Research on Multi-directional Gas Drainage Technology in Goaf of Working Face

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Abstract: According to the abnormal gas overrun quadrant in the mined-out area during the initial mining and normal mining of a mine, the causes of some gas outbursts were analyzed, and the multi-directional extraction method for low-level drilling, middle-level drilling and high-level drilling was designed and constructed. Successively connect and replace the mined-out gas, and the effect analysis shows that each borehole achieves and exceeds the expected effect, which improves the efficiency of gas extraction in the mined-out area and relieves the gas pressure during the normal mining of the working face.

1. Introduction
Domestic scholars have researched for a long time on the gas problems in the mined-out area during the initial mining and normal mining [1]-[5]. Li Fenglong [6] conducted a large-diameter high-position drilling to replace the pseudo-inclined high-drainage roadway at No. 1 Coal Mine in Yangmei. The results show that the large-diameter high-position drilling can successfully solve the uneven gas emission and frequent frequent mining in the face overrun problem.

Feng Shanqin [7] aimed at the problem of gas overrun in the initial mining period of the fully mechanized caving face of Yangmei No. 5 Coal Mine, and adopted the method of comprehensive gas control by reducing the air pressure and combining with the buried pipe in the goaf and the middle and low post-high extraction roadway.

On the basis of a large amount of practical experience, the author proposes to use low-level drilling and middle-level drilling in the working face to pump gas in the goaf during initial mining, and high-level drilling mainly draws gas in the goaf during normal mining. The technology can solve the gas in the goaf during the initial mining and recovery. Taking 5302 working face of a mine as an example, the extraction effect is significant after adopting this technology.

2. Overview of working face and its problems
The 5302 working face is located in the east well panel of a mine. The main mining is 3# coal seam. The average thickness of the coal seam is 6m. The maximum gas content is 24.8 m³/t. The average value is 22.85 m³/t. After ground drilling and extraction, the gas content of coal seam is 8.47 m³/t~ 13.76 m³/t, with an average of 10.51 m³/t. Figure 1 shows the layout of the roadway near the cutout of the 5302 face: the 5302 face adopts a three-entry and two-return ventilation system. Roadway 53021 and 53025 are the main air inlet roadway, Roadway 53023 is the auxiliary air inlet lane, roadway
53022 and 53024 are return air Roadway. The distance between the initial mining section is about 50m, and the normal working face is entered after the general working face is pushed over 50m.

The working face adopts large mining height comprehensive mining technology. Gas is abnormal during initial mining and mining, and gas overrun exists. The reasons are as follows:

1. The gas drainage time of coal seam in the initial mining section is relatively short. The gas drainage drilling in the initial mining section is the latest due to the construction sequence.
2. The failure of the roof during the initial mining is not timely, causing the accumulation of gas in the goaf when the roof collapses, and it is easy to cause gas overrun.
3. During the initial mining, the roof cracks are not fully developed, which results in high-level boreholes or high-drainage Roadway that cannot be connected to the mined-out area.
4. During the initial mining period, the mining height is 3.8m, and the mining along the coal seam floor will result in a large amount of residual coal gas accumulated in the goaf.
5. There are pressure relief areas in front of the working face during initial mining and mining.

3. Drilling arrangement

3.1 Arrangement of low-level drilling
During the initial mining, the coal seam above the support collapsed and the amount of residual coal gas was large. Low-level drilling was arranged. The residual coal collapsed above the support and the low-level borehole was exposed to extract the residual coal gas. The level of low-level drilling is selected within the range of direct roof, about 6m away from the roof. The interval between the boreholes is 10m. After the cut is taken, the upper coal seam collapses and the low-level holes play a role. The layout is shown in Figure 2.

3.2 Implementation plan of median drilling
In the initial mining stage, the roof span is not complete, and the fall zone and fissure zone are not clearly defined. For this, the central borehole of the primary mining section is designed to extract the gas in the goaf of the primary mining section. The 5302 area has a total of 5 holes in the 24# Liaison Lane. The final hole is within 5m ~ 25m of the coal seam roof, as shown in Figure 3 and Figure 4.
3.3 Implementation plan for high-level drilling

According to the experience of high-level drilling on site, the final hole position of high-level drilling is generally in the range of 5 ~ 8 times of mining height. In order to study the layout of high-level drilling in more detail, high-level drilling is arranged in the range of 5 ~ 10 times mining height.

In the 5302 working face 21# Liaison Lane, design 3 holes in the drainage area of the goaf gas. The final hole level is in the range of 40m ~ 60m in the coal seam roof, as shown in Figure 5 and Figure 6. After the old roof collapsed, high-level drilling played a role.

4. Analysis of drilling effect

In order to analyze the gas extraction effects of various boreholes, the gas parameters of each borehole,
such as negative pressure, pure quantity and concentration, are collected every day to provide data support for the analysis of the borehole extraction effects.

4.1 Analysis of gas drainage effect of low-level drilling

The following results can be seen from Figures 7 and Figures 8:

1. At the initial stage of mining, the suction negative pressure, gas concentration and pure flow of the low-level borehole fluctuate up and down, showing: (1) The negative pressure fluctuates around 10Kpa; (2) The concentration is around 20%; (3) The pure quantity is about 5m³/min.

2. Reason for analysis: During initial mining, roof cracks have developed but are relatively incomplete. This phenomenon leads to high negative pressure, but relatively low purity and concentration, indicating that coal gas pressure is not completely relieved.

3. The design of the low-level drilling is reasonable, and the low-level drilling meets or exceeds the most expected use: (1) The low-level drilling has played a role during the initial mining of the working face (drainage cuts and coal gas). After the first roof pressure, the borehole remains intact and continues to function steadily during the normal mining of the working face (beyond the original assumption).

4. The drainage effect of the low-level drilling reduces the gas volume at the working face. Two aspects are considered: (1) the increase of the drainage volume; (2) the negative pressure effect of the low-level drilling can affect the division of the three gas zones in the goaf.

4.2 Analysis of the effect of gas drainage in mid-hole drilling

It can be seen from Fig. 9: In the initial period of mining, the negative pressure is large, but the flow rate and concentration are small, indicating that the fracture of the median pore layer has not yet developed.
From Figure 10 and Figure 11 we can see:

1. During the initial mining period
   (1) When the working face has not been pushed through the cut-out, the median hole is drilled, and the concentration and pure amount are small.
   (2) The turning point occurs when the working face advances to 15m~16m, and the pure amount of 1# and 2# mid-hole has the highest value, reaching 8 ~ 9m³/min. The concentration is more than 50%, but this phenomenon has remained for about 15h.
   (3) When the working face is advanced to about 24m, the highest value of the 4 # and 5 # boreholes in the initial mining period is 2.3m³/min and the concentration is 23%.
   (4) When the working face is advanced to 29m, the highest value of the 5 # borehole in the initial mining period is 2.1m³/min, and the concentration is 23%.
   (5) In the early mining period, the above-mentioned boreholes showed their highest values in sequence with the progress of the working face. Although it only lasted about 1d, it is definitely not accidental. It is related to the distance between each borehole and the return wind. It is the initial period when the roof is under pressure, the most vigorous period, and the active period of fissure closure.
   (6) The median drilling achieves the expected effect. The 1# and 2# drilling holes can pump 15,000 cubic meters of gas in the highest ten hours, and the 4# and 5# drilling holes can pump 0.36 million cubic meters of gas.

2. During normal mining
   (1) The mining face is within the range of 50m~100m. From the scalar point of view, 1#, 2#, 3#, 4# and 5# drill holes are basically reduced in sequence, which is the distance between them and the return side related.
   (2) During normal mining, the pure quantity of 3# and 4# drilling holes is 4m³/min, and the concentration is about 15%. The median drilling has played an important auxiliary role.
   (3) After the first roof pressure, the roof cracks are completed and the vertical three belts are formed. The high concentration and large flow gas enter the high borehole drainage range under the factors of relatively high negative pressure in the high borehole and low density. It is determined that the gas concentration of the central borehole is low and small.
4.3 Analysis of gas drainage effect of high-level drilling

Figure 12. The relationship between the negative pressure of the high-level drilling and the driving distance of the working face

Figure 13. The relationship between the gas concentration in the high-level drilling and the driving distance of the working face

Figure 14. The relationship between the gas scalar quantity of the high-level drilling and the driving distance of the working face

From Figure 12 to Figure 14 we can see:

1. The change of negative pressure to a certain extent reflects the development speed of the fissures in the layer where the borehole is located; after the fissures are fully developed, various extraction parameters will be stable and want to increase.
2. The working face is pushed to 32m~42m, the pure quantity of the 1# high-level drilling rapidly rises to 9m³/min, the pure quantity of the 2# high-level drilling rapidly rises to 15m³/min, and the gas concentration reaches more than 80%. After 300m of working face mining, the replaced high-level borehole began to take effect.

5. Conclusion
(1) The low-level drilling can extract the gas from the cut-off coal and pressure relief, and the gas in the goaf. It can play a role during the initial mining and normal mining of the working face.
(2) During the initial mining of the working face, the mid-drilled hole can play a role before the high-drilled hole does not come into play before the roof is initially mined and pressed. This period is very critical and there is no very effective gas drainage method. Hole drainage greatly eases the pressure of gas control before high-level drilling does not work; after high-level drilling works, its auxiliary role cannot be ignored.
(3) When the drilling position of the high position is correct, the normal drainage pure volume is 10~20 m³/min, and the gas drainage efficiency is high.
(4) The low-medium-high three-hole drilling extraction mode achieves the expected results, improves the efficiency of gas extraction, and is an effective method for controlling gas overruns.
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References:
[1] Chen Liang, Xu Xiaokai, Shang Rongya, etc. (2015) Differences between gas drainage from goaf by thousand-meter scale boreholes and high-level boreholes and their improvement[J]. China Coal, 41(2):92-95.
[2] Song Yibo. (2008) Practice of gas comprehensive management in high gas and fully mechanized face[J]. Coal Technology, 1:65-67.
[3] Tan Yongfu, Zhao Xin, Gao Yutao, etc. (2008) Comprehensive gas control technology for fully mechanized coal mining face in single coal seam[J]. Safety in Coal Mines, 10:72-74.
[4] Zhang Mingfu, Zhang Xing'an, Cao Bangqing, etc. (2007) Gas control in fully mechanized caving face of single extra thick coal seam in high gas mine[J]. Energy Technology and Management, 4:26-27.
[5] Zhang Jilin, Wei Dong, Cai Fengguang. (2001) Gas drainage method and optimization principle in Yangquan mining area[J]. Coal Geology & Exploration. 4:17-19.
[6] Li Fenglong, Yang Hongmin, Chen Liwei. (2015) Large diameter and high position drilling to control gas emission in initial mining face[J]. China Coal, 41(4): 114-117.
[7] Feng Shanqin. (2015) Governance technology of gas instability in the first mining period of fully mechanized caving face[J]. Energy Technology and Management. 40(5):46-48.