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Study on Gas Control Technology in Soft and Thin Seam with High Gas Content

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Abstract

The problem of gas control in soft and thin seam with high gas content has been puzzling the safety production of coal mine, and the pre-drainage of borehole gas in this seam is one of the effective measures to solve this problem. According to the occurrence characteristics of soft and thin coal seam with high gas content in a mine in Shanxi, this paper studies the reasonable hole sealing depth and drilling construction technology of this coal seam, and determines that the reasonable hole sealing depth of pre-drainage drilling is 18m, and the optimal drilling construction technology is pneumatic directional drilling, which improves the gas pre-drainage concentration of this coal seam to more than 52%, improves the gas control effect of this coal seam, and provides important reference for gas control of other coal seams with similar occurrence conditions.

Keywords

Gas Control in Thin Coal Seam; Sealing Depth; Drilling Technology; Efficient Drainage.

1. Introduction

Pre extraction of gas from drilling holes in this coal seam is one of the effective measures for controlling gas disasters in coal mines [1]. However, many coal mines suffer from problems such as gas leakage, collapse, and blockage during drilling, which severely limit the effectiveness of drilling and extraction, especially in high gas, soft, and thin coal seams, where this impact is particularly evident. In response to the characteristics of gas occurrence in high gas, soft and thin coal seams, through the study of reasonable sealing depth and drilling construction technology [2], the concentration and purity of drilling and extraction in this coal seam are increased, and the gas content in this coal seam is reduced to the lowest level before backfilling, minimizing the impact of gas disasters on the safe and efficient production of coal mines.

A certain mine in Shanxi Province is a high gas mine. It mines the 2 # coal seam, with a maximum original gas content of 11m3/t, a maximum burial depth of over 800m, a minimum solidity coefficient of 0.36, and a coal seam thickness of 0.5~2.23m. The roof and floor of the coal seam are mainly composed of mudstone, and the geological structure belongs to a simple type. The 2 # coal seam adopts a U-shaped ventilation method, with a comprehensive mechanized full height mining method and a fully collapsed roof management method. The high gas content, deep burial, thin and soft coal seams in the 2 # coal seam seriously restrict the safe and efficient production of the mine.

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2. Research on Reasonable Sealing Depth of Drilling

2.1. Analysis of Drilling Cuttings Volume Method

After the disturbance caused by tunnel excavation, the stress concentration of the surrounding coal body is transferred to the deep and reaches a new equilibrium state. From the side of the tunnel to the deep coal body, the stress distribution state is sequentially divided into pressure relief zone, stress concentration zone, and original rock stress zone [3]. According to the state of coal fragmentation, it is divided into crushing zone, plastic zone, elastic zone, and unaffected zone. The height of coal fractures in the depressurization zone is highly developed, providing a favorable channel for air to enter the extraction boreholes in the roadway [4]. The coal body in the stress concentration area undergoes elastic compression with fewer cracks, but the extraction boreholes in this area are prone to problems such as collapse and blockage. The original rock stress zone is consistent with the original coal body state.

Due to the stress concentration transferring to the deeper part after excavation of the tunnel, the amount of drilling debris in the pressure relief area is small and slowly increasing. The amount of drilling cuttings in the stress concentration area increases rapidly and reaches its maximum value at the peak stress. The amount of drilling cuttings in the original rock stress area returns to a stable state. Therefore, the distribution range of pressure relief zone, stress concentration zone, and original rock stress zone around the roadway can be determined by measuring the amount of drilling cuttings at different depths. The distribution of stress and fragmentation status of the coal body around the tunnel is shown in Figure 1.

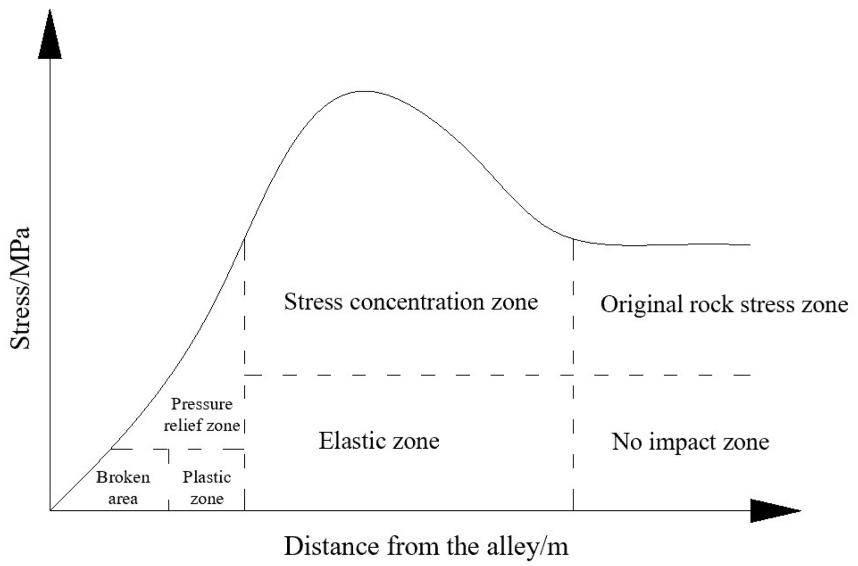

Figure 1. Schematic diagram of stress and fragmentation status distribution of coal around the roadway

Based on the variation law of coal drilling debris in different stress distribution areas around the roadway, the stress distribution range of the surrounding coal seam roadway in the 2 # coal seam of the mine is determined. Handheld pneumatic drilling rig is used in the 12 machine alley, with supporting equipment Φ42mm drill bit was used to construct 5 drilling holes for measuring the amount of drilling cuttings. The amount of drilling cuttings was measured for each 1m of drilling, and the relationship between the measured values of drilling cuttings and the depth of the hole is shown in Figure 2.

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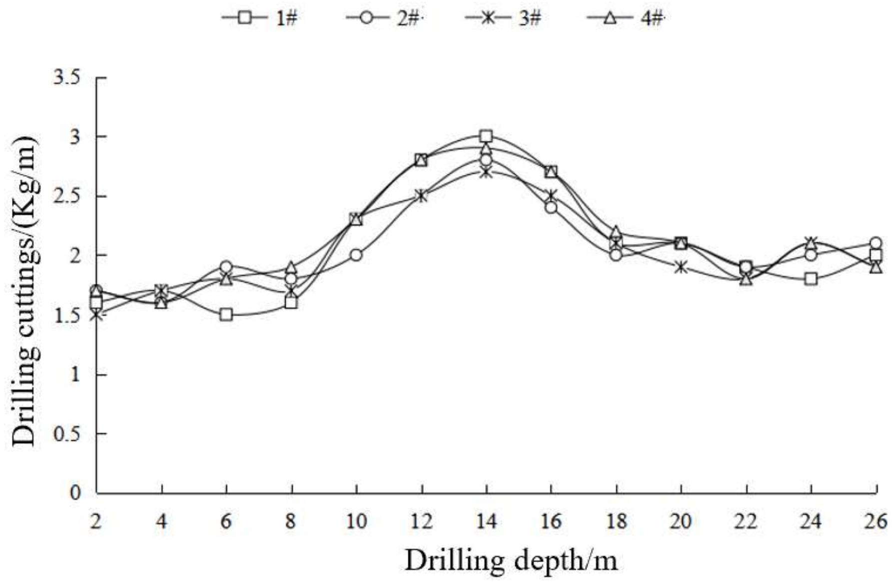

Figure 2. Curve of variation in measured values of drilling cuttings at different hole depths

From Figure 2, after the excavation disturbance of the tunnel, the range of the pressure relief zone is 0-8m, and the range of the stress concentration zone is 8~18m. In order to prevent drilling problems such as gas leakage, collapse, and blockage as much as possible, the sealing depth of pre drilled holes in this coal seam should exceed the stress concentration area, with a minimum sealing depth of 18m.

2.2. Comparative Analysis of Pumping Effects at Different Sealing Depths

Based on the analysis results of the drilling cuttings method, a comparative experimental study was conducted on the pumping effect at different sealing depths on site. Five pre drilled holes were constructed successively in the 12 machine roadway, with construction parameters of hole depth of 100m, hole diameter of 96mm, and hole spacing of 5m. The "two plugs and one injection" pressure grouting sealing process was adopted for all holes, with sealing depths of 6m, 15m, 18m, and 21m, respectively. Screen pipes were installed under the entire hole section. After the grouting fluid solidifies, the pressure measuring steel pipes (1.5m/piece) are lowered to different hole depths. The parameters such as CH4 concentration and O2 concentration at different hole depths are measured using a pumping parameter detector. The connection method of the measuring device is shown in Figure 3, and the measurement results are shown in Figures 4 and 5.

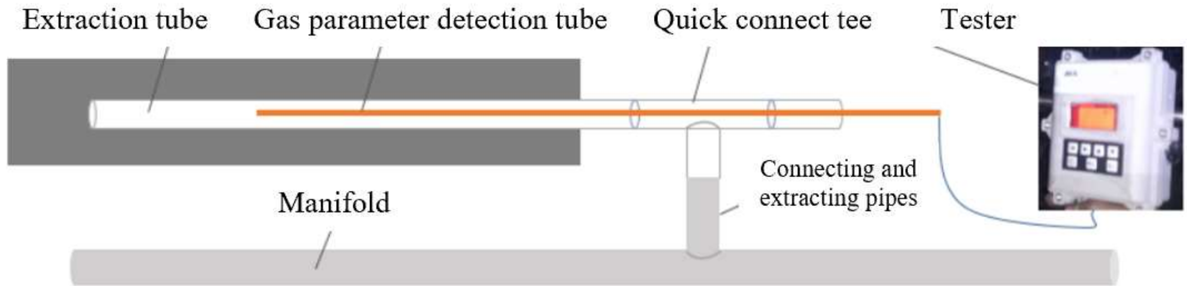

Figure 3. Schematic diagram of the connection of the extraction parameter de**tector**

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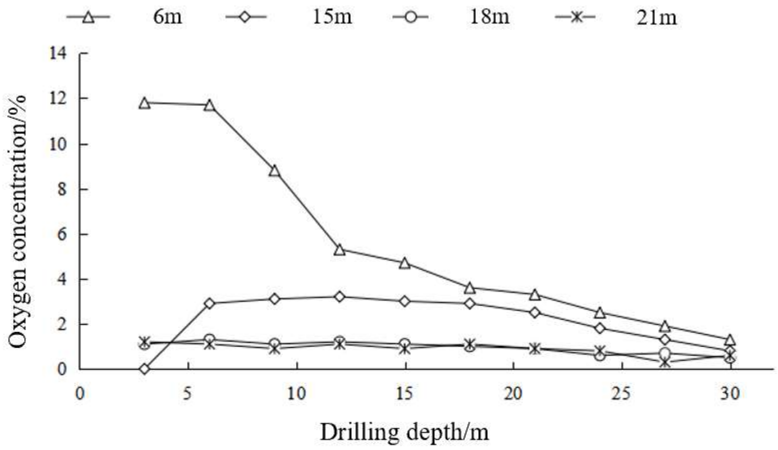

Figure 4. Changes in O2 concentration values with different sealing depths as a function of pore depth

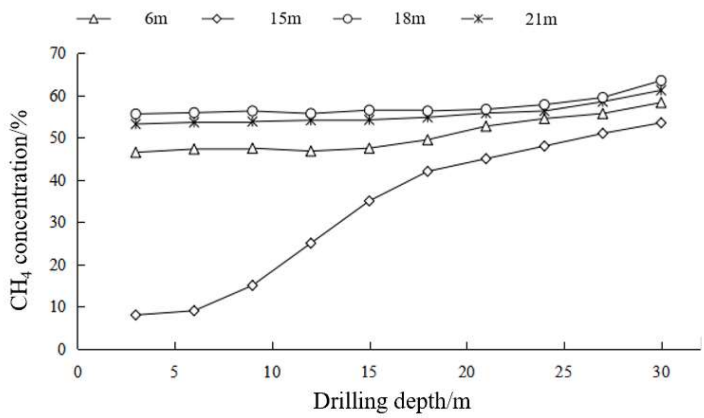

Figure 5. Changes in CH4 concentration values with different sealing depths as a function of pore depth

From Figure 4 to Figure 5, it can be seen that when the sealing depth is 6m, the concentration values of gas and oxygen in the borehole show a "stepped" pattern with the increase of hole depth, and there is a serious gas leakage phenomenon. When the sealing depth is 15m, the range of O2 concentration value variation is 0.8%~3.2%, and the range of CH4 concentration value variation is 46.5%~58.3%, indicating slight air leakage. When the sealing depth is 18m, the range of O2 concentration value changes from 0.5% to 1.3%, and the range of CH4 concentration value changes from 53.2% to 61.2%. The oxygen concentration value in the drilling hole decreases to a lower level. When the sealing depth is 21m, the variation range of O2 concentration value is 0.3%~1.2%, and the variation range of CH4 concentration value is 55.6%~63.5%, which is relatively small compared to the measured oxygen concentration value at a sealing depth of 18m. Therefore, based on the comparative analysis of the measurement results of extraction parameters at different sealing depths, a reasonable sealing depth of 18m was established.

3. Research on Different Drilling Construction Techniques

The construction techniques for drilling in this coal seam include pneumatic conventional drilling, hydraulic directional drilling, pneumatic directional drilling, etc. Each construction technique has different advantages and disadvantages. In response to the occurrence characteristics of high gas, soft, and thin coal layers in the 2 # coal seam of the mine, a

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comparative experimental study was conducted on the application of different drilling techniques in this coal seam to determine the optimal drilling construction technology, in order to ensure construction efficiency and extraction effect.

3.1. Test Plan

In the 12 machine roadway, the test boreholes are divided into three groups: A, B, and C, and comparative tests are conducted using ordinary boreholes, hydraulic directional boreholes, and pneumatic directional boreholes for construction. The drilling layout is shown in Figure 6, and the construction parameters are shown in Table 1

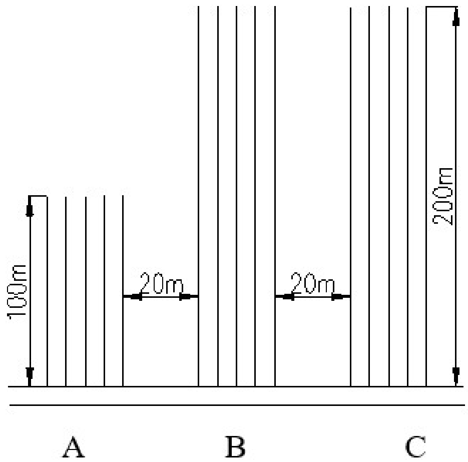

Figure 6. Experimental scheme for drilling layout of different construction techniques

Table 1. Experimental drilling construction parameters

Group	Drilling type	Hole spacing /m	Aperture/mm	Hole depth/m	Sealing depth/m	Construction equipment
A	Ordinary diamond (air discharge slag)	5	96	100	18	ZDY-6500LPS mining crawler type ordinary drilling rig, Φ 73mm drill pipe, Φ 94mm alloy drill bit
B	Hydraulic directional drilling	5	96	200	18	ZYL-8500D tracked directional drilling rig for mining, BLY410/8 pump truck
C	Pneumatic directional drilling	5	96	200	18	Screw type mobile air compressor for coal mines, MLG25.5/25-250G (A) type, ZYL-8500D directional drilling rig

3.2. 3.2 Comparative analysis of construction effects

Statistics were conducted on the construction efficiency of drilling holes in groups A, B, and C, as well as the proportion of screen tube placement (the ratio of screen tube placement to hole depth), as shown in Table 2. According to Table 2, it can be seen that for the occurrence characteristics of the 2 # coal seam in the mine, compared with pneumatic conventional drilling and hydraulic directional drilling, pneumatic directional drilling shows significant advantages in construction efficiency, hole formation efficiency, and the proportion of screen tube lowering.

Table 2. Comparative analysis of drilling construction effects among different groups

Group	Daily average footage/(m/d)	Ratio of sieve tube placement/%	Main issues
A	120	81.06	The drilling trajectory is uncontrollable, and when the hole depth reaches 50-60m, it is easy to see the top and bottom. A single hole requires multiple adjustments to the inclination angle and repeated construction, with large coal dust
B	84	76.87	Severe borehole collapse and poor slag return
C	105	83.62	Add a set of air compressor equipment and high-pressure pipelines, as well as large coal dust

3.3. Comparison and Analysis of Pumping Effects

Observing the extraction data of drilling holes A, B, and C for three consecutive months, the relationship between the average extraction concentration and pure quantity of each group of drilling holes is shown in Figures 7 to 8.

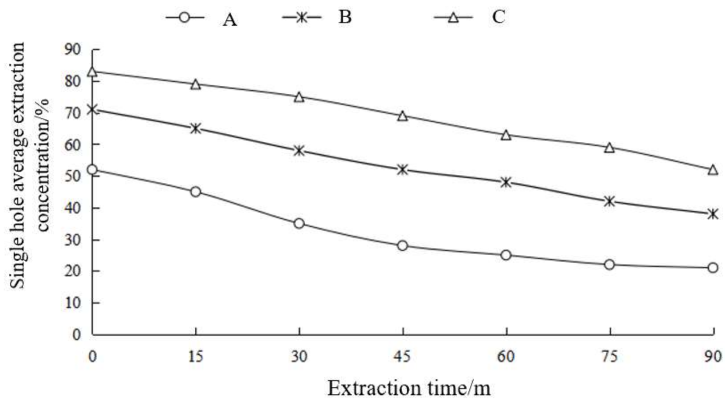

Figure 7. Changes in average extraction concentration of different boreholes

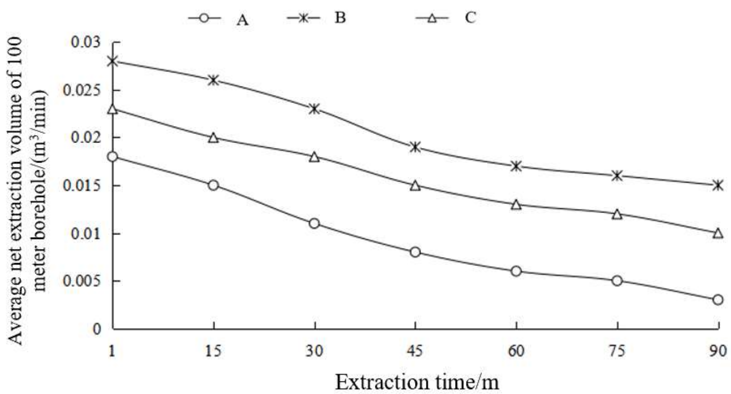

Figure 8. Changes in average extraction purity of different boreholes

From Figures 7 to 8, it can be seen that the extraction concentration of pneumatic conventional drilling is 21% to 52%, and the average extraction pure amount of 100 meter drilling is 0.003m3/min~0.018m3/min. The extraction concentration of hydraulic directional drilling is 38%~71%, and the average extraction pure amount of 100 meter drilling is 0.01m3/min~0.023m3/min. The extraction concentration of pneumatic directional drilling is

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52%~83%, and the average extraction purity of 100 meter drilling is 0.015m3/min~0.028m3/min. After comparative analysis, the concentration and purity of gas extraction by pneumatic directional drilling are better than those of pneumatic conventional drilling and hydraulic directional drilling, and the attenuation rate of extraction effect is relatively slow. Therefore, the construction technology of pneumatic directional drilling is more conducive to improving the gas extraction efficiency of this coal seam.

4. Conclusion

Through theoretical analysis, on-site testing and other methods, the depth of borehole sealing and drilling construction technology in this coal seam were studied, and the main conclusions were drawn as follows:

(1) By using the method of drilling cuttings and comparing the extraction effects at different sealing depths, it was determined that the reasonable sealing depth for the coal seam drilling in this mine is 18m.

(2) Through comparative experiments of pneumatic ordinary drilling, hydraulic directional drilling, and pneumatic directional drilling, it was found that pneumatic directional drilling has more advantages in construction efficiency, hole formation efficiency, screen tube lowering ratio, and extraction effect, which is more conducive to gas control in this coal seam.

(3) To ensure the effectiveness of gas control in high gas, soft and thin coal seams, it is necessary to determine a reasonable sealing depth and choose a scientific drilling construction technology.

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