Research on the Effective Scope of Low-permeability Hard Coalbed Coupling and Enhanced Permeability Technology

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Abstract: Due to poor gas permeability, high gas content, and hard coal quality at the JiuLiShan coal mine, gas extraction is difficult, and hydraulic perforation has limited effect. This study proposes a permeability enhancement method combining loosening blasting and hydraulic perforation to improve coal seam gas permeability and extraction efficiency. Field tests confirm the technology's effectiveness, showing that the combined method significantly enhances the coal body's permeability. The effective influence radius of the 1# test group (small explosives) is 4-6m, while the 2# test group (large explosives) extends this range to 6-8m, leading to a sustained increase in gas extraction. This approach offers an effective solution for enhancing permeability in complex coal mine conditions.
***Keywords*:** loose blasting, hydraulic punching, combined anti-reflective technology

1. Introduction

Coal seams in China usually have the characteristics of high gas content, low gas permeability, complex occurrence conditions and difficulty in extraction [1]. Hydraulic drilling technology has been widely used in many coal mines due to its remarkable effect in relieving pressure and increasing permeability, as well as preventing and controlling coal and gas outbursts. Hydraulic drilling uses high-pressure water to impact the coal seam, with the rock roadway as a barrier, effectively destroying the stress field of the coal rock around the borehole to form a pressure relief area, thereby improving the gas permeability of the coal body, promoting gas emission, reducing the risk of outburst, and ensuring the safe excavation of the roadway [2-3]. After a large amount of gas is discharged, the pressure of the coal around the borehole further decreases [4]. Water entering the coal seam increases the moisture in the pores of the coal, wetting the coal and reducing its elasticity and increasing its plasticity, thereby extending the pressure relief zone and reducing the risk of coal seam outburst [5]. Water jet drilling technology is particularly suitable for high in-situ stress, high gas content and soft coal seams [6-7], and has also been widely recognised in recent years for increasing the permeability of medium and soft coal seams [8].

The poor gas permeability, high gas content, and hard coal quality at Jiaozuo Jiu Li Shan coal mine limit the effectiveness of hydraulic perforation. Therefore, new pressure relief and permeability enhancement technologies are needed. A feasible strategy is combining loosening blasting with hydraulic drilling. Loosening blasting generates cracks in the coal mass, improving permeability, while hydraulic drilling ensures a more uniform pressure relief, enhancing gas control and reducing outburst risks.

2. Related theories

2.1 Mechanism of loose blasting and anti-reflective treatment

The loose coal seam blasting and permeability enhancement technology utilizes stress waves and high-pressure gas from explosions to expand and stabilize internal cracks in the coal seam, thereby increasing its permeability. Following the blast, the coal seam structure becomes looser, creating more pores and channels that facilitate gas drainage and coalbed methane collection. This technology has demonstrated significant permeability enhancement in coal mine gas drainage and methane extraction, effectively improving gas drainage efficiency, reducing the risk of gas outbursts, and increasing coalbed methane extraction.

2.2 Mechanism of water-jet drilling for enhanced transparency

Coalbed hydraulic fracturing and enhanced permeability primarily work through the impact and crushing effects of high-pressure water on the coal seam. This process generates numerous micro-fractures and pores, significantly boosting the coal seam's gas permeability. The high-pressure water alters the coal's internal structure by expanding along natural fractures and weak zones, gradually creating more interconnected flow channels. This reduces the resistance to gas flow and greatly enhances gas extraction efficiency.

3. Field tests and results

3.1 Introduction to the test location

The Jiulishan Coal Mine is located in Jiaozuo City, Henan Province, and is managed by Jiaozuo Coal Industry Co., Ltd. The mine covers an area of 18.60 km2 and was founded in 1970. The 1609 working face has a strike length of 801 m and a dip length of 134 m. The thickness of the coal seam ranges from 6m to 12.93m, with an average thickness of 7.53m. The coal seam has a high gas content, ranging from 9.72 to 18.85m3/t, and the coal seam has poor air permeability, which increases the difficulty of extraction. These geological conditions make gas management a key task in this area, and effective permeability enhancement techniques are required to ensure safety and efficiency.

3.2 Test methods and equipment

The specific process of the loose blasting procedure, as shown in Figure 1, involves the following steps: First, the charging operation is carried out, followed by connecting the footline in the hole. Next, a first conductivity test is conducted to verify the circuit's smoothness. Then, explosives are placed at the predetermined position in the hole, and a second continuity test is performed to ensure the circuit's accuracy and stability. Afterward, a hole plug is installed, and the hole is sealed with water, which is then further injected into the hole to complete the hole preparation. A third continuity test is conducted, and finally, the circuit is connected, and the blasting operation is executed.

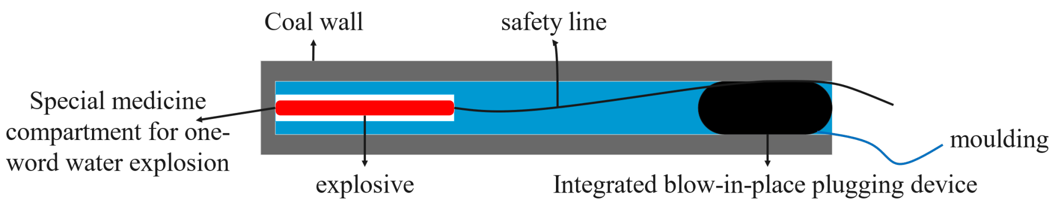

Figure 1. Loosening and blasting process

The plugging machine used in this test is the FKSL-135/16 mining plugging machine (see Figure 2), designed specifically for drilling and blasting operations. The device seals the hole and extracts gas by expanding a rubber expansion body using hydraulic pressure. When connected to the pressure waterway and the water pressure exceeds 10 MPa, the expansion body rapidly expands (increasing in diameter and decreasing in length). Due to the high friction coefficient of the rubber, the expansion body tightly adheres to the coal seam borehole wall, creating a stable seal. The gas is then directed through the main pipeline and extraction pipeline for efficient extraction. When the high-pressure water circuit is disconnected, the water in the expansion body is automatically discharged, and the expansion body returns to its original state due to the high elasticity of the rubber material and the recovery ability of the reinforcing layer.

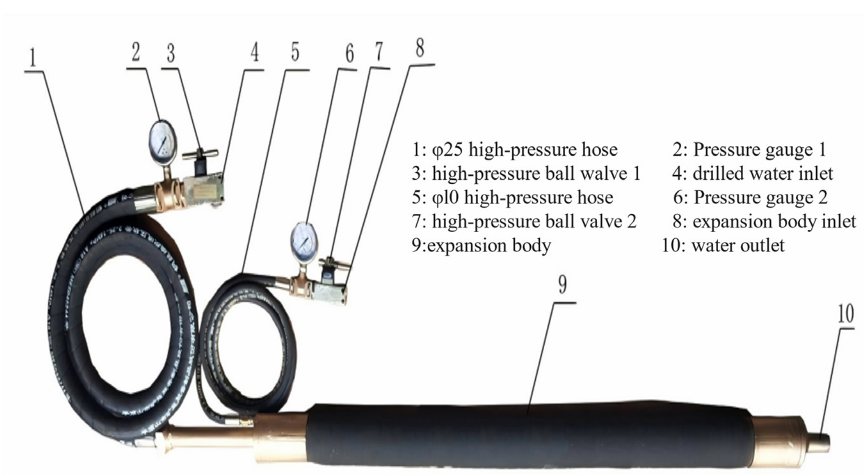

Figure 2. FKSL-135/16 mine plugging device

3.3 Test plan

To study the effect of coupling measures, such as loose blasting and hydraulic punching, on pressure relief and permeability enhancement in the surrounding coal mass, an experiment was conducted at drill site 128# in the 1609 bottom extraction gallery. Two groups of test holes were arranged in the test area. Group 1 used a blasting charge of 1 explosive roll per meter, while Group 2 used 2 explosive rolls per meter. Observation holes were placed around the test holes at varying distances from the hole bottoms to assess the actual impact of the coupling measures. Each test hole group included one coupling measure hole and three air permeability coefficient test holes, with distances of 4m, 6m, and 8m between the test holes and the measure holes. The effective influence range of the coupling measure hole on the surrounding coal mass under different blasting strengths was evaluated by continuously monitoring flow rate changes in the air permeability test holes, as shown in Figure 3.

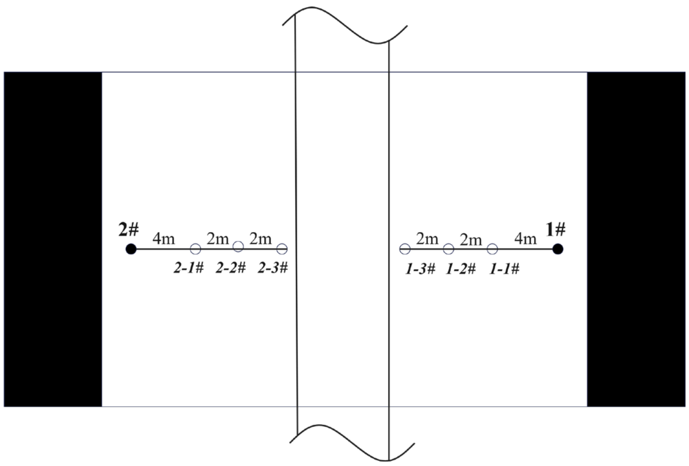

Figure 3. Top view of borehole layout for combined anti-disturbance measures with different blast strengths

3.4 Test results

The following conclusions can be drawn from Figure 4:

In test group 1#, the pure gas drainage flow rate of extraction hole t1-1 initially increased, then decreased, and eventually stabilized at a certain value. Meanwhile, the flow rates of extraction holes t1-2 and t1-3 continued to decrease, although the rate of decrease gradually slowed. The average pure flow rates of the extraction holes t1-1, t1-2, and t1-3 were 0.0328, 0.0087, and 0.0007, respectively. The average pure flow rate of t1-1 was 3.8 times higher than that of t1-2 and 4.6 times higher than that of t1-3. This suggests that the blasting and perforating measures did not significantly affect the t1-2 and t1-3 extraction holes, indicating that their effective influence radius is likely between 4-6 meters.

In test group 2, the flow rates of extraction holes t2-1 and t2-2 followed a similar trend, initially increasing, then decreasing, and finally stabilizing. In contrast, the pure flow rate of extraction hole t2-3 continued to decrease, although the rate of decrease gradually slowed. The average pure flow rates of extraction holes t2-1, t2-2, and t2-3 were 0.0336, 0.0338, and 0.0007, respectively. The average flow rates of t2-1 and t2-2 were 4.7 times higher than that of t2-3, indicating that the effective influence radius of test group 2# ranged between 6 and 8 meters.

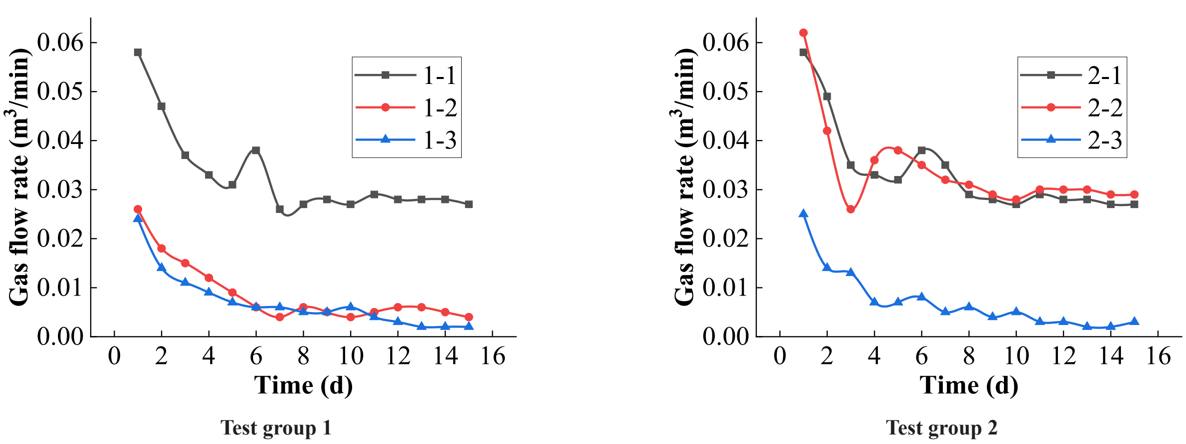

Figure 4. Variation of the pure flow rate of each air permeability coefficient pore

4. Conclusions

This study analyzed the impact of combining loosening blasting with hydraulic perforating technology on enhancing the permeability of low-permeability hard coal seams, with the effectiveness of the combined process verified through field tests. The results indicated that the coupling technology of loosening blasting and hydraulic perforating effectively increased the gas permeability of the coal seam, thereby improving gas drainage efficiency. In the 1# test group, the effective influence radius of the coupling measures was 4-6 meters, while in the 2# test group, this radius expanded to 6-8 meters. Additionally, the gas extraction flow rate showed an initial increase, followed by a decrease, and eventually stabilized over time, confirming the significant effect of this technology on improving coal seam permeability. This study provides both theoretical and practical foundations for applying coal seam permeability enhancement technology in complex conditions.

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