Application on removing outburst with dig-hole drillings in coal seam

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Abstract. In order to resolve the problem that low gas drainage concentration, poor results of the gas drainage through crossing hole which cause removing the outburst inadequate, we adopt dig-hole drillings technology on the base of designing crossing hole which is used to drainage gas. It can increase disturbance around the coal, increase the expansion deformation degree of the coal around the drilling, make pressure relief of the coal seam more fully, strengthen the permeability of coal seam, increase the effect of drainaging gas and removing outburst and reduce the possibility of coal and gas outburst.

1. Introduction

Coal is an important energy and basic raw material for industrial development in China, and has an important strategic position in the national economy. In recent years, with the increase of mining mechanization intensity and the increase of mining depth, the geological conditions become more and more complex, and the phenomenon of gas power becomes more and more obvious, coal, rock and gas dynamic disasters occur from time to time. The frequent occurrence of coal and gas outburst has seriously damaged the production system, it can destroy the mine roadway facilities, destroy the mine ventilation system, make the mine roadway filled with gas and coal (rock) thrown objects, resulting in people suffocation, coal flow buried people, even may cause gas explosion and fire accidents, leading to production interruption, seriously affecting the safety and efficiency of coal mining. Therefore, the prevention and control of coal and gas outburst has become the focus of coal mine safety science and technology work at home and abroad.

2. Mechanism of coal and gas outburst

Coal and gas outburst is a dynamic phenomenon in which coal (rock) and gas are suddenly ejected from the coal (rock) wall to the working space in a very short time, accompanied by sound and strong force energy effect.

Because coal and gas outburst is an extremely complex dynamic phenomenon, the understanding of the mechanism of coal and rock mass destruction and development in the process of coal and gas outburst is still at the stage of qualitative analysis and hypothesis, it is not clear which factors play the main role in the process of outburst and how they interact with other factors, but some prominent phenomena can only be explained, and can not form a unified and complete theoretical system.

There are several hypotheses about the mechanism of coal and gas outburst:
(1) single factor hypothesis
Gas Dominant role hypothesis, in-situ stress dominant role hypothesis, the chemical nature of the role hypothesis
(2) the hypothesis of integrative action
At present, many researchers at home and abroad have a consensus on the mechanism of coal and gas outburst: Coal and gas outburst is the result of the combined action of in-situ stress, gas and physical and mechanical properties of coal, it is believed that high pressure gas plays a decisive role in the development of outburst, and that in-situ stress is the factor that excites outburst, the physical and mechanical properties of coal are the factors that prevent outburst [1].

3. Principle of pressure relief by hole drilling
Hollowing hole drilling is a hollowing process which is carried out on the basis of conventional hole drilling through layers. In the predetermined depth of the drilling hole, the coal body is rotated and cut by increasing the diameter of the drilling tool through the automatic diameter-changing and hole-expanding drill tool, so that the diameter of the drilling hole is enlarged, and the surface area of the inner wall of the drilling hole is increased, and the cracks in the surrounding coal body are enlarged, the stress in the surrounding coal body is released, the coal body is fully relieved, the permeability of the coal bed is enhanced, the gas drainage effect and effective influence radius are improved, and the gas content and gas pressure in the coal bed are reduced, in order to eliminate conflict quickly.

4. Field Test

4.1. Mine Profile
Huainan Mining Group Pan Yidong Coal Mine 1252(1) Yunshun is located in Xiyi (11-2) mining area. The normal coal thickness of 11-2 coal is 2.8 m, the measured maximum gas pressure is 1.9 MPa, the maximum gas content is 10.36 m3/t, the normal gas emission is 2 m3/min, the coal seam permeability is poor. Before driving in this coal seam, the floor roadway is first arranged along the working face design roadway, using the floor, the floor roadway is arranged strip type through layer drilling hole, eliminating the outburst danger of the coal body in front of driving, advance cover driving construction [2], The control range of drilling hole is 15m outside the contour line of both sides, and the final coal point of drilling hole is arranged at 10m* 5m interval. In order to improve the concentration and effect of drilling and extraction, one hole through roadway and two holes on both sides of roadway are selected in each row of boreholes.

4.2. Hollowing and drilling equipment and technology
1) Reaming equipment
(1) Drilling rig:ZDY-3200S type fully hydraulic tunnel drill for coal mine belongs to the type of low rotation speed and high torque. It is suitable for the construction of large diameter boreholes with compound slice bit, and is mainly used for the construction of near horizontal and long distance gas drainage boreholes in coal mine, it can also be used to drill holes in ground and tunnel near horizontal engineering. The speed of the drilling rig is 50–175r/min, the maximum torque is 3200N•m, the lifting capacity is 70KN, the feeding capacity is 102KN, the motor power is 37KW, the mass of the main engine is 1180kg, and the external dimension is 2.30m×1.10m×1.65m.
(2) Drilling tools: The BZ 150-II automatic diameter-changing reaming drill is adopted, and 133mm compound slice bit is used for drilling during construction. The diameter of the reaming hole of the expanded cutter body can reach 260mm when the fixed position is reached. See figure 1 for details.
Figure 1. Schematic diagram of type 150-II automatic diameter-changing reaming tool

(3) CX type precession vortex flowmeter with low flow rate and small flow rate and its concentration sensor are selected for gas drainage investigation.

2) Hole drilling arrangement and parameters

In order to investigate the effect of hole-drilling and coal-drawing, an investigation test was conducted in No. 5 drilling site. As shown in figures 2 and 3, the drill site layout drill hole parameters are shown in table 1.

Figure 2. Borehole profile
Figure 3. Schematic Diagram of drill hole

Table 1. Design and construction parameters of test drilling hole

| Hole number | Angle with center line of drilling field /° | Elevation Angle /° | Coal Hole depth /m | Coal Stop Hole depth /m | End Hole depth /m |
|-------------|------------------------------------------|-------------------|-------------------|------------------------|-----------------|
| 3           | To the left                               | 24.8              | 41.7              | 34.6                   | 39.2            | 39.7            |
| 5           | To the left                               | 35.3              | 51.3              | 30.6                   | 34.0            | 34.5            |
| 7           | To the left                               | 54.8              | 61.4              | 28.3                   | 31.3            | 31.8            |
| 12          | To the left                               | 7.0               | 44.3              | 33.0                   | 37.4            | 37.9            |
| 14          | To the left                               | 10.7              | 56.4              | 28.7                   | 31.9            | 32.4            |
| 16          | To the left                               | 20.7              | 71.4              | 26.2                   | 29.0            | 29.5            |
| 21          | To the right                              | 12.1              | 43.9              | 33.3                   | 37.7            | 38.2            |
| 23          | To the right                              | 18.3              | 55.5              | 29.1                   | 32.2            | 32.7            |
| 25          | To the right                              | 33.4              | 69.4              | 26.6                   | 29.4            | 29.9            |
| 1           | To the left                               | 19.3              | 33.8              | 40.4                   | 44.8            | 45.3            |
| 2           | To the left                               | 22.0              | 37.4              | 37.1                   | 41.2            | 41.7            |
| 4           | To the left                               | 35.3              | 51.3              | 30.6                   | 34              | 34.5            |
| 6           | To the left                               | 54.8              | 61.4              | 28.3                   | 31.3            | 31.8            |
| 8           | To the left                               | 70.5              | 65.1              | 27.9                   | 30.8            | 31.3            |
| 9           | To the left                               | 90                | 68.5              | 27.9                   | 30.7            | 31.2            |
| 10          | To the left                               | 5.3               | 35.2              | 39                     | 43.2            | 43.7            |
| 11          | To the left                               | 6.2               | 39.4              | 35.6                   | 39.5            | 40              |
| 13          | To the left                               | 8.6               | 49.9              | 30.7                   | 34              | 37.9            |
| 15          | To the left                               | 14.1              | 63.6              | 27.2                   | 30.2            | 30.7            |
| 17          | To the left                               | 37.1              | 79                | 25.8                   | 28.5            | 29              |
| 18          | To the left                               | 90                | 85.6              | 26.1                   | 28.8            | 29.3            |
| 19          | To the left                               | 9.2               | 35                | 39.3                   | 43.5            | 44              |
| 20          | To the right                              | 10.7              | 39.1              | 35.8                   | 39.8            | 40.3            |
| 22          | To the right                              | 14.8              | 49.3              | 31                     | 34.4            | 34.9            |
| 24          | To the right                              | 23.7              | 62.3              | 27.6                   | 30.6            | 31.1            |
| 26          | To the right                              | 52.8              | 75.7              | 26.2                   | 28.9            | 29.4            |
| 27          | To the right                              | 90                | 76.7              | 26.7                   | 29.7            | 30.2            |
3) Drilling and hollowing construction technology in coal seam section

(1) A 133mm bit is installed at the front end of the new drilling tool in small diameter drilling. Under the action of the drilling machine thrust, the back drilling body drives the sliding wedge forward into the tail of the tool body and locks the tool body, thus realizing small diameter drilling, the holes are drilled by pressure air and slag discharge (the air pressure is 1~1.2 MPa when the air pressure is supplied by the moving air compressor). Drill bit through 11-2 coal into the floor 0.5 m stop, accurate record see stop coal position.

(2) When the reaming hole is drilled to a predetermined hole depth, the outer rod is pulled back, and the back drilling body drives the sliding wedge to slide back and exits from the tail of the cutter body, so that the cutter body is unlocked. Under the action of rotating Centrifugal Force, the Cutter Body is fully opened to the maximum position and the hole wall is cut, with the withdrawal of the drill pipe, the hole reaming operation was realized, and the diameter of the hole reaming was up to 260 mm. [3]

(3) During hole drilling with hole-cutting bit, it is necessary to drill gently and slowly to ensure that the coal dust is fully discharged out of the hole to prevent gas overshoot and fire inside the hole caused by holding the hole. For every hole reaming 1~2 m, the gas density must be checked by the portable gas meter. When the reaming bit is drilled to the 11-2 coal stop position, the pressure air in the hole should be kept, and the coal dust in the hole should be discharged before the drill can be lifted.

(4) Drill withdrawal. Before retracting drilling, stop rotating first, turn off pressure air, wait for biplane bit to reset, then slowly retracting drilling.

4.3. Result analysis

The observation data of hollowed-out bores coal cutting quantity effect are as follows: Table 2.

| Hole number | Through length (m) | Total coal pulled out(kg) | Actual amount of coal pulled out (kg/m) | Theoretical coal yield (kg/m) | Increase the amount of coal pulled out (kg/m) |
|-------------|-------------------|--------------------------|----------------------------------------|-----------------------------|---------------------------------------------|
| 3#          | 5.1               | 361                      | 70.78                                  | 54.48                       | 16.3                                        |
| 5#          | 3.4               | 213                      | 62.65                                  | 54.48                       | 8.7                                         |
| 7#          | 3.1               | 198                      | 63.87                                  | 54.48                       | 9.39                                        |
| 12#         | 4.5               | 286                      | 63.56                                  | 54.48                       | 9.08                                        |
| 14#         | 3.3               | 213                      | 64.55                                  | 54.48                       | 10.07                                       |
| 16#         | 2.8               | 176                      | 62.86                                  | 54.48                       | 8.38                                        |
| 21#         | 4.4               | 291                      | 66.14                                  | 54.48                       | 11.66                                       |
| 23#         | 3                 | 209                      | 69.67                                  | 54.48                       | 15.19                                       |
| 25#         | 2.9               | 182                      | 62.76                                  | 54.48                       | 8.28                                        |

According to the analysis of above data, the average amount of coal pulled out from hole drilling is 65.2 Kg/m, which is 10.72 KG/m more than that from theory, which is 10.72 kg M more than the theoretical amount of coal pulled out, the actual diameter of hole-pulling drill hole is 278mm, which greatly increases the exposed area of coal seam in the drill hole, improves the single-hole extraction effect of the drill hole, so as to eliminate outburst in outburst coal seam better.

2) Investigation on the effect of hole drilling and extraction

When the actual flow rate of a single hole is less than the measurement accuracy of the device, the single-hole flowmeter shows zero. Therefore, in the drilling site, 9 hole-holing holes are selected to be connected to the pipeline for all-way extraction, and the same way, in the drilling site, 9 conventional holes with longer length through coal sections than the length through hole-holing and through coal sections are selected to be connected to the pipeline for all-way extraction, along with the rest of us. A single-hole inspection device is installed on the two-way pumping-production pipeline, and the two-way pumping-production pipeline is pumped at the same time.
The comparison curves of hole drilling parameters with conventional drilling parameters are obtained by statistics, as shown in Figure 4 and Figure 5.

**Figure 4.** Comparison curve of concentration between hollowed-out hole and conventional drilling

**Figure 5.** Comparison curve of mixed flow rate and extraction purity rate between hollowing hole and conventional drilling

It is not difficult to get the following results by comparing the curves of hole-drilling and conventional hole-drilling and extraction parameters:

1. The average extraction concentration of hole drilling is more than 2 times that of conventional drilling
2. The average mixed flow rate of hole drilling is more than twice that of conventional drilling
3. The average extraction purity of hollowed-out drilling is more than four times that of conventional drilling.

The specific parameters are shown in Table 3.

**Table 3** Table of extraction parameters for hollowing holes and conventional holes

| Pore type       | Average extraction concentration(%) | Mean pumping-production mixed flow(m³/h) | Average pure flow rate of extraction(m³/h) |
|-----------------|-------------------------------------|----------------------------------------|------------------------------------------|
| Holing and drilling | 29.04                              | 0.04342                                | 0.011693                                 |
| Holing and drilling | 14.46                              | 0.01974                                | 0.002495                                 |
5. Conclusion
In order to solve the problem that the concentration of gas drainage is low and the effect of gas drainage is poor when the coal seam is pre-pumped through the seam drilling hole, which results in the incomplete elimination of outburst in the coal seam, thus leading to the coal and gas outburst accident, in the design of drilling hole, the selection of a part of the drilling hole hollowing technology. Through the above analysis, it is concluded that hole drilling has the characteristics of large area of single hole drainage, high concentration of drainage, large amount of gas drainage and good drainage effect. Here's how it works:

(1) The key points and implementation process of hollowing and drilling technology are analyzed.
(2) Based on the comparison of theory and practice, it is found that the average amount of coal pulled out by hole-drilling is 65.2 kg/m, which is 10.72 kg/m higher than that by theory. The actual diameter of hole-drilling is 278 mm, this greatly increases the exposure area of the coal seam in the borehole.
(3) By gas drainage comparison, it is found that the average extraction concentration of hole-holing drill is more than 2 times of that of conventional drill, and the average mixed flow rate of hole-holing drill is more than twice of that of conventional drill. The average extraction purity of hollowed-out drilling is more than four times that of conventional drilling.

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