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Improvement of Gas Drainage Efficiency of Low-Permeability Coal Seams Using Ultra-High Pressure Hydraulic Cutting Technique

Yongjiang Zhang\textsuperscript{1,2}
1. State Key Laboratory of the Gas Disaster Detecting, Preventing and Emergency Controlling, Chongqing 400037, China; 2. China Coal Technology and Engineering Group Chongqing Research Institute, Chongqing 400039, China  
E-mail: zhangyj_1026@163.com

Abstract. With the increase in the coal mining depth, the dynamic disasters of deep coal seam under the combined effects of high crustal stress and high gas pressure seriously restrict the safety production of the coal mines. Moreover, it is very difficult to lower the gas content of the low-permeability coal seams. Even though numerous boreholes have been drilled inside the coal seam and gas drainage have been performed for a long period. High-pressure water jet cutting technology can effectively increase the exposure area of coal seams, improve the gas flow state in coal seams, so that the coal can be evenly and fully discharged in a certain range, and then the goal of rapid discharge and permeability enhancement can be achieved. After cutting the coal seam between 1m and 2m interval, a uniform pressure relief space is formed inside the boreholes to increase the permeability of the coal seam and improve the gas drainage efficiency. The field test results shows that the equivalent diameter of boreholes with cutting is about 5 times that of boreholes without cutting. The gas drainage radius of boreholes with cutting is 2.8 times that of boreholes without cutting, which significantly shortens the gas drainage time of the coal lane strip, and then attributes to realizing the rapid and safe excavation of coal seam roadway. This technique can provide reference significance for the modification of low-permeability coal seams in the similar condition area.

1. Introduction
The deep coal seams in Chinese coal mines show remarkable characteristics of "high stress, high pore pressure, high temperature and low permeability". At present, for coal seams without the protective layer mining conditions, the prevention and control of coal and gas outburst and coal rock gas dynamic disasters mainly use ground drilling and coal mine underground pre-pumping, which is mainly divided into straight drilling and penetrating drilling. Two ways. Ground drilling and mining technology has the advantages of large aperture, high extraction rate, large extraction radius, and good ground construction conditions, but the construction cost is high. Compared with drilling and drilling on the ground, the coal mine underground drilling and penetrating drilling are easier to implement, but most areas under the coal mine are because of the small diameter of drilling and the low permeability of coal seams. The gas volume is small and the gas concentration is low; increasing the diameter of drilling, improving the permeability of coal seams and reducing the stress state of coal strata is one of the commonly used methods to improve the effect of this measure. High-pressure hydraulic drilling cutting and unloading pressure enhancement technology, which is powered by water, scour and strip coal around boreholes and increase the number of cracks in coal, can greatly improve the flow state of
gas in coal seams and create favorable conditions for gas extraction. It can not only weaken or eliminate outstanding forces, but also greatly change the physical and mechanical properties of outstanding coal seams, so as to relieve pressure and prevent protrusions. It is an important development direction for coal mine to improve gas permeability and gas release ability.

2. Process of Ultra-High Pressure Hydraulic Cutting

In the case of soft coal seam, because of the soft coal seam, there is a common situation of drilling hole, and drilling hole causes the flow mode of gas extraction to change. From the radial gas flow that originally used drilling as the center line to the ball flow with drilling coal as the center of the ball, the drilling effect is affected, and the deep part of the coal seam is basically not affected by pumping. The two factors of low permeability and cave-hole in coal seam make it difficult for conventional drilling methods in soft and thick protruding coal seams to play a role.

According to the characteristics of soft coal seam through drilling, the best effect of strengthening pumping is the high pressure water discharge and increase penetration technology. The technique of water jet pressure reduction is mainly used to cut and flush the coal around the borehole to form a large area of pressure relief and penetration in the borehole to achieve the purpose of increasing the permeability.

The equipment can not only solve problem of permeability improved in layer-through borehole, but also solve the difficult problem of large area pressure releasing and permeability improved in bedding borehole. Schematic diagram of process of ultra-high pressure hydraulic cutting is shown in Fig 1.

![Figure 1. Schematic diagram of ultra-high pressure hydraulic cutting](image)

1-diamond bit for hydraulic cutting; 2- high / low voltage converter; 3-shallow helix drilling rod for hydraulic cutting; 4- drilling rig; 5-ultra-high rotating mio; 6-nipple; 7- ultra-high rubber tube; 8-ultra-high clean water pump; 9- water tank

Technology and equipment is not only suitable for pressure releasing and permeability improved for bedding borehole of working face, layer-through borehole and uncovering coal in cross-cut, and rock burst prevention under high ground stress, high gas and low permeability, but also suitable for ultra-high pressure cutting in roof and working face roof caving partial. Cutting depth in bedding borehole can attain more than 80~100m, which can attain more than 80~120m in layer-through borehole. Cutting radius can attain 1.0~1.5m.

3. Application of Ultra-High Pressure Hydraulic Cutting

3.1. Basic Situation of Test Area

Cutting test area of 1# coal seam is bulk mainly and flake little with developed fracture. Thickness of coal is 3.54~7.7m and the average is 6.6m. Gas content of 1# coal seam is 5.8~9.2m³/t and gas pressure is 0.8~1.4MPa, consistent coefficient (f) of coal is 0.5~0.9 and buried depth is 820m.

Using ultra-high pressure hydraulic cutting on 1415A tail entry bed plate tunnel to 1# coal roadway strip interval, cutting strike and inclination distance is 20m and 10m, type of bit is φ113mm. Plan and profile of ultra-high pressure hydraulic cutting drilling are shown as Fig2 and Fig3.
Figure 2. Plan of ultra-high pressure hydraulic cutting drilling

Figure 3. Profile of ultra-high pressure hydraulic cutting drilling

3.2. Effect Analysis for Pressure Releasing and Permeability Improved using Ultra-high Pressure Hydraulic Cutting

Comparative analysis of drainage effect between drilling with cutting and drilling without cutting is shown as Fig4 to Fig7.

Figure 4. Contrast diagram of equivalent diameter between drilling with cutting and drilling without cutting
Figure 5. Contrast diagram of gas content between drilling with cutting and drilling without cutting

![Contrast diagram of gas content between drilling with cutting and drilling without cutting](image)

Figure 6. Contrast diagram of drainage quantity daily between drilling with cutting and drilling without cutting

![Contrast diagram of drainage quantity daily between drilling with cutting and drilling without cutting](image)

Figure 7. Contrast diagram of gas remainder quantity under the same drainage condition between drilling with cutting and drilling without cutting

![Contrast diagram of gas remainder quantity under the same drainage condition between drilling with cutting and drilling without cutting](image)

Analyze gas drainage concentration and scalar comparatively on 1415A tail entry bed plate tunnel between drilling with cutting and drilling without cutting:
① After using ultra-high pressure hydraulic cutting, exposed area of coal seam was increased and equivalent diameter of drilling was enlarged. The average of equivalent diameter of drilling with cutting is 627mm and it of drilling without cutting is 124mm, equivalent diameter of drilling with cutting is 5 times that of drilling without cutting, gas flow state is improved in coal seam to create advantage for gas emission, and effect of cutting is significant.

② After using ultra-high pressure hydraulic cutting, the average of initial speed from borehole gas emission with cutting is 2.98L/min, and it of drilling without cutting is 1.29L/min, initial speed from borehole gas emission with cutting is 2.3 times that of drilling without cutting.

③ After using ultra-high pressure hydraulic cutting, coal pressure is released full, gas drainage quantity during 20d of drilling with cutting is 7936m3 and it of drilling without cutting is 2645m3, gas drainage quantity of drilling with cutting is 3 times that of drilling without cutting and gas drainage radius is 2.8 times, which can reduce engineering quantity of drainage drilling.

④ After using ultra-high pressure hydraulic cutting, gas content of drilling with cutting decreases about 38% and it of drilling without cutting decreases about 21% when draining 15d, gas content of drilling with cutting decreases about 53% and it of drilling without cutting decreases about 30% when draining 30d. Decreasing range of gas content of drilling with cutting is 1.8 times than that of drilling without cutting under the same condition, which can shorten gas pre-drainage time effectively.

4. Conclusions
(1) Using high pressure water jet to increase the exposed area and improve the gas flow state is an effective way to improve the gas extraction efficiency of coal seam.

(2) Using ultra-high pressure hydraulic cutting in 1415A tail entry bed plate tunnel, fractures of 1# coal seam was effectively increased, exposed area of coal seam was enlarged, desorption and flow of gas were improved and time of coal roadway strip gas pre-drainage is shortened by 1/3.

(3) Ultra-high pressure hydraulic cutting can make pressure in coal seam release uniform, change stress condition of coal seam, eliminate risks of high ground stress and gas dynamic phenomenon during coal seam tunnel excavating, which can realize fast and secure excavating.

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