Research on and Application of Roof Management Technology in 8.8m Ultra-high Fully Mechanized Mining Face

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Abstract: Aiming at the problems of high mining intensity and difficult roof management in a fully mechanized mining face with an ultra-high mining height of 8.8m, this article predicts the pressure parameters and rules of the working face based on the roof management technology of the 12402 fully mechanized mining face in Shangwan Coal Mine. The selection of the working surface bracket and the on-site roof safety management system are explained and analyzed. The results show that the analogy method can be used to predict the mining pressure parameters and rules of the working face to meet the needs of the application of large mining heights; the conventional techniques such as forced caving, "Scraped roof support moving method" and "Advanced drawing support method" are still effective under the condition of 8.8m mining height. The roof safety management system formed during construction guarantees the safe and efficient production of the ultra-high mining height working face, and provides a reference for the popularization of the mining technology of ultra-high mining height.

1. Introduction

The 8.8m Ultra-high fully mechanized mining technology is the first-applied in China and even the world. As the premise of safe and efficient mining, the rationality and effectiveness of the roof management technology is the key. In order to ensure the application of this technology, many domestic scholars have carried out related research. Yang Junzhe and Liu Qianjin [1] studied the mining pressure occurrence law of the 8.8 m super-large mining face in Shangwan Coal Mine based on on-site monitoring of support pressure in response to the problem of strong mining pressure. The bearing capacity of the hydraulic support was studied by Liu Guozhu[2], Wang Haijun and Sun Hongfa[3] studied the supporting strength of the hydraulic support on the working face. Li Fei and Liu Hunju [4] analyzed the stability of the hydraulic support on the working face, and relevant control schemes are proposed. However, the above studies are mostly for the analysis of the single elements of roof management in working face. This paper elaboration and analysis the roof management technology of 8.8m large mining height working face systematically in order to provide a reference for the promotion and application of Ultra-high fully mechanized mining technology.

2. Project Overview

The 12402 fully mechanized mining face is the second fully mechanized mining face in the 12th coal
The working face is arranged along the trend, with a width of 300m, length of 5271.8m, and mining height is 8.8m. The ground elevation of this fully mechanized mining face is 1178-1314m, the seam floor elevation is 1044.34-1067.40m. The thickness of the covering layer on the working face is 115-270m. The thickness of the overlying loose layer is 2-23m, which is mainly earthy yellow medium and fine-grained aeolian sand, loose and unconsolidated. The thickness of the overlying bedrock is 104-240m. The old roof of the working face is gray-white siltstone, with a thickness of 5.68-20.34m, compressive strength of about 14.5-36.6MPa. Direct-top is fine-grained sandstone, with a thickness of 2.1-8.07m, and compressive strength of about 13.3-15.2MPa. The working face is arranged along the coal seam, and is composed of working face, main entry, return air entry, auxiliary entry, main withdrawal roadway, auxiliary withdrawal roadway and other cross-cut, of which return air entry is secondary mining roadway. The working face is mined with a sloping long-wall receding one-time full-height integrated mechanized coal mining method, and all-caving method is used to manage the roof.

3. Support technology of working face

3.1. Analysis of support height and strength of Hydraulic powered support

3.1.1. Calculation of Hydraulic powered support height

a. Maximum height of Hydraulic powered support

\[ HZ_{\text{max}} \geq M_{\text{max}} + S_{1} \]  \hspace{1cm} (1)

Where

- \( HZ_{\text{max}} \) - the maximum support height of coal seam, mm
- \( M_{\text{max}} \) - maximum mining height of mining face, taking 8600mm.
- \( S_{1} \) - the maximum thickness of the first collapse of the pseudo-top, 200mm.

\[ HZ_{\text{max}} \geq 8600 + 200 = 8800 \text{mm} \]

b. Minimum height of Hydraulic powered support

\[ HZ_{\text{min}} \leq M_{\text{min}} - S_{2} - g - e \]  \hspace{1cm} (2)

Where

- \( HZ_{\text{min}} \) - minimum support height of coal seam;
- \( M_{\text{min}} \) - The minimum mining height of the mining face is 6500mm;
- \( S_{2} \) - The amount of sinking of the top plate, take 200mm;
- \( g \) - The thickness of floating gangue above the top beam and under the base, take 50mm;
- \( e \) - The amount of support retraction when moving the frame, take 100mm;

\[ HZ_{\text{min}} = 6500 - 200 - 50 - 100 = 6150 \text{mm} \]

In summary, the selected support height of the Hydraulic powered support is 4.0-8.8m, which meets the maximum and minimum support requirements.

3.1.2. Calculation of the strength of the Support

Use two empirical formulas to calculate the maximum value.

a.

\[ P = 9.81 hrk \]  \hspace{1cm} (3)

Where

- \( P \) - reasonable supporting strength of fully mechanized mining face, kN/m².
- \( H \) - mining height, m, 8.6m.
- \( R \) - gravity density of roof rock, t/m³, 2.5 t/m³.
- \( K \) - The ratio of the thickness of the overlying rock layer and the mining height that the support in the fully mechanized mining face should support is generally 4-8. When the mining coal is thick that under the not good roof condition with obvious period pressure, the high multiple should be selected[5]. According to the mining situation of adjacent mining face, \( k = 7 \).

\[ P = 9.81 \times 8.6 \times 2.5 \times 7 = 1476.40 \text{ (kN/m}^{2}) = 1.47 \text{ MPa} \]
3. Where

\[ P \geq \frac{9.8M \cdot r \cdot d \cdot B}{1000(K-1)\cos a} \]  

(4)

\[ P \geq \frac{9.8M \cdot r \cdot n \cdot \cos a}{1000(K-1)} \]  

(5)

Where

- \( P \): Supporting strength, MPa
- \( M \): Thickness of mining, 8.6m
- \( R \): The bulk density of the top rock, 2.5t/m³
- \( D \): The dynamic load factor of the roof, 1.3
- \( A \): The inclination of coal seam, 3°
- \( B \): Additional resistance coefficient, 1.2
- \( N \): Unbalanced safety factor, 1.75
- \( K \): The slate rock fragmentation coefficient, 1.25.

3.2. Selection of support

3.2.1. Selection of support for working face

According to the above calculation and analysis, the support of the working face is selected. A total of 128 supports are arranged in the fully mechanized mining face, of which there are 5 end supports (3 heads and 2 tails) and 6 transition supports (3 heads, 3 tails). See the table 1 for details.

It can be seen from the comparison that the support strength of the selected hydraulic support, end support, and transition support exceeds 1.47MPa, and the support can meet the requirements of support load, support height and other requirements.

Table 1. Technical data table of hydraulic supports

| Item                  | Technical parameters | Support | End support | Transition support |
|-----------------------|----------------------|---------|-------------|-------------------|
| Model                 | ZY26000/40/88D       | ZYT26000/30/55D | ZYG26000/40/88DA(ZYG26000/40/88DB) | ZY26000/40/88G |
| Minimum support height (mm) | 4000            | 3000     | 4000         | 4000              |
| Maximum support height (mm) | 8800            | 5500     | 8800         | 8800              |
| Hydraulic height adjustment (mm) | 4800           | 2500     | 4800         | 4800              |
| Working resistance (kN)       | 26000        | 26000    | 26000        | 26000             |
| Supporting strength (MPa) | 1.71-1.83    | 1.51-1.60 | 1.54-1.61   | 1.62-1.73         |
| Initial support force (kN)  | 19782         | 19782    | 19782        | 19782             |

3.2.2. Selection of advanced support

a. Advanced support of the main entry

The main transportation entry is the roadway affected by once time mining, and the strength of the advanced support is calculated as follows.

\[ P = 9.81hrk \]  

(6)

Where

- \( P \): Supporting strength, MPa
- \( h \): Height of support, m
- \( r \): Radius of the main transportation entry, m
- \( k \): Coefficient of the main transportation entry, 1.0
h—the height of roadway, 4.6m  
r—the bulk density of the top rock, 2.5t/m³  
When k is 2, P=225.63 (kN/m²)=0.23 (MPa)

ZYDC33700/29/55D type advanced support was selected, and calculate the support strength of the support as: \( P_1 = \frac{F}{S} = 242.1 \text{ (kN/m²)} = 0.24 \text{ (MPa)} > 0.23 \text{ (MPa)} \)

b. Advanced support of the return air entry
The return air entry is the roadway affected by twice time mining. According to the characteristics of the previous mining roadway of Shangwan Coal Mine, the mining pressure of the secondary mining roadway is strong, but the leading pressure of the secondary mining roadway is within 20 meters of the working face. The sinking of the roof and the roof is the largest, and the leading pressure is weakened 20 meters away from the working surface, so the parameter k of 20 meters ahead is calculated by 6 and the parameter k of 20 meters outside is calculated by 4. That is, the support strength of the advanced bracket must meet the following conditions.

\[ P_1 = 9.81hrk = 676.89 \text{ (kN/m²)} = 0.68 \text{ (MPa)} \]
\[ P_2 = 9.81hrk = 451.26 \text{ (kN/m²)} = 0.45 \text{ (MPa)} \]

Choose ZQL2×24500/25/47D (Type I) and ZFDC81100/29/55D (Type II) advanced supports, use Type I brackets within 20m from the working surface, use Type II brackets beyond 20m, and support the total length of 44.6 m, of which the length of type I support is 23.4m (3 groups), and the length of type II support is 21.2m (2 groups).

The support strength is calculated as below:

\[ P_1' = \frac{F}{S} = 1163.34 \text{ (kN/m²)} = 1.16 \text{ (MPa)} \]
\[ P_2' = \frac{F}{S} = 698.81 \text{ (kN/m²)} = 0.69 \text{ (MPa)} \]

It is meet the requirements of advanced support for return air entry.

3.3. Prediction of rock pressure
With reference to the mining pressure statistics of the 12401 mining face (mining height of 8.8 meters) mined in Shangwan Coal Mine and the 12206 mining face (mining height of 7 meters) in the same coal seam, the mine pressure law of the 12402 working face can be obtained by analogy analysis that the first mining face of the working face needs to adopt the forced blasting method. The initial pressure step should not exceed 45m, and the periodic pressure step should be 10-14m.

4. Roof safety management
The 12402 working face has large mining space and high mining intensity, and the roof activities are intense. In addition, due to the thin thickness of the direct roof and insufficient filling of the mined-out area, the break type of basic roof is different from the conventional mining face[6]. There is no significant resistance increase during the non-compression of the working face, but the impact load of the support on the working face is large when the pressure is applied [7,8], the working surface pressure is significant.

4.1. Roof management during initial mining

4.1.1. Mandatory caving
In order to ensure safety, after cutting 6 cycle (5m) at the beginning of the working face, deep hole pre-splitting blasting is used for forced caving. Forced caving must be carried out strictly in accordance with the requirements of special safety technical measures to ensure safety.

4.1.2. Safety management due to the initial pressure coming
During the initial pressure, the coal wall will be compressed and become crispy. When the slab is seriously recovered near the shearer drum, the slab coal will fall over a large area. The maximum pressure of support can be reached to 52MPa. Before the first pressure comes, the mining height must be controlled at 7m, and the deviation should not exceed ±0.2m. It is strictly forbidden to increase and
decrease the mining height at will. Because the face is digging along the bottom, there is a top coal of nearly 3m thick. After the initial mining, the bottom must be gradually lifted and mining along the top. When it is advanced to 40m, ensure that the working face is fully recovered along the top and the working face is gentle. In addition, special safety technical measures such as production and personnel protection must be properly organized and strictly implemented.

4.2. Periodic pressure management
The duration length of periodic pressure is 1.5-6.5m, with an average of 3.8m. The middle of the working face appears strong when the pressure is coming, and rib spalling of mining face is serious. Therefore, the roof management must be strengthened during the pressure period. The special person is responsible for checking the initial support force to ensure that it rises above the set value. At the same time, we must strengthen the organization, advance quickly, and get rid of pressure. In the case where the roof is separated from the floor, the "scratching and moving support method" is used for operation. When the roof is relatively broken and there is a roof falling phenomenon, the advance drawing method should be used for operation [9].

4.3. Construction performance
Since the recovery of 12402 working face in September 2019, it has normally advanced by 800m with a total recovery of 5 million tons of coal. No roof accident has occurred, indicating the rationality and reliability of the existing roof management technology and measures.

5. Conclusion
● The type selection of hydraulic support, end support, transition support and two along-slot advanced supports in working face is reasonable. After field verification, it meets the roof support requirements of 8.8m large mining height fully mechanized mining face.
● The analogy method is used to predict the parameters and rules of the mining pressure in the working face, which is still reasonable and practical in the field application, and can meet the needs of rapid promotion and application of roof support technology.
● The roof safety management system formed during on-site construction guarantees the safe and efficient production of super large mining height working face, and has certain practical guiding significance. At the same time, it has been verified that the conventional processes such as forced caving, "scrapping roof moving method" and "leading support method" are still effective under the 8.8m high mining height.

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