Application of short hole rapid extraction technology in excavation face

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Abstract: The gas concentration of the return air was high during the 3605 backwind measures lane in the Shanxi coal mine, and the measure of using gas discharge holes had little effect, which seriously affected the excavation efficiency. Through the use of short drilling in the head-on construction, the rapid sealing of Capsule sealer, and the short-term extraction measures of the repair class, the gas concentration of the back air during the roadway excavation was significantly reduced, which greatly improved the tunneling efficiency of the 3605 backwind measures lane. According to the gas concentration during the excavation of 3605 backwind measures lane before and after the monitored short hole extraction, the gas concentration of the back air decreased by 0.14~0.16 % and the gas concentration of the working surface decreased by 0.04~0.1 % under the same digging speed conditions, ensuring the safe digging of the working face.

1. Introduction
In order to ensure the smooth excavation of the high gas heading face, the necessary drainage methods must be adopted. Generally, several methods are adopted for gas treatment in the mining face, such as increasing the ventilation volume, hitting the release hole head-on, arranging the long-hole drilling head-on, or the step-type ear drill field on both sides of the pressure relief zone. Increasing the amount of air can solve the limited gas and easily cause the wind speed to exceed the standard; head-on release holes are generally suitable for mines with good air permeability; head-mounted long-hole drainage and pressure relief zones on both sides are arranged for step ear drilling, the amount of work is large, and the single-lane tunneling seriously affects the construction period [1-4]. A certain mine in Shanxi belongs to a high gas mine. The main coal mine is No. 3 coal seam. The gas content is 6.5m³/t~13.7m³/t. The gas content varies greatly in different regions and at different depths. For the gas content of 8m³/t~10m³/t, the purpose of gas management can be achieved by head-on construction of gas drainage holes. The maximum gas content measured in the 3605 return airway area is 8.9m³/t. During the excavation, the gas emission is large, and the gas concentration in the return air often reaches 0.77% or more. The maximum gas concentration is 0.82%. The effect of using the gas drainage hole construction method is very small, which seriously affects the tunneling efficiency. In order to completely solve the gas problem in the working face, a method of constructing short boreholes in the driving face and using a recyclable capsule plugging device for sealing and extraction is proposed.

2. Working Face Overview
The mine mainly mines No. 3 coal seam, with an average coal seam thickness of 5.6m and a gas
content of 6.5m³/t ~ 13.7m³/t. The 3605 return air measures lane is located in the six panels of the mine. The design section is rectangular and the section size is (width) 5.6×(height) 3.5m. The roadway is driven along the roof of the coal seam. The measured maximum gas content is 8.9m³/t. The outburst prevention index K1 is 0.15~0.32 (measurement depth 10m). The amount of cuttings S is 3.8~4.6kg (measurement depth 10m). The roadway uses anchor rods, the net, steel belt, and anchor cable are combined to support the roadway. The roadway excavation construction is a one-way digging into the roadway at a full section, and the driving speed is 7m/d.

The 3605 return air measures the lane using pressure-entry ventilation, which is arranged according to dual fans and dual power supplies and a single fan. The local fan model is FBDY-NO6.7, the working surface is equipped with 460m³/min, and the return air flow gas concentration during the tunneling is 0.69~0.82%, average 0.76%, gas emission 3.17~3.77m³/min, average 3.47 m³/min.

3605 Return air measures have a large amount of gas emission. If no effective measures are taken, the gas in the working face will inevitably be overrun, which will affect the working efficiency of the working face. In order not to affect the mining of the working face, the recyclable capsule plugging device was tested for sealing and drainage, and the overhaul short-hole drilling head was used to extract the gas from the working face.

3. Short hole extraction mechanism
Due to the influence of the excavation operation, the stress of the original coal body reached a state of equilibrium again. First, the stress was concentrated in front of the working surface, and the maximum stress was 1 to 2 times higher than the original stress. When the stress concentration value reached the yield limit of the coal body, the plastic failure of this part of the coal body causes the concentrated stress to shift to the deep part, thereby forming a pressure relief area, a stress concentration area and an original stress area [5]. The distance from the maximum stress point to the coal wall is called the plastic limit stress area, such as shown in Figure 1.

![Figure 1. Schematic diagram of stress distribution in front of tunneling face](image)

In the plastic limit stress zone, the coal structure is damaged, and the phenomenon of expansion and expansion occurs. A large number of cracks are generated and penetrate each other. The permeability of the coal seam has greatly increased, creating favorable conditions for gas drainage. Under the action of negative pressure, a large amount of coal gas is extracted, effectively reducing the gas content of the coal body in front of the driving face, and ensuring the safe and rapid driving of the working face.

Theoretical research shows that the length of the pressure relief zone is inversely proportional to the internal friction angle and cohesive force, and proportional to the ground stress and coal seam inclination [6]. In practice, the length of the pressure relief zone is generally between 4 and 6 m.

4. Quick extraction scheme for short boreholes in heading face

4.1. Parameter determination
Short holes (75mm in diameter and 12m in depth) are being constructed at the heading of the tunnel.
The short holes are arranged in two rows and a total of 8 short holes are arranged. There are 4 drainage holes arranged in each row, with a single row drilling interval of 0.9m and a horizontal projection pitch of 0.45m; the drilling opening height is 1.2m and 2m [7] [8]. The drilling arrangement is shown in Figure 2.

![Figure 2: Short drilling layout of tunneling face](image)

4.2. Sealing process
The short drilling extraction in the mining face requires the characteristics of shallow sealing depth, short drainage time, and reusability. It has special requirements for the hole sealing device and the sealing technology. The requirements for the plugging device are "simple operation, light weight, and reuse"; the requirements for the plugging process are "easy operation, tight sealing, and fast connection" [9] [10]. The rubber sealer has a simple structure, is quick and easy to use, and can be reused. It is very suitable for short-hole drilling and extraction of the driving face. The sealing principle of the rubber sealer mainly includes water (pneumatic) pressure type, push type and insert type. Through market research on these three kinds of plugging device, finally decided to choose a capsule plugging device, which has the advantages of light weight, fast sealing speed, easy operation, reusable and so on.

4.3. Drilling sealing and drawing
Insert a φ50mm capsule plugging device into the working face to be drilled, and then inject water with a certain pressure into the rubber plugging device to expand it to fully fit the drilling hole to ensure the tightness of the drilling hole. The manifold is connected to the 8 boreholes to be pumped (the area with a larger drainage volume can be considered to increase the number of manifolds and reduce the number of bores per manifold), and finally merge the manifolds into the gas pipes for drainage. The construction team should reasonably arrange the drilling time to ensure that the maintenance class has a gas drainage time of not less than 4 hours.

4.4. Construction process
(1) By strengthening the management of handover shifts, the use of night and early shift shifts will allow the construction of short boreholes. According to a few days of testing, the use of anti-outburst rigs only takes 15 minutes for each drilling construction, which can guarantee the completion of the head short drilling construction before 9 o’clock in the morning shift.
(2) Draw and seal the short short boreholes in a timely manner to ensure that the extraction time of the short boreholes reaches 4 hours.
(3) Complete the daily overhaul of the excavation equipment during the short borehole extraction period;
(4) After the extraction time of the short-term borehole reaches 4 hours, release the pressure of the rubber hole sealer to its original state and take it out, and place it as required for the next use.
(5) Normal excavation can be started after extraction is completed, and 6 ~ 7m is excavated every
day, leaving a lead of 5m.

5. Analysis of gas governance effect

5.1. Short hole extraction test parameters
Table 1 is the data of short-hole drilling for a week in a row at the 3605 return air measures. It can be
seen from Table 1 that the total drainage volume of the short-cut borehole is 0.27 ~ 0.39 m³ / min, and
the average drainage volume is 0.34 m³ / min. The coal seam reserves in the drainage area are 209.8t,
and the gas content is calculated according to 8.9 m³ / t. The coal seam gas reserves in the drilling
control range are 1867 m³. According to the actual drainage data of short boreholes, the average
borehole drainage volume is about 0.34 m³ / min. According to the calculation of 4 hours of borehole
drainage, the amount of gas extracted from the short borehole is about 81.6 m³, and the gas content of
raw coal has decreased by 0.37 m³/t.

| Number of days | Mix amount (m³/min) | CH4 (%) | scalar (m³/min) | Number of boreholes | Single hole flow (m³/min) |
|----------------|--------------------|---------|----------------|--------------------|-------------------------|
| 1              | 4.535              | 6.9     | 0.31           | 8                  | 0.039                   |
| 2              | 4.387              | 7.5     | 0.33           | 8                  | 0.041                   |
| 3              | 4.788              | 8.2     | 0.39           | 8                  | 0.049                   |
| 4              | 4.908              | 7.5     | 0.37           | 8                  | 0.046                   |
| 5              | 3.982              | 6.7     | 0.27           | 8                  | 0.033                   |
| 6              | 4.37               | 7.4     | 0.32           | 8                  | 0.040                   |
| 7              | 4.645              | 7.8     | 0.36           | 8                  | 0.045                   |

5.2. Analysis of gas drainage effect before and after the test
In order to verify the effect of the short-hole fast-sealing and quick-drawing test, the gas concentration
before and after the short-drilling extraction test at the 3605 return airway roadway mining face and
the progress of each working face were statistically calculated. The test of the morning shift
(maintenance course) is mainly based on the middle shift driving conditions and gas concentration.

Based on the statistical data of the middle shift heading and gas concentration of the tunnel driving
face of the 3605 return air measures, the chart is generated as shown in Figure 3. From June 1 to June
6, before taking the drainage measures, plan to remove 4, 5 The gas concentration during day
excavation is relatively low. The average shift in the middle shift is 2.5m. The return gas concentration
is 0.69 ~ 0.82%, the average gas concentration is 0.75%, the working surface gas concentration is 0.41
~ 0.54%, and the average gas concentration is 0.48%. From June 7 to On June 15th, during the
short-hole rapid extraction test, except for the excavation on June 9th, the average shift in the middle
shift was 2.67m. The return gas concentration was 0.46 ~ 0.69%, and the average gas concentration
was 0.59%, compared with the gas concentration before extraction. Decreased by 0.16%, the
extraction effect is significant; the gas concentration in the working face is 0.18 ~ 0.65%, and the
average gas concentration is 0.38%. Compared with that before the extraction, the gas concentration is
decreased by 0.1%, and the extraction effect is significant.

Judging from the gas emission during the middle shift, without considering the influence of factors
such as ventilation distance and coal wall gas emission, compared with the period when no short hole
drainage measures were taken, the short hole in the mining face was used for rapid extraction. After
the measures were taken, under the condition of ensuring that the gas did not exceed the limit, the
tunneling efficiency increased significantly, and under the same tunneling footage (3m), the return air
flow and the gas concentration at the working face decreased significantly.
Figure 3. The relationship between gas concentration and excavation footage in middle shift

6. Main conclusion

(1) During the test with water-filled rubber plugging device, the total drainage volume of the short-cut boreholes is 0.27 ~ 0.39 m$^3$/min, and the average drainage volume is 0.34 m$^3$/min. Heading short borehole drainage gas extraction volume is about 81.6 m$^3$ for 4 hours, and the drainage effect is considerable.

(2) According to the driving data of the production shift and the monitoring data of the gas probe, the drainage efficiency during the sealing and drainage with the water injection rubber sealer was significantly increased compared with that before the drainage measures were taken. The return air flow and the gas concentration in the working face decreased significantly.

(3) The speed of the working face's driving efficiency mainly depends on the effect of the short borehole drainage. To ensure the sealing quality and the extraction time of the short borehole, the safe and efficient mining of the working face can be guaranteed.

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