Numerical simulation study of roof cutting and roadway protection under the condition of deep dynamic pressure

Abstract: In order to study the difficulty of supporting the surrounding rock in the mining area due to the dynamic pressure of the working face, the Daqiang coal mine is used as the background to study the key parameters of the cut-roof roadway protection using the method of theoretical analysis and numerical simulation. Theoretical analysis shows that the destruction of the surrounding rock of the main roadway in the mining area is mainly affected by the stress of the deep plateau rock and the mining stress of the adjacent working face. Using deep-hole energy-accumulating blasting technology to cut the roof of the retreat channel at the end of the adjacent working face in advance, not only can effectively prevent the transfer of mining stress in the working face, but also protect the purpose of the retreat channel and the main roadway in the adjacent mining area. Numerical simulation studies have found that: (1) when the top cutting height reaches the basic top position and the top cutting angle is about 30°, the protection of the surrounding rock of the retreat channel and the adjacent main roadway is the most effective; (2) Too early or too late cutting time will also affect the effect of preventing the transfer of mining stress, thus failing to achieve the purpose of cutting off the transfer of mining stress to adjacent roadways. Therefore, finding the right top-cutting time is also very important; (3) If a support body that can provide high prestress and withstand large deformations of surrounding rock is applied in the main roadway of the adjacent mining area, the support body and the surrounding rock can be coupled, so that better stability control effect can be achieved. This research can effectively provide help for the stability design of main roadways affected by dynamic pressure.

Keywords: Deep roadway; Top cut pressure relief; Retracement channel; energy-gathered roof cutting

1. Introduction
With the sustained and rapid economic development, there is an increasing demand for underground resources such as coal. With the consumption of shallow resources, coal mines are continuously extending to the deep [1]. In the process of coal mining, the objective movement law of the overlying strata of the stope caused the coal mine roadway to be affected by dynamic pressure. In the shallow mining stage, it has already had a certain impact on coal mine safety. With the continuous increase of coal mining depth, the stress of the original rock continues to increase. The surrounding rock change law of deep coal mine roadway affected by mining is becoming more and more complicated [2-3]. Therefore, the support problem of the main road adjacent to the deep-buried coal mining area has become a hot research topic.
Meng Yi [4] analyzed the key factors of repeated failure of the roadway by comprehensively using theoretical analysis, numerical simulation and field measurement methods in view of the large deformation of the surrounding rock and the failure of the supporting structure in the 500-level roadway in Caocun Coal Mine. Xu Wentao et al. [5] used the first mining area of Yangliu Mine in Huaihe, Anhui Province as the research background, established an indoor similar material model, installed strain sensing optical cables with high sensitivity and good durability in similar models, and
adopted BOTDA distributed optical fiber sensing technology. Combined with close-range photography technology, the development, deformation and destruction of the separation layer during the mining process are dynamically monitored and researched. Yu Weijian et al. [6] aimed at the large deformation of deep-buried soft rock roadways under repeated disturbances in mining, and used methods such as field investigation, stress field analysis of the surrounding rock of the roadway, and numerical simulation tests to conduct research.

He Manchao[7] first carried out the field test of cutting the roof along the trench in Bajiao Mine, Sichuan Province, and achieved great success. Subsequently, more research topics on top-cutting were proposed, and successful field tests were successively carried out [8-11]. Academician He Manchao also conducted extensive research on soft rock roadway support in coal mines [12-13]. Due to the special movement law of the overlying strata in the coal mine stope, the roadway around the coal mine stope is affected by dynamic pressure, and most scholars have carried out detailed research on this [14-16]. However, scholars have seldom studied the mechanism of roof cut and roadway support. This article mainly uses theoretical analysis and numerical simulation to study the roadway cutting roof protection in the deep-buried coal mine mining area, and explore the key parameters of roof cutting, so as to better ensure the stability of the surrounding rock of the mining area roadway.

2. Project Overview

Daqiang Coal Mine is located in Liaoning Province and belongs to the Tiefa mining area. The mine area is 54.41 km³ and the designed production capacity is 1.5 million tons per year. The design service life is 50.6 years, the mining depth is 1000~1200m, the coal seam inclination is 15°, and the maximum horizontal stress is 34.87~39.38MPa, which is 1.41~1.59 times the vertical stress. The roof of the coal seam is dominated by mudstone and sandy mudstone, and the floor is dominated by mudstone and fine sandstone.

There are three main alleys in the mining area of Daqiang Coal Mine, namely the return air alley, the belt transportation main alley and the track main alley. The 0901 working face adjacent to the main road is composed of two roadways, a mining face and a withdrawal channel. The coal thickness is about 11m. The top coal mining method is adopted for the mining, and the mining height is 4.8m. The length of the working face is 240m, and the length of the two troughs is about 1300m. The layout of the working face is shown in Figure 1.

![Figure 1. 0901 working face roadway layout](image)
3. Model establishment
According to on-site drilling, exploration and sampling, as well as indoor experiments, the basic parameters of different rocks are obtained, as shown in Table 1. According to the parameter assignment, the basic geological model is established. The length of the model is 200m, the width is 160m, the height is 150m, and the coal seam inclination angle is 13°. Among the three main lanes in the mining area, the track lane is the closest to the 0901 working face. In order to simplify the model, only the changes in the surrounding rock of the track lane are studied. The location of the withdrawal channel is established according to the location of the stop line, that is, it is about 50m away from the main lane of the track. as shown in picture 2.

Table 1. Value table of surrounding rock parameters of main roadway

| Lithology          | Density (Kg/m³) | Bulk (Gpa) | Shear (Gpa) | Cohesion (Mpa) | Friction (°) | Tension (Mpa) |
|--------------------|----------------|------------|-------------|----------------|--------------|---------------|
| Siltstone          | 2650           | 10.67      | 4.92        | 4.03           | 34           | 2.9           |
| Mudstone           | 2440           | 9.03       | 6.08        | 7.9            | 33           | 2.4           |
| Marl               | 2520           | 4.64       | 3.64        | 5.65           | 32           | 1.08          |
| Siltstone          | 2540           | 15.83      | 7.31        | 2.2            | 34           | 2.6           |
| Sand mudstone      | 2440           | 9.03       | 6.08        | 7.9            | 32           | 2.4           |
| Calcareous shale   | 1860           | 3.51       | 2.62        | 1.37           | 34           | 0.73          |
| Marl               | 2440           | 9.03       | 6.08        | 7.9            | 32           | 2.4           |
| Coal               | 1400           | 1.05       | 0.96        | 1.2            | 35           | 1.0           |
| Mudstone           | 2520           | 11.11      | 7.32        | 7.0            | 31           | 2.67          |
| Siltstone          | 2480           | 25         | 12.89       | 3.7            | 36           | 3.49          |
| Fine sandstone     | 2550           | 25.93      | 10.61       | 4.03           | 34           | 2.46          |
| Sandy mudstone     | 2620           | 19.79      | 16.11       | 4.87           | 39           | 3.28          |
| Coarse sandstone   | 2710           | 24.77      | 24.34       | 7.9            | 38           | 3.28          |
| Conglomerate       | 2620           | 19.79      | 16.11       | 4.87           | 39           | 3.54          |

a）Geological model  b) The location of the main alley and the retracement channel

Figure 2. Model establishment
According to the construction design, the original support of Daqiang Coal Mine is mainly $\phi 26.8 \times 8300$mm anchor cables with a row spacing of $1600 \times 1600$mm; $\phi 22 \times 2400$mm anchor rod with 800 $\times 800$mm spacing; then sprayed with 300mm concrete and erected a steel shed for support. It is still unable to fully control the deformation of the surrounding rock at this supporting strength, so the original supporting anchor cable is replaced with a high pre-tightening anchor cable. Simulate the two
types of support separately to observe the deformation of the surrounding rock of the main roadway. As shown in Figure 3.

![Figure 3. Establishment of Supporting Body for Track Main Roadway](image)

4. Research on Key Parameters of Cutting Roof and Protecting Roadway

4.1. Choice of top cutting height

According to the formula 1 proposed by the predecessors to determine the top-cut height[11]

$$H_{slit} = \frac{H_{slit} - \Delta H_1 - \Delta H_2}{K - 1}$$  \hspace{1cm} (1)

Among them \(H_{slit}\) is the height of the cut seam, \(H_{seam}\) is the thickness of the coal seam, \(\Delta H_1\) is the amount of roof subsidence, \(\Delta H_2\) is the amount of bottom heave, and \(K\) is the coefficient of swelling, generally taken as 1.3~1.5.

After calculation, the slit height is 20m.

4.2. Choice of cutting angle

Choose 15°, 30° and 45° for the kerf angle respectively to simulate respectively, and compare the total displacement (Figure 5) and the Z-direction stress (Figure 6) to find the appropriate kerf angle. According to the stress diagram in the Z direction, it can be seen that when the slit angle is 30°, the stress concentration on the main roadway and the retreat channel of the track is the smallest. In addition, the maximum displacement of the surrounding rock in the main roadway of the track is the smallest, so it is more appropriate when the slit angle is 30°.
5. Research on High Preload and Constant Resistance Coupling Support

In the case of the original support, the surrounding rock convergence of the main track roadway is relatively large. After the top of the retreat channel is cut and relieved, the numerical simulation analysis shows that the convergence of the surrounding rock has been reduced. If the original support of the track main roadway is replaced with a constant resistance coupled support with high pre-tightening force, the stability control effect of the surrounding rock will be better. The pre-tightening force of the original supporting anchor cable is 120kN. The high pre-tightening force and constant resistance anchor cable developed by He Manchao can exert a pre-tightening force of 350kN.
numerical simulation, the long anchor cable is replaced with a constant resistance anchor cable, and the anchor rod is replaced with a short constant resistance anchor cable, as shown in Figure 7. The simulation result is shown in Figure 8. The convergence of the surrounding rock of the main track roadway has changed from the original 0.15m to 0.08m.

![Figure 7. Replace the original supporting anchor cable with a high pre-tightening anchor cable](image)

![Figure 8. Simulation effect drawing of high pre-tightening force anchor cable](image)

6. Conclusion

Numerical simulation of the track roadway in the mining area of Daqiang Coal Mine under the original support shows that the most severe deformation of the track roadway is at the upper right, and the convergence is about 0.15m. In addition, the convergence of the surrounding rock of the track main roadway is mainly affected by the high ground stress and dynamic pressure. Cut the top and relieve pressure on the adjacent 0901 working face retreat channel. After calculation, the top-cut height is 20m and the top-cut angle is 30°. And replacing the low prestressed anchor cable in the original support with a high prestressed constant resistance anchor cable is more conducive to the support of the surrounding rock of the main track roadway.

7. Reference

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