Experimental study on rock cross-cut coal uncovering with ultra-high pressure hydraulic slotting

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Abstract. In view of the coal seam with low permeability, high gas content, high gas pressure and high outburst risk, the rock cross-cut coal uncovering is carried out, and the Xinji No.1 Coal Mine in Anhui Province is selected as the engineering background. The experimental study on the rock cross-cut coal uncovering by the ultra-high pressure hydraulic slotted crosscut is carried out, and the amount of slag discharged by the hydraulic slotting and the initial velocity of gas emission are investigated. The results show that after the ultra-high pressure hydraulic slotting measures are adopted, the equivalent radius of the uncovering area of the coal seam group is increased by 31.9 times, the average initial velocity of gas emission is increased by 3.5 times, the amount of drilling work is reduced by 47%, and the coal is discharged by the slotting. The chip rate is more than 3 ‰ and the coal uncovering time is shortened by 50%. Based on this, the paper tests the effect of the measures in the area of rock cross-cut coal uncovering. The maximum residual gas content is 4.4m3/t, and the maximum residual gas pressure is 0.16MPa. The practice shows that the hydraulic slotting measures can greatly reduce the residual gas pressure (content) of the coal seam. Therefore, the ultra-high pressure hydraulic slotting technology can be used as an effective means for rock cross-cut coal uncovering in high gas and low permeability coal seam, and it can provide important reference and reference for similar conditions.

1. Introduction
The coal and gas outburst induced by coal mining is a very complex geological dynamic disaster, which seriously threatens the safety and efficient production of coal mine [1-2]. There are many holes, poor effect and long period in the conventional pre extraction method for outburst prevention of rock cross-cut coal uncovering. The excavation speed and safety threat of rock cross-cut coal uncovering, the outburst coal seam seriously restrict the mining replacement and safety production of the mine [3-4].

Hydraulic slotting pressure relief and permeability enhancement technology is to wash and strip the coal around the borehole, increase the cracks in the coal, improve the gas flow state in the coal seam, create favorable conditions for gas extraction, change the original stress and fracture state of the coal, and ease the stress tension state in the coal and surrounding rock, which can not only weaken or eliminate the power of outburst, but also reduce the stress tension state in the coal and surrounding rock. It can greatly change the physical and mechanical properties of outburst coal seam, play the role of pressure relief and outburst prevention, and improve the permeability and gas release ability. Many
domestic scholars [5-9] have carried out a lot of research on the theory, laboratory test and field application of high-pressure hydraulic slotting, and obtained a lot of research results.

2. Overview of test working face
The maximum gas pressure of coal seam 6 in the coal uncovering area is 2.3MPa, and the maximum gas content is 8.6m³/t. In order to eliminate the danger of outburst in the coal uncovering area of coal seam 6, the measures of extraction drilling and ultra-high pressure hydraulic slotting are adopted to strengthen the effect of outburst elimination and shorten the coal uncovering time.

The hole bottom spacing is designed as 5m. There are 50 boreholes for construction measures in the coal uncovering area of coal seam 6. The diameter of the boreholes is 113mm, the cutting pressure is 80MPa ~ 100MPa, the cutting spacing is 1m, and the cutting time of single knife is 4min ~ 5min (the slag discharging time is increased by 5min for the down hole). After the completion of each drilling, the ultra-high pressure hydraulic slotting work shall be carried out immediately, and the sealing depth shall not be less than 5m. See Fig. 1 for the completion of drilling.

![Fig. 1 As built section of measures drilling in the area of rock cross-cut coal uncovering](image)

3. Analysis on the effect of ultra-high pressure hydraulic slotting

3.1 Analysis of slag discharge by hydraulic slotting
During the rock cross-cut coal uncovering, the seam cutting operation was carried out for the extraction drilling hole, and the amount of coal dust discharged from some drilling holes was counted. The statistical results are shown in Table 1.

| Borehole No. | Dip angle (°) | Hole depth /m | Coal hole length /m | Nozzle parameters /mm | Amount of coal dust per knife /t | Slotting time /min | Amount of coal dust discharged /t |
|--------------|---------------|---------------|---------------------|-----------------------|-------------------------------|-------------------|----------------------------------|
| J63-1        | 1.9           | 30.2          | 7.2                 | 2.0                   | 0.43                          | 50                | 2.58                             |
| J63-3        | 1.6           | 28.1          | 7                   | 2.0                   | 0.39                          | 55                | 2.16                             |
| J63-5        | 1.5           | 29.1          | 6.3                 | 2.0                   | 0.34                          | 45                | 1.7                              |
| J63-7        | -2.5          | 33.2          | 8.3                 | 2.0                   | 0.41                          | 132               | 3.28                             |
| J65-3        | -2.8          | 30.7          | 6.7                 | 2.0                   | 0.39                          | 112               | 2.34                             |
| J65-6        | -3            | 31.7          | 6.8                 | 2.0                   | 0.38                          | 98                | 2.28                             |
| J62-6        | -2.9          | 32            | 7.6                 | 2.0                   | 0.33                          | 120               | 2.31                             |
| J61-6        | -5            | 27.5          | 6                   | 2.0                   | 0.28                          | 80                | 1.5                              |
| Average      |               |               |                     |                       | 0.4                           | 86.5              | 2.3                              |
The coal output of single knife is 0.3t ~ 0.43t, with an average of 0.4t. The equivalent cutting radius calculated by the coal output of single knife is 1.5m ~ 2.3m, and the analysis of cutting effect is shown in Fig. 2 and Fig. 3.

![Fig. 2 interval distribution and proportion of coal scraps discharged by a single knife](image1)

![Fig. 3 interval distribution and proportion of equivalent radius](image2)

It can be seen from Fig. 2 and Fig. 3 that the amount of coal dust discharged by a single knife is relatively uniform, and the equivalent radius is 1.8m-1.9m, accounting for 38%. The average slotting time of the upper hole single knife is 8min ~ 9min, and the average slotting time of the lower hole single knife is 16min ~ 19min. The coal reserve in the control area is 5365t, and the total coal discharge from the slit is 18.15t. The uniform coal dust discharge rate in the control area of the measure hole is 3.38 ‰, and the pressure relief effect is good. The drilling radius is 56.5mm, and the average equivalent radius of the drilled hole after cutting is 1.8m. Compared with the measure hole before cutting, the equivalent radius increases by 31.9 times. After adopting the ultra-high pressure hydraulic cutting measures, the exposed area of the coal body in the drilling hole is increased, the equivalent diameter of the drilling hole is increased, and the gas flow state in the coal seam is effectively improved, which creates favorable conditions for gas emission, and the cutting effect is significant.

### 3.2 Comparative analysis of initial velocity of gas emission

Select a group of slotted and uncut boreholes with basically the same length of coal to carry out a comparative study on the initial velocity of gas emission from boreholes, and the measurement results are shown in Figure 4.

![Fig. 4 Comparison of initial gas emission speed between slotted and uncut holes](image3)

After taking slotting measures, the initial velocity of gas emission is 15.6 L / min ~ 19.3 L / min, with an average of 17.26 L / min. the initial velocity of gas emission from non-slotted holes is 4.2 L / min.
min ~ 5.7 L / min, with an average of 4.93 L / min. The average initial velocity of gas emission after slotting is 3.5 times of that of non-slotted holes, with significant penetration enhancement effect.

4. Evaluation on the effect of measures in the area of rock cross-cut coal uncovering

4.1 Residual gas content after drainage
The average original gas content of coal seam 6 in -700m central pedestrian inclined shaft is 8.6m³/t. In the coal uncovering area, the control line of pre drainage borehole is designed to be 12m away from the two sides of the roadway, and the coal seam reserves within the control range are 5365t, and the total amount of coal gas is 45602m³. The extraction time is 60 days. The total amount of gas extraction is 21000 m³ and the gas extraction rate is 46%. The residual gas content of the working face before excavation is 4.5m³/t.

The effect of the measures in the area of rock cross-cut coal uncovering is tested. The maximum residual gas content is 4.4m³/t, and the maximum residual gas pressure is 0.16MPa. During the coal uncovering period, the gas is normal, and the gas concentration in the return air flow of the working face is below 0.2%, so the coal seam can be uncovered safely and smoothly.

4.2 Effect analysis of slotting measures
Under the premise of gas drainage reaching the standard, when no hydraulic slotting measures are adopted for coal seam 6 in the uncovering area, the number of construction slotting holes is 92, and the extraction time is 120 days; after the slotting measures are adopted, the actual construction slotting holes are 50, the extraction time is 60 days, the drilling work quantity is saved by about 47%, and the extraction time to meet the standard is shortened by 50%.

5 Conclusion
(1) After adopting the ultra-high pressure hydraulic slotting measures, the equivalent radius of the coal uncovering area at the crosscut of the coal seam group is increased by 31.9 times, the average initial gas emission speed is increased by 3.5 times, the drilling work volume is reduced by 47%, the rate of coal cuttings discharged by the slotting is more than 3 ‰, and the uncovering time is reduced by 50%, thus realizing the safe and efficient uncovering of coal.

(2) It has been proved by practice that the ultra-high pressure hydraulic slotting measures can increase the exposed area of the coal body in the borehole, increase the equivalent diameter of the borehole, effectively improve the gas flow state in the coal seam, and create favorable conditions for gas emission, which is an effective means for the prevention and control of coal and gas outburst.

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