Research on hydraulic permeability enhancement technology of high, medium and low pressure coal seam with deep well and high ground stress

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Abstract. Aiming at the problem of poor gas extraction, long outburst time and low pre-drainage efficiency in the drilling zone of the floor tunnel through the drilling, the problem of mining excavation replacement is severely restricted. Dingji Coal Mine has carried out ultra-high pressure, medium pressure, and low pressure hydraulic cutting coal seam enhanced permeability gas extraction technology tests. Through continuous exploration and summary, it has achieved remarkable results, maximized extraction, and accumulated rich hydraulic coal Through experience. The results show that: the high-pressure hydraulic coal seam anti-reflection pre-draining unit has a maximum extraction pure volume of 3.1m³/min, the single-hole average extraction pure volume is 0.008m³/min; the medium-pressure hydraulic coal seam anti-reflection pre-extraction unit has a maximum extraction pure volume of 2.2 m³/min, single-hole average extraction pure volume is 0.005m³/min; low-pressure hydraulic coal seam permeability enhancement unit extraction pure volume is maximum 1.3m³/min, single-hole average extraction pure volume is 0.002m³/min. 1351(1)Yunshun's gas pre-drainage rate reached 65.2% after adopting high-pressure hydraulic coal seam penetration enhancement measures. Through statistical analysis of the anti-burst prediction index during coal tunnel footage, the sensitive index is relatively small, and the effect of pre-draining outburst is better. The lane enters 200m per month. The permeability enhancement technology of hydraulic coal seam has a significant effect on the pre-drainage of gas in high ground pressure outburst coal seam. It provides an effective method for improving the gas pre-drainage and outburst work, which is worthy of in-depth promotion and application.

1. Introduction
Most coal seams in China are characterized by heterogeneity, low pressure, low permeability and low gas saturation. The low permeability and non-uniformity of coal seams make it difficult for conventional methods to effectively extract gas, with long pre-drainage time and low pre-drainage efficiency. It seriously restricts the replacement of mine safety production, and how to increase the permeability of the coal seam and improve the permeability has become a bottleneck problem restricting the mine gas drainage, especially to solve the problem of coal seam outburst in areas with high outbursts and serious outbursts, which is a very urgent task. The pre-drainage and anti-outburst
technology of hydraulic coal seam anti-draining effectively solved the problem, and achieved a staged breakthrough [1-2]. It is of great significance to popularize the technology of hydraulic permeability enhancement through experiments and research to guide and solve the problem of gas drainage in coal seams with high ground pressure [3-5].

Huainan Mining Group Dingji Coal Mine is a typical "three high and one deep" mine, with high ground pressure, high gas, and high ground temperature, and the coal seam is buried deep. It is a deep well and high ground pressure mining, with high ground stress and complex structural stress. The mine is an outburst mine. At present, the main coal seams 11-2 and 13-1 are all outburst coal seams. Due to complex geological conditions and poor coal seam permeability, the permeability coefficient is 0.01315m²/MPa²·d. After various types of pre-drainage outburst drilling, the gas drainage concentration is low, the attenuation is fast, and the drainage effect is poor. Since 2011, the mine has continuously innovated and practiced to solve the bottleneck problem of difficult gas extraction. It has carried out deep hole pre-splitting blasting, hydraulic fracturing, and fixed-point digging, which have certain effects on improving gas extraction. However, it has not yet met the requirements for extraction. In view of the coal seam occurrence characteristics, high-pressure hydraulic penetration enhancement work was carried out in 1351 (1) Yunshun floor roadway, which achieved remarkable results and achieved the goal of high negative pressure, high concentration and large flow for a long period of time to ensure that the high ground pressure is seriously out of the area Quick and safe tunneling of coal lanes. In the later period, we continued to explore on the basis of successful experience of high-pressure hydraulic coal seam anti-reflection, and further practiced the medium-pressure and low-pressure hydraulic anti-reflection pre-extraction outburst technology. The best and the most cost-effective, a breakthrough has been made through on-site practice, and research and discussion will be carried out here.

2. Working principle of permeability enhancement of hydraulic coal seam
Using high-pressure water jet impact cutting, the coal seam of the drilled coal hole section is repeatedly impacted and cut to form a flat slot with a certain width and height in the coal body. The area also provides a favorable space for the deformation and expansion of the coal body. After cutting, the coal seam produces uneven deformation and destruction in the formation pressure, causing displacement and expansion of the surrounding coal body, increasing cracks in the coal body, and changing the original stress of the coal body And crack conditions, the coal body is fully relieved of pressure, which improves the permeability of the coal seam and the gas release ability, realizes the purpose of pressure relief and permeability enhancement of the coal seam, and creates favorable conditions for gas drainage.

3. Application of hydraulic coal seam permeability enhancement technology on site
The hydraulic coal seam antireflection technology is becoming more and more mature. In the existing hydraulic seam antireflection technology, the antireflection method suitable for different coal seams is explored by changing the operating pressure, operating time, and hole layout method. High-pressure, medium-pressure, and low-pressure hydraulic coal seam penetration enhancement tests were carried out on the floor roadway, 1222 (3) Yunshun floor roadway, and 1351 (1) rail-side floor roadway, respectively.
High-pressure hydraulic anti-reflection equipment and process: mainly composed of GF-100 high-pressure water pump, high-pressure rubber tube, special anti-reflection drill, high and low pressure converter, hydraulic slit shallow spiral drill pipe, high-pressure rotary joint. High-pressure hydraulic anti-reflection technology realizes the integration of drilling and anti-reflection technology. The drilling construction is in place. After replacing the high-pressure water tail, the anti-reflection operation can be performed directly. The operation is simple and the efficiency is high.
Medium pressure hydraulic anti-reflection equipment and process: mainly composed of BZW200-56 clear water pump, self-made anti-reflection drill bit, threaded drill pipe, rubber tube, etc. After the drilling is in place, the drill pipe is withdrawn to replace the anti-reflective drill bit, and then
sent to the coal body section in the hole again. After the pipeline is connected in place, the coal body will be hydraulically enhanced per meter once.

Low-pressure hydraulic anti-reflection equipment and process: mainly composed of ordinary drill bits, threaded drill rods, rubber pipes, etc. Low-pressure hydraulic enhanced permeability uses the underground natural hydraulic impact force to repeatedly expand the coal body in the hole to achieve the purpose of increasing permeability and expanding the hole, improving the drilling extraction effect. After the drilling is completed, the drill bit is retracted to the coal stop Slowly advancing and retreating the drill pipe uses the natural water pressure of the mine to repeatedly expand and increase the penetration of the coal section throughout the entire process.

3.1 1351 (1) Yunshun floor road high-pressure hydraulic enhancement
1351 (1) Yunshun Floor Lane is located in the south zone of 11-2 East Mine of Coal Mine. Coal seam elevation is -950~ -770m, 11-2 coal seam thickness is 1.8~2.5m, measured gas content is 8.0m³ / t, and gas pressure is 1.4Mpa. The hydraulic pressure increases the operating pressure 60-100Mpa, according to sees the coal section length to carry on the hydraulic slitting, each hole slitting 2~knife, the slitting time is not less than 15 minutes.

3.2 1222 (3) Yunshun floor lane medium pressure hydraulic enhancement
1222 (3) Yunshundi Pumping Lane is located in the 13-1 mining area in the west of the mine. The coal seam elevation is -805~ -760m, 13-1 coal seam thickness is 3.5~4.0m, the measured gas content is 7.5m³/t and the gas pressure is 1.2MPa. The hydraulic pressure of the site is 20~40MPa, the cutting slot is 2-3 knives per hole, and the cutting time is 30 minutes per knife.

3.3 1351 (1) Low-pressure hydraulic anti-reflection for rail-floor roadway
The 1351 (1) rail along the bottom of the pumping road is located in the east of the second south of the mine, coal seam elevation -950~ -770m, 11-2 coal seam thickness 1.8~2.5 meters, the measured gas content of the largest 8.4m³/t, gas pressure 1.4MPa. The water permeability increasing pressure is 4MPa, and the coal body section in the hole is repeatedly expanded and flushed no less than 3 times, and the operation time is about 1 hour.

4.Research and Analysis on the Effect of Pumping with Hydraulic Enhancement of Permeability

4.1 Comparison of coal output by hydraulic enhanced penetration cutting (rushing)
Through investigation and analysis, the high-pressure hydraulic penetration enhancement takes a short time, and the coal output during the penetration enhancement is large. The coal output per hole is more than 1.2t, accounting for more than 81%; the medium pressure hydraulic penetration enhancement takes a long time, and the coal output per hole takes The amount of 0.8-1.0t accounts for 79%; the single-hole coal output of low-pressure hydraulic anti-reflection is less, and the time of permeation increase is longer. The single-hole anti-reflection coal output is less than 0.5t, accounting for 73%. Through investigation and analysis, the measures for enhancing the permeability of hydraulic coal seams in different pressure sections will have a certain impact on the effect of permeability enhancement due to the hardness coefficient of the coal seam and the length of the operating time.

4.2 Comparison of the effects of pre-draining and anti-outburst with hydraulic anti-reflection

4.2.1 Comparison of extraction concentration 1351(1) After adopting high-pressure hydraulic measures in Yunshundi pumping roadway, the highest inspection concentration of unit extraction was 86%, and it decayed to 77% after extraction in January. The extraction concentration was very good and the duration of high-concentration extraction long. 1222 (3) After adopting medium-pressure hydraulic penetration enhancement measures in Yunshundi pumping roadway, the pumping concentration reached a maximum of 58%, and the pumping concentration attenuated to 45% after one
The pumping concentration was relatively high and stable. 1351 (1) rail along the floor roadway using low-pressure hydraulic measures has poorer extraction effect, but the extraction effect is significantly higher than that without any penetration enhancement measures. See ‘figure 1’ for the comparison of the extraction concentration of hydraulic pre-drainage unit of hydraulic coal seam.

![Figure 1. Contrast diagram of extraction concentration of strip pre-extraction unit](image1)

4.2.2 Unit extraction pure quantity analysis

The high-pressure hydraulic coal seam anti-reflection pre-draining unit has a maximum extraction capacity of 3.1m³/min, and the single-hole average extraction pure volume is 0.008m³/min; the medium-pressure hydraulic coal seam anti-reflection pre-draining unit has a maximum extraction capacity of 2.2m³/min, the single-hole average extraction pure volume is 0.005m³/min; the low-pressure hydraulic coal seam antireflective unit extraction pure volume is maximum 1.3m³/min, and the single-hole average extraction pure volume is 0.002m³/min. At the same time, the amount of extraction varies depending on the original gas content and permeability coefficient of the coal seam at the survey site. See ‘figure 2’ for the comparison of the pre-pumped pure volume of hydraulically enhanced coal seam.

![Figure 2. Contrast diagram of pumping pure volume of hydraulic pre-draining unit](image2)

5. Investigation on footage of pre-draining coal roadway in hydraulically enhanced anti-reflection strip

Through inspection and comparison, the gas pre-drainage rate of 1351(1) Yunshun adopted high-pressure hydraulic coal seam penetration enhancement measures reached 65.2%. Through statistical analysis of the anti-burst prediction index during coal tunnel footage, the sensitive index is relatively small, and the effect of pre-draining outburst is better that the coal roadway has a single monthly feed of 200 meters per month, and the return air gas concentration during the coal roadway footage is less than 0.2%. There are no over-predicted indicators and gas-overrun accidents, and the high-gas coal seam mining operation has been realized.

6. Conclusions

The hydraulically enhanced permeability enlarges the exposed area of the coal body in the hole and
increases the extraction cracks, which provides the conditions for the continuous high concentration extraction of the extraction concentration of the pre-draining evaluation unit. The comparative analysis of the high-pressure hydraulic enhanced permeability pre-drainage has the best effect, and the outburst coal seam achieves 200 meters per month in a single feed.

Medium pressure hydraulic coal seam anti-reflection operation has low pressure, lower operation safety risk, and better extraction effect. To ensure the on-site coal seam anti-reflection operation, the anti-reflection operation time must be extended according to the coal seam hardness. Because the medium-pressure cutting slot is a self-made drill, it is impossible to realize the integration of drilling and penetration enhancement, and a drill replacement is required. The process is more complicated and the efficiency is lower.

Low-pressure hydraulic anti-reflection measures are safe and easy to operate. Through on-site inspection, this permeability enhancement measure is suitable for enhancing the permeability of coal seams with hardness coefficient $f < 0.5$. Due to the softness of the coal body, the coal output in the hole is relatively large during the permeability enhancement, which is more significant for lifting the soft coal seam.

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