Experimental study on cutting and sealing technology of drilling hole in bedding drainage

Yongjiang Zhang 1,2, *

1Chongqing Research Institute CO., Ltd of China Coal Technology Engineering Group, Chongqing, China
2National Key Laboratory of Gas Disaster Monitoring and Emergency Technology, Chongqing, China

*Corresponding author e-mail: zangyj_1026@163.com

Abstract. Aiming at the problem that it is difficult to guarantee the quality of hole sealing and air leakage easily appear in bedding drilling of coal seam with high gas and low permeability, a new type of hole sealing process is put forward, which is assisted by cutting seam in the hole sealing section with the help of ultra-high pressure hydraulic cutting technology. Field tests show that, compared with the traditional "two blocks and one injection" sealing process, the initial concentration of gas extraction boreholes in the slit sealing process increases by 1.5~2 times, the extraction concentration increases by 2~3.5 times, and the gas extraction concentration exceeds 60% within 30 days.

1. Introduction
It is more difficult to seal the hole in the bedding hole, especially in the bedding hole with high gas content and low permeability, which directly affects the gas extraction effect and effective extraction radius [1-2]. The hole sealing section of borehole is in the influence range of roadway loose circle, especially in the fracture zone and the plastic zone, the coal body is damaged to a high degree and fractures are developed [3-4]. If the hole sealing depth of borehole does not exceed the crack area of roadway, the sealing effect cannot be guaranteed. If the hole sealing section is too long, it will not only form a blind area of extraction, increase the difficulty of coal seam gas control, leave a safety hazard for later coal seam mining, but also increase the cost of hole sealing. According to incomplete statistics, more than 60% of the extraction boreholes in China's coal mines have poor seal, and more than half of the boreholes have extraction concentration less than 30%, failing to meet the industrial utilization requirements [5-6]. In this paper, through the deep research and optimization of the hole sealing technology of the drainage drilling along the stratum, it is beneficial to improve the sealing quality of the borehole, strengthen the gas extraction effect, and promote the economic benefits of coal production.

2. Principle of cutting and sealing holes
The technical principle of water-cut joint grouting for hole sealing in bedding gas extraction drilling hole is a new type of hole sealing technology, which is based on the traditional principle of "two blocks and one injection" hole sealing technology, and adopts the method of cutting joint to assist hole sealing in the hole sealing section with the help of ultra-high pressure water-cut technology, as shown in Fig. 1.
The method of grouting with pressure is used to change the characteristics of coal around the gas extraction borehole and to seal the micropores and fissures. Through the grouting equipment, the slurry material is injected into the space of the sealing section of the gas extraction borehole and the coal body disturbance inside the hole wall around the cutting and seam slot at a certain pressure. Under the action of the grouting pressure, the slurry can split and expand the coal body cracks in the hole wall, fill the pores and the concave-convex surface of the coal body, and increase the slurry diffusion range. Under the action of large osmotic pressure gradient, it penetrates into the micro fracture of the coal body and generates cohesion. After the slurry solidifies, barrier baffle is formed to achieve the purpose of applying active support to the coal and rock mass around the borehole and sealing the gas leakage channel.

3. Experimental study on hole sealing depth of bedding borehole

The drillings method is used to judge the distribution of stress zones around the roadway. Under normal conditions, the greater the stress of coal, the greater the amount of cuttings in the drilling direction, and the lower the amount of cuttings when the stress changes. A coal electric drill with a diameter of 42mm was used to arrange 6 test holes on the two sides of a coal roadway in a mine, with a spacing of 5m for single hole and a drilling depth of 15m. Through the statistics of drill cuttings per unit footage, the curve fitting of drill cuttings statistics of each borehole is carried out to provide a basis for the determination of surrounding rock stress partition of roadway, as shown in Fig.2.
As can be seen from Fig.2, within the hole depth range of 0~3m, the cuttings of each test borehole are small and the cuttings per unit footage are equivalent. The cuttings increased linearly in the range of 3~7m and reached a maximum of more than 6.0kg/m at about 7m. With the increase of hole depth, the cuttings decreased gradually and became stable after 12m. Thus, it can be speculated that 0~4m inside the roadway surrounding rock is the coal crushing zone, 4~7m is the plastic zone and 7~12m is the elastic zone.

Based on theoretical calculation and cuttings analysis, it can be seen that the surrounding rock of roadway 0~3m is the crushing zone, 4~6m is the plastic zone, 6~12m is the elastic zone, and the inner rock 12m is the original rock stress zone. Thus, it can be determined that the sealing depth of the optimized gas extraction borehole should be $6m \leq L \leq 12m$. In addition, the sealing process of the cutting seam belt requires cutting the annular groove in the sealing segment, with the position of the cutting seam no less than 6m and the spacing of the sealing slot above 2m. Considering the influence of cutting seam in the sealing section, the sealing depth should be 6~12m.

4. Experimental study on the position of seam and slot in bedding hole

When ultra-high pressure water jet is cutting seam in coal body, it mainly controls the water jet pressure and cutting time to control the seam depth. According to the seam cutting test of ultra-high pressure water jet, when the water jet pressure is 30MPa and 50MPa, the coal output of the borehole is respectively 15~18kg and 30~50kg within 1min. When 30MPa and 50MPa water jets are used to cut the coal for 1min, the seam depth is about 0.25~0.30m and 0.37~0.5m respectively. The reasonable seam depth of bedding drilling should be controlled at 0.25~0.5m.

5. Field test

5.1. Testing program

The drilling area of a mine was selected as the test area. The spacing of the slit test holes B1~B16# was 5m, and the diameters of the contrast holes and the slit holes were 113mm. According to the field test conditions, a total of 4 groups of comparative test boreholes were arranged, including 4 boreholes in a single group, with the hole spacing of 5m, the hole aperture of 113mm, the hole depth of 140m, the azimuth of 230° and the dip angle of -2°~2°. No. P group drilling (1-4#) adopts the traditional "two blocks and one injection" hole sealing process, and the designed hole sealing depth is 15m. The drill hole in test group no. G1~G3 (5~16#) adopts the cutting seam belt pressure sealing process. The designed sealing depth is 10m, 12m and 15m respectively. The cutting depth of two single seam grooves designed for each group of test boreholes was 0.3m and 0.5m respectively, and comparative investigation was conducted. See Fig.3 for the plan of drilling arrangement. See Tab.1 for the specific parameters of the test plan.

Fig.3 Hole sealing test drilling arrangement plan
Tab.1 Test drilling hole sealing scheme and parameters

| Group | Number  | Depth of the hole sealing/m | Slot number | Slot position /m | Slot depth /m |
|-------|---------|-----------------------------|-------------|------------------|--------------|
| S     | 1#、2#、3#、4# | 15                          | \           | \                | \            |
|       | 5#、6#     | 10                          | 1           | 6                | 0.3          |
|       | 7#、8#     | 10                          | 1           | 6                | 0.5          |
| S1    | 9#、10#    | 12                          | 2           | 6、9             | 0.3          |
| S2    | 11#、12#   | 12                          | 2           | 6、9             | 0.5          |
| S3    | 13#、14#   | 15                          | 3           | 6、8、10         | 0.3          |
|       | 15#、16#   | 15                          | 3           | 6、8、10         | 0.5          |

5.2. Analysis on the effect of cutting seam sealing hole thickening

After the completion of drilling, grouting should be carried out in time to seal the hole according to the design plan of sealing the hole, and the extraction pipe and the extraction pipe network should be connected to pump. The data of borehole extraction on 45d were calculated. In order to visually investigate the variation and attenuation of borehole gas concentration in each group, the measured borehole extraction data were plotted as shown in Fig.4.

It can be seen from Fig.4 that gas extraction effects of boreholes in each group show obvious differences under different hole sealing technologies and parameters. The gas extraction concentration of P group (1~4#) drilling hole with traditional "two blocks and one injection" sealing method is relatively low, and the concentration decays to about 10% after 45d of extraction and the attenuation rate is relatively high. By comparing the variation of borehole concentration in group G1–G3, it can be seen that the borehole extraction concentration in group G1 (5~8#) increased by about 25% compared with that in group P, but the gas concentration decreased rapidly. During the investigation period, the basic extraction concentration of G2 group (9~12#) and G3 group (13~16#) remained above 60% and the concentration attenuation rate was small, and the gas extraction effect was significantly
improved. The drilling with cutting seam and pressure sealing technology can effectively improve the sealing property of the drilling hole, reduce the air leakage in the drilling hole and enhance the gas extraction effect.

Through field test and research, it is verified that the drilling hole sealing effect is better by using the cutting seam belt pressure sealing technology. From the comprehensive consideration of the sealing effect and the sealing economy, the reasonable sealing parameters are the sealing depth of 12m, the sealing seam depth of 2 holes and the cutting seam depth of 0.5m.

6. Conclusion
(1) In this paper, a new type of hole sealing process is presented, which is assisted by ultra-high pressure hydraulic cutting technology.
(2) The field test results show that compared with the traditional "two blocks and one injection" sealing technology, the gas extraction borehole with slit belt pressure sealing technology increases the initial concentration by about 1.5~2times, the gas extraction concentration increases by about 2~3.5times, and the gas extraction concentration exceeds 60%.
(3) Through comparative analysis, it is determined that the reasonable sealing parameters should be the sealing depth of 12m, the number of slot is 2, the position of slot is 6m away from the hole mouth, and the slot depth is 0.5m.

Acknowledgments
This work was financially supported by the National Key Research and Development Program of China (2017YFC0804206), Special project of science and technology innovation and venture capital of Tiandi Technology Co., Ltd.(2018-TD-MS076), General project of Chongqing Research Institute Co., Ltd.(2019YBXM31).

References
[1] Ma Z H, Pan R K, Ma Z Y, et al. Study on Air Leakage Law and Hole Sealing Technology in Gas Drainage by Bedding Borehole [J]. Coal Science and Technology, 2020, 1-7.
[2] Guo L D, Zhao X S, Zhang Y J, et al. Study on borehole sealing technique with sealing and isolation integration to gas drainage borehole along seam[J]. Coal Science and Technology, 2018, 46(5) : 114-119.
[3] Wang X P, Lin G L. Properties and Sealing Effect of New Colloidal Materials for Drilling and Sealing for Gas Extraction [J]. Mining Safety & Environmental Protection, 2019,46(5):56-59.
[4] Qiao Y D, Cheng H M. Research on Leakage Channel and Pressurized Hole Sealing Technology for Bedding Drainage Hole Based on COMSOL [J]. Coal Engineering, 2019, 51(7) :114-119.
[5] Lu G C. Application of Capsule with Pressure Sealing Process in Gas Extraction Drilling Along Coal Seam [J]. Industrial Safety and Environmental Protection, 2018, 44(8) :28-30.
[6] Li G G, Chen S J, Zhao X F.. Study on influencing factors of gas leakage in gas extraction by holedrile along seam [J]. Journal of North China Institute of Science and Technology, 2018, 15(3): 16-20.