Research on gas natural emission in high pressure hydraulic reaming drillings

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Abstract. The research on gas natural emission in high pressure hydraulic reaming drillings is carried out at Guanyinshan Coal. This antireflection technology greatly improves the efficiency of gas natural emission, and within the limit value, the efficiency is greatly related to the rate of drilling slag. This research provides a reference for the high pressure hydraulic reaming in this mine, and also for similar mines to improve the efficiency of gas natural emission and control reaming shotcreting.

1. Introduction

With the expansion of mining scale and the increase of mining depth, the pressure of gas control in coal mines has greatly increased. Gas has become a key problem restricting the efficient development of coal enterprises. In the mine without protective mining conditions, we usually use drilling to drain (drainage) coal seam gas, in order to prevent and control coal and gas outburst, reduce gas emission and reduce the number of air flow gas overrun in the working face [1-3].

A large number of field tests show that large diameter drilling has a great advantage in improving the efficiency of gas drainage. However, there are also some technical problems, such as the increased risk of drilling induced outburst, the serious hole collapse, the difficulty of slag removal, the short hole forming length, and the increase of the geometric multiple of the rig load. Especially in the cross layer drilling and extraction, the effective coal hole section often only accounts for a small part of the whole drilling hole, and it is impossible to construct all large-diameter drilling holes [4]. With the advantage of controlling the diameter of rock hole section and increasing the diameter of coal hole section, the high-pressure hydraulic reaming technology has become the main trend of improving the efficiency of through layer drilling.

In recent years, with the rapid development of hydraulic reaming technology, many mining areas have carried out corresponding field tests in view of their own coal and gas reserves, forming a series of research results. The C5 coal seam of Guanyinshan coal mine has the limit conditions of large dip angle, coal quality broken and soft, local water bearing, thick and so on. In order to improve the efficiency of gas control, and also solve the problem that it is difficult to extract (arrange) with the common technology in the water bearing area, the application research of high pressure hydraulic reaming technology is carried out. In the reaming operation, a lot of gas is often emissiond or ejected from the borehole, which seriously affects the construction safety. Through statistical analysis of relevant parameters, we know the lifting effect of expanding technology on the self drainage of drilling gas, and we can also analyze the correlation between the rate of drilling slag and the rate of gas self drainage, and then effectively control the expanding and shotcreting.
2. Overview of test area [5]
Guanyinshan coal mine is located in Weixin County, Zhaotong City, which is a state-owned infrastructure mine. It adopts the construction mode of one mine and two wells, with a design production capacity of 2400k.

In this study, well 1 of Guanyinshan coal mine is selected. Its strike length is about 12.4km, and dip width is about 1.9-2.5km, and the area is about 30.1km². The inclined shaft development is adopted, which is divided into four levels of ± 800m, ± 500m, ± 250m, ± 0m. The current infrastructure construction work is concentrated at the level of ± 800m. Most of the C1 coal seams in the mine field are minable, all of C5 coal seams are minable. We arrange field test in the 106 gas drainage roadway.

The basic parameters of C5 coal seam in the test area is listed in table 1.

| Parameter name               | Dimension | Parameter value   |
|------------------------------|-----------|-------------------|
| Thickness of coal seam       | m         | 2.6~4.8           |
| Coal seam dip                | °         | 34~39             |
| Firmness coefficient         | -         | 0.17              |
| Damage type                  |           | III~IV            |
| Maximum gas pressure         | MPa       | 1.86 (indirect method) |
| Maximum gas content          | m³/t      | 12.95             |
| Attenuation coefficient      | d⁻¹       | 0.59~1.1          |
| Air permeability coefficient | m²/MPa²·d | 0.607~2.67        |
| Initial release velocity     | mmHg      | 38                |

3. Basic principle of high pressure hydraulic reaming [6-8]
High pressure hydraulic reaming is a kind of technology to improve the efficiency of drilling gas drainage. In the constructed drilling, the drilling machine is used to drive the high pressure drill pipe and bit, and the high pressure water is used to strike, cut or peel the coal wall. Through the drill pipe rotation, the drill hole diameter is continuously enlarged, the diameter of the drill hole is expanded, the exposed area and pressure relief range is also increased. With this technology, we can improve the permeability of the coal seam and the gas drainage effect, and further reduce the gas pressure of the coal seam.

High pressure hydraulic reaming destroys coal and rock mass by jet, the main functions are: ① jet impact; ② water wedge; ③ stress wave produced by jet; ④ cavitation. Jet impact force and stress wave play an important role in the whole process of reaming, while water wedge and cavitation promote the expansion and accelerated failure.

4. High pressure hydraulic reaming equipment and technology

4.1. High pressure hydraulic reaming equipment
Main equipment of high pressure hydraulic reaming is listed in table 2.

| No. | Equipment name               | Specification and model |
|-----|------------------------------|-------------------------|
| 1   | Diamond hydraulic reaming bit| Φ113                    |
| 2   | High and low pressure conversion device | GFQ-73                   |
| 3   | High pressure reaming drill pipe | GFZG·Φ73×1000-3         |
| 4   | High pressure rotating dynamic seal water tail | SW                      |
| 5   | High pressure hose            | Φ25-4SP-40M             |
| 6   | Straight joint                | Φ51-25                  |
| 7   | High pressure ball valve       | KJ25                    |
| 8   | Tee joint                     | KJ25                    |
| 9   | High pressure pump set        | BYW315/55               |
4.2. Technical process [9-10]
High pressure hydraulic reaming process mainly includes:
1) Connect the bit, high and low pressure conversion device and drill pipe, and use hydrostatic water to drill to the required depth;
2) The pipe is connected with water pump by high-pressure rotating water tail;
3) Start the water pump, the water is transmitted to the high and low conversion device through the pipe and pipe, and the high-pressure water cuts the borehole wall through the rotation of the drill pipe;
4) The high-pressure water drill pipe is moved at a proper speed along the drilling axis, and the reaming operation is started;
5) When the drill pipe moves for a certain length, the water supply can be suspended, one or several drill pipes can be added or removed, and then the reaming can be continued;
6) When the length of reaming section meets the design requirements, turn off the water, pull out the drill bit and high and low converter, and the reaming is finished.

4.3. Research plan
The test site is arranged in 106 gas drainage roadway. The drilling design of common and high-pressure hydraulic reaming boreholes is shown in Figure 1.

![Figure 1. Design of ordinary and enlarging drilling test](image)

1) Measurement of self draining gas
In the process of drilling construction, the measuring points shall be arranged at the place where the air flow is stable and the distance from the working point is not less than 20 m. The air volume, gas concentration and other parameters shall be measured. The blowout preventer is connected to extraction line after passing through the steam water separator. At the place where is not less than 20 m away from the work location of the extraction line, manual and electronic measurement devices are arranged to measure the air volume, gas concentration and other parameters.

After the completion of drilling, the extraction pipe shall be buried within 10 minutes, and the hole shall be temporarily sealed with polyurethane. After the gas in the hole is emission stably (30th to 40th minutes), the researcher use the gas meter to measure the gas volume of ordinary drilling and high-pressure hydraulic reaming drilling for 10 minutes per minute.

The layout of the measurement system is shown in Figure 2.
2) Slagging rate measurement
In the process of high-pressure hydraulic reaming drilling, the ore car, iron bucket or sedimentation tank are used to collect the drilling slag. By precipitating, drying and weighing, the researcher could calculate the average slag rate per minute.

5. Investigation on the effect of gas self drainage with high-pressure hydraulic reaming

5.1. Self drainage rate of gas in borehole
1) Self drainage of drilling gas during construction
Before the high-pressure hydraulic reaming, the conventional process should be used to complete the drilling. In the process of construction, by measuring the ventilation and gas parameters at the upper and lower sides of the operation point, the self drainage gas rate of the drilling hole in the process of conventional drilling and reaming operation can be obtained. It can be seen from the calculation and analysis, the self drainage rate of the boreholes during the conventional drilling is 0.02 ~ 1.3m³/min, with an average of about 0.53m³/min; the self drainage rate of the boreholes with hydraulic reaming is 0.7 ~ 14.3m³/min, with an average of about 4.73m³/min. In the process of construction, the reaming technology can improve the effect of gas self drainage to 9.1 times that of conventional drilling.

2) Self drainage of gas in borehole after completion
After temporary hole sealing and natural exhaust air flow becoming stable, gas meter can be used to measure the self exhaust gas volume and gradient.
According to the calculation and analysis, during the period of 30-40 minutes after the completion of drilling, the gas self drainage gradient of common drilling is 7.88-15.32l/min, with an average of about 11.44l/min; the gas self drainage gradient of hydraulic reaming drilling is 32.07-195.07l/min,
with an average of about 93.69 l/min. The reaming technology improves the gas self drainage effect to 8.2 times of the ordinary drilling.

5.2. Correlation between slagging rate of reaming and gas self drainage rate

In the process of reaming, the slag emission rate can be effectively controlled by controlling the water pressure. Under different water pressure, the amount of slag are counted every 5 minutes, and the gas self emission rate is measured during reaming operation.

It can be seen from the calculation and analysis. At the rate of 0.01 ~ 0.16 t/min, there is a significant positive correlation between the gas self emission and the slag emission rate. At the rate of 0.16 ~ 0.2 t/min, there is a tendency to blow holes; when the slag emission rate is greater than 0.18 t/min, there is a tendency to hole collapse and plugging are common, especially when the rate is more than 0.22 t/min (some holes have collapsed at a smaller rate), the test holes have collapsed.

6. Conclusion

Through the research on the application of the self drainage rate with hydraulic reaming, the following conclusions can be obtained.

1) The high-pressure hydraulic reaming technology can effectively improve the gas self drainage rate of drilling: in the reaming operation, the average gas self drainage rate is about 4.73 m³/min, about 9.1 times of the conventional drilling; after the completion of drilling, the average gas self drainage rate is about 93.69 l/min, about 8.2 times of the ordinary drilling.

2) At the rate of 0.01-0.16 t/min, there is a significant positive correlation between the gas self emission and the slag emission rate; at the rate of 0.16-0.2 t/min, there is a tendency to blow holes; when the slag emission rate is greater than 0.18 t/min, there is a tendency to hole collapse.
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