Gas Drainage Technology in Goaf with Large Diameter and High Rock Trend Drilling

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Abstract: Taking 1302 fully mechanized caving face of Weijiadi Coal Mine as the research object, aiming at the characteristics of large gas emission and frequent gas exceeding limit during mining, this paper analyzed the difficult problems of gas control in working face, determined the theoretical height of caving zone and fissure zone of working face according to the gas cascade control mode formulated by Weijiadi Coal Mine and the principle of pressure relief gas, and inspected the "three zones". The reasonable horizon and arrangement of drilling holes along the strike of large diameter and high position rocks are determined. The field practice results show that the gas extraction technology of large diameter and high rock trending borehole has good extraction effect, the maximum gas concentration is 26.5% and the maximum gas extraction volume is 14000 m$^3$. It effectively solves the problem of return air flow and upper corner gas exceeding the limit. The gas concentration of return air flow is basically kept at 0.2%~0.25%, which ensures the safety of mine production.

1. Introduction

Gas is one of the five major natural disasters in coal mines. In the process of underground mining activities, the most serious accidents are gas explosion and gas outburst, which seriously threaten the safety of life and property of underground personnel. With the increase of coal production and mining depth, gas disasters become more and more serious. Because of the complexity of gas concealment, occurrence and emission, and the difficulty of gas control, coal mine safety production and the healthy development of coal industry have been seriously restricted for a long time, which has become the primary problem to be solved in coal mine safety production.

There are many measures for gas prevention and control, such as gas drainage by boreholes along layers, gas drainage by drilling through layers, gas drainage by high-level boreholes and gas drainage by surface drilling. From the point of view of practicability and economy, gas drainage by high-level boreholes has low construction cost, good gas drainage effect and relatively high performance-price ratio. Many scholars [1-6] optimize the parameters and technical design of high-level boreholes. A lot of research has been done. Aiming at the difficult problem of gas control in 1302 working face of Weijiadi Coal Mine, Jingyuan Coal Mine, Gansu Province, this paper analyzed the superiority of gas drainage technology in the process of gas drainage by implementing roof-to-high rock drilling.
2. Overview of working face

1302 working face is located in the west-first mining area of Weijiadi Coal Mine. Its strike length is 1650m and inclination length is 200m. The coal seam is soft, poor permeability, high gas content, and the inclination length of working face is designed to be 200m. It is the first one in Jingyuan Coal Mine Area of Gansu Province. It belongs to the original coal seam within 400m from the cut hole, and there is an unmined coal seam on it. According to the exploration of coal seam gas content by Chongqing Coal Science Academy, the gas content of 1302 working face is 9.17 m$^3$/t, and the total amount of gas is about $5 \times 10^7$ m$^3$. After the formation of working face, only bedding boreholes are arranged, and only gas extraction is carried out for less than one year. The residual gas in coal body is about $3 \times 10^7$ m$^3$. The maximum absolute gas emission is 23.86 m$^3$/min during the mining period. The existing gas extraction measures of bedding boreholes and high-level boreholes are used. It is difficult to ensure that the gas in the working face is within the safe range, especially when the gas in the goaf is gushing in a large amount in a short time due to the roof falling. Therefore, 1302 working face takes corresponding gas control measures according to the principle of "step control, one-side-one-policy" of Weijiadi coal mine gas control.

3. Technical Principle

After mining, the goaf is formed in the back of the coal seam, and pressure relief space appears in the goaf, resulting in the movement of overlying strata, which causes pressure relief. The fractures in the strata form "vertical three zones" in the vertical direction, namely: bending subsidence zone, fracture zone and caving zone; transversely, three zones are formed, that is, the support influence zone, separation zone and re-compaction zone of the coal wall. The roof strata above the goaf are bent, fractured and broken into blocks due to the action of gravity. They sink irregularly in the goaf, forming a caving zone whose height is generally 3-5 times the thickness of the goaf. The collapsed rock blocks have a certain degree of fragmentation and swelling, so that there are larger cracks between the blocks, and gas can flow freely through the gap between the blocks. The gas in the fracture zone pours into the goaf through the interlayer fracture. However, the coal and rock strata far away from the mining seam and above the fissure zone are hardly broken due to relatively small mining impact, which can not form vertical fracture through the rock strata, but can produce large separation fissures. The separation cracks formed near the overlying long-distance coal seam in the curved subsidence zone provide a channel for the gas accumulation and circulation of pressure relief in the coal seam, while the gas extraction by surface drilling in thick coal seam is carried out by means of the cracks formed in the fissure zone of the goaf. The main technical schematic diagram is shown in Figure 1.

![Figure 1. Schematic diagram of pressure relief gas](image)

A(a-b) coal wall support influence zone; B initial fracture point; B(b-c) fracture separation zone; C(c-d) re-compaction zone
4. Layout of large diameter and high position boreholes

According to the principle of pressure relief gas, a high-level drilling field is constructed at 150 m interval in the return air lane. The high-level drilling field enters the coal seam roof above 5 m through the construction inclined lane and excavates the drilling field in the coal seam roof. The number of boreholes is about 10-15, the length of boreholes is about 170m, the location of the drilling site is about 5 m above the coal seam roof, and the downward range of the air tunnel is controlled by boreholes along the inclined direction. In order to ensure the extraction effect of roof drilling when the working face passes through the drilling field, the pressure stubble of the front and back drilling field is not less than 20m, as shown in Fig. 2. Because the development of roof fissures in goaf is a function of time, the horizon of the vertical drilling end hole is related to the advancing speed of the working face. The drilling end hole is generally located at the top of the caving zone and the lower part of the fissure zone. When the advancing speed of the working face is faster, it is necessary to reduce the layers of the drilling hole appropriately, otherwise the effect of gas extraction is not good. Under the action of working face mining, the overlying strata fall and form cracks. Under the action of negative pressure and gas buoyancy, a large number of goaf gas enters into roof cracks, and drills along the roof direction into the mine drainage pipe network to be pumped out.

Specifically, to 1302 mining face, the specific setting scheme of high-level boreholes is as follows: a high-level drilling field is constructed in the range of 150m along the working face and 5m upward along the roof stratum in 1302 air return roadway. The high-level boreholes are divided into two rows and eight rows. According to the inclination angle of coal seam along strike, the inclination angle of high-level boreholes is designed to be 10 degrees, the azimuth angle is 0 degrees, 5 degrees, 10 degrees, 15 degrees, and the inner diameter is 1084;m, the hole depth is 150-180 m, and the hole is sealed with 89m casing. The vertical position of the final hole of each borehole is in the caving zone and the fault zone.

![Diagram of layout of high-level boreholes along high-level strike](image)

**Figure 2.** Diagram of layout of high-level boreholes along high-level strike
(a) Plane maps; (b) Trend profiles
5. Analysis of Gas Drainage Effect

According to the gas geology law of Weijiadi Coal Mine and the gas cascade control model formulated by the mine, 1302 coal mining face implemented the gas extraction technology of high-level boreholes along the roof strike on the basis of gas extraction by boreholes along the seam. The gas extraction concentration and quantity of high-level boreholes in a week were counted. As shown in Figure 3, the maximum gas concentration of gas extraction reached 26.5%, the maximum gas extraction amount is 14000 m$^3$, and the gas extraction effect is good.

![Figure 3. Statistics of Gas Drainage from High-level Boreholes](image)

Statistical analysis of the gas concentration in the air return channel during the mining period in a week shows that the maximum gas concentration in the air return channel is 0.24%, which is less than that stipulated in the "Coal Mine Safety Regulations", thus ensuring the normal and safe mining of the working face.

![Figure 4. Change of Gas Concentration in Return Channel](image)
6. Conclusion
(1) According to the principle of gas pressure relief, the bending subsidence zone, fissure zone and caving zone formed during mining in 1302 working face are calculated, and the reasonable horizon and layout mode of large diameter rock trending high borehole in working face are determined.

(2) The final hole of large diameter and high position boreholes should generally be within the roof fracture zone. The gas extraction effect is good. The maximum gas concentration is 26.5% and the gas extraction volume is 14 000 m$^3$.

(3) Through the implementation of large diameter rock high-level borehole gas extraction technology, the maximum concentration of gas in the air return channel is 0.2%-0.25% during the mining period of coal face, which is far less than that stipulated in the "Coal Mine Safety Regulations", and good results have been achieved, which ensures the safe production of coal face.

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References
[1] BI Huijie, DENG Zhigang, ZHAO Shankun, et al. Research on gas drainage technology of directional high-level borehole in high gassy fully-mechanized mining face[J]. Coal Science and Technology, 2019, 47(4): 134-140.
[2] ZHANG Li, LIAN Zhenshan, PAN Tiezhu, et al. Study on Design of High Level Drilling Based on Distribution Characteristics of Overburden Fractures[J]. Safety in Coal Mines, 2019, 50(3): 154-158.
[3] ZHAO Hui-bo. Application of roof high position borehole along strike in working face upper corner gas control[J]. Coal Engineering, 2018, 50(12): 69-72.
[4] LI Yanming. Upper corner gas control based on high level directional long borehole[J]. Coal Science and Technology, 2018, 46(1): 215-218.
[5] ZHANG Ju-feng, YANG Feng-feng, LEI Wu-lin, et al. A Study on Gas Control Technology in Long Distance Working-Face of Low Air Permeability and High Concentration of Gas[J]. Journal of Longdong University, 2016, 27(3): 101-105.
[6] LIU Yun-feng, ZHANG Ju-feng, XIE Ya-dong, et al. Integrated Application of High Level Borehole Gas Drainage and Grout Spraying Fire Prevention and Control in Goaf[J]. Coal Science and Technology, 2013, 41(4): 53-56.
[7] ZHANG Ju-feng, YU Lan, YANG Ri-li, et al. Integration Technology of Gas Drainage and Water Injection and Dust Prevention in High Gas Coal Seam[J]. Coal Technology, 2018, 37(04): 159-160.