Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2024, 11(1):162-168

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Reasonable Horizon Design and Engineering Application of High-level Directional Drilling

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Abstract In order to study the reasonable horizon of high-level directional drilling for gas extraction when mining close to a thin coal seam group, the 202 working face of Dangjiahe Coal Mine was used as the background, RFPA numerical simulation and drilling water injection experiments, on-site gas extraction parameter measurements were used to comprehensively analyze and determine the scope of the roof fracture zone, and the effect of different horizons of the fracture zone on the extraction effect of the drilling holes was studied, and the results showed that the reasonable horizon of the directional drilling at the test face was 15.5-17.5m; the experimental results are applied in the 204 working face, after the implementation of which, the amount of gas extracted by the high level drilling holes accounted for 42.3%-50% of the total amount of gas extracted from working face, and the concentration of gas in the air return corner of working face was kept at about 0.5%, and the concentration of gas in the corner of the return air was less than 0.5%, which ensured the progress of the coal mining face, and provided references for the treatment of gas in mines with similar conditions.

Keywords Roof directional drilling; reasonable horizon; gas extraction; fracture zone

1. Introduction

For mines mining close to the coal seam group, preventing and controlling the gas in the working face is the key to mine safety and the focus of ensuring safe production. At present, China mainly adopts the method of over-pumping of gas by drilling holes to control this problem [1]. However, the pre-extraction of gas by drilling requires the construction of control roadways, and there are problems such as large amount of construction drilling, long gas extraction period, and high cost of development and maintenance of control roadways. In addition, most of the mines are constructed by ordinary drilling rigs, which are affected by the drilling track drift and the permeability of the coal seam, etc. After a certain period of time of coal seam gas extraction, a large amount of gas still remains, and once the coal seam breaks up during the production process, the residual gas is desorbed, and the amount of gas discharged by the wind will exceed the regulations [2].

Directional drilling is a technology developed in recent years with precise control of drilling trajectory and realization of deep hole drilling, which is mostly used in domestic coal mines for extracting gas in the airspace by drilling high level holes in the roof construction. By arranging directional drilling holes in the fissure zone of the roof plate through the kilometer directional drilling rig to extract the gas from the overlying rock layer, coal layer and the corner of the working face, it can effectively solve the problem of overlimit of the gas in the corner of the working face and the return airway caused by the large amount of gas outflow from the hollow area or the neighboring layer [3]. How to arrange the extraction drill holes in the reasonable overburden layer to maximize the effect of gas extraction is the key to the effective treatment of gas by this method.

Numerous scholars have conducted extensive research on how to determine the optimal gas extraction layer. Qian Minggao [4] proposed the theory of "O" type pressure relief circle in the overlying rock layer by studying the distribution characteristics of mining fissures in the overlying rock layer after coal seam mining, and then arranged the extraction boreholes in this fissure zone to achieve the best extraction effect. Yuan Liang [5] proposed a method to determine the high level ring-shaped fissure body for efficient gas extraction in low permeability coal seam group by the dynamic changes of the surrounding rock stress field, fissure field and gas flow field in the process of mining deep coal seams. Zhang Mingjie [6]. The optimal methane filtration interval was determined by studying the mechanism of methane filtration and purification by the spatial mesh structure of the fissure zone in the roof of the coal seam. Song Bin [7]. Combined the permeability- effective stress flow-solidity coupling model with COMSOL for coal rock samples with different damages, and comparatively analyzed the effects of changes in conditions such as fissure permeability and drilling gas on the ratio of extraction volume, and proved that the cumulative gas production of a single hole in high extraction holes can be effectively improved by increasing the radius of extraction holes and arranging the holes in the area with higher gas pressure. Hu Jie et al. [8] proposed a gas extraction technology combining full-coverage extraction by near-field directional drilling and interlayer pressure relief extraction by far-field layer-penetrating drilling to realize targeted and efficient management of gas during the mining back of protective seams in mines with a cluster of proximally protruding coal seams. Zhang Mingjie [9] analyzed the influence of mining movement on coal seam roof fissure, and studied the arrangement and parameters of high directional drill holes.

This paper takes the No. 2 coal seam of Dangjiahe Coal Mine of Shaanxi Fuyuan Coal Co., Ltd. as the research background, and completes the research on the top plate long drilling efficient gas extraction technology through the research on the suitable drilling arrangement location and extraction process, closely combined with the directional long drilling construction equipment process, to effectively realize the gas management of the back mining face, ensure the smooth progress of the back mining work, and provide reference for the gas management of mines with similar conditions.

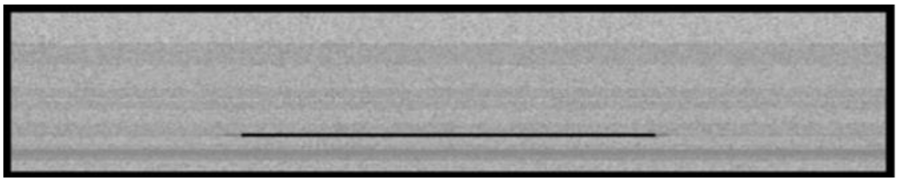
2 Coal Seam Roof Rift Zone Layering Study

2.1 Overview of the working face

The Dangjiahe Coal Mine contains three coal seams in the well field, which are numbered as No.1 coal seam, No.2 coal seam and No.3 coal seam in order from top to bottom. The thickness of No.1 and No.3 coal seams is too thin, and they are not mineable. The average thickness of No.2 coal seam is 1.8m, and the coal seam is nearly horizontally developed. The physical difference between No.2 coal seam and surrounding rocks is obvious, the top plate of the coal seam is fine-grained sandstone and siltstone, with a thickness of 1.75-11.21m, and an average thickness of 7.37m. The upper rock layer of the coal seam is basically interbedded with fine sandstone and siltstone. The upper part of the coal bed is basically fine sandstone and siltstone interbedded. The strength of the coal bed is relatively small and the Poisson's ratio is large, which makes it a weak rock bed.

2.2 Simulation Analysis

In order to accurately determine the location of the coal seam roof fissure zone formed after mining the No.2 coal seam, RFPA software was used to carry out numerical research on the three zones of the roof of the No.2 coal seam mining area. The simulated width of the working face is 260 m, the coal thickness and the roadway height are 2 m. After the face is mined back, the top plate of the coal seam spans down to form a fallout zone, the rock layer above the fallout zone undergoes excessive bending and deformation, resulting in the rock layer rupture to form a fissure zone, and the rock layer above the fissure zone bends down to form a bending and sinking zone. The simulation results before and after mining are shown in Figure 1.



(a) Prior to workface recovery

(b) After the workface is mined back

Figure 1: Top slab overburden damage before and after mining back to the working face

The black line in the figure represents the coal seam with a width of 260m and a height of 2m in the working face, the white spots represent the damage degree of the rock layer, and the long dotted lines running through the left and right represent the junction of different lithologies. Through analyzing and judging, it can be seen that the height of the area jointly damaged by the fallout zone and the fissure zone is 22~29m, and there may be a slight rupture in the upper part of the coal seam above 29m, but it is difficult to lead to the communication of fissures to form a new fissure zone.

2.3 Drill hole water injection test

The height range of the fissure zone was accurately determined by the method of roof drilling and water injection at the working face site. Firstly, according to the working face mining height of 1.8m and the rock properties of the sandy mudstone roof, a suitable empirical formula [10] was chosen to calculate the upper and lower height limits of the fissure zone (m):

$$H_{21} = \frac{100\Sigma M}{3.1\Sigma M + 50} \pm 4.0 = 17 \pm 4.0$$

$$H_{22} = 10\sqrt{\Sigma M} + 15 \approx 28$$

ΣM --Cumulative mining thickness, single layer thickness of 1 ~ 3 m, cumulative thickness of not more than 15 m, ± number of items for the error.

The net-like fracture structure in the middle and upper space of the top plate fracture zone of the coal seam is similar to the thick layer composed of filter membrane, which produces pure filtering effect on CH_4 through viscous flow and Knudsen diffusion, and makes the gas extraction effect of high level drilling holes in this interval good. The upper limit area of the roof rift zone is near the bending and sinking zone, and the rift development degree is low, so it is not easy to judge the location by observing the water returning from the drilling holes, but it can be judged by observing the change of water pressure of drilling holes' water injection. When drilling to the designed hole depth, exit the drill pipe and push in the water injection sealer connected to the high-pressure water pipe to the position of 10 meters from the final hole, the high-pressure water pipe is installed with a pressure gauge and connected to the pressure water. In the process of water injection, always watch the pressure gauge, if the water injection pressure drops, it means that the water injection sealer is located in the fissure zone, you need to close the valve of the water pipe and shorten the distance between the water injection sealer and the final hole to inject water again to observe; if the water injection water pressure has been in a declining state, then the final hole in the fissure zone, you need to construct a new borehole; if the borehole injection water pressure is basically unchanged, then it means that the water injection sealer is located in the bending and sinking zone, you need to close the valve of the water pipe and back off to inject water. It is necessary to close the water pipe valve and back off the water injection sealer to 20m from the final hole, and open the water pipe valve to inject water again. If the water pressure is still stable and unchanged, repeat the above operation and back off the water sealer; if the water pressure drops, close the water pipe valve to shorten the distance between the water sealer and the final hole until the water pressure drops significantly, then the location can be determined as the upper limit of the fissure zone, and the distance between this location and the coal seam can be regarded as the upper limit of the height of the fissure zone of the roof plate.

Combining the results of the above studies, it was finally determined that the lower limit height of the roof rift zone in the 202 working face of Dangjiahe Mine is 12.6m, and the upper limit height is 23.9m.

3 Analysis of field tests and extraction effects

3.1 Coal seam roof rift zone high level drill hole design

This test drilling site is arranged in the coal pillar of 204 upper trench near the side of 202 lower trench, in order to determine the optimal range of extraction layers in the coal seam roof fissure zone, the drilling site is designed with 6 high level drill holes, each high level drill hole passes through the top plate above the coal pillar and the top plate of the roadway of 202 lower trench to enter into the coal seam roof fissure zone of the 202 face, the design parameters of the drilling holes are as shown in Table 1, and the arrangement of the drill holes is as shown in Fig. 2.

Table 1: 202 Workface I Drillfield Drilling Design Parameters Table

Aperture number (e.g. on a cell phone)	Design elevation angle/(°)	Height/m	Hole depth/m
1# Drilling	10.5	11.55	300
2# Drilling	12	13	300
3# Drilling	12.5	15	300
4# Drilling	12.8	16	300
5# Drilling	12.8	17	300
6# Drilling	13	18	300

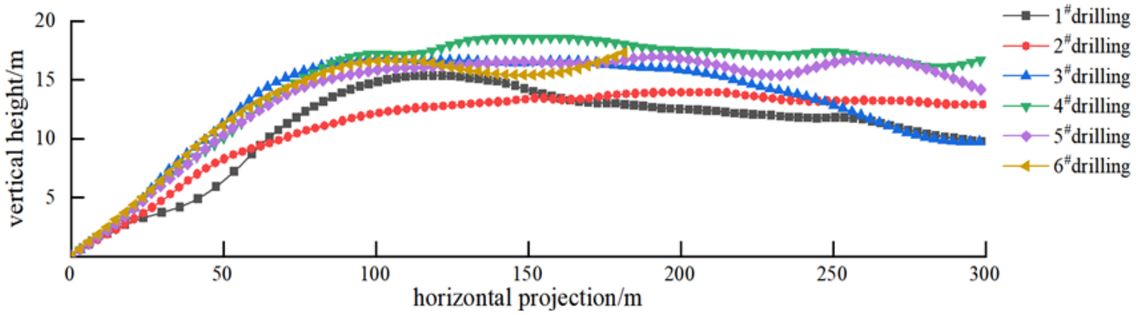
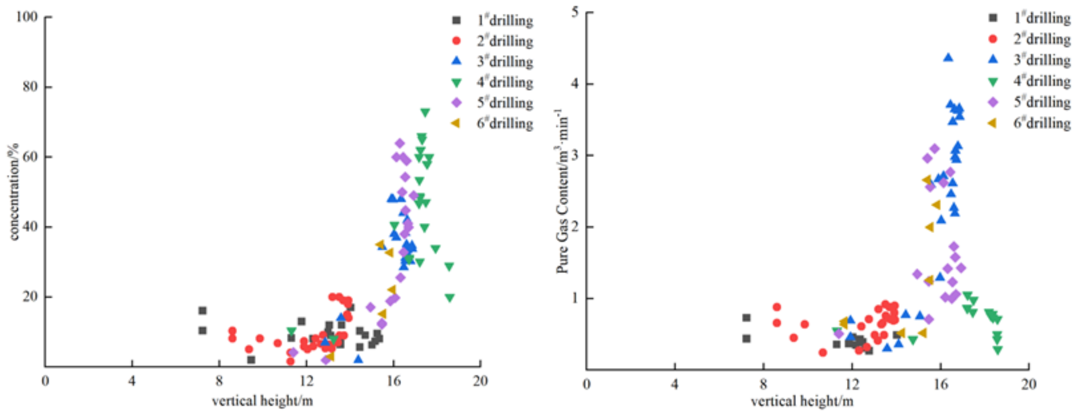


Figure 2: Profile of the actual drilling trajectory of the high level drill holes in Drill Field I of Workface 202

3.2 Analysis of extraction effects

In order to study the influence of the vertical height of the borehole on the extraction effect of the borehole, the completed borehole was sealed and pumped, and the parameters such as the concentration of the extracted gas, the mixing volume, and the pure volume were continuously observed. The concentration and pure volume corresponding to the vertical height of the drill hole were plotted as scatter plots, see Figure 3.



(a) Concentration-height scatter plot (b) Pure volume-drop height scatter plot

Figure 3: 202 Workface I Drillfield Pumping Concentration, Pure Volume Scatter Plot

Figure 3 shows that the extraction concentration in the I drill site is polarized. There is a positive correlation between the extraction gas concentration and the extraction height, and the high concentration scattering points are basically concentrated in the interval of 15.5~17.5m of vertical height. Although the gas concentration in drill hole 4# is high, the stratigraphic position of this drill hole is too high, the surrounding fissures are poorly developed, and the air intake channel of the extraction drill hole is insufficient, so the pure volume of extraction is not high. Drill holes 3# and 5# have a reasonable stratigraphic position, and the effective length of the main section of the drill hole is long, so they have a high pure volume. To summarize, the reasonable layer position of drill hole arrangement for No.2 coal seam is 15.5~17

4. Promoting Applications

The reasonable layer arrangement parameter is obtained from I drill site test, and is popularized and applied in 204 working face. According to the relationship between the layer position and the thickness of No. 2 coal seam in the rift zone of 202 working face, combined with the mining height of 1.8m in 204 working face, it is determined that the vertical distance between the layer position and No.2 coal seam of the reasonably arranged drill holes is 15.5~17.5m, which is in the middle and upper part of the rift zone, and the change of the layer position should be changed synchronously with the change of the height of the fall-out zone and the height of the rift zone.1# ~5# The designed vertical height of the drill holes range from 15.5~17.5m. The design parameters are shown in Table 2. The design parameters are shown in Table 2, and the actual drilling trajectory is shown in Figure 4.

Table 2: 204 Workover IV Drillfield Drilling Design Parameters Table

Aperture number (e.g. on a cell phone)	Design elevation angle/(°)	Height/m	Design hole depth/m
1# Drilling	10.5	15.5	400
2# Drilling	12	16.0	400
3# Drilling	12.5	16.5	400
4# Drilling	12.8	17.0	400
5# Drilling	12.8	17.5	400

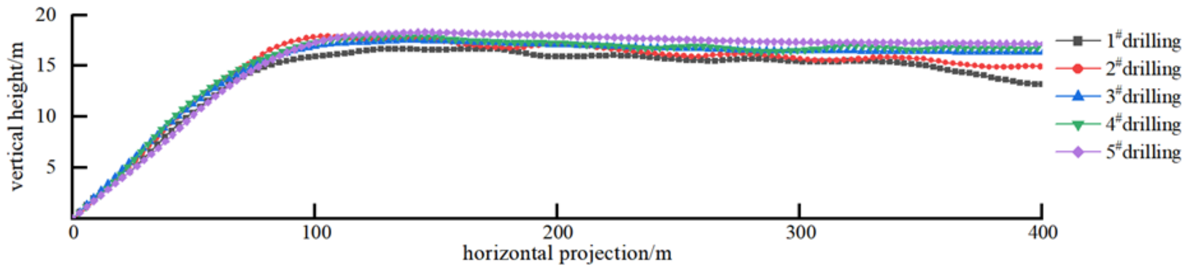


Figure 4: 204 Workover IV Drillfield High Level Drill Trajectory Profile of Actual Drill Trajectory

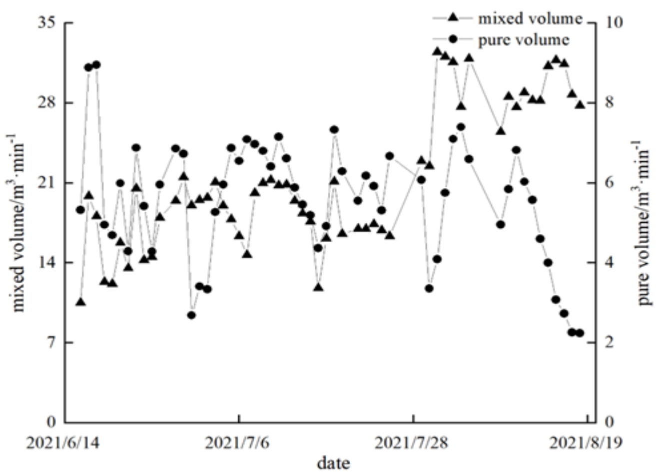


Figure 5: 204 working face IV #Scatter plot of drilling field extraction parameters

As can be seen from Figure 5, in general, the pure volume of gas extracted from the IV# drillfield is 5.5~7.5 m^3/min, and the maximum pure volume of gas extracted is 8.95 m^3/min. Taking July 30 as the cut-off date, the volume of gas mix extracted from the IV# drillfield can be divided into before and after phases, with the volume of gas mixed in the early phase being 10~20 m^3/min, and that in the later phase being 25~32 m^3/min. Although the total volume of gas mixed in the IV #the total gas mixing volume of the drilling field shows two stages before and after, but the pure volume of extracted gas is basically stable.

Field tests and popularization and application show that the amount of gas extracted from the high fissure drill holes during the production period of the back-mining face accounts for 42.3%~50% of the total amount of gas extracted from the face, and the gas concentration in the return-air flow of the face is reduced by 0.1% on average, and the gas concentration of the falling corners of the face stays below 0.3%, which improves the production capacity of the workface.

In summary, after comparing and analyzing the relationship between the gas extraction effect and the layer position of directional drilling, it can be determined that the gas extraction concentration gradually increases with the increase of the layer position of drilling, which further verifies that the gas distribution law in the fissure zone is consistent with the empirical calculation and numerical simulation results. When the vertical height between the extraction drill holes and the coal seam is less than 15.5m, the gas concentration in the coal seam roof slit zone is low, and if the drill holes are arranged in this area, it should be mainly aimed at the management of the gas accumulation in the corner of the return air; when the vertical height between the extraction drill holes and the coal seam is 15.5-17.5m, the gas concentration in the coal seam roof slit zone in the area is the highest, and the pure amount of extraction is higher and the value is stable, so it is the best stratum of the drilling arrangement; when the vertical height between the extraction drill holes and the coal seam exceeds 17.5-17.5m, the gas concentration in the slit zone is the highest, and the pure amount of extraction is higher and the value is stable. When the vertical height between the extraction drill hole and the coal seam exceeds 17.5m, the fissure development in this area is poor, and the microscopic fissure and primary rock slabs are dominant, so although the concentration of the gas is higher in this area, the pure amount of the gas extracted is lower, and the overall effect of the extraction decreases.

5. Conclusion

1) Numerical simulation and drilling water injection experiments were used to determine the height of the top plate fissure zone in the 202 working face of the Dangjiahe Mine to be 12.6~23.9 m. The implementation of high-level directional drilling was carried out for the extraction experiments, and the layers with the best extraction effect were 15.5~17.5 m. The top plate fissure zone in the 202 working face of the Dangjiahe Mine was 12.6~23.9 m in height.
2) Combine the reasonable drilling layer position obtained from 202 working face with the thickness of coal seam, determine the reasonable layer position for arranging fissure zone drilling holes in 204 working face, and popularize the application, the effect of extraction is obvious, the pure volume of gas extracted during the period of effective extraction accounted for 42.3% to 50% of the total amount of extraction, the concentration of gas in the return air of the working face was kept at 0.5%, and the concentration of gas in the corners of the return air was less than 0.5%, which ensured the return mining The gas concentration in the return air of the working face is kept at 0.5%, and the gas concentration in the corner of the return air is less than 0.5%, which ensures the smooth progress of the mining work.

References

[1]. LIU Lizong. Influence of long distance lower protective seam mining on pressure relief effect of overlying coal and strata [J]. China Energy and Environmental Protection, 2021, 43 (06): 242-247.

[2]. WANG Qinming. Comprehensive gas control technology in mining face with close multi-coal seam protection layer [J]. Coal Science & Technology Magazine, 2021, 42 (04): 109-113+117.

[3]. LI Hongwei, CHEN Liuyang, SONG Zhenyu. Gas drainage technology of coal winning regions in construction of floor gas drainage roadway [J]. China Energy and Environmental Protection, 2017, 39 (05): 213-216+222.

[4]. QIAN Minggao, XU Jialin. Study on the “O-shape” circle distribution characteristics of mining-induced fractures in the overlaying strata [J]. Journal of China Coal Society, 1998, (05): 20-23.
[5]. YUAN Liang, GUO Hua, SHEN Bao-tang, QU Qing-dong, XUE Jun-hua. Circular overlying zone at longwall panel for efficient methane capture of mutiple coal seams with low permeability [J]. Journal of China Coal Society, 2011, 36 (03): 357-365.
[6]. ZHANG Mingjie, DENG Wenbo, TAN Zhihong, TANG Kaimin, JIANG Shan, SHANG Zhijian. Research on filtering methane with spatial reticular stucture in coal seam roof fracture zone [J]. Coal Science and Technology, 2023, 51 (S1): 96-103.
[7]. SONG bin. The law of gas seepage and the method to determine the stratum of high drilling hole in large mining height working face [D]. China University of Mining and Technology, 2020.
[8]. HU Jie，FENG Kangwu，SUN Chen，CHEN Yu. Research on pressure-relief gas drainage mode of adjacent coal seams in upper protective layer mining of close thin coal seam group [J]. Journal of Safety Science and Technology, 2021, 17 (11): 65-71.
[9]. ZHANG Mingjie, ZHANG Qing-tang, MA Geng. Application and research on high level gas drainage technology in single poor penetration thick seam [J]. Coal Science and Technology, 2003, (12): 80-82.
[10]. WANG Fuhou. Determination method of caving ＆fracture zone height for gas drainage by high level borehole [J]. Coal Technology, 2008, (08): 75-76.