Study on Gas Drainage Technology of High-level Borehole in Fully Mechanized Caving Face

Peng Zhang *
China Coal Technology & Industry Group Taiyuan Research Institute Co., Ltd., Taiyuan 030032, China.

*Corresponding author e-mail: 419802281@qq.com

Abstract. In view of the problem of gas safety in fully mechanized caving face under complex geological conditions, taking high-level borehole gas extraction as the main gas control means to improve the extraction effect and ensure gas safety during mining, this paper takes 131301 fully mechanized caving face of Xinji No. 1 Coal Mine of Zhongmei as an example to study and analyze the layout of high-level borehole. Through the actual measurement, the gas concentration in the upper corner retaining wall is basically controlled below 0.2%, and in the return air lane is controlled below 0.08%, which shows that this method has achieved good gas drainage effect and ensured gas safety during mining.

Key words: Fully mechanized top coal caving face; thick coal seam; complex geological conditions; pressure relief gas extraction; high borehole.

1. Preface
At present, the main means and methods of gas control in underground working face and goaf are high extraction roadway, high roof drilling, and upper corner buried pipe extraction. After mining in the working face, a certain range of fracture zone will be formed above the goaf. Gas in the goaf can be directly extracted by arranging high-level roof drilling and high extraction roadway in the fracture zone. The main method of gas drainage in goaf is high extraction roadway, which has the advantages of large amount of gas drainage and simple management of gas drainage. However, the construction period of high extraction roadway is relatively long, and the cost of manpower and materials is relatively high, which is easy to cause the tension of mining replacement and high mining cost[1-3]; the upper corner buried pipe drainage is mainly used to reduce the gas concentration in the upper corner, which cannot be used in goaf Large scale gas extraction[4,5]; roof high-level drilling has the advantages of flexible layout, simple construction and operation, strong pertinence, large initial extraction concentration and flow[6-8]. In this paper, according to the actual extraction situation of high-level drilling in 131301 working face of Xinji.

2. Principle of gas drainage by high level drilling
The mining of coal seam destroys the original stress equilibrium state of the overlying coal seam and causes the stress redistribution of the rock mass. When the redistributed stress exceeds the ultimate strength of coal and rock, it will cause deformation and damage of the overlying strata, and form a
separate fracture, which is conducive to pressure relief gas extraction. After mining, the collapse zone, fracture zone and bending subsidence zone are formed in the vertical direction above the goaf. From the point of view of pressure relief gas flow channel, the gas in goaf is easy to accumulate in the annular fracture area of goaf roof due to the light gas proportion and gas floating upward. The problem of gas emission from goaf to working face and gas accumulation in laotangjiiao can be solved by drilling high-level holes in the air tunnel to the roof and extracting gas from the goaf behind the working face[9,10]. The high-level borehole extraction method of roadway side is shown in Figure 1.

![Figure 1. Gas extraction by high-level long boreholes in roadway sidewall drilling field](image)

3. Engineering survey
The working face 131301 is located in the third horizontal mining area, with F10 fault in the South and 131303 goaf in the north. The average workable strike length of the working face is 1207.6m, the cutting hole length is 66m, and the mining elevation is -394.7~-420.4m.

The average thickness of pure coal in 13 coal seam is 5.75m, the average thickness of containing gangue is 0.63m, and the average dip angle of coal seam is 9°. 131301 working face adopts the technology of single strike long wall backward comprehensive caving, and roof management adopts the total caving method. The measured gas pressure of 13 coal seam in 131301 working face is 0.30MPa, and the gas content is 4.24m$^3$/t

4. Design of high level drilling and extraction
According to the distribution law of the "upper three zones" of the coal face, the high-level drilling holes should be arranged in the fracture zone, and the height of the fracture zone and the collapse zone should be calculated. See formula (1) and formula (2) for calculation formula.

$$H_m = \frac{m}{(K-1)\cos \alpha} \quad (1)$$

$$H_{li} = 20\sqrt{\sum M} + 10 \quad (2)$$

Formula: $m$ is the mining height, m; $m$ is the rock thickness, m; $\alpha$ is the coal seam dip angle, ° and K is the coefficient of dilatancy.

According to the lithology of 13-1 coal seam and roof of 131301 working face, according to formula (1) and formula (2), it is calculated that the height of the cross fall zone of 13-1 coal seam in 131301 working face is 16.3m, and the height of the fracture zone after mining is 83m.

A total of 17 roadway side drilling sites are designed for the air roadway of working face 131301, each of which is constructed with 8 boreholes, with a hole diameter of $\phi$ 94mm, and a drilling stubble of more than 40m. The boreholes are constructed and extracted one month ahead of the working face pushing schedule.
5. Analysis of gas drainage effect
In this effect analysis, the high-level boreholes of 4 drilling fields are selected for gas drainage analysis. Among them, there are 17# drilling fields in the first drilling field, 15# drilling fields in the depression angle recovery, 10# drilling fields in the elevation angle recovery, and 7# drilling fields in good conditions.

5.1. Analysis of gas drainage effect in the 17# drilling field of the first drilling field
The drilling parameters of the 17# drilling field are shown in Table 1 below, and the gas concentration curve with time in 2018 is shown in Figure 2.

| Number | Actual azimuth (°') | Actual slope angle (°) | Practical Kong Shen (m) | Top coal with a vertical distance of 13 from the final hole (m) | Distance from the final hole to the north side of the air lane (m) |
|--------|---------------------|------------------------|-------------------------|---------------------------------------------------------------|---------------------------------------------------------------|
| 1#     | 278 ° 26'           | 17°                    | 56                      | 20                                                            | 5                                                             |
| 2#     | 283 °               | 26°                    | 62                      | 30                                                            | 10                                                            |
| 3#     | 288 ° 59'           | 31°                    | 65                      | 35                                                            | 15                                                            |
| 4#     | 277 ° 58'           | 2°                     | 80                      | 10                                                            | 5                                                             |
| 5#     | 281 ° 36'           | 8°                     | 79.2                    | 18                                                            | 10                                                            |
| 6#     | 285 ° 14'           | 11°                    | 80.5                    | 22                                                            | 15                                                            |
| 7#     | 284 °               | 33°                    | 71                      | 40                                                            | 10                                                            |
| 8#     | 282 °               | 13°                    | 83                      | 25                                                            | 10                                                            |

Figure 2. Curve of gas concentration changing with time in 17# drilling site

It is known from Figure 2 that 17# drilling field is the first drilling field in the working face. According to the concentration curve of drilling gas drainage, it can be seen that 1# 2# 3# 7# high-level drilling has good drainage effect. The vertical distance between the final hole and the top coal of 13 coal seam is large, so the extraction effect is the best. The reason for this phenomenon is that the roof falls slowly and the cracks are not obvious during the initial mining.
5.2. Analysis of gas drainage effect in 15# drilling field

The drilling construction parameters of the 15# drilling field are shown in Table 2 below, and the gas concentration curve with time in 2018 is shown in Figure 3.

| Number | Actual azimuth (°) | Actual slope angle (°) | Practical Kong Shen (m) | Top coal with a vertical distance of 13 from the final hole (m) | Distance from the final hole to the north side of the air lane (m) |
|--------|--------------------|------------------------|-------------------------|---------------------------------------------------------------|---------------------------------------------------------------|
| 1#     | 277°41′            | 20°32′                 | 117                     | 25                                                            | 5                                                             |
| 2#     | 279                | 22                     | 118                     | 30                                                            | 10                                                            |
| 3#     | 282°49′            | 25                     | 120                     | 35                                                            | 15                                                            |
| 4#     | 285                | 29                     | 124                     | 45                                                            | 20                                                            |
| 5#     | 277                | 17                     | 133                     | 25                                                            | 5                                                             |
| 6#     | 279                | 19                     | 136                     | 30                                                            | 10                                                            |
| 7#     | 282                | 22                     | 137                     | 35                                                            | 15                                                            |
| 8#     | 284                | 25                     | 140.5                   | 45                                                            | 20                                                            |

Figure 3. Curve of gas concentration changing with time in 15# drilling site

It is known from Figure 3 that from 17# drilling field to 15# drilling field working face, according to the curve chart of gas drainage concentration of drilling hole, except for 7# high-level drilling hole, the drainage effect is relatively ideal. The reason for this phenomenon is that the gas density is relatively small, when the working face is mining downward, the gas drifts towards the roof of the goaf, reducing the amount of overflow from the upper corner retaining wall and the comprehensive mining support, improving the drainage effect to a certain extent, and the mining downward is conducive to the gas safety of the working face.
5.3. Analysis of gas drainage effect in 10# drilling field

The drilling parameters of the 10# drilling field are shown in Table 3 below, and the gas concentration curve with time in 2018 is shown in Figure 4.

### Table 3. Drilling construction parameters in 10# drilling site

| Number | Actual azimuth (°′) | Actual slope angle (°′) | Practical Kong Shen (m) | Top coal with a vertical distance of 13 from the final hole (m) | Distance from the final hole to the north side of the air lane (m) |
|--------|---------------------|------------------------|-------------------------|------------------------------------------------|-------------------------------------------------|
| 1#     | 92.8 282            | 5                      |                         | 20                                              | 5                                               |
| 2#     | 93.7 284            | 11                     |                         | 30                                              | 9                                               |
| 3#     | 94.8 287            | 14                     |                         | 35                                              | 13                                              |
| 4#     | 96.2 289            | 17                     |                         | 40                                              | 17                                              |
| 5#     | 97.6 291            | 20                     |                         | 45                                              | 21                                              |
| 6#     | 112.2 281°28′       | 3                      |                         | 20                                              | 5                                               |
| 7#     | 112.7 283°19′       | 8                      |                         | 30                                              | 9                                               |
| 8#     | 113.5 285°10′       | 10°17′                 |                         | 35                                              | 13                                              |
| 9#     | 114.9 287           | 12°52′                 |                         | 40                                              | 17                                              |
| 10#    | 116.2 289           | 15                     |                         | 45                                              | 21                                              |

![Figure 4. Curve of gas concentration changing with time in 10# drilling site](image)

As shown in Figure 4: from 14# drill field to 10# drill field working face elevation mining, according to the borehole gas extraction concentration curve, 2# 3# 5# high-level borehole extraction effect is good but not stable. With the change of 5-17m distance from the horizontal to the air tunnel, the height of the vertical to the coal seam roof is corresponding to 12-30m. The reason for this phenomenon is that it is difficult to extract gas in goaf and the position of roof crack is not stable.
5.4. Analysis of gas drainage effect in 7# drilling field

The drilling parameters of the 7# drilling field are shown in Table 4 below, and the gas concentration curve with time in 2018 is shown in Figure 5.

Table 4. Drilling construction parameters in 7# drilling site

| Number | Actual azimuth (°) | Actual slope angle (°) | Practical Kong Shen (m) | Top coal with a vertical distance of 13 from the final hole (m) | Distance from the final hole to the north side of the air lane (m) |
|--------|--------------------|------------------------|------------------------|-----------------------------------------------------------------|-----------------------------------------------------------------|
| 1#     | 276                | 18                     | 90                     | 15                                                              | 0                                                               |
| 2#     | 279                | 23                     | 86                     | 20                                                              | 5                                                               |
| 3#     | 281°44′           | 27°40′                 | 94                     | 30                                                              | 10                                                              |
| 4#     | 285                | 31                     | 96                     | 35                                                              | 15                                                              |
| 5#     | 287                | 33                     | 100                    | 40                                                              | 20                                                              |
| 6#     | 276°7′            | 13                     | 104                    | 20                                                              | 0                                                               |
| 7#     | 278.5              | 18                     | 108                    | 30                                                              | 10                                                              |
| 8#     | 280                | 23                     | 114                    | 35                                                              | 15                                                              |
| 9#     | 283                | 25                     | 114                    | 40                                                              | 20                                                              |
| 10#    | 285                | 28                     | 116                    | 40                                                              | 20                                                              |

As can be seen from Figure 5, the working face between 7# and 9# drilling sites is in good condition, and the gas extraction concentration effect of each borehole is good, reaching 90% at the maximum. With the change of the distance from the horizontal to the air lane of 5-24m, the height from the vertical to the coal seam roof is corresponding to the change of 5-35m. The reason for this phenomenon is that when the roof of the working face is in good condition, there is a certain fluctuation in the gas extraction concentration, because during the 7# drilling field extraction, the mining of the working face has been increased by 2 times, and new cracks are constantly generated in the roof.

6. Conclusion

When the coal face adopts the high-level drilling as the main means to control the gas during the mining, it is necessary to formulate the targeted plan according to the situation of the working face. During the mining period, the working face 131301 of No.1 Coal Mine of Zhongmei Xinji Coal Mine adopts the following measures: in the section with complex geological conditions and many faults, the effect of gas drainage is not stable, and the high-level drilling is densified; in the section with mining at the depression angle, the height of the final hole from the coal seam roof can be reduced properly; in the section with mining at the elevation angle, the drilling angle should be sufficient for the coal seam slope,
and the drilling holes should be arranged at multiple levels, and the upper corner buried pipes should be increased. The method of drainage quantity can effectively solve the gas problem during the mining period of the working face, thus ensuring the gas safety of the first working face after the resumption of production.

References

[1] Li Xin. Discussion on the layout of high drainage roadway and gas drainage effect in Gaohe coal mine [J]. Coal mine modernization, 2019, (06), 166-167+170.

[2] Jin Xiaohua, Wang Juan, Hua Mingguo. Study on gas drainage layout layer in high extraction roadway of fully mechanized top coal caving face [J]. China Science and technology of work safety, 2018, 14 (4): 95-100.

[3] Xu Yongjia. Study on the reasonable layout of high drainage roadway and the determination of the final roadway location in high gas mine [J]. Coal science and technology, 2018, 46 (11): 93-100.

[4] Liu Qingjun. Study on gas drainage and utilization technology of surrounding rock fracture zone overlying goaf [J]. Energy and environmental protection, 2018, 40 (7): 93-95.

[5] Ren Zhenxing. Research on gas drainage technology in the upper corner of comprehensive mining face [J]. Energy and energy saving, 2019, (2): 134-135.

[6] Zhang Haiquan, Wang Huifeng, Wang Xiangdong. Study on large diameter high-level drilling instead of high drainage roadway for gas drainage [J]. Coal science and technology, 2012, 40 (6): 51-53.

[7] Wang Ming, Fang Xinqiu, Xu Ruiqiang, et al. Comprehensive gas drainage technology of large bore and ultra long directional drilling [J]. Coal engineering, 2011, 43 (5): 46-48.

[8] Cai Wepeng, Liu Jian, Sun Dongsheng, Jiang Erlong. Research and application of gas drainage technology by high-level drilling in roof strike [J]. China Science and technology of work safety, 2013, (12): 35-38.

[9] Zhang Xiaolei, Cheng Yuanping, Wang Liang, et al. Optimization design of roof high position drilling in coal and gas outburst mining face [J]. Coal science and technology, 2014, 42 (10): 66-70.

[10] Xiao Lihui, Chen Yu, Wang Kuanhai, Kong Wei. Study and analysis of high-level directional drilling instead of high-level gas drainage technology in Xinji No.2 coal mine [J]. Coal technology, 2018, 37 (11): 201-203.