

# Green Mining-The Only Way for Sustainable Development of Coal Mine

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**Abstract:** As the main energy in China, coal is an important guarantee for China's energy security and economic development. In the face of the goal and fall of a modern powerful country In order to meet the requirements of carbon peak and carbon neutralization, the traditional coal mining technology in the past has been backward, and coal enterprises must be green and ecological protection. To develop, green mining has become the only way for sustainable development of coal mines. This paper first analyzes the requirements of coal mining under the background of the new era. This paper introduces the connotation of green coal mining, and then analyzes several main green mining technologies, including water-preserved coal mining, coal and tile. Co-mining, gangue emission reduction, subsidence reduction mining, underground coal gasification, etc. Finally, the significance of green coal mining to the development of coal mines is expounded. The future of color mining technology is prospected.

**Keywords:** Coal mining, Green mining, Coal and gas co-mining, Sustainable development.

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## 1. Introduction

Coal is the basic energy and important industrial raw material of our country. Since the founding of the People's Republic of China, more than 96 billion tons of raw coal have been produced, which provides reliable energy guarantee for national economic and social development. China's energy resource endowment conditions for 'rich coal, lack of oil and gas', coal consumption accounted for 56.2 % of total energy consumption, natural gas, hydropower, nuclear power, wind power, solar power and other clean energy consumption accounted for 25.9 % of total energy consumption [1-2]. At present, China's energy demand is still on the rise. Although the proportion of coal in the total energy consumption is declining, considering that it is difficult for renewable energy to replace traditional fossil energy on a large scale in the short term, coal will still be the 'ballast' and 'stabilizer' of China's energy supply [3]. However, while seeing that coal has made important contributions to China's social and economic development, we should also pay attention to a series of geological disasters and environmental problems caused by its mining process.

In the new era, with the implementation of the requirements of 'lucid waters and lush mountains are invaluable assets', 'sustainable development', 'carbon peak, carbon neutrality' and high-quality development, the development of green mining has become an inevitable choice and major demand for high-quality development of coal in the new era. Coal mining has higher requirements for environmental protection, higher requirements for resource recovery rate and deep mining. The coal industry needs to comprehensively promote intelligent green mining and clean and efficient utilization of coal on the basis of comprehensively ensuring energy security, and accelerate the construction of a modern coal industry system characterized by intelligence, green and low carbon. Promote the high-quality development of the coal industry [4].

## 2. The Connotation and Development of Green Mining Technology

As a typical sedimentary rock, the overlying rock of coal seam is usually layered rock mass. After coal mining, a large area of movement and deformation will occur, and various mining fissures will be formed, which will become the migration channel of geological fluids such as water and gas. It will bring about engineering problems such as underground water inrush, aquifer structure damage and gas outburst, and will also cause surface subsidence, which will affect the buildings, land and ecological environment on the surface [5].

In order to solve the above problems, Academician Qian Minggao put forward the concept of green mining in the 21st century, in order to achieve 'low mining, high utilization and low emission', and systematically expounded its technical framework system [6-8].

The basic concept of green mining is to understand the available resources such as coal, coalbed methane and water from the perspective of generalized resources. The basic starting point is to prevent or minimize the adverse effects of coal mining on the environment and other resources from the perspective of mining; the basic means is to control or use the mining strata breaking movement; the goal is to achieve the maximum resource recovery rate with the minimum mining damage and achieve the best economic, environmental and social benefits. The connotation of green mining is mainly reflected in the following five aspects:

(1) From the perspective of generalized resources, understand and treat all available resources in the underground and aboveground space scales of the mining area and the full time scales before, during and after mining;

(2) Prevent or minimize the adverse effects of coal mining on the environment and other resources, and further repair or even enhance the ecological environment of the mining area;

(3) The key paths are fine pre-mining exploration, effective damage reduction in mining, post-mining recovery and utilization, and green and low-carbon operation of the whole

life cycle of coal mines;

(4) The main means is to continuously promote the deep empowerment of advanced technologies such as intelligence and digitization to coal green mining technology;

(5) The main goal is to achieve the best environmental, economic and social benefits.

From the analysis of the above connotation characteristics, the common characteristics of green mining are as follows: First, change the deep cognition of coal mine waste and strengthen the migration and transformation of harmful substances. Second, effective strategies must be applied from the source to control and mitigate the environmental damage caused by coal mining. There is no concept of first destruction and then governance. It is necessary to change and adjust the traditional mining methods to achieve the goal of protecting the environment.

With the continuous development of science and technology and the full implementation of the new development concept, the content of coal green mining technology is becoming more and more abundant, and a complete green mining technology system has been formed.

Among them, the types of available resources in the mining process are increasing, such as coal gangue, which was previously considered to be a pollutant. With the progress of chemical and power generation technology, it is transformed from a pollutant to a resource with economic value through resource utilization. The abandoned underground space of coal mine is transformed into available resources with the maturity of carbon storage, pumped storage and other technologies. In addition, the combination of green mining and intelligent mining has formed a new 'intelligent green mining technology', which has also been widely used in the field of coal mining. Intelligent green mining technology mainly includes intelligent filling mining technology, coal-rock-water-ring intelligent integration technology, gas intelligent extraction technology, mine disaster intelligent early warning technology, etc. [9].

### 3. Application of Green Mining Technology in Coal Mine

Green mining technology is a mining system that advocates improving the utilization rate of coal resources and minimizing the impact of mining on the environment. The main components of the green mining system are reflected in the following aspects: for the protection of water resources, there is 'water-preserved mining' green mining technology; aiming at gas drainage, there is 'coal and gas co-mining' green mining technology; in view of the protection of land and infrastructure, there is 'filling mining' green mining technology; in view of the land occupation and environmental pollution caused by gangue discharge, there are 'underground coal gasification' green mining technology and intelligent green mining technology combined with intelligence. The following is a detailed analysis and introduction of the above green mining technologies.

#### 3.1. Water-preserved Mining Technology

Water is one of the key elements to maintain the stability of regional ecological environment. Therefore, the research and implementation of water resources protection and utilization technology in the process of coal mining (i.e., water-preserved coal mining technology) is an important prerequisite for realizing green mining of coal mines. Due to

the movement and destruction of mining strata, the disturbance of coal seam mining to groundwater is inevitable. The light will change the elevation and runoff direction of the bottom interface of the aquifer, and the heavy will destroy or even drain the water body. When the water inflow of the destroyed water body is large, it will cause mine water inrush disaster. Therefore, water-preserved coal mining should include the following four levels of connotation: first, to avoid water inrush accidents in coal mining face, to achieve safe and efficient mining of working face; secondly, technical measures should be taken to reduce or avoid the damage of coal mining to aquifers and protect groundwater resources. Thirdly, take measures to repair or promote the self-healing of the aquifer after mining damage, and promote the aquifer to return to the original state of occurrence; fourth, it is necessary to carry out resource utilization of mining leakage water resources (i.e. mine drainage), and to achieve 'coal and water co-mining' to a certain extent [10].

Water-preserved mining is the ground water protection work carried out by using the technology of overburden separation grouting, coal extraction and procurement filling. Combined with the law of rock movement, it can optimize the coal mining method, control the uneven settlement of overburden rock, reduce the development height of water-conducting fracture, and improve the safety of coal mining.

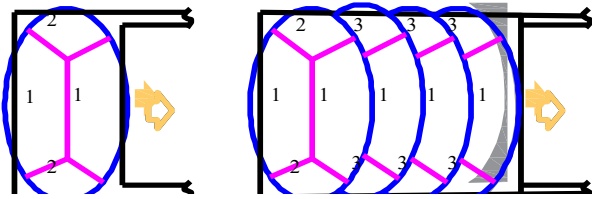
In the practical application of water-preserved mining technology, it is necessary to select different water-preserved mining methods according to different geological conditions. The specific points are as follows: First, water-preserved mining can be directly applied in mining areas with large thickness of aquiclude or no aquifer. Secondly, in the mining area with aquifer distribution and small thickness of aquiclude, it is necessary to carry out water-preserved mining after being familiar with the failure law of overburden rock and the height of water level. Thirdly, in the mining area with rich water but shallow coal seam, the problem of groundwater leakage should be dealt with before mining to prevent leakage [11].

#### 3.2. Common Extraction of Coal and Gas

In the process of coal mining, it is often accompanied by the escape of gas. Gas, also known as coalbed methane, is generally stored in the coal seam gap. It is a toxic gas, and direct discharge will cause serious air pollution. If gas can be used reasonably, it can also be used as an energy source for alkanes. The co-mining technology of coal and gas is mainly through the investigation and analysis of the cracks in the coal mining face, to understand the path and law of gas pressure relief and migration, optimize the gas extraction process, so as to reduce the gas leakage from the source while mining coal resources, and greatly improve the gas extraction rate [12].

In coal seam mining, with the continuous advancement of the working face, the space pressure of the rock around the coal seam changes, and the gas stored in the coal seam will be released. At this time, gas extraction can be carried out. In order to improve the effect of gas extraction, it is necessary to theoretically analyze the movement law of pressure relief gas and demonstration layer in goaf, and pay attention to the influence of gas and demonstration layer movement on mining-induced cracks. Among them, the 'O' type channel theory has a high guiding value for gas extraction. As shown in Figure 1, the 'O-ring' theory means that after the key stratum is broken, the middle of the goaf is compacted, and the two sides cannot be compacted due to the cantilever effect

of the 'masonry beam'. From the plane point of view, there is a fracture development area around the goaf, which is called 'O-ring'. The 'O-ring' is the 'gas river' that collects gas. Therefore, the extraction borehole is arranged in the 'O-ring', and the extraction effect is better [13].



**Figure 1.** The 'O-X' fracture characteristics of overlying strata

At present, the main coal and gas co-mining technologies are underground gas pre-drainage technology and surface drilling gas drainage technology. The underground gas extraction technology is mainly based on borehole extraction, that is, the gas in the coal seam is directly extracted by negative pressure drilling. According to the layer of borehole layout, gas extraction boreholes are mainly divided into coal seam boreholes, cross-layer boreholes and high-level boreholes. The first two boreholes are used for gas pre-extraction, and the latter borehole is used for extraction during coal seam mining [14].

### 3.3. Filling Mining Technology

In the process of coal mining, surface subsidence will not only lead to the damage of ground buildings, but also lead to the destruction of the ecological environment. According to mine mechanics, surface subsidence is the result of overlying strata movement after coal mining. In view of this situation, the filling mining technology is adopted. The so-called filling mining technology is to use other materials to fill the goaf formed by coal seam mining after coal seam mining, and then effectively control the movement of overlying strata in coal seam. In the past, this technology was only used for 'three under and one above' (under buildings, under railways, under water bodies and on confined water bodies) coal mining. With the improvement of environmental protection requirements, this technology has broad application prospects, and the key is to find suitable filling materials. Filling materials not only have low cost, but also have high strength after filling. After the implementation of the green concept, the green filling technology is improved by effective treatment, and there are three main ways:

(1) The method of filling the gap of caving gangue in goaf by grouting cementation. The remarkable feature of this filling technology is to use the gangue produced in the roof caving to make it a supporting material in the filling process, fill the gap between the special material and the gangue, ensure that it can be consolidated, and then form a whole, increase the mechanical strength, so as to promote the upper rock layer to issue a significant supporting function, prevent and solve the ground subsidence, settlement and other bad phenomena.

(2) Cemented filling method. The technical method is mainly based on the generated material of gangue river sand as filling material, mixed gangue and river sand, and then generate toothpaste-like semi-fluid, which is filled into the goaf, which can make the mechanical support body more stable and consolidated, and promote the upper rock layer to play an effective support function.

(3) High water filling method. High water filling mining is to transport the prepared high water filling material to the

filling bag (bag) in the goaf of the working face through the pipeline, and form a fixed shape support body after solidification, which plays the role of supporting the roof. Because of its good fluidity, it can be drilled to the goaf through the ground for perfusion, and can also be directly transported to the goaf through the pipeline [15].

Although there are many advantages of green filling technology, there are also shortcomings, such as high requirements for filling materials, shortage of filling materials, high filling costs, and low filling efficiency. In the future, China should continue to make breakthroughs in the development of new filling materials, the development of key filling equipment, and the construction of new intelligent filling technology.

### 3.4. Underground Coal Gasification Technology

In the traditional coal mining, it will cause serious environmental pollution problems. There are many influencing factors in the mining process, it is difficult to ensure safety, and there is also a problem of high cost in the transportation process. Therefore, in coal mining, underground coal gasification technology can be applied. Underground coal gasification technology refers to the use of certain technology to make coal not fully burned, and generate flammable gases under thermal and chemical effects [16].

The technology is to build a gasifier underground. During gasification, the coal seam is first ignited from the inlet hole, and the gasification agent passing through the inlet hole passes through the coal seam in the oxidation zone, and then different combustion conditions are generated to produce  $H_2$ ,  $CH_4$  and other gases. These gases are discharged from the exhaust hole as raw materials for coal chemical industry and power station. Compared with the traditional coal mining technology, this technology can collect the available energy after the combustion of underground coal, leave the burned gangue and ash in the underground, reduce the large accumulation of coal gangue in the application of traditional coal mining technology and the surface depression caused by the mining process, reduce the environmental pollution, and also reduce the energy loss in production and utilization, and reduce the production cost. Therefore, the application of underground coal gasification technology can improve China's energy efficiency, avoid accidents in coal mining, reduce manpower, reduce production costs, and reduce environmental pollution in mining areas. It is a new type of green coal mining technology.

There are many advantages of underground coal gasification, but the problems can not be ignored:

(1) It is difficult to control the gasification process in the underground reaction process, and the composition of the synthetic gas fluctuates too much.

(2) Affected by coal seam and geology, it is easy to cause mutual ventilation between mines.

(3) The underground combustion is not well controlled, and the monitoring of underground gasification process should be strengthened.

The above problems need to be further solved in the future development. Only by solving these problems can we make better use of underground coal gasification technology to promote the high-quality and sustainable healthy development of the coal industry.

### 3.5. Intelligent Green Mining Technology

Intelligent green mining is an important way to promote the deep reform of coal production mode and development mode. Its essence is to apply intelligent mining technology to green mining process, so as to achieve the coordinated development of coal resources development and ecological environment protection.

Intelligent green mining is essentially based on safe and efficient mining to conform to the laws of natural ecology, rely on intelligent mining technology to optimize mining technology, promote the coordinated development of resource mining and ecological environment protection, so as to realize the high utilization, high safety, low emission and high fidelity of the original ecosystem of coal scale mining. From the perspective of generalized resources and ecological environment, intelligent green mining relies on intelligent mining technologies such as transparent self-perception, self-learning, self-adaptation, and self-adjustment to develop, utilize, and protect coal seams and associated gas, water, and coal gangue. Establish a composite ecological constraint mechanism between coal mining and natural ecological laws, maximize the stability of the original ecology of the natural ecosystem, prevent or minimize the adverse effects of coal mining on the natural ecological environment, and achieve coordination between mining and ecological environment [9]. Intelligent green mining technology mainly includes intelligent filling mining technology, coal-rock-water-environment intelligent integration technology, gas intelligent extraction technology, mine disaster intelligent early warning technology and so on. Intelligent and digital technology is of great significance to improve the level of green coal mining technology.

## 4. Current Challenges

The existing green mining technology is not fully adapted to the current conditions and situation of the industry. It is necessary to deepen the research on the movement law of mining strata, explore the green mining technology model suitable for the characteristics of different mining areas, the green mining design of the whole life cycle of coal mines, and the research and development of green mining technology with high efficiency and low cost, so as to meet the needs of the continuous development of the coal industry.

The green mining technology system of coal mine with low ecological damage needs to be improved urgently. At present, a green mining theory and technology system based on filling mining, coal and gas co-mining, water-retaining mining, and non-pillar mining has been constructed. As the focus of coal development shifts to the west, it is urgent to develop a theoretical and technical system suitable for the ecologically fragile areas in the west.

The government should increase support to help coal enterprises change to the direction of green mining. In the past, China's coal mining was extensive mining, which caused great damage to the ecological environment. After decades of development, coal enterprises have formed a fixed pattern. The development of green mining technology requires the reinvestment of human, material and financial resources, which will inevitably have an impact on traditional coal enterprises. The government should increase support for the green development of coal and introduce relevant policies to help coal enterprises smoothly transition to green mining.

## 5. Conclusion and Prospect

Green coal mining plays an important role in balancing coal mining and ecological environment protection. In recent years, coal green mining has been developing towards the direction of the whole life cycle, and gradually formed a new development model of intelligent green 'fine pre-mining exploration, effective loss reduction in mining, and post-mining recovery and improvement'. In addition, green mining continues to absorb new development concepts and new technologies, and embark on an intelligent green low-carbon development path. Coal green mining technology, represented by coal mine underground reservoir, intelligent green filling mining and ecological reconstruction of mining area, has made great contributions to promoting green low-carbon transformation and high-quality development of coal industry.

In the future, China should make full use of emerging technologies such as intelligence and digitization to enable green coal mining, further reduce the comprehensive cost of green coal mining and improve efficiency, so as to lay a solid foundation for the high-quality development of China's coal industry.

## References

- [1] WANG Shuangming, SUN Qiang, QIAO Junwei, et al. Geological guarantee of coal green mining [J]. Journal of China Coal Society, 2020, 45(01):8-15.
- [2] WANG Shuangming. Thoughts about the main energy status of coal and green mining in China [J]. China Coal, 2020, 46(02):11-16.
- [3] Prospective Industry Research Institute. Analysis report on development prospects and investment strategic planning of China's coal industry in 2018-2023 [R], 2018.
- [4] LIU Ju, QIN Kun. Progress of green coal mining technology in China [J]. Mining Safety & Environmental Protection:1-9.
- [5] XU Jialin. Research and progress of coal mine green mining in 20 years [J]. Coal Science and Technology, 2020, 48(09):1-15.
- [6] QIAN Minggao, ZXU Jialin, MIAO XIExing. Coal mine green mining technology [J]. Journal of China University of Mining, 2019, 44(8):2285-2295.
- [7] QIAN Minggao. On sustainable coal mining in China [J]. Journal of China Coal Society, 2010, 35(04):529-534.
- [8] QIAN Minggao, XU Jialin, WANG Jiachen. Further on the sustainable mining of coal [J]. Journal of China Coal Society, 2018, 43(01):1-13.
- [9] GUO Wenbing, WU Dongtao, BAI Erhu, et al. Current situation and prospect of intelligent green mining technology in coal mines in China [J]. Journal of Henan Polytechnic University (Natural Science), 2023, 42(05):1-17.
- [10] XU Jialin. Green technique in coal mining [M]. Xuzhou:China University of Mining and Technology Press, 2011
- [11] Du Junwu, Yi Yongzhong. Application analysis of green mining technology in coal enterprises [J]. Resource conservation and environmental protection, 2018, (06): 44.
- [12] SONG Shuopeng. Application of green mining technology in coal mine [J]. Mining Technology, 2022, 22(05):202-205.
- [13] Xu Jialin. Green mining theory and technology of coal mine [J]. Shanxi coal, 2022, 42(04): 1-3.
- [14] ZAHNG Ningning. Green Mining Technology and Its Application in Coal Mines under New Situation [J]. Energy and Energy Conservation, 2023, (02):219-221.

[15] LIU Jiangong, LI Xinwang, HE Tuan. Application status and prospect of backfill mining in Chinese coal mines [J]. Journal of China Coal Society, 2020, 45(01):141-150.

[16] ZHAO Yuzhuo. Research on green mining technology and application of coal mine under the new situation [J]. Low Carbon World, 2023, 13(05):67-69.