Research on Application of Directional Long Drilling Fracturing Technology in 1930 Coal Mine

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Abstract: The solidity coefficient of the main coal seam in Xinjiang Coking Coal Group 1930 Coal Mine is below 0.3, which is a soft outburst coal seam with poor air permeability, a small effective range of gas drainage drilling, low porosity of soft coal seam, low gas drainage rate, and unsatisfactory drainage effect. Using directional drilling equipment to construct directional long drilling, combined with the hydraulic fracturing pump set independently developed by Xi’an Research Institute, directional drilling were constructed in the 1930 coal mine 1600 level 6# coal seam, and hydraulic fracturing was carried out. The results show that after the hydraulic fracturing of the 6# coal seam, the production has been stable for nearly 6 months. During the period, the average gas drainage rate of the drilling was 134.9m³/d (maximum 561.7m³/d), which was 2.10 times that before fracturing. The average drainage concentration is 1.90%, which is 1.45 times that before fracturing. At present, the total amount of gas drainage is 25,900 m³, which is 4 times the original amount. This technology has achieved enhanced permeability of broken soft coal seam, increased drainage volume, extended drainage time, and advanced gas outburst elimination at a long distance. It provides a technical guarantee for the enhanced permeability enhancement of the broken soft low-permeability outburst coal seam and the high-efficiency underground gas drainage.

1. Introduction
Under the action of multi-stage tectonic movement in my country, the compound superposition of coal-forming basins is obvious, and coal seam are severely deformed by structural compression and shear deformation. The coal seam has developed micro-pores, is broken and soft as a whole, and has strong adsorption. The permeability coefficient is mostly 0.01m²/(MPa•d). This results in coal seam with broken soft, low permeability and high gas outburst. The original gas drainage is difficult. Mining is dangerous. Soft coal seam is widely distributed in my country, accounting for about 50% of coal reserves. The coal is soft and has poor air permeability. Many soft coal seam have high gas content, high ground stress, and complex geological structures. They are dangerous and difficult to drill along the coal seam. Prone to abnormal phenomena such as jet hole and stuck drill, low porosity, shallow depth, and hole collapse easily after hole formation[1]. The coal seam firmness coefficient is mostly 0.1 to 0.5, the air permeability coefficient is 0.01 to 0.001m²/(MPa•d), and the gas content is more than 10m³/t, which brings great troubles to the safe and efficient production in the mining area[2].

The 1930 coal mine is located in the central and eastern part of the Aiweiergou mining area south of Urumqi. The solidity coefficient of the main coal seam is below 0.3, which is a soft outburst coal seam with poor air permeability, a small effective range of gas drainage drilling, low porosity of soft coal, low gas drainage rate, and unsatisfactory drainage effect. The 6# coal seam of the 1600 level is
located at the bottom of the upper section of the Badaowan Formation. Containing 0 to 1 layer of gangue, the lithology is siltstone, carbonaceous mudstone, and the structure is simple. The total thickness of the coal seam is 1.16-4.94m, with an average of 2.98m, which is a stable coal seam that can be mined in the whole area. The top slab of the coal seam has very coarse lithology, gray-white coarse sandstone, partially containing gravel; the floor is dominated by dark gray-gray-black siltstone. The upper distance is 18.7-20.76m from 5# coal seam, with an average of 19.58m. In order to ensure the safe mining of the working face, the directional drilling technology was used to advance the directional long drilling of the coal seam in the 6# coal seam of the 1600 level, and hydraulic fracturing was carried out to explore the effective solution to the technology and technology of gas treatment in the soft, low permeability coal seam. To provide a reference for gas governance under similar conditions.

2. Research on the mechanism of directional long drilling fracturing to increase permeability

Through the construction of long directional drilling in the coal seam under the coal mine, relying on high-pressure fracturing equipment and technology, high-pressure clean water is injected into the coal body at a flow rate greater than the coal seam's filtration loss, which promotes the gradual increase of the water pressure acting on the coal body. When the pressure is greater than the coal seam After the rupture pressure, the coal seam is cracked. Specifically, the pressure water injected by the fracturing pump starts to enter the fracturing zone of the hole wall after the pump is upshifted, and the pressure starts to rise immediately until the displacement is stable. Thereafter, the injection flow rate remains unchanged, and the injection pressure fluctuates up and down in a zigzag pattern. It can be considered that the pressure data fluctuating up and down in a zigzag shape reflects the behavior of "cracking-expansion and extension" after clear water is pressed into the coal seam cleat cracks[3]. At the beginning, the fracturing water gradually fills the primary pores and cracks of the coal body through seepage; as the pressure of the fracturing water continues to increase, the stress around the fracturing hole rises to produce micro-cracks; the pressure further increases, and the micro-cracks continue Development and extension. At this stage, the coal body is prone to form main fractures, and the fracturing water expands along the direction of the main fracture; when the energy of the fracturing water is accumulated enough to overcome the ground stress and the strength of the coal body, the coal body resistance fails and the main fractures rapidly expand. At this time, the free space in the fracture increases, and the injected water pressure decreases rapidly; and under the continuous injection of the fracturing pump, a cyclic process of re-energy storage and fracture expansion occurs in the coal body, that is, the pressure data curve is in a zigzag shape. The process of fluctuating up and down[4].

3. Engineering test of directional long drilling fracturing

3.1 Directional Long Drilling Technology and Design

Directional drilling technology refers to a drilling method that reasonably designs the drilling trajectory and uses special tools to extend the drilling trajectory to the predetermined target according to the design requirements. The axis of the drilling changes from bend to straight or from straight to bend. Special tools include hole bottom building tools, trajectory measuring devices, etc. According to the different bottom hole drilling tools used, the downhole directional drilling technology in coal mines can be divided into stable combination drilling tool directional drilling technology and hole bottom power drilling tool directional drilling technology[5]. According to the different measuring devices and supporting drill pipes used, the underground directional drilling technology in coal mines can be divided into sliding directional drilling technology and compound directional drilling technology. The technology and process used by the author of this article is the sliding directional drilling process of bottom hole power drilling tool + wired measurement while drilling device. The schematic diagram of the directional drilling process is shown in Figure 1.
The design location of the drilling site is about 24m vertical to the target coal seam floor, and two main holes are designed. The specific design is shown in Figure 2 and Figure 3. Drill holes from the rock layer, penetrate the layer at a certain inclination into the target coal seam, and drill directionally along the coal seam. In order to increase the drilling distance of the target coal seam as much as possible, it is necessary to conduct an in-depth analysis of technical parameters such as stratum undulation, structure, and coal seam thickness near the working face. Branch points are reserved at intervals of 100m. When coal is drilled and the top or bottom cannot be accurately judged, branch directional drilling is carried out. To ensure re-entering the coal seam for construction.
3.2 Hydraulic fracturing technology and design

(1) Fracturing method: Aiming at the physical properties of the 6# coal seam of the 1930 coal mine and the drilling layout, the comb-shaped drilling hydraulic fracturing method is drilling integral fracturing;

(2) Hole sealing method: Drawing on the construction technology of oil and shale gas hydraulic fracturing, the comb-shaped drilling hydraulic fracturing hole sealing method adopts cement mortar sealing technology;

(3) Coal seam fracture pressure estimation: The buried depth of the directional hole coverage area of 6# coal seam at the level of 1600m is about 270m. With reference to the existing coalbed methane injection\pressure drop test results in Xinjiang, the coal seam fracture pressure gradient data is 1.69-2.33MPa/100m, using known conditions to estimate the fracture pressure of 6# coal seam to be 4.56-6.29MPa\(^6\);

(4) Pump injection pressure calculation: The pump injection pressure is the sum of coal seam fracture pressure, pipe string friction and hydrostatic pressure. The injection pressure of 6# coal seam at the level of 1600m is 4.84-6.57MPa;

(5) Calculation of water injection volume: Calculate the overall fracturing water injection volume based on the design fracturing influence range, coal seam thickness, porosity and other parameters of the target coal seam. According to calculations, the theoretical water injection rate for fracturing hole A1 is 374m\(^3\), and the theoretical water injection rate for fracturing hole A2 is 420m\(^3\).

During the hydraulic fracturing construction process, the water injection operation has accumulated water injection of 978 m\(^3\), of which hole A1 has accumulated water injection of 444 m\(^3\) and hole A2 has accumulated water injection of 534 m\(^3\). The maximum instantaneous flow of water injection reaches 24m\(^3\)/h, and the maximum water injection pressure is 7.5MPa. In the actual construction of 8 shifts, the total amount of water injection exceeded the theoretical calculation value. The main reason was that many coal seams were soft and broken, and the branching caused by this increased the water storage capacity of the coal seam and drilling; the maximum pumping pressure for fracturing operations was 6.1-7.5 MPa, in line with the calculated coal seam fracture pressure estimation value, so the pump injection pressure can achieve the purpose of coal seam fracture. The curves of gas drainage volume and drainage concentration before and after hydraulic fracturing in holes A1 and A2 are shown in Figure 4.

![Figure 4 Curves of gas drainage volume and drainage concentration before and after hydraulic fracturing in holes A1 and A2](image)

Identifying the occurrence of multiple fractures is the prerequisite for adjusting the fracturing parameters and predicting the effect of fracturing during the fracturing process. During the fracturing process, the main monitoring parameters are the pump injection pressure and flow rate. Generally, the development form of the fracture can be judged according to the change shape of the pressure curve during the fracturing process. The wave-shaped pressure curve can be used as a basis for judging the occurrence of
multiple cracks. The pumping pressure fluctuates in the process of transferring from one fracture system to another fracture system. After multiple fracture systems are transformed and formed, they are characterized by the wave shape (sawtooth) of the pumping pressure. The pump injection pressure curve monitored during the project construction process is shown in Figure 5. The drilling pump injection pressure curve as a whole fluctuates up and down in a zigzag shape, representing the communication and extension of the cracks.

![Figure 5 Pressure curve during construction (wave type)](image)

4. Key technology of directional long drilling fracturing construction

4.1 Fracture drilling design technology

The location of the construction opening is located in a relatively stable rock formation. During the process of entering the target coal seam, due to the limitation of the curvature of the drill pipe, there will be a blind area of 50m-100m in the construction. It can be solved in two ways. One method is to use conventional drilling rigs to construct through-layer drilling for covering construction; the other method is to use directional long drilling for end-to-end overlap construction when designing the entire working face for directional long drilling and fracturing, covering the blind area[7]. The bottoming or topping during the drilling process will inevitably require branching to re-enter the coal seam, which will cause major changes in the inclination and azimuth of the directional long drilling, increase the bending section, and increase the friction between the drill pipe and the hole wall, which is important for construction safety and drilling tools. A lot of dangers are hidden. By adopting a reasonable radius of curvature for branching of the side drill, turning the hole back and forth at the branch point, and optimizing the drilling process, so as to reduce the safety risks in the hole and equipment.

4.2 Fracturing to increase permeability technology

As the hole depth increases, the hydraulic fracturing pressure decays faster, and the effect of fracturing the coal near the bottom of the hole is weaker. Therefore, it is necessary to adopt the form of staged fracturing for construction. During the fracturing process, the integrity of the rock and coal seam and the tightness of the drilling are required to be high. This mainly refers to the existence of cracks, structures, faults, and series of holes around coal seam and rock formations, which make the hole pressureless and cause fracturing failure. Therefore, it is necessary to select a working face with less structure, and at the same time, analyze and judge the return water and slag situation during the construction of the directional long drilling to determine whether the construction drilling has the fracturing condition or not. The tightness of the drilling is mainly affected by the length of the plugging casing and the quality of the plugging cement grouting. The length of the casing can be increased to make the orifice pipe run into the stable formation, and the method of multiple grout filling and pressure test inspection can be used to ensure the integrity of the hole sealing.

5. Conclusion

(1) Through the construction of directional long drilling in this coal seam and hydraulic fracturing, the
gas drainage effect is obvious, and the average gas drainage volume and average drainage concentration of the fracturing drilling are greatly improved compared to before fracturing. It can be seen from the statistics of gas drainage volume and drainage concentration curves before and after hydraulic fracturing in holes A1 and A2: before fracturing, the gas drainage volume in drilling showed a rapid decay trend; after 30 days of pre-drainage, drilling The hole gas drainage volume has been reduced to 64.1m³/d, and the drainage concentration has dropped to 1.31%. Before hydraulic fracturing, the overall gas drainage curve of the drilling showed a large initial gas drainage volume and rapid attenuation, which is a typical law of gas drainage in low-permeability coal seam. After hydraulic fracturing, production was stabilized for nearly 6 months. During the period, the average gas drainage rate of the drilling was 134.9m³/d (maximum 561.7m³/d), which was 2.10 times that before fracturing, and the average drainage concentration was 1.90%, which is fracturing. 1.45 times the previous. At present, holes A1 and A2 have accumulated 25,900 m³ of gas, which is 4 times the original amount. The average drainage concentration is 1.44%, and the daily average drainage gas flow is 108m³.

(2) Based on directional long drilling and combined with hydraulic fracturing technology, a set of construction technology suitable for soft and low permeability coal seam in the 1930 coal mine of Xinjiang Coking Coal Group was developed.

(3) By adopting key technologies such as branching technology, eye-cutting technology, optimized construction technology, and hole sealing, grouting and sealing, the extraction efficiency is further improved, and the gas outburst of the broken soft coal seam is eliminated in advance.

(4) Due to the poor porosity of broken soft coal seam, it is still very difficult to construct directional long drilling. At the same time, in order to achieve the purpose of crushing the coal seam under pressure, fracturing drilling have high requirements on the sealing performance of the entire drilling. This also limits the use of hydraulic fracturing long drilling technology under certain circumstances. Therefore, a large number of engineering tests are required to make orientation The hydraulic fracturing technology of long drilling has been further improved.

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