Study on the support performance of portal support under different confining pressure

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Abstract. In this paper, a certain section and hydraulic support of Hongyang No.3 coal mine are taken as the research object. The numerical model of coupling between the tunnel and hydraulic support is established by using the finite element software ABAQUS. The Mises stress of the tunnel and support under different confining pressure is analyzed. The results show that: Under different confining pressure, the maximum Mises stress appears at the arch foot of the tunnel, with the increase of confining pressure, the Mises stress at the arch foot is rising, and the increase of Mises stress at the left arch foot is greater than that at the right arch foot. The uneven stress of the tunnel increases, and the tunnel is more prone to damage. With the increase of the confining pressure, the Mises stress of the middle pillar of the portal support decreases continuously. The load is mainly borne by the columns on both sides. The middle pillar cannot play its bearing capacity, which is not conducive to the support of the tunnel.

1. Introduction
The hydraulic support is an important equipment to ensure the working space and safety production in the modern high-yield and efficient mine. Scholars have done a lot of research on the performance of the hydraulic support, such as: Heng Li used numerical simulation method to establish the stope stress field, and applied load on the roadway roof to simulate the initial support force, and obtained the conclusion that increasing the initial support force can effectively reduce the probability of coal wall spalling [1]. Leiping Chen analyzed the hydraulic support by means of indirect loading, which provided a reference for the design of the hydraulic support [2]. Xinke Liu simulated the hydraulic support column, and applied impact load to the column, studied the dynamic characteristics of the column under impact load [3]. At present, most of the experimental or numerical methods for the hydraulic support are to directly load the hydraulic support or directly load a part of the support for analysis. In order to make the numerical results closer to the reality, this paper establishes the numerical model of the portal support by numerical simulation method and considers the coupling of the hydraulic support and the surrounding rock for calculation. The supporting effect of the hydraulic support and the stress characteristics of the hydraulic support are analyzed.

2. Numerical model
In this paper, the tunnel anti scour support of Hongyang No.3 Mine is taken as the research object, and the numerical model of portal support is established by using the finite element software ABAQUS in the proportion of 1:1 (as shown in Fig.1). The hydraulic support is made of Q550 steel, its elastic
modulus is 200GPa and Poisson's ratio is 0.3. The yield strength is 550MPa, the constitutive model of steel is calculated according to the ideal elastic-plastic constitutive model, and the hardening property of steel is taken as the safety reserve, which is not calculated.

![3D drawing of hydraulic support.](image1.png) ![Finite element model of hydraulic support.](image2.png)

**Figure 1.** Hydraulic support.

The numerical model of surrounding rock is established according to the geological conditions of Hongyang No.3 Mine, which are sandstone, coal seam and sandstone from top to bottom. The material properties are shown in Table 1. The coupling model of surrounding rock and hydraulic support is shown in Fig.2.

![Coupling diagram of surrounding rock of hydraulic support.](image3.png)

**Figure 2.** Coupling diagram of surrounding rock of hydraulic support.

| Name   | Density (kg/m³) | Young modulus (MPa) | Poisson's ratio | Friction angle (°) | Cohesion Yield Stress (MPa) |
|--------|-----------------|---------------------|-----------------|--------------------|-----------------------------|
| Sandstone | 2400           | 6000                | 0.26            | 45                 | 15                          |
| Coal   | 2540            | 12501               | 0.3             | 30                 | 5                           |

**Table 1.** Properties of surrounding rock

The model simulates the change of the underground portal support with a buried depth of 800m. The vertical stress is calculated according to formula (1) according to the burial depth, surrounding rock density and gravity acceleration. The density of surrounding rock is 2000kg/m³, the acceleration of gravity is 10m/s², the buried depth is 800m, the calculated vertical stress is 16MPa, and the horizontal force is set as 0.5, 0.75, 1, 1.25 and 1.5 times of the vertical stress to simulate the tunnel compression from different directions (Hereinafter referred to as the confining pressure). The front, back and bottom of the rock mass are completely fixed. According to the literature of Zhi Tang and Dezhong Kong [4,5], the friction coefficient between the hydraulic support and the roof and floor is 0.3.
\[ \sigma_v = \rho gh \]  

(1)

3. Result Analysis

3.1. Mises stress analysis of tunnel

Fig. 3 is the Mises stress nephogram of the tunnel under confining pressure of 0.5. It can be seen from the figure that the Mises stress value of the left and right arch footings of the roadway is the maximum, which is 38.8MPa and 36.5Mpa. Under other confining pressure, the maximum position of Mises stress is at the arch foot of the tunnel. Therefore, the arch foot is the most easily damaged position in the tunnel. Fig. 4 shows the Mises stress curve of the left and right arch feet of the tunnel under different confining pressure. It can be seen from the figure that with the increase of the confining pressure, the Mises stress of the left and right arch feet of the tunnel increases continuously, and the increase of the Mises stress of the left arch feet is faster than that of the right arch feet, indicating that the uneven stress of the tunnel is increasing, and the tunnel is more prone to damage. Therefore, this kind of support has a better supporting effect in the tunnel with a small confining pressure.

Figure 3. Cloud chart of Mises stress under confining pressure of 0.5.

Figure 4. Curve of Mises stress of left and right arch footings under different confining pressure.

3.2. Mises stress analysis of hydraulic support

According to statistics, the failure and instability of the pillar are the most common when the accidents happen in the fully mechanized face [6]. Therefore, hydraulic prop is the main research object. Fig. 5 shows the Mises stress nephogram of the hydraulic support when the confining pressure of 0.5. Take
the reference points in the middle of three columns, and analyze the stress of columns under different confining pressures.

![Image of Mises stress nephogram](image)

**Figure 5.** Mises stress nephogram of hydraulic support under confining pressure of 0.5.

Fig. 6 shows the Mises stress curve of the pillars under different confining pressures. It can be seen from the figure that with the increase of confining pressure, the Mises stress of the middle pillar decreases continuously, and the load is mainly borne by the left and right pillars. The middle pillar cannot play its bearing capacity, which is not conducive to the support of the tunnel.

![Image of Mises stress curve](image)

**Figure 6.** Curve of Mises stress of pillars under different confining pressure.

4. Conclusion

1. Under the different confining pressure, the maximum value of Mises stress in the tunnel appears at the arch foot, and with the increase of force ratio, the Mises stress at the arch foot increases continuously, and the increase of Mises stress at the left arch foot is greater than that at the right arch foot, the stress heterogeneity of the tunnel increases, and the tunnel is more prone to damage.

2. With the increase of the confining pressure, the Mises stress of the middle pillar of the portal support decreases continuously. The load is mainly borne by the pillar on both sides. The middle pillar cannot play its bearing capacity, which is not conducive to the support of the tunnel

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