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Experimental Study on Directional Long Hole Gas Drainage in Thick Coal Seam Roof

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ABSTRACT
In order to study the application of roof directional drilling in thick coal seam gas control, and compare the input of roof directional drilling and roof high suction roadway, the roof directional long hole gas extraction test was carried out in Jincheng mining area. After the completion of the construction of the high-level long hole in the roof, the daily average net amount of gas drainage is stable at 17000m^3~20000m^3, and the cumulative net amount of gas drainage is about 2.8 million m^3. Compared with the roof high drainage roadway, the investment of roof directional long drilling to control the gas in the mining face can be reduced by 50%, the construction period can be shortened by 33%, and the manpower can be reduced by 30 people. Through the experimental data, the feasibility of the application of high and long drilling in thick coal seam is proved.
Keywords: *Thick coal seam, roof directional long drilling, gas extraction, gas control.*

1. INTRODUCTION

Coal mine gas disaster is one of the main safety disasters in the process of mine construction and production[1]. The gas disaster is destructive and brings great hidden trouble and loss to the coal mine. In recent years, gas pre-extraction technology has significantly reduced the gas content in the coal seam of the working face. However, with the development of comprehensive mechanized coal mining technology in the coal mine, the accelerated advance speed of the working face leads to a sharp increase in gas emission during mining, which has become a key factor restricting the safe and efficient mining of some mines [2]. Therefore, it is necessary to drill into the fracture zone above the roof during the mining of the working face to extract gas and ensure the safety of the mining of the working face.

At present, the common methods to use roof fracture field for gas control include: roof high drilling, roof high drainage and roof directional long drilling, etc. [3]. The advantages of long directional drilling of roof [4-7] mainly include large extraction volume, short construction period and low extraction cost. Moreover, because the drilling hole is long, the concentration of gas extraction is higher than the traditional drilling hole, and the extraction time is long. In order to investigate the extraction effect of high-level long borehole in thick coal seam, the extraction experiment of high-level long borehole in Jincheng mining area was carried out.

2. PRINCIPLE OF GAS EXTRACTION BY ORIENTING LONG HOLE IN ROOF

According to the mechanical model proposed by Qian Minggao[8], in vertical direction, mining-induced fracture field can be divided into caving zone, roof fracture zone and bending subsidence zone. Around the roof of goaf, an annular mining-induced fracture zone, or "O" ring, is formed[9]. Under the action of mining stress, a large number of roof cracks develop, which greatly increases the permeability coefficient of coal seam. The gas in the goaf mainly comes from the mining coal seam, adjacent coal seam and residual coal in the goaf. The gas accumulates and moves in the mining-induced crack, and finally accumulates in the "O" ring. Based on the above principle, by arranging directional long drill holes in the mining-induced fractures of the roof, so that the holes are always in the fracture zone of the roof, the mining-induced fracture channels can be fully utilized to achieve the purpose of gas extraction.

3. ROOF DIRECTIONAL LONG HOLE EXTRACTION TEST

3.1. Overview of test working face

Working face 3112 mainly mines No.3 coal seam, which is located at the lower part of Shanxi group. The thickness of the coal seam is 4.72~6.00m, with an average of 5.35m. The dip Angle of the coal seam is 3°~15°, with an average of 8°. Coal strata are generally developed, joint coal is developed, not easy to spontaneous combustion, simple to complex structure, containing 1~4 layers of mudstone or carbonaceous mudstone. The coal dust is not explosive and the ground temperature is normal.

3.2. The design of high-level and long hole in roof

3.2.1 Height determination of horizontal section

Because the overlying rock of working face is mainly mudstone, sandy mudstone and middle sandstone, it is middle hard rock. At the same time, the working face adopts the mining technology of full height at one time, the roof is treated with all caving methods, and the maximum caving zone and fracture zone height of the working face are respectively 13.46m and 80.17m (including caving zone), based on the distribution theory of "three zones" of coal overburden.

3.2.2 Determination of horizon in horizontal section

On the one hand, the design of the target horizon in the horizontal section of the drilling hole needs to consider the drilling capacity and the drilling construction difficulty, and select a reasonable height horizon; on the other hand, it needs to consider the lithology characteristics of the horizon, so it is not easy to arrange the long drilling hole in the argillaceous rock layer, clay layer and other soft rock layers.

According to the comprehensive histogram of the roof strata of coal seam 3, there is a layer of silty mudstone and medium fine sandstone mixed layer with a thickness of about 16m above the roof; there is a layer of mudstone and siltstone mixed layer with a thickness of about 14m above the roof with a thickness of about 21m; there is a layer of fine and medium grained sandstone mixed layer with a thickness of about 2.8m above the roof with a thickness of more than 36m, and then upward is the mixed layer mainly composed of mudstone and sandy mudstone.

Therefore, it is reasonable to set the target horizon of the horizontal section of the borehole in the mudstone and siltstone mixed layer about 20 m away from the roof of coal seam 3, or the fine and medium grained sandstone mixed layer about 36 m away from the roof of coal seam 3. Considering the construction of long directional drilling in the roof of 3112 face, the horizontal section of 3112 face is designed in the fine and medium grained sandstone mixed layer about 36m away from the roof of coal seam 3.

3.2.3 Determination of horizontal distance of return air side

In order to solve the problem of gas concentration in the upper corner, the high drill hole should be arranged on the side of the return air lane as far as possible. According to the "O" ring theory, there is an "O" ring around the goaf with separation fissure development, and its surrounding width is about 35m. Therefore, the horizontal distance between the main hole (horizontal section) of the high drill hole and the middle line of the return air lane should not exceed 40m. According to the actual conditions of the test working face, in order to facilitate gas extraction, it is more appropriate to control the horizontal distance between the borehole and the return air lane contour within 25m.

3.3. Overview of test working face

The drilling site is located in the track groove of the 3112 working face, 446.04m away from the cut hole of the working face. Since the goaf gas is extracted by intubation in the early stage of mining, and the effective radius of control is about 100m, the depth of the long drilling hole is 400m. The drilling field is arranged along the roof of no. 3 coal seam, and the size of the drilling field is about 5m×8m, so as to meet the construction requirements of the drilling machine. The high-position drilling of the roof is constructed in the connection roadway, and 4 drilling holes are constructed in the roof rock layer of the large mining surface of 3112, and 1 drilling hole is constructed in the small coal pillar.

The height difference between the main hole (horizontal hole section) of 1#, 2#, 3#, 4# and 5# and the roof of the coal seam is 35m, 40m, 45m, 50m and 24m respectively, and the distance from the roadway contour of track 3112 in the horizontal direction is 5m, 15m, 25m, 35m and 25m respectively. The horizontal projection of each borehole trajectory is shown in Fig.1.

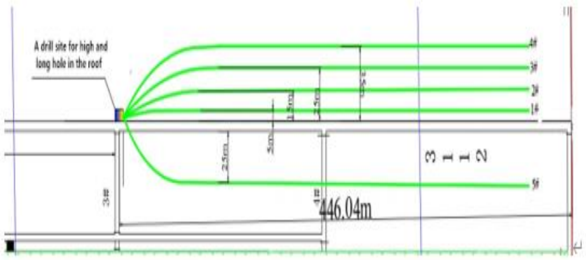

Fig.1 Schematic diagram of horizontal projection of borehole

3.4. Gas extraction effect of high directional long hole in roof

The drilling site began pumping on September 9, 2018, and by March 12, 2019, after the working face was pushed through the drilling site, the concentration was significantly reduced, for a total of 185 days of pumping. The extraction concentration of 5 boreholes was monitored every day, and the gas extraction mix of one borehole was measured in 7 days. The extraction of the five boreholes is shown in Table 1.

Table 1 Statistical table of test borehole extraction

Drilling serial number	**1**	**2**	**3**	**4**	**5**
Maximum extraction concentration（%）	62	60	81	27	73
Mean extraction concentration（%）	18.1	15.9	23.1	13.5	19.6
Maximum extraction scalar（m^3/min）	2.8	4.5	8.6	4.9	4.9
Mean extraction scalar（m^3/min）	1.5	1.9	2.1	2.0	2.7

The relationship between extraction gas scalar and time is shown in Fig.2.

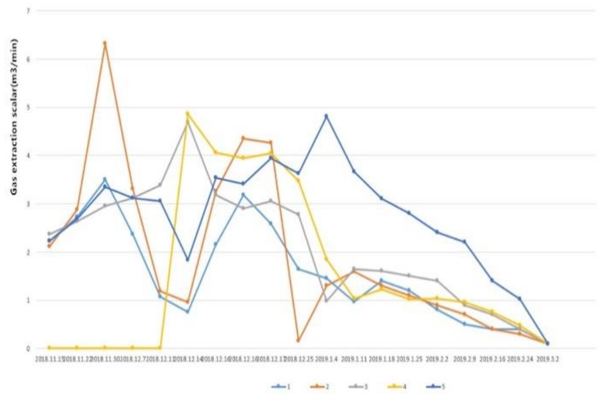

Fig. 2 The relationship between extraction gas scalar and time

With the advance of the working face, the average gas extraction volume of the five boreholes gradually stabilized at 12m^3/ min-14m^3 /min, and the average daily total gas extraction volume stabilized at 17000m^3/d-20000m^3/d before December 2018, and then gradually decreased. As of March 13, 2019, the cumulative gas extraction volume was about 2.8 million m^3. During the extraction of the long drill hole of the roof, no other supplementary drill hole was constructed, and the gas concentration of the return air on the working face was controlled at about 0.3%, and no over-limit occurred, which played a key role in controlling the gas concentration on the working face.

4. ECONOMIC ANALYSIS

The basic premise is to achieve the same gas extraction effect as the roof directional drilling, and 5 directional drilling holes are required to be equal to the roof high-drainage roadway, so as to analyze the investment cost, time limit and human resources of the two extraction methods. The statistical analysis of these two gas extraction methods is shown in Table 2.

Table.2 Statistical analysis of data of two gas extraction methods

Method	**The unit price / (yuan/m)**	**The total length/m**	**Total cost/ten thousand yuan**	**Number of human**	**Time limit /month**
Roof high suction lane	10000	500	500	45	4.5
Roof directional long drill	1000	2500	250	15	3

Under the condition of the same gas extraction effect, compared with the high drainage roadway of roof, the investment of arranging the directional long drilling hole of roof can be reduced by 50%, the construction period can be shortened by 33%, and the manpower can be saved by 30 people. Meanwhile, it can also ensure the smooth progress of the working face without over-limit.

To sum up, the technical scheme of arranging roof directional drilling to control gas in mining face is of high cost performance.

5. CONCLUSION

(1) Through the extraction of the top hole, the average extraction volume of the five holes was stable at 12m3/min-14m3/min, and the cumulative gas extraction volume was about 2.8 million m^3. During the extraction of the long drill hole of the roof, no other supplementary drilling projects were carried out, and the concentration of return air gas on the working face was controlled at about 0.3%, which realized the safe and efficient extraction of the test mine.

(2) Under the condition of the same gas extraction effect, compared with the high-drainage roadway of roof, the investment of orienting long drilling of roof can be reduced by 50%, the construction period can be shortened by 33%, and the manpower can be reduced by 30 people, indicating that the application of high-altitude and long drilling technology of roof to control gas has less investment, shorter construction period and better application prospects.

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REFERENCES

[1] Wang Wei. Research on rapid evaporative cooling technology for local heat damage in mine [D]. Qingdao: Shandong University of Science and Technology, 2009.

[2] Zhai Cheng, Lin Baiquan, Wu Haijin. Application of high-position drilling of roof in gas control [J]. Coal Engineering, 2005 (9): pp.4-6.

[3] Cai Wenpeng, Liu Jian, Sun Dongsheng, et al. Research and application of gas extraction technology for top strike drilling [J]. China Work Safety Science and Technology, 2013,9(12): pp.35-38

[4] Zhao Xusheng, Sun Dongling. Method of integrated drainage of gas by directional long borehole [J]. Coal Science and Technology, 2001,29 (3):pp.13-15.

[5] Yao Jinguo, Liang Minfu,Yuan Baoning, et al. Gas extraction technology for directional drilling of super long distance roof [J]. Coal Engineering, 2015,47 (3): pp.61-64.

[6] Zhao Xusheng, Zou Yinhui. Experimental study on gas drainage from adjacent strata by long horizontal borehole [J]. Mining Safety and Environmental Protection, 2000,27 (S1):pp.13-15.

[7] Wang jun, Wei Guoshan, Yan Dawei, et al. Application of horizontal long borehole gas extraction technology for roof rock in daxing mine [J]. Coal Mine Safety, 2008 (12):pp.36-39.

[8] Qian Minggao, Miao Xiexing, He Fulian. Analysis of key blocks of "masonry beam" structure in stope [J]. Acta Coal Sinica, 1994,19 (6): pp.563.

[9] Qian Minggao, Xu Jialin. Study on "O" ring characteristics of mining-induced fracture distribution in overburden rock [J]. Acta Coal Sinica, 1998,23 (5): pp.469.

[10] Geng C., Zhao Z., Xue Z.; Xu P., Xia, Y., Preparation of Ion-Exchanged TEMPO-Oxidized Celluloses as Flame Retardant Products.Molecules, 24(2019)947 ,

[11] P. Xu; N. Na; S. Gao; C. Geng, Determination of sodium alginate in algae by near-infrared spectroscopy, Desalination and Water Treatment, 168(2019)117-122.