Research and Engineering Practice of Gas Accurate Drainage Technology with Hole-substituted Roadway in Mabao Coal Mining Area of Jinneng Group

Xiaopeng Wang1,2*

1State Key Laboratory of The Gas Disaster Detecting, Preventing and Emergency Controlling, Chongqing 400037, China
2China Coal Technology and Engineering Group Chongqing Research Institute, Chongqing 400037, China

*Corresponding author’s e-mail: 18623001556@163.com

Abstract. Take Jinneng Group Mabao Coal Industry as an example, the company carried out research on the precise gas extraction technology in hole-substituted roadway in the mining area, instead of high-drilling lanes and roof high-drilling holes for gas drainage, to achieve better gas drainage effects and projects benefit. Actively exploring the gas management model of Jinneng Group's high and overburden mines and mine goafs is of great significance for safe and efficient production of the mine.

1. Introduction

Jinneng Group currently has 65 production mines with a coal production capacity of 77.2 million tons/year, of which 15 are high gas mines, 3 are outstanding mines, and 2 are mines that are managed according to protrusions. They are mainly distributed in Yangquan, Jinzhong, Changzhi, and Jincheng areas. The mines are widely distributed, the geological conditions are complicated, and the gas disasters are very different. The coal seam of the group's mine has poor gas permeability, and the overall gas pre-drainage effect is not ideal. The gas emission volume in the mining face is between 20-35m³/min. The tile drainage lane was originally used to solve the gas emission problem in the goaf. The formulation of the relevant provisions of the Coal Mine Safety Regulations (2016) and the implementation of the Shanxi Province's "Canceling Tile Rows" document, the mine's high-intensity rapid and efficient coal mining has led to increasingly serious gas emission problems in the adjacent layers of the fully mechanized working face and in the goaf. The corner gas problem on the working surface has become a bottleneck problem restricting the safe production of coal mines, which greatly limits the mine's production capacity.

At present, gas drainage in adjacent strata and goafs usually uses high-drainage lanes and high-level boreholes for gas drainage [1-4]. The high-drainage roadway drainage goaf gathers the gas floating in the fissure zone and the pressure relief gas in the adjacent layer, which has a good drainage effect, but the construction cost is high, the cycle is long, the management is difficult, and the later maintenance is difficult; The roof high hole is mainly used for extracting pressure relief gas and a small amount of adjacent layer gas in the fracture zone of mining layer. The location of drainage hole is poor, the effective drilling hole is less, the pore size is small, the engineering quantity is large, and the construction and management of drilling site is difficult. Based on this, taking Jinneng Group
Mabao Coal Industry as an example, the company carried out research on the precise gas drainage technology of hole-substituted roadway in the mining area, and actively explored Jinneng Group's high and sudden mine adjacent layers and the goaf gas management model, Safe and efficient production is of great significance.

2. Principle of precise gas extraction in hole-substituted roadway in mining area

2.1. Precise extraction of pressure relief gas in gas enrichment area

With the advancement of the mining working face, the overburden strata under the influence of mining, the gas permeability of coal and rock in the mining area increased several times, and a large amount of gas accumulated, forming an enrichment area. The technique of replacing the tunnel with a hole is to construct a certain number of roofs to oriented long boreholes. Through precise control of the drilling trajectory, the drill holes are arranged in the O-ring near the return air lane side, and the drilling trajectory is along the roof crack. The effective extension of the belt can realize stable and efficient drainage of gas in the gas-rich area, and ensure high-concentration, large-flow, and long-term drilling gas drainage effects [5-7].

The technical principle is shown in Figure 1.

![Figure 1. Illustrated by the principle of hole-substituted roadway technology.](image)

2.2. Large-diameter drilling replaces high-drainage drainage

According to the calculation formula of pipeline friction resistance in GB50471-2018 "Design Standard for Gas Drainage Engineering of Coal Mine", under the condition of straight pipe with the same drilling depth and negative pressure, the drilling diameter is increased from 94mm to 153 mm. Gas drainage flow increased by approximately 2.5 times.

Increasing the diameter of the directional borehole increases the exposed area of the borehole wall and the pressure relief range, which is conducive to the communication between the borehole wall and the mining fracture, and allows more pressure relief gas to flow along the mining fracture to the borehole. At the same time, the area of the flow channel for pressure relief gas was increased, and the volume of gas extracted per unit time was increased, so that it could replace the drainage effect of the roadway [8].

3. Test face overview

3.1. Drilling arrangement

Mabao Coal Industry is a high-gas mine, currently mining 8# and 15# coal seams, 15# coal seams have a thickness of 4.6-5.6m, an average of 5.1m, and an inclination angle of 2° -14° . The coal seam structure is relatively simple, and the average distance from the 9# coal seam is 56.39m.

The 15203 fully mechanized mining face belongs to the 152 mining area, with a length of 220m and a trend of 1113m. It adopts a comprehensive mechanized coal mining method, and all collapse methods are used to manage the roof. The direct roof is mudstone with an average thickness of 6.8m, the old roof is fine-grained sandstone with an average thickness of 8.2m, and the direct bottom is an
aluminum mudstone with an average thickness of 1.3 m. The actual measured coal gas content of the 15203 working face was 6.44 m$^3$/t. The "U" ventilation method was used at the working face, and the air distribution volume was 1458 m$^3$/t. According to the production practice of the Marburg coal mine, after the 15#$ coal seam is mined, the gas emission from adjacent layers accounts for about 28% of the total gas emission, and the gas from the coal remaining at the bottom of the working face constitutes the main gas source of the goaf. It is easy to cause gas corners on the working surface and gas overrun in the return air lane.

4. Determining the range of mining pressure relief gas enrichment area

4.1. Theory of mining pressure relief gas enrichment area

According to the research by related scholars in the "three horizontal zones" and "vertical three zones", after the impact of mining, the overlying strata will respectively undergo the coal wall support affected zone, separated layer zone, and re-compacted zone. Falling zone, fissure zone and bending sinking zone [9], see Figure 2.

![Figure 2](image.png)

A—coal wall support affected area (a-b); B—separation zone (b-c); C—re-compaction zone (c-d);

Figure 2. Schematic diagrams of the "three horizontal zones" and "vertical three zones" of the overlying strata.

After the working face is mined, there are some interconnected mining fissures around the goaf, namely, "O" rings [9]. The existence of "O" rings provides space and channels for pressure relief gas storage and flow [10], as shown in Figure 3.

![Figure 3](image.png)

Figure 3. "O" ring in goaf.

Drainage drilling is arranged in an area where the fractures of the strata are fully developed and can exist stably for a long time, which can ensure high gas drainage concentration, slow attenuation and high drainage efficiency.

4.2. Determination of mining pressure relief gas enrichment area

4.2.1. Determination of fracture zone height
In this paper, the height of caving zone and fissure zone in fully mechanized mining face is calculated by empirical formula. According to the geological prospecting data of Mabao Coal Mine, the direct top of 15# coal seam is mainly mudstone, sandy mudstone, local siltstone and medium fine sandstone. According to the results of rock mechanics parameters, the average compressive strength of mudstone is 27.5 MPa, so it is calculated according to medium hard rock strata:

\[
H_m = \frac{100 \sum M}{4.7 \sum M + 19} \pm 2.2 = \frac{100 \times 5.1}{4.7 \times 5.1 + 19} \pm 2.2 = 14.07m \sim 9.67m
\]

So the maximum height of the caving belt of 15203 fully mechanized mining face is 14.07m.

The old roof of 15# coal seam is usually K2 limestone, so the height of fracture zone of 15203 fully mechanized coal face can be calculated according to hard rock strata:

\[
H_{ll} = \frac{100 \sum M}{1.6 \sum M + 3.6} \pm 5.6 = \frac{100 \times 5.1}{1.6 \times 5.1 + 3.6} \pm 5.6 = 37.78m \sim 48.98m
\]

So the fractured zone height of 15203 fully mechanized coal face is 48.98m.

4.2.2 Determination of the horizontal distance between the end hole point and the return air channel

Based on the theory of "O" ring of mining fracture, the horizontal distance between the end hole point and the return air channel can be calculated by the following formula:

\[
S = \left[ H - (B + H \cot \theta) \right] \frac{\sin \alpha}{\cos \alpha} + \left( B + H \cot \theta \right)
\]

In the formula: S: the horizontal distance between the final hole point of the extraction hole and the return air along the trough; H: the vertical distance between the final hole point of the extraction hole and the coal seam; B: the distance between the extraction hole and the outer boundary of the "O" ring. Under general conditions, the value range of "B" from 0 to 34 m; \( \alpha \): coal seam dip angle; \( \theta \): The connection between the outer boundary of "O" ring and the mining boundary and the dip angle of coal seam.

\( H = 49 \) m, \( B = 34 \) m, \( \theta = 65^\circ \), \( \alpha = 14^\circ \). The results show that the maximum horizontal distance is 67m and the control range is 67m.

From the above calculation, it can be seen that the range of mining pressure relief gas enrichment area in 15203 fully mechanized mining face: the vertical distance from the roof is 15~49m, and the return air is 0~67m.

5. Test scheme of precision gas extraction in roadway with hole

5.1. Extraction scheme

According to the actual situation of 15203 fully mechanized mining face, the drilling field is arranged on the side of the mining side 60m from the backwind notch. The size of the directional drilling field is 8m long, 4.5m deep and 4.5m high, the hole spacing is 0.6m, the target hole spacing is 8m, the hole height is 1.5m from the roof, the maximum hole depth is 400m (strike length), and the hole diameter is 94mm.

In the early stage of Marburg coal industry, the roof high rock drilling field was arranged along the trough in the 15108 working face, and the high adjacent layer was drilled for extraction. During the drilling construction, it was found that there was a layer of K2 limestone about 20m from the roof, which was hard, difficult and difficult to collapse, and the extraction effect was poor at a height of 38m from the roof crack zone and 40m from the return air channel. Therefore, the drilling is arranged in the area 15m from the roof vertical distance and 8m from the return air slot.

Drilling parallel to 15203 return trough, and the drilling distance of 1#, 2#, 3#, 4# and 5# hole is 40m, 32m, 24m, 16m and 8m. Drilling hole height 2m from roof, spacing 0.7m. The height of the end hole of 1 # hole is 38m from the roof, and the height of the end hole of 2 # hole is 38m from the roof.
Besides, the height of the end hole of 3#, 4#, and 5# is 15m from the roof. The completion diagram of the hole is shown in figure 4.

5.2. Analysis of gas extraction effect
In order to investigate the effect of gas extraction by hole, the drainage system is designed. D377 × 4mm spiral welded steel pipe is arranged in the drilling yard. Automatic metering device and orifice plate flow rate are installed in the main pipeline and each drilling hole to realize the metering investigation of each individual drilling. Under the condition that the extraction negative pressure is 15KPa, the statistics of gas extraction in 15203 fully mechanized mining face within 70 days of long drilling are shown in figure 5.

As can be seen from figure 6, 1# drilling hole is arranged in the fracture zone, and the gas extraction effect is the best, the maximum single hole gas concentration can reach 80%, the average gas concentration is 62.2%, and the maximum single hole gas extraction volume is 9.85 m³/min. Between the caving zone and K₂ limestone, the gas in the goaf is the best. The maximum single hole gas concentration can reach 78%, the average gas concentration is 51.4%, and the maximum single hole gas extraction volume is 6.42 m³/min. The gas emitted from the goaf and the adjacent layer of 15203 working face has been effectively controlled by the maximum single hole extraction gas concentration of 78%, the average gas concentration of 51.4%, and the maximum single hole gas extraction volume of 6.42 m³/min.

6. Conclusion
1. Through the accurate control of the directional drilling track of the roof direction by the directional drilling rig, according to the characteristics of the gas emission from the actual face, the gas drainage in the gas enrichment area is carried out with the large diameter of 153mm drilling hole, the maximum extraction capacity of the single hole reaches 10m³/min and the drilling field reaches 15m³/min, and the gas drainage effect of the tunnel is realized preliminarily, which effectively solves the problem of "U" type ventilation in the 15203 working face of Mabao coal industry, and the upper corner gas treatment problem is realized, and the safe and efficient mining is realized.
2. The range of stope enrichment area based on the occurrence condition of 15# coal seam in Mabao coal industry is obtained, and it is concluded that the gas extraction effect is the best at the distance of 38m from the roof of coal seam and 35m from the coal wall of return air along the trough, and 18m from the roof of coal seam and 20m from the coal wall of coal seam in goaf, and the effect of gas extraction is the best at the distance of 38m from the roof of coal seam and 35m from the coal wall of return air along the trough.

3. For the complex roof strata of Mabao coal industry, the gas extraction concentration is high and the pure quantity is large, and the drainage effect is 3~4 times that of the ordinary gas extraction borehole.

References
[1] Deyi N 2016 Research progress and development direction of gas control technology in coal mine in china. J. Safety in Coal Mines 47 L161
[2] Liang Y 2008 Research on key technologies for safe mining of low penetration high gas coalbed group. J. Rock Mechanics and Engineering 07 L1370
[3] Liang Y, Junhua X, Nong Z and Ping L 2013 Current status and prospect of key technologies for coalbed gas extraction and coal and gas co-production J. Coal Science and technology. 41 L6
[4] Liang Y 2009 Gas drainage theory and co-production technology system of coal and gas. J. China Coal Society. 34 L1
[5] Jun F, Zhijun S and Quanxin L 2015 Drilling technology and equipment for high directional large diameter long drilling of roof. J. Mining Research and Development. 35 L92
[6] Jianguo Z 2017 Construction technology and development trend of coal seam roof high directional drilling. J. Coal Science and Technology. 45 L137
[7] Baoyong Y 2016 Study on high directional long drilling technology. J. Coal Science and Technology. 44 L5
[8] Jianguo Z 2017 Construction of gas control system of shenma group of ping coal in china J. Coal Science and Technology. 45 L1
[9] Jiaming X, Minggao Q 1997 Study on the distribution characteristics of mining fractures in overcast rock. J. Ground Pressure and Strata Control. 45 L213
[10] Minggao Q, Jiaming X 1998 A study on the characteristics of "O" circles in fracture distribution in overburden mining. J. China Coal Society. 05 L20