Application and analysis of short-hole rapid extraction technology in high gas long distance driving face

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Abstract. Aiming at the poor coal seam permeability and rapid attenuation of bored gas flow in the Huoerxinhe Coal Mine in Shanxi, the high return gas concentration in the long-distance tunneling of the coal roadway affects the speed of the coal roadway, and it is proposed to use a short time for maintenance. The new ideas for rapid and centralized drainage of boreholes during heading are to extract small-scale gas in a short time and high intensity, reduce ventilation pressure, and increase the speed of coal roadway. The application of the 3605 return air circulation in the Huoerxinhe coal mine shows that the short-drilling fast extraction process is adopted in the maintenance class, and the monthly footage of the work face is increased by 50% on the premise that the return air flow and the gas concentration in the work face are reduced by 20%. Realize the effective treatment of the long-distance coal roadway driving face of low-permeability coal seam, and ensure the safe production of the working face.

1. Introduction

Mine gas is one of the main factors affecting the safe production of coal mines. The gas problem has always been a major problem that restricts mine production capacity and affects mine safety and economic benefits [1-2]. As the mine development area extends deeper, the gas permeability of coal seams is getting worse and worse under the influence of ground stress; the gas drainage effect of coal roadway working face is not good, and the abnormal gas emission is increasing frequently [3-7]. With the increase of the mechanized strength of the mine, and the long trough design of the working face at the same time, most mines need to face the problem of gas management in the long-distance coal roadway working face [8-11]. For this reason, this article analyzes the source of gas emission from the long-distance coal roadway working face in Huoerxinhe Coal Mine, Shanxi. Using the overhaul time, a short drilling fast extraction process is adopted. Time and high-intensity drainage of small-scale gas can achieve the purpose of reducing the heading face and return air flow ventilation pressure, increasing the heading speed, and ensuring safe production. At the same time, it provides new ideas for solving the gas management problems of high gas long-distance coal roadway driving face.

2. Analysis of gas management status and source of gas in driving face

2.1 Status of gas management in driving face
Huoxinhe Coal Mine is a high-gas mine. It mainly mines No. 3 coal seam. This seam is located in the lower part of the Shanxi Formation. The coal seam thickness ranges from 4.49 to 7.17 m, with an average thickness of 5.65 m. There are 0 to 2 layers, generally 1 layer, and it is stable about 0.78 m away from the bottom plate (average thickness 0.30 m). The gas content of No. 3 coal seam is 7 to 14 m$^3$/t; the attenuation coefficient of borehole gas flow is 0.0861 to 0.4161 d$^{-1}$, the permeability coefficient is 0.0914 to 0.1936 m$^2$/ (MPa$^2$·d)$^{-1}$; the initial gas release speed $\Delta P$ is 12 to 18. The solidity coefficient of coal is 0.46 to 0.47, and the porosity is 2.13 to 3.04%.

The coal mine roadways are excavated along the roof of the coal seam. The cross section of the roadway is 4.8 m × 3.3 m. Using the comprehensive digging process, the entire section is dug at one time. The production class uses the “one digging and one digging” construction method. The daily footage is 4-6 m, the average footage is 5 m, and the monthly average footage is 150-170 m. At present, the driving face adopts the method of first exploration, then extraction and then digging (“ear drill field + head extraction method”), and the extraction is performed before reaching the standard [12]. The schematic diagram of gas drainage in the coal mining face is shown in Figure 1.

![Schematic diagram of head gas drainage in coal roadway driving face.](attachment:image)

Due to the fast digging speed, fast coal seam gas release speed, the long working face along the trough design, and the large exposed coal wall area, the return air flow at the digging face has the risk of exceeding the limit. The coal roadway digging speed is slow, which seriously affects the mine Mining connection and safe and efficient production.

2.2 Gas source analysis during the excavation

The main mining coal mine is No. 3 coal seam, No. 3 coal seam is a single thick coal seam, the average thickness of the coal seam is 5.65 m. From the perspective of the gas emission characteristics of the mine, the gas in the mining face mainly comes from the coal seam; Analysis shows that the gas concentration of the return air flow fluctuates greatly during the normal excavation of the roadway. The concentration of the return air flow maintenance gas is generally between 0.3% and 0.5%, with an average of 0.35%; the return air flow production gas concentration is generally between 0.5 and 0.8%, with an average of 0.65%. Due to the long design of the roadway and the large exposed area of the coal wall, the gas emission from the coal wall accounts for nearly 55-60% of the return air gas.

3. Principle of rapid extraction in short boreholes

At present, in the mining process of high-gas mine coal roadway working face, gas drainage is the most important factor that affects the drilling footage, especially high-gas, low-permeability coal seam coal roadway, with long extraction time and poor extraction effect. It is not conducive to the normal mining connection of the mine, and at the same time causes waste of the excavation personnel. The rapid drilling process for short boreholes in the mining face is to use a maintenance class time to quickly extract the gas in the mining face using the method of fast hole sealing and pumping to reduce...
the gas in the mining area as much as possible and reduce the gas emission in the working face during the tunneling process. Method of mine ventilation pressure to increase coal roadway driving speed.

First, a hand-held anti-outburst rig was used to quickly construct multiple short boreholes at the heading. The short boreholes were distributed horizontally or equally across the coal seam. The design length of the short boreholes was about 12-15m. Quick hole sealer is used to seal the hole, and the length of the hole is 2-3m. Finally, quick extraction is performed, and the time of a maintenance class is used for gas pressure relief drainage. In the area where the gas is abnormally increased, the drainage time can be appropriately extended to ensure Tunneling safety.

Quick extraction of short boreholes controls the short heading distance, wide control area, and high drilling utilization rate; and the special short hole sealer is used for quick and easy access. The gas will be removed from the drainage pipe in a short time, reducing the mine ventilation pressure and increasing the driving speed. It is especially suitable for high-efficiency and low-permeability coal seam heading working face for efficient extraction and fast heading, and more safely and efficiently to deal with the problem of high gas heading working face and return air flow gas limit. The schematic drawing of short borehole drainage is shown in Figure 2.

![Figure 2 Schematic diagram of rapid extraction of short holes.](image)

4. Design scheme for rapid extraction of short boreholes

4.1 Overview of the test area

The short-drilling rapid drainage test location is located in the 3605 return air trough of the Huoerxinhe Coal Mine, which is arranged in the No. 3 coal seam. The thickness of the coal seam is 5.3 to 5.9 m, and the inclination angle is 0° to 5°, with an average of 2.5°. Judging from the geological advance hole exploration, there is no large geological structure in the tunneling area. Driving along the roof of the coal seam, the section of the roadway is 4.8m × 3.3m. The roadway opens in the east return wind alley, and is dug from west to east. The gas in the heading face mainly comes from the coal seam. The gas content of raw coal reaches 10 ~ 13m³ / t. After the drainage standard is reached, a statistical analysis of the gas emission from the excavation shows that when the roadway is normally excavated, the gas concentration in the return air is 0.53 ~ 0.79%, and the gas concentration in the working face is 0.33 ~ 0.44%.

4.2 Drilling construction and connection

4.2.1 Drilling construction method

Make use of the off-duty handover time of the production shift, and use anti-outburst drilling rigs to construct short drill holes (hole diameter 75mm, hole depth 12m) on the heading face. The short drill holes are arranged in two rows, and the upper hole is 2m away from the bottom plate. The lower hole is drilled. 1.2m away from the bottom plate; 4 extraction holes are arranged in each row, with a single row drilling interval of 0.9m and a drilling projection interval of 0.45m; the drilling opening height is
1.2m and 2m. The drilling arrangement is shown in Figure 3, and the drilling parameters are shown in Table 1.

![Figure 3 Schematic layout of drilling parameters for short boreholes.](image)

**Table 1 Construction parameters for rapid extraction of short boreholes.**

| Numbering | Height of opening from floor of roadway (m) | Distance from opening to left lane (m) | Angle between drilling and heading face (°) | Construction length (m) | Inclination (°) |
|-----------|------------------------------------------|--------------------------------------|----------------------------------------|-------------------------|----------------|
| Up1       | 2                                        | 0.45                                 | 90                                     | 12                      |                |
| Up2       | 2                                        | 1.35                                 | 90                                     | 12                      |                |
| Up3       | 2                                        | 2.25                                 | 90                                     | 12                      |                |
| Up4       | 2                                        | 3.15                                 | 90                                     | 12                      | Coal seam     |
| Down1     | 1.2                                      | 0.9                                  | 90                                     | 12                      | inclination   |
| Down2     | 1.2                                      | 1.8                                  | 90                                     | 12                      |                |
| Down3     | 1.2                                      | 2.7                                  | 90                                     | 12                      |                |
| Down4     | 1.2                                      | 3.6                                  | 90                                     | 12                      |                |

4.2.2 Drilling, sealing and drawing

The drainage holes that have been constructed are sealed with recyclable quick hole sealers. Drilling extraction time is 4 ~ 6 hours or longer. Quick extraction drilling has short effective drilling, short extraction time, and small extraction flow; DN75 manifold is used to connect 8 bores, and a diversion tube is installed at the end of the manifold; designed to drill more areas or extract In areas with large production volume, consider increasing the number of manifolds and reducing the number of bores per manifold.

4.3 Observation of drilling parameters

After drilling and drawing, technicians conduct real-time observation on the concentration, flow rate, negative pressure and other parameters of the manifold extraction every day.

5. Application effect analysis of short drilling

5.1 Drainage effect analysis

During the short drilling test (10 days of test), the total mixed gas extraction volume from the mining face was 1.89 ~ 3.08 m³/min, with an average of 2.33 m³/min; the extraction concentration was 8.78 ~ 15.56%, and the average extraction concentration was 11.90%; Gas volume is 0.24 ~ 0.31 m³/min, average volume of pure gas is 0.27 m³/min, drilling time is 4-5.5 hours, average 5 hours; total gas volume is about 69.10 ~ 96.54 m³ in one cycle. The average daily total drainage volume is 80.32 m³. The specific drainage effect is shown in Table 2.

The coal seam reserves in the drainage area are 209.8 t, and the gas content is calculated according to 8 m³/t. The coal seam gas reserves in the drilling control range are 1678.4 m³. During the test, the
average daily total drainage volume was about 80.32m³/ min. The gas reserve was 4.78%, and the gas content in the drainage area decreased by about 0.38m³/t.

Table 2 Extraction effect of test drilling.

| time | Mixing amount (m³/min) | Extraction concentration (%) | Scalar (m³/min) | Negative pressure (kPa) | Extraction time (min) | Total drainage gas (m³/min) |
|------|------------------------|------------------------------|-----------------|------------------------|-----------------------|-----------------------------|
| 6.1  | 1.92                   | 12.54                        | 0.24            | 26.8                   | 300                   | 72.23                       |
| 6.2  | 3.05                   | 9.44                         | 0.29            | 24.5                   | 240                   | 69.10                       |
| 6.3  | 1.98                   | 15.56                        | 0.31            | 26.8                   | 270                   | 83.18                       |
| 6.4  | 2.46                   | 9.14                         | 0.22            | 24.5                   | 300                   | 67.45                       |
| 6.5  | 2.28                   | 10.46                        | 0.24            | 25.4                   | 330                   | 78.70                       |
| 6.6  | 2.13                   | 11.52                        | 0.25            | 26.5                   | 270                   | 66.25                       |
| 6.7  | 3.08                   | 8.78                         | 0.27            | 22.8                   | 300                   | 81.13                       |
| 6.8  | 2.32                   | 12.61                        | 0.29            | 21.8                   | 330                   | 96.54                       |
| 6.9  | 1.89                   | 15.15                        | 0.29            | 23.5                   | 330                   | 94.49                       |
| 6.10 | 2.28                   | 13.76                        | 0.31            | 22.5                   | 300                   | 94.12                       |

From the perspective of pure gas drainage volume, drainage concentration and total drainage volume per minute, the drilling drainage effect is better. Due to the short drainage time, the total gas drainage volume is low, and the drainage gas drainage volume and concentration The attenuation is not noticeable.

5.2 Gas concentration analysis of working face and return air flow during driving

In order to verify the effect of the fast plugging test, the distribution of gas concentration in the working face and return air flow before and after the test, and the distribution of the footage in each working face were statistically calculated. The specific parameters are shown in Table 3.

Table 3 Gas concentration in working face and return air flow during driving.

| Time (before test) | Heading footage (m) | Maximum concentration (%) | Time (Under test) | Footage (m) | Maximum concentration (%) |
|--------------------|---------------------|---------------------------|-------------------|-------------|---------------------------|
|                    |                     | Return flow | Working face | Return flow | Working face |
| 5.21               | 5.60                | 0.76       | 0.40       | 6.1         | 8.80         | 0.68        | 0.31        |
| 5.22               | 6.40                | 0.78       | 0.42       | 6.2         | 8.00         | 0.64        | 0.29        |
| 5.23               | 4.80                | 0.73       | 0.41       | 6.3         | 8.00         | 0.65        | 0.31        |
| 5.24               | 5.60                | 0.79       | 0.39       | 6.4         | 9.60         | 0.66        | 0.30        |
| 5.25               | 5.60                | 0.71       | 0.38       | 6.5         | 7.20         | 0.62        | 0.27        |
| 5.26               | 5.60                | 0.68       | 0.35       | 6.6         | 8.80         | 0.63        | 0.33        |
| 5.27               | 6.40                | 0.72       | 0.41       | 6.7         | 8.80         | 0.65        | 0.30        |
| 5.28               | 6.40                | 0.65       | 0.40       | 6.8         | 9.60         | 0.60        | 0.23        |
| 5.29               | 5.60                | 0.74       | 0.39       | 6.9         | 8.00         | 0.58        | 0.28        |
| 5.30               | 4.80                | 0.76       | 0.39       | 6.10        | 8.00         | 0.63        | 0.28        |

From May 21st to May 30th, before the short-hole drilling and drainage measures were taken, the average daily footage was about 5.7m, the average gas concentration in the return air flow was 0.73%, and the average gas concentration in the working face was 0.39%. From June 1 to June 10, during the fast-sealing test, the average daily footage was about 8.5m, the average gas concentration in the return air flow was 0.63%, and the average gas concentration in the working face was 0.29%. Regardless of factors such as air volume and coal wall gas emission, before and after rapid extraction using short boreholes, under the premise that the daily footage is increased by 2.8 m, the gas concentration in the working face and the return air flow has decreased by 0.1%, and the gas concentration has decreased
significantly. The change and comparison of gas concentration in the working surface and return air flow before and after the test are shown in Figure 4.

According to the heading footage of the production class and the monitoring data of the gas probe, during the fast sealing of the test, the gas concentration in the return air flow decreased, the gas emission in the working face was uneven, and the gas concentration in the working face and return air flow decreased significantly.

5.3 Heading Speed Analysis
The cumulative monthly footage of coal lanes implemented by rapid drilling with short boreholes is about 250m, and the gas concentration of return air flow during the face mining is controlled to be less than 0.7%; In the excavation project, the gas concentration in the return air flow reached 0.79%. Compared with the traditional direct extraction after the extraction is achieved, the short-hole rapid extraction method will remove some of the gas from the extraction system and reduce the ventilation pressure of the long-distance tunneling. The speed of coal lane driving has increased by nearly 50%.

6. Conclusion
The short-hole rapid extraction technology of the coal mining heading working face overcomes the shortcomings of the existing technology in terms of time and space. By using the maintenance class time, the gas drainage in the mining face is changed from a long distance to a short distance and efficient extraction. Mining, reducing the ventilation pressure of the long-distance coal roadway driving face; thereby improving the driving efficiency. The rapid drainage technology of short boreholes in the coal mining heading face has been applied to the 3605 return air tunnel of the Huoerxinhe Coal Mine in Shanxi Province, and the drainage effect is obvious. The cumulative monthly footage of the coal mining tunnel has been increased from 170m to 250m, an increase of nearly 50%. The short-drilling rapid extraction technology has achieved good application results in long-distance coal roadway driving faces, and at the same time provides a reference for its wide-scale promotion and application.

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