Research and Application of Hydraulic Strengthening Technology in Excavation Face of Wangpo Coal Mine

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Abstract: In order to effectively solve the problems of low pre-drainage efficiency, long pre-drainage time and slow tunnelling speed under the condition of broken coal seam in Wangpo Coal Mine, the test and application of ultra-high pressure hydraulic slitting pressure-reducing anti-reflection technology in 3310 transportation and excavation face. According to the analysis of the amount of cuttings, the effect of gas drainage and the extraction radius, the radius of the slit is 1.46~1.61m, the flow rate of single hole drainage can be increased by 1.5~5.5 times, and After pre-draining for 7 days, the pre-drainage holes arranged at a pitch of 5 m at the bottom of the hole can be drawn to the standard. The results show that the ultra-high pressure hydraulic slitting technology can effectively improve the coal seam pre-drainage effect, greatly improve the gas drainage efficiency, shorten the gas drainage time to the standard and increase the coal roadway excavation speed by 35%. In addition, the hydraulic slitting technology can increase the effective influence radius of the drainage hole and reduce the amount of pre-drainage holes.

1. Introduction

The occurrence conditions of coal seams in China are more complex, and the high gas and outburst coal seams are widely distributed. Gas is the main disaster factor threatening the safe and efficient production of coal mines. With the increase of mining depth, mining conditions are constantly changing, and the difficulty of gas control is increasing. At this stage, gas drainage is the main means of mine gas prevention and control. Due to the influence of burial depth and mountain cover, most of the soft and broken coal seams in China, and the gas drainage conditions are congenital insufficient. The widespread existence of soft and broken coal seams seriously restricts the role of gas drainage in gas control[1,2].

How to increase the gas drainage efficiency in the existing soft coal seam is the key measure. Based on the geological conditions of coal seams in China, universities and scientific research institutes have been committed to theoretical research on gas drainage promotion, forming a series of permeability enhancing and drainage promoting technologies, including carbon dioxide fracturing, deep hole presplitting blasting, hydraulic fracturing, hydraulic punching, hydraulic cutting, etc[3-6].

High pressure water jet technology has been widely used in mining, oil drilling and metal cutting fields since its industrial application in the last century. In the field of coal mine, high pressure water jet is mainly used for hydraulic coal mining, roof cutting pressure relief and gas pressure relief and permeability enhancement in low permeability coal seam. In recent years, with the continuous progress of equipment manufacturing technology, the use of high-pressure water drilling hole expansion, slitting has achieved remarkable results, not only increasing the drainage effect, but also expanding the effective drainage radius of the borehole, reducing the amount of drilling work. Based
on the research of low-pressure hydraulic punching equipment and technology, the problems such as
difficult slag discharge and easy blockage in soft coal seam and downward hole have been solved.
Chongqing Research Institute of China Coal Science and Technology Group Co., Ltd. has developed a
set of ultra-high pressure hydraulic cutting equipment with overall working pressure of 90-100 MPa
and medium and high pressure hydraulic fracturing pressure relief and permeability increasing
equipment of 50-60 MPa, and formed a complete set of antireflection technology system It can
significantly improve the permeability of coal seam, rapidly reduce the stress of coal and rock strata,
improve the applicability of series equipment, solve the problems of low drainage efficiency of
outburst coal seam with low permeability and poor pressure relief effect of stress dominated coal seam.
It has been widely applied in Huainan, Hancheng, Furong, Liuzhi and other mining areas in Anhui,
Shaanxi, Furong, Guizhou and other mining areas, which has achieved good results, shortened the
time of gas control and improved The permeability of coal seam is improved, and the amount of
drilling work is reduced, which has remarkable technical and economic benefits.

Wangpo coal mine No3 coal seam gas content is high, coal seam is relatively broken, along the
seam drilling pre extraction standard time is long, pre drainage drilling engineering quantity is large,
coal roadway single entry efficiency is low, restricted the mining replacement of the mine, therefore,
research and test hydraulic slotting permeability increasing technology, rapid pressure relief and
permeability enhancement of coal seam, in order to realize safe and efficient driving of heading face.

2. Ultra-high pressure hydraulic slotting technology

2.1 Mechanism of slotted pressure relief and permeability enhancement

The movement of gas in coal seam can be divided into three stages: desorption, diffusion and seepage.
Generally speaking, the lower the coal seam stress, the lower the degree of coal seam pore compaction,
the larger the seepage channel, the greater the gas passing capacity and permeability[7]. Hydraulic
slotting can make coal seam deformation and fracture, reduce coal stress and improve coal seam
permeability. Ultra high pressure hydraulic slotting technology is to use high-pressure water jet to cut
and impact the coal seam in the coal hole section of the drilling hole in the through layer or bedding
drilling, forming irregular cutting gap in the coal body. The ultra-high pressure hydraulic cutting
technology system is shown in Figure 1. First of all, the gap formed by cutting can increase the
exposed area of coal body, and make the coal body in the drilling hole can be fully depressurized.
After the pressure relief, the original tiny cracks in the coal seam open, which increases the
permeability of the coal seam, creates favorable conditions for the gas emission in the coal body,
realizes the purpose of pressure relief and permeability enhancement of the coal seam; after cutting the
coal body around the seam, after the original stress balance state of the coal body is broken, the in-situ
stress is increased Under the action of coal fracture, a new seepage channel is formed, which improves
the permeability of coal seam.

![Figure 1. Schematic diagram of ultra-high pressure hydraulic slotting process](image-url)
2.2 Ultra high pressure hydraulic slotting equipment
GF-100 ultra-high pressure hydraulic slotting device is mainly composed of diamond hydraulic slotting bit, high and low pressure conversion slotter, hydraulic slotting shallow spiral drill pipe, ultra-high pressure rotary joint, ultra-high pressure hose, ultra-high pressure water pump, etc.

The ultra-high pressure water pump and the high and low pressure conversion slotter are the core equipment to realize the high-pressure cutting in low-pressure drilling. The ultra-high-pressure hydraulic slotting equipment is equipped with two types of water pumps: 80L/min and 125L/min. the rated pressure is 100MPa. The flow rate water pump can be selected according to the specific coal seam slag discharge effect. When the water pressure is less than 15MPa, the front end of the slotter can be opened to realize low-pressure drilling; when the water pressure is greater than 15MPa, the front end will be automatically closed to realize high-pressure slotting, so as to realize the slotting without drilling back.

3. Industrial test of ultra-high pressure hydraulic slotting

3.1 Overview of test surface
The 3310 working face of Wangpo coal mine is located in the south wing of the third mining area. The north side of the working face is connected with four development roadways. The south side is the mine field boundary. The East and west sides of 3310 working face are solid coal. The floor elevation of working face is from +485m to +445m. The average thickness of coal seam is about 5.5m. The coal seam structure is simple, the average dip angle of coal seam is 3° and the local maximum dip angle is 6° and the minimum value of coal firmness coefficient is 0.76. The failure type of coal is class II, and the gas content of coal seam is 7.2 ~ 11.9 cubic meters per ton.

3.2 Hydraulic slotting scheme design
In order to improve the drilling construction and slotting efficiency, the drilling field is designed to be 60m with a length of 6.5m × 3.0m, and the ultra-high pressure water pump is designed to be placed in the drilling site. The length of slotted drilling is designed to be about 80m, and 11 bedding boreholes are designed head-on, as shown in Fig. 2. The drilling control is 80m in front of the roadway, 15m in width on both sides of the roadway, and the final spacing of slotted boreholes is 5m. The cutting of drilling seam starts at 3m from the bottom of the hole and stops cutting at 10m away from the head-on. Each drill hole is cut by 3-24 cutters. Each cycle of 11 boreholes is cut by 161-220 cutters in total after seam penetration enhancement, cut seam and seal hole for connection and drainage.

![Figure 2. 3310 design of hydraulic slotting hole for bedding hole of return air duct](image-url)
In order to analyze the effect of ultra-high pressure hydraulic slotting test, the debris removal amount, gas drainage concentration, gas drainage volume and residual gas content are selected as the inspection indexes. During the slotting process, the amount of coal chips discharged from each slotted hole is counted. A group of data such as gas concentration, flow rate and negative pressure are measured every day in the slotting test borehole. After pre pumping for a period of time, the data are statistically analyzed. According to the investigation results of the first cycle, the parameters of No.3 Coal Seam in Wangpo coal mine, such as the slotting radius and effective extraction radius, are analyzed and obtained, which provides the basis for the design of drilling parameters and slotting parameters in subsequent circulation.

4. Investigation on effect of ultra high pressure hydraulic cutting

According to the design scheme, the ultra-high pressure hydraulic slotting test was carried out. A total of 16 cycles of slotting tests were carried out in 3310 transport gateway driving face. The construction length of each cycle was 80m, and the advance distance of 20m was reserved. The safe driving of roadway was 60m. The total length of 3310 transport gateway is 1020.4m. The amount of cuttings discharged from slotted holes is statistically analyzed in the process of hydraulic slotting, and the slotting effect is investigated and analyzed from the aspects of gas drainage concentration, drainage pure quantity and drainage radius.

4.1 Investigation of slotting radius

In the first cycle, a total of 11 boreholes were constructed for ultra-high pressure hydraulic slotting. The spacing of single cutter slotting was 3M, and the slotting test pressure was 75-90mpa. The coal body was cut into uniform small particles with particle size of 0.5-1.5cm. Under the joint action of high-pressure water and spiral drill pipe, the coal body was smoothly discharged to the orifice. In the slotting test process, the statistical data of chip removal per cutter are shown in Table 1.

Table 1. 3310 statistics of drilling and slotting in the first cycle of transportation gateway

| hole number | hole depth /m | number of slotting knives | slotting time /min | coal chip quantity /t |
|-------------|---------------|---------------------------|--------------------|----------------------|
|             |               |                           | total time | single time | total | single |
| 1           | 49.5          | 13                        | 180       | 14         | 4.20  | 0.323  |
| 2           | 68.5          | 19                        | 220       | 12         | 4.85  | 0.255  |
| 3           | 82.0          | 24                        | 305       | 13         | 5.80  | 0.242  |
| 4           | 81.0          | 24                        | 205       | 9          | 5.65  | 0.235  |
| 5           | 80.5          | 24                        | 270       | 11         | 5.70  | 0.238  |
| 6           | 80.5          | 24                        | 265       | 11         | 6.30  | 0.263  |
| 7           | 80.5          | 24                        | 240       | 10         | 6.15  | 0.256  |
| 8           | 81.0          | 24                        | 250       | 10         | 4.90  | 0.204  |
| 9           | 82.0          | 24                        | 225       | 9          | 6.20  | 0.258  |
| 10          | 63.5          | 18                        | 160       | 9          | 4.50  | 0.250  |
| 11          | 63.0          | 11                        | 145       | 13         | 2.30  | 0.209  |
| average     | 73.8          | 21                        | 224       | 11         | 5.14  | 0.248  |

4.2 Investigation on gas drainage effect

All the slotted boreholes were connected for pumping, and the extraction concentration and pure quantity were counted. The single hole drainage concentration is more than 60% after the ultra-high pressure hydraulic cutting is adopted, and the single hole drainage concentration is still stable at more than 40% after a week of continuous cutting, which indicates that the ultra-high pressure hydraulic cutting greatly increases the permeability of coal seam and ensures the high-efficiency drainage of drilling along the seam. In a week after seam cutting, the average daily pumping volume of 100m coal hole is 250-650 cubic metre, but the daily pumping volume is less than 100 cubic metre when the seam is not slotted. The pumping effect is increased by 1.5-5.5 times by using ultra-high pressure hydraulic cutting and permeability increasing measures.
### 4.3 Investigation of extraction rate

The measured original gas content in 3310 transport gateway test area is 10.5 cubic meters per ton. When the average residual gas content is reduced to 8.0 cubic meters per ton (the pre-drainage rate is 25%), the theoretical calculation shows that the drainage reaches the standard after 7 days of pre-drainage. Therefore, the ultra-high pressure hydraulic slotting and permeability increasing measures are adopted, and the hole bottom spacing is 5m when the holes are pre-drained for more than 7 days, which can effectively reduce the strip gas of 3310 transportation gateway and achieve the drainage standard.

### 5 Conclusion

The cumulative application distance of ultra-high pressure hydraulic slotting and permeability increasing technology for strip bedding measure boreholes in 3310 transport gateway is 1020.4m, the cuttings removal amount of single hole is 0.95 ~ 6.30t, the average single hole is 5.14t, the average 100m coal hole is 7t, and the equivalent seam depth is 1.46 ~ 1.61m.

After using ultra-high pressure hydraulic cutting, the single hole drainage concentration is more than 60%, and the single hole drainage concentration can still be stable at more than 40% after a week of combined mining. The average daily pumping volume of 100m coal hole in a week is 250-650 cubic meters, which improves the extraction effect by 1.5-5.5 times compared with that without slotting.

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