementation of the project. In this regard, Hou Jinling [11] used the hierarchical analysis method + fuzzy comprehensive judgment method as the basis for the coal thickness, hydrodynamic conditions, geostress, gas-bearing area, geological structure and other factors into the model considerations, to establish a coalbed methane ground well applicability evaluation index system. Liu Xiaolei et al [12] utilized the characteristics of the bubbling fall zone, fissure zone and curved subsidence zone formed by coal mining, carried out the buttressing of straight wells and horizontals in the transition area of the fissure zone and curved subsidence zone, and realized three-dimensional pumping in space and simultaneous pumping in time in different areas by utilizing segment sealing and gradient negative pressure pumping technology, which effectively solved the problems of instability of the straight well bore brought by the joint pumping.

4.2. “Three-zone linkage” three-dimensional pumping technology

The “three-zone linkage” three-dimensional extraction model researched by Jincheng Group initially realizes the co-development of two resources, coal and CBM, and ensures that CBM extraction and coal development are coordinated and carried out in an orderly manner by adopting the technologies of surface drilling and extraction, up-and-down joint extraction, and drilling and extraction of coal seams in the planning, preparation and production areas of the mines, respectively. According to the cycle of coal mine production, succession and planning, the well field is divided into the unmined area (coal mining area after 5 years), the mining area (coal production in production and coal production succession area within 5 years), and the mined area (closed and stable area that has been mined), and different extraction technologies and extraction methods are adopted for different areas respectively, so as to realize the integrated and coordinated development of coal and gas extraction in high-gas mines [13]. The characteristics of the “three-zone linkage” three-dimensional gas extraction mode can be summarized as “three combinations”, specifically embodied in the spatial concept of the combination of up and down the well, the ground and underground gas extraction; in time, it is reflected in the convergence of the coal mine is completely consistent with the coal mine, the coal mine planning area, the implementation of ground pre-extraction, the coal mine preparation area, and the coal mine preparation area. The implementation of ground pre-extraction, coal mine preparation area to implement the implementation of joint extraction, coal mine production area to implement the implementation of underground gas extraction, to ensure that each area are fully extracted; in the way to reflect a variety of extraction methods combined, that is, a combination of ground extraction, long drilling extraction and down layer drilling extraction methods [14]. The “three-zone linkage” three-dimensional extraction adopts progressive extraction, in the return mining face of the multi-digging roadway arrangement, in the outer roadway to the next neighboring face in advance of the construction of long drilling holes, the length of which can cover both sides of the roadway of the next face, in the period of digging the face of the next face of the digging area of the extraction in advance, ensuring that the next face has one to one to one hole, and the next face has one to two to three holes. Ensure that the next face has 1 to 3 days of extraction time; ensure that the

next face of the roadway excavation in the strip has been extracted to ensure that the gas content of the return face is also reduced to a lower level, so progressive forward to ensure that the pumping, digging and mining of the succession of normal. The “three-zone linkage” three-dimensional extraction utilizes the role of mining pressure relief, improves the permeability of coal seams, maximizes the extraction of coal mine gas, overcomes the poor permeability of soft tectonic coal seams, which makes it difficult to extract gas, and it is difficult to control the gas exceeding the limit in the upper corner of the corner, and it is difficult to extract the gas with a low concentration, which solves the problems of difficulty in extracting gas, large investment, and difficult to utilize the gas with a concentration lower than 10%, and helps to realize the goal of “three-zone linkage”. This solves the problems of difficult gas extraction, large investment, and difficult utilization of gas concentration less than 10%, which is conducive to the realization of the goal of maximizing the gas extraction in the mine area and “zero discharge” of the gas in the mine area, and overcomes the limitations of the succession of coal production caused by a single downhole gas extraction. At the same time, Jincheng Group has introduced the large-scale development of shale gas into the development and utilization of coal bed methane, and has adopted U-shaped wells to carry out segmental fracturing, with the daily gas production of a single well exceeding 6,000 m3, which is 9-10 times higher than that of mines in the same area with the same conditions. Now in the abandoned mines and coal mining hollow area test 17 hollow wells, single well average daily output of more than 2,500m3, according to the number of abandoned mines in Shanxi, the resource volume of the hollow area is about 200 billion m3 or more, if all the development of the hollow area of the coal bed methane extraction volume of nearly 3 billion m3.

4.3. Coal and Gas Co-mining Technology

Coal seam mining can promote the fissure development is favorable for gas extraction, and at the same time, gas extraction also provides safety guarantee for coal mining. Coal and gas co-mining technologies mainly include the roadway method of coal and gas co-mining, the stay-roadway drilling method of coal and gas co-mining without coal pillars, and the surface drilling coal and gas co-mining and so on [15]. Roadway coal and gas co-mining is a typical model for safe and efficient mining of high gas and low permeability coal seams, which mainly includes pre-extraction before mining and pressure relief gas extraction during mining. Coal and gas co-mining with pillarless drilling method is also aimed at the group of high gas and low permeability coal seams. It adopts pillarless drilling method, which retains the roadway along the edge of the coal seam's empty area to eliminate the accumulation of gas in the upper corner of the corners of the coal seam and reduce the heat damage of the mining system, and at the same time reduces the influence of ground temperature and ground pressure. Ground drilling coal and gas co-mining is for the complex low-penetration and high-gas coal seams that are difficult to be mined by existing technology, ground drilling is used to extract the unloaded gas in the dynamic area, realizing the coal and gas co-mining.

5. PROBLEMS AND RESEARCH DIRECTION OF GAS EXTRACTION TECHNOLOGY

5.1. Problems of Gas Extraction Technology

Theoretical research problems: At present, the research on the basic theories of mine gas overlay law, gas seepage-diffusion theory, and the mechanism of gas accident outbreaks can not keep up with the development of new technology, new techniques and new equipment for gas extraction. The development of new technologies, new techniques and new equipments for comprehensive gas extraction is driven by market competition, and is constantly updated, breaking through and innovating, so that innovative ideas can be transformed into new products and new equipments in a shorter period of time. However, the research on basic theories is often promoted gradually under the

framework of the national scientific research program, which constantly highlights that new gas extraction technologies are “useless”. The phenomenon of “no use”, that is, the current gas flow law of coal rock body before and after mining is not clear, and the gas enrichment degree of coal rock body under different mining conditions and different damage degrees is not clear, resulting in the arrangement of extraction boreholes without reliable theoretical guidance, and the effect of extraction can not meet the requirements.

Problems of extraction technology: Existing gas extraction technology focuses on solving common gas problems, such as reducing the gas content, gas pressure and gas concentration of coal beds to achieve the purpose of preventing gas accidents. With the rapid development of science and technology, the general and universal prevention and control technology for gas accidents has been developed and improved, and significant achievements have been made, but it still fails to meet the requirements of reducing the proportion of gas accidents and deaths. However, it is still unable to meet the requirements of reducing the number of gas accidents and the proportion of fatalities, and has failed to make further breakthroughs in the prevention and control of gas accidents.

Popularization and application of technology and equipment: The popularization and application of gas extraction technology and equipment are not strong enough. Coal mines are dependent on the traditional construction techniques and technologies in use to maximize economic benefits and stick to the old rules; frontline workers are bound by the enterprise salary system to maximize their own interests, making it difficult to promote them.

5.2. Research Direction of Gas Extraction Technology

Research direction: ① mine gas basic theory research and accelerate the imminent need to match the current development of gas extraction technology and equipment; ② the need to solve the generic, universal gas problems to the direction of special gas problems to solve special stratigraphic combinations, special tectonics, deep mining, special gas overburden state of the face of the gas problems encountered for the specific problems encountered in the study of the corresponding ;③ It is necessary to study the triggering source of gas accidents, occurrence mechanism, development pathway, chain effect, destructive strength and targeted special prevention and control technologies and measures.

6. CONCLUSION

Summarized and analyzed the development process of gas extraction technology, extraction pressurization technology, strengthened extraction hydraulic penetration technology research status. For the gas extraction technology in the actual production problems will have what development trend, combined with information given three directions. The main problems faced by gas extraction technology are put forward, and the research direction of gas extraction technology is discussed. Gas extraction is the fundamental solution to prevent and control coal and gas accidents, and the development of gas extraction theory, technology and engineering application is the fundamental solution to prevent and control coal mine gas accidents.

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