Study on Technology of Hydraulic Cutting Seam of Ultra-high Pressure with Strip Predrilling

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Abstract. It is well known that the most fundamental means of gas management is gas extraction, the most difficult problem of gas extraction is low permeability of coal seam. Hydraulic cutting seam technology in recent years in uncovering coal, eliminate outburst danger has made great progress, therefore, to carry out the hydraulic cutting seam technology in the coal seam gas extraction from aspects of strengthening research is of great significance. Hydraulic slotting make around borehole in the coal gas by one-way two-way radial flow into radial and axial flow, based on the perturbation of the slot width, average single-hole gas from coal extraction from scalar, extraction radius of investigation, analysis of the hydraulic cutting seam technology and drilling data of extraction technology, the average single-hole extraction is obtained by 3 times.

1. Introduction
China's coal seam permeability coefficient is generally low, and gas extraction is difficult. At the same time, with the gradual increase of coal mining depth, the ground stress increases, further reducing the permeability coefficient of the coal seam, resulting in a small effective impact range of the borehole. The drilling engineering volume is large, the extraction efficiency is low, and the conventional gas drainage method is difficult to play a role. Therefore, the coal seam anti-reflection technology has always been the research focus of gas prevention technology. Expanding the effective extraction range of extraction drilling and improving the gas drainage effect of coal seams is particularly important for gas control of low permeability coal seams. Since the water jet rock breaking technology has been industrialized since the last century, it has been widely used in mining, oil drilling and metal cutting.

In recent years, with the continuous advancement of equipment manufacturing technology, the use of high-pressure water has achieved certain results in drilling holes and slitting. Hydraulic slitting technology uses high-pressure water jet to destroy the stress concentration zone around the borehole, thus eliminating the bottleneck effect of restricting coal rock permeability in borehole drainage. At the same time, the slotting slot produced by jet cutting coal seam on one hand increases the exposed area of coal rock in the borehole, and on the other hand provides creep space for coal rock, thereby reducing the stress of coal seam and increasing the permeability of coal seam. In the past, the hydraulic slitting technique used a jet pressure of 30 to 60 MPa, and the jet depth of the jet to the coal seam was 500 to 800 mm. Both field practice and theoretical research show that the greater depth of the kerf will lead to a corresponding increase in the exposed area of the coal body and the creep
pressure relief space of the coal body, resulting in better pressure relief and anti-reflection effects. The company has developed a complete set of hydraulic slitting equipment with ultra-high jet pressure, and special equipment for system integration, special equipment for drilling and cutting suitable for underground coal mine is the main development trend of hydraulic slitting.

2. Overview of the excavation work face of the experimental site
The location of this ultra-high pressure hydraulic slit test is 150112, which is arranged in the north and south. To the north of the roadway is the security coal pillar of the return air shaft industrial square, the south is the unmined area, the east is the planned 150106 working face, and the west is the well field boundary. The corresponding surface is located in the northwest of the seedling base of Heshun County, and the surface is a hilly area. The 150112 transport has a design length of 865 m and is driven along the top of the 15\(^{\#}\) coal seam. The coal seam of the 150112 transport channel is the 15\(^{\#}\) coal seam in the lower part of the Taiyuan Formation. The coal seam is stable, the variation of coal thickness is small, and the coal seam structure is relatively simple. The coal quality is not changed much, and it is all lean coal. The thickness of 15\(^{\#}\) coal seam is 4.5-5.83 m, and the average inclination angle is 5°. The underground field investigation has soft stratification, which is 0 m from the top plate, 200 to 1500 mm in thickness, and 1000 mm thick in the local area. The pinch is distributed in the coal seam, unstable, and the coal seam joint fissure is relatively developed. The 150112 transport has a gas content of 10-13 m\(^3\)/t. 15\(^{\#}\) coal seam original gas pressure $P=0.68-2.0$ MPa, coal seam average gas content $W=11.82$ m\(^3\)/t, average residual gas content 3.23 m\(^3\)/t, coal-to-gas adsorption constant $a=42.644$ m\(^3\)/t, $b=0.828$ MPa\(^{-1}\). The coal seam permeability coefficient is 0.096-4.595 m\(^2\)/MPa\(^{2}\), and the borehole gas flow attenuation coefficient=0.0386-0.0487 d\(^{-1}\).

3. Slot design

3.1. Drilling arrangement
According to the 5 m hole bottom spacing, the hydraulic slit test drilling is arranged. The number of drilling holes per cycle is 11 and the drilling design length is 80 m. The 20 m compression distance is reserved. The roadway is controlled by 15 m outside the contour of the roadway 2\(^{\circ}\)-3\(^{\circ}\).

![Figure 1. Hydraulic sew drilling plan design plan.](image)

Table 1. Table of Design parameters for hydraulic slit drilling

| Hole number | Inclination angle (°) | Length(m) | Hole number | Inclination angle (°) | Length(m) |
|-------------|----------------------|-----------|-------------|----------------------|-----------|
| 1\#         | 2                    | 80        | 7\#         | 3                    | 80        |
| 2\#         | 3                    | 80        | 8\#         | 3                    | 80        |
| 3\#         | 3                    | 80        | 9\#         | 3                    | 80        |
| 4\#         | 3                    | 80        | 10\#        | 3                    | 80        |
| 5\#         | 3                    | 80        | 11\#        | 2                    | 80        |
| 6\#         | 3                    | 80        |             |                      |           |
3.2. Selection of main equipment

Ultra-high pressure clean water pump (100 MPa): flow is 125 L/min, pressure is 100 MPa, a pump box; ultra-high pressure hose: bearing pressure is more than 100 MPa, inner diameter 19 mm; high and low pressure conversion sewer: pressure greater than 15 MPa, front end closed, pressure is less than 15 MPa, water flowing out of front end, working pressure is 120 MPa; hydraulic slit shallow spiral integral drill pipe: sealing performance can withstand pressure 120 MPa, integral drill pipe; diamond composite piece bit; Ultra-high pressure rotating tail: working pressure 150 MPa, flow is 420 L/min.

4. Comparative Analysis of hydraulic slit effect

One cutting seam group and one uncut group were selected for data tracking. Among them, 11 holes are drilled for cutting and 11 holes without cutting. A total of 150 joints were recorded, 146 successful seams were cut, the success rate of cutting reached 97.3%, holding drilling twice, and high pressure pump station maintenance once.

4.1. Investigation on the amount of Coal produced by hydraulic cutting

The slots formed by cutting joints are simplified into cylinders, and the depth of seam grooves is calculated by the amount of coal slag collected on site.

\[ r = \left( \frac{M}{\pi \times h \times K \times \gamma} \right)^{1/2} \]  

In the equation: \( r \) is that the radius of slot after slit, m; \( M \) is the amount of coal produced after slit, t; \( \pi \) is the circumferential rate 3.14; \( h \) is the width of slot after slit, m; \( K \) is the loss rate of coal after slit, the value of \( k \) is between 0.7 and 0.95; \( \gamma \) is the bulk density of coal, t/m\(^3\).

The average amount of coal cut out per knife is 0.35t. The width of seam is 0.08m, and the radius of slot is calculated as in the equation (1).

| Hole number | Inclination angle (°) | Hole depth (m) | Number of slotting knives | Slit pressure (MPa) | Slit spacing (m) | Single knife coal output (t) |
|-------------|-----------------------|----------------|--------------------------|---------------------|------------------|-----------------------------|
| 1#          | 2                     | 80             | 16                       | 90                  | 3                | 0.460                       |
| 2#          | 3                     | 80             | 16                       | 90                  | 3                | 0.313                       |
| 3#          | 3                     | 81             | 17                       | 80                  | 3                | 0.264                       |
| 4#          | 3                     | 120            | 18                       | 90                  | 3                | 0.260                       |
| 5#          | 3                     | 120            | 18                       | 85                  | 3                | 0.311                       |
| 6#          | 3                     | 120            | 18                       | 85                  | 3                | 0.263                       |
| 7#          | 2                     | 120            | 20                       | 90                  | 3                | 0.205                       |
| 8#          | 3                     | 120            | 20                       | 90                  | 3                | 0.285                       |
| 9#          | 3                     | 81             | 21                       | 90                  | 3                | 0.276                       |
| 10#         | 3                     | 80             | 16                       | 90                  | 3                | 0.281                       |
| 11#         | 2                     | 80             | 19                       | 90                  | 3                | 0.272                       |

4.2. Comparison of extraction purity

Within 20 days of extraction, the average daily extraction purity of hydraulic slit drilling is 399.45 m\(^3\)/d, and that of ordinary drilling hole is 136.91 m\(^3\)/d, and that of hydraulic slit drilling is about 3 times of that of ordinary drilling.

The attenuation rate of gas extraction volume in hydraulic slit drilling is much lower than that in ordinary drilling. In the first week of extraction, the average daily extraction volume of hydraulic slit drilling and ordinary drilling is 389.76 m\(^3\)/d and 144.20 m\(^3\)/d. In the second week of extraction, the average daily extraction volume of hydraulic slit drilling and ordinary drilling is 381.62 m\(^3\)/d and 134.02 m\(^3\)/d, and that of hydraulic slit drilling and ordinary drilling is 321.55 m\(^3\)/d and 105.11 m\(^3\)/d in the third week of extraction. The extraction data show that after the hydraulic slit technology is used to
cut the seam in the coal seam, the number of gas migration channels in the coal and rock increases greatly, the gas extraction efficiency is significantly improved, and the attenuation rate of the gas extraction volume decreases significantly with time.

4.3. Comparison of effective radius of extraction
The effective radius statistics of the extraction and extraction time of 10, 20, 30, and 40 day for hydraulic cutting and drilling and common drilling are shown in table 3.

| Extraction time (d) | Hydraulic slit extraction radius (m) | Ordinary drilling extraction radius (m) |
|---------------------|-------------------------------------|---------------------------------------|
| 10                  | 0.82                                | 0.44                                  |
| 20                  | 1.33                                | 0.68                                  |
| 30                  | 1.66                                | 0.81                                  |
| 40                  | 1.86                                | 0.88                                  |

4.4. Comparison of driving speed
Before the hydraulic slit is used in the 150112 transportation channel, the gas emission from the roadway is large and the driving speed is seriously restricted. Using a driving cycle before hydraulic seam cutting, the average daily excavation of roadway is 2.25 m. After using hydraulic slit pressure relief and antireflection technology, the average daily excavation of roadway is 5.65 m. After using hydraulic seam, the average daily excavation speed of roadway is 2.51 times higher than that before cutting seam, and the effect of hydraulic seam cutting technology is obvious. The gas emission from coal seam is significantly reduced and the driving speed is greatly increased by a large number of coal seam gas extraction.

5. Conclusion
Through the experimental investigation in the Yiyuan marginal coal industry, the coal output, gas extraction purity and effective radius of hydraulic seam drilling are analyzed and compared with those of ordinary boreholes, and the following conclusions are drawn:

1. The average coal output of hydraulic slit drilling is 0.35 t, the width of slit slot is 0.08m, and the equivalent radius of slit is 1.45 m.

2. Within 20 days, the hydraulic slit is 399.45 m³ / d, the average daily pumping purity of ordinary drilling is 136.91 m³ / d, and the daily pumping purity of hydraulic slit drilling is about 3 times of that of ordinary drilling.

3. The effective radius of hydraulic seam drilling is 0.82, 1.33, 1.66, 1.86 m, and the effective radius of 40 d is 0.44, 0.68, 0.88 m, respectively, and the effective radius of 40 d is 2.1 times of that of ordinary drilling. The effective radius of hydraulic seam drilling is 0.82, 1.33, 1.66 and 1.86 m, respectively, and the effective radius of 40 d hydraulic slit drilling is 2.1 times of that of ordinary drilling.

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