Experimental Study Via Dynamic Prediction Model on High Pressure Hydraulic Slotting and High Efficiency Gas Drainage Technology under Complex Geological Conditions

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Abstract. In view of the difficult problem of dynamic disaster prevention and control in deep high gas, high stress and low permeability coal seam, the change law of drilling stress after seam cutting through drilling and bedding drilling is revealed by using numerical simulation method. The high-pressure hydraulic slotting method is used in Xinji Mining Area to carry out pressure relief and permeability increase test on coal seams. The test results are as follows: the slotting radius reaches 2.5m, and the net amount of gas extraction is 4.5 times higher than that of ordinary drilling holes, so as to realize efficient gas extraction in coal seams and reduce the risk of coal seam outburst. The technology of high-pressure hydraulic slotting, pressure relief and permeability enhancement can be used as a supplementary means for the prevention and control of coal seam dynamic disasters in deep mines.

Keywords. High pressure hydraulic slotting; gas drainage; bedding slotting; numerical simulation

1. Introduction
Under the condition of deep high ground stress, high gas and low permeability coal seam, the difficulty of gas drainage is increased, and the coal and gas outburst disaster still occurs [1-3] after the pre drainage of coal seam gas. The pressure of the existing reaming and slotting equipment in China is relatively low, and the pressure is generally 40-60mpa, which can not realize the function of drilling while drilling and slotting without withdrawing the drill pipe, and there are defects in technology and equipment. In the low permeability coal seam, the permeability increasing effect and construction efficiency are low, and the influence of hole expanding depth and seam cutting on fracture is small (300 mm ~ 800 mm) [2]. The existing hydraulic punching technology and equipment can not meet the prevention and control needs of coal and gas outburst [4-14]. Therefore, it is urgent to develop high-pressure hydraulic slotting technology and technology for pressure relief and permeability enhancement, so as to realize rapid pressure relief and permeability enhancement under high stress, high gas and low permeability conditions. By adopting high-pressure hydraulic slotting method (pressure 90-100mpa), coal seam pressure relief and permeability enhancement are realized, gas
drainage effect is improved, gas disaster in deep high stress and low permeability coal seam is solved, and gas disaster is realized Mine safety production.

2. Mechanism of pressure relief and permeability enhancement for high pressure hydraulic slotting
After the construction of ordinary drilling, because the small diameter of the drill bit affects the exposed area of the coal body, the gas migration path is limited; at the same time, because the stress around the drilling hole is concentrated, the circumferential stress is far greater than the original rock stress, making the original fracture closed to form a "bottleneck effect" to restrict the gas drainage. In order to realize the rapid pressure relief and outburst relief of the coal seam, the rapid drainage is realized through the construction of intensive drilling, or the construction is large and straight Increasing the exposed area of coal body by radial drilling will result in large quantities of drilling work and high construction cost, which is not conducive to wide application.

Ultra-high pressure hydraulic slotting is to cut coal body in the borehole by using the water hammer pressure and stagnation pressure of ultra-high pressure water jet to form a flat slot with a certain width and depth. The formation of macro slot not only increases the exposed area of coal body, but also provides the space for deformation of coal rock. After the coal body under pressure is slit by ultra-high pressure water jet, with the discharge of the slit coal slag, the parameters such as the stress distribution, fracture development and the corresponding permeability coefficient of the coal rock near the seam slot change, the water content of the coal seam increases, the internal stress of the coal rock decreases, causing the crack opening of the coal body under pressure, and the permeability of the coal body increases. At the same time, because the cutting slot provides the space for the deformation of coal and rock, the coal body will not undergo elastic-plastic deformation due to pressure bearing after the earth stress is reloaded. When the cutting slot forms the macro channel for gas flow, a large number of secondary fractures will be formed at the upper and lower sides of the slot. The macro slot and a large number of secondary fractures together constitute the flow path of analytical gas, and the gap between the slots should be reasonably controlled. Through the joint action of radial flow and slotted interlayer flow, the annular net flow self depressurization can be realized between drilling holes. The pressure relief of coal body is uniform and sufficient, the overall permeability coefficient of coal body can be greatly improved, the influence range of extraction is increased, and the extraction effect is significantly improved [15-22].

3. Numerical analysis of stress variation in slotted drilling
Combined with the actual situation of the mining area, the Mohr Coulomb constitutive model is established by FLAC3D numerical simulation software. The stress distribution law of cross seam drilling and bedding hole slotting under different coal seam hardness (0.5, 0.8, 1.0) conditions were simulated. The slotting pressures of simulated through layer drilling and bedding drilling are 60MPa, 80MPa and 100MPa.

**Figure 1.** Numerical calculation model
For cross layer drilling, when the firmness coefficient is 0.5, 0.8 and 1.0, the vertical stress changes between adjacent slots after cutting with different cutting pressure. With the increase of firmness coefficient, the minimum vertical stress decreases gradually.

![Figure 2. The curve of vertical stress variation under different stiffness factors](image)

For bedding drilling, when the coal firmness coefficient is 0.5, 0.8, 1.0, the horizontal stress changes between adjacent seams after cutting with different cutting pressure. With the increase of firmness coefficient, the minimum horizontal stress decreases.

![Figure 3 Variation curve of horizontal stress under different firmness coefficients](image)

To sum up, when the coal seam hardness is constant, the greater the slotting pressure is, the greater the vertical stress relief degree around the slot is, and the better the slotting pressure relief effect is; when the slotting pressure is constant, the greater the coal seam hardness is, the smaller the vertical stress relief degree around the slot is, and the worse the slotting pressure relief effect is. For bedding drilling and slotting, when the seam hardness is constant, the greater the slotting pressure is, the greater the horizontal stress relief degree around the slot is, and the better the slotting pressure relief effect is; when the slotting pressure is constant, the greater the coal seam hardness is, the smaller the horizontal stress relief degree around the slot is, and the worse the slotting pressure relief effect is.

4. Overview of test area
The test area is 220108 working face in 2201 mining area. The coal seam 1 in 2201 mining area consists of 1 upper coal and 1 coal. The average thickness of 1 upper coal is 3.4m, and the average thickness of 1 coal is 3.9m. The average distance between 1 coal and 1 coal is 0.9m, and the average inclination of coal seam is 5°. In the test area of 220108 working face, the measured maximum gas pressure is 1.65mpa, the measured gas content is 7.0m3/t, the soundness coefficient of coal seam group 1 in the test area is \( f = 0.48 \), and the initial gas release speed is 8. In 220108 working face, 50
Slotting holes were drilled along the seam to carry out the slotting test. The spacing between boreholes is 10m, and the design plan of boreholes is shown in Figure 4. According to the research and determination of ultra-high pressure hydraulic slotting parameters of typical low permeability and medium hardness coal seam in Xinji Mining Area, the back slotting process is adopted during the slotting period, with nozzle diameter of 2.0mm, slotting interval of 3M, slotting pressure of 90-100mpa, maximum pressure slotting time of 5min, slotting rotation speed of 40R/min and cross slotting.

**Figure 4.** Construction plan of drilling along the layer

5. Effect analysis of high pressure hydraulic slotting

5.1 Analysis of slag removal effect

During drilling and slotting, the pressure is 90-100mpa, the slotting time of single hole is 1-2.5h, the average slotting time of single hole is 1.2h, and the slotting time of single knife is 10min. During the seam cutting process, the coal body is cut into small particles with a particle size of 0.5-1.5cm. See Figure 5. Under the joint action of water and spiral drill pipe, the coal body is smoothly discharged to the orifice, and there is no hole plugging in the seam cutting process.

**Figure 5.** Coal particle size produced by drilling and slotting in the bedding

There are 50 seam cutting holes in machine lane of 220108 working face, each of which has 19-20 cutters, with an average drainage of 58-72l / min per minute, and an average discharge of 0.43t per cutter. According to the calculation, the groove radius formed after cutting is 2.2-2.5m. During the slotting test, see Figure 6 for the average slag discharge of each slotted hole.
5.2 Analysis of coal seam permeability

Before the ultra-high pressure hydraulic slotting in the machine lane of the 220108 working face, drill holes in the middle of any two adjacent boreholes, test the natural gas emission of the 1 coal seam boreholes, and use the simple drainage method to measure.

According to the measured data of natural gas emission, measured gas pressure and drilling construction parameters of 1 coal seam, the original permeability coefficient of 1 coal seam in machine lane of 220108 working face is 0.04582 m²/MPa²·d.

The permeability coefficient of coal seam 1 is 1.191 m²/MPa²·d, which is 26 times higher than the original coal seam.

5.3 Comparative analysis of pumping capacity

After the completion of drilling and slotting in the machine lane of 220108 working face, the gas drainage investigation (a total of 50 drill holes along the seam) is carried out. In addition, the data of 500m long drilling and mining in the original organic lane of coal seam group 1 in the mine is selected, and 100 effective drainage are compared and investigated. The change curve of average extraction purity of slotted drilling and effective extraction single hole within 60 days is shown in Figure 7.

![Figure 6. Change chart of average coal output of single cutting in slotted drilling](image)

![Figure 7. Change curve of average extraction volume of single hole between slotted drilling and effective extraction](image)

It can be seen from Figure 4 that the maximum average extraction purity of single hole of slotted drilling is 0.255 m³/min, the minimum is 0.128 m³/min, and the average is 0.178 m³/min; the maximum average extraction purity of single hole of common drilling is 0.108 m³/min, the minimum is 0.012 m³/min, and the average is 0.040 m³/min. The average single hole extraction pure quantity slotted drilling is 4.5 times that of ordinary drilling.
5.4 Comparison and analysis of drilling quantities and standard time of extraction

The comparison between slotted drilling and ordinary drilling is shown in Figure 8.

![Figure 8. Comparison between slotted drilling and ordinary drilling](image)

From the figure, we can see that within the same 500m range, the number of slotted holes is 50, the number of ordinary holes is 100, and the amount of drilling work after ultra-high pressure hydraulic slotting is reduced by 50%. On the premise of reducing the amount of drilling work, due to the improvement of single hole extraction effect, the standard time of extraction is shortened, from 80 days when the seam is not cut to 50 days after the seam is cut, and the standard time of extraction is shortened by about 40%.

6. Conclusion

(1) The high-pressure hydraulic slotting increases the equivalent radius of gas drainage borehole. The average amount of chip removal per cutting seam is 0.43t, and the radius of slot formed after cutting seam is calculated to be 2.2 ~ 2.5m.

(2) The high-pressure hydraulic cutting improved the fracture network of coal seam and significantly improved the gas drainage. The permeability of the seam after cutting is 26 times higher than that of the original seam, and the average extraction volume of single hole is 4.5 times higher than that of the common hole.

(3) High pressure hydraulic slotting technology is adopted in the coal seam with complex geological conditions, which can reduce 50% of the drilling work quantity of disaster prevention and reduce the time of reaching the standard of extraction by about 40%.

(4) The technology of high-pressure hydraulic slotting, pressure relief and permeability enhancement can be used as a supplementary means to prevent and control the coal seam dynamic disaster under complex geological conditions in deep mines.

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