Study on the development law of advancing support pressure on fully mechanized caving face

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Abstract: In order to master the law of pressure manifestation in fully mechanized caving face, numerical simulation method is adopted to establish a physical and mechanical model for analysis. The results show that the load on the working face support is mainly the deformation pressure produced by the deformation of the top coal and the basic roof. Therefore, increase of the setting force and working resistance can improve the structural state of the roof and maintain the stability of the lower top coal. The supporting pressure in front of the working face is distributed approximately in a parabola, the peak is located at 4m to 8m in front of the coal wall, and the stress concentration factor at the peak point is 1.3 to 1.7.

1. Instruction
In recent years, with the continuous development and improvement of the performance of fully mechanized caving equipment, the resource recovery rate and production efficiency of fully mechanized caving face have been improved. This paper takes the geological conditions of a mine in Shanxi province as the engineering background, establishes a numerical model, and uses FLAC3D to analyze the law of the advancing support pressure in fully mechanized caving face, in order to provide essential data and designing basis for the mining in similar working faces.

2. Engineering Background
The 9# coal seam is located in the lower part of Shanxi Formation, and the upper distance is 40.90~56.15m from the 5# coal seam, with an average of 50.13m. The thickness of the coal seam is 7.45~13.30m, with an average thickness of 11.8m, which is a very thick coal seam. The roof is limestone, dark gray, cryptocrystalline, dense and massive, with high level of argillaceous components, well-developed joints, and full of calcite veins, tough in nature, about 16m thick; The false roof is mud stone, gray, semi-hard, medium-thick layered, containing plant fossils, with joints, and the horizontal bedding thickness is 0.5-1m; The coal seam floor is sandy mud stone, light black, thin-layered, horizontal bedding, containing mica fragments, well-developed fissures, and plant debris fossils, with a thickness of about 3m. The comprehensive histogram is shown in Figure 1.1. According to our theoretical research and practical experience of top coal mining, the mining height of 9# coal seam is recommended to be 3.5m, the top coal thickness is 8.3m, and mining-to-caving ratio is 1:2.37.

3. FLAC3D Numerical Simulation Analysis
3.1. Model Establishment
In order to ensure the reliability of the working resistance of the support, the FLAC3D numerical simulation software is used to simulate the three-dimensional dynamic mining of the 9# coal with fully
mechanized top coal caving. a three-dimensional numerical model was established, the size of the model is 380×400×340 meters, the simulated condition is that: mud-stone floor is 3 meters, the shear-mined coal seam is 3.3 meters, the caving seam is 8.5 meters, the limestone roof is 16 meters, The controlling distance of the support is 5.8m, and the working face is 250m long.

The Mohr-Coulomb criterion was used in the calculation. Each excavation is 6 m, and a total of 120 m is excavated. Divide the calculation grid according to the geometric size of the model, assign the physical and mechanical parameters of coal to the rock mass of the corresponding layer, establish the numerical calculation model, apply load to the model according to the depth of the model before calculation, and provide constraints on the side and bottom of the 3D model. First, the initial stress field is constructed according to the simulated conditions. The vertical stress of the rock mass is calculated according to the weight of the rock mass, and the horizontal stress $\sigma_x$ and $\sigma_y$ of the rock mass are calculated according to (1.1~1.2) times of $\sigma_z$. A uniform vertical compressive stress is applied to the upper surface of the model. The vertical and horizontal displacements of the surface are fixed, and horizontal compressive stresses varying with depth are applied to both sides of the model.

3.2. Vertical displacement distribution of working face

![image](image.png)

(a)Working face advance of 12m  (b) Working face advance of 30m  
(c)Working face advance of 42m  (d) Working face advance of 54m

Fig 2 initial collapse of main roof

It reflects that the initial collapse of the basic roof after the mining and caving in the middle working face. It can be seen from the figure that as the working face continues to advance, the vertical displacement of the basic roof continues to increase, and the basic roof collapses after 54m in the working face. Fig. 5 shows the vertical displacement distribution of the top coal in the roof control zone of the support when the working face support strength is 1.17Mpa.
Fig 3 Vertical displacement diagram of top coal within support control area

It can be seen that when the supporting strength is 1.17Mpa, the vertical displacement of the top coal within the support control range is small, and the maximum subsidence is 40mm. The support can effectively restrain the roof sinking and the surrounding rock of the working face is stable.

Fig 4 Vertical displacement diagram of roof

Figure 4 is Vertical displacement diagram of limestone roof when the support strength is 1.17Mpa. It can be seen that the vertical displacement of the upper coal strata is generally greater than that of the lower strata. The amount of limestone roof subsidence gradually increases from the back of support to the goaf, the roof revolves and deforms and the limestone roof collapses to fill the mined-out area.

This shows that there is no separation phenomenon among the top coal in front of the working face, the immediate roof and the main roof. That top coal is always in a compressed state in the vertical direction, the Separation phenomenon that the displacement of lower parts within top coal is larger than the upper parts only occurs behind the support. Therefore, the loading on the support is mainly the deformation pressure generated by the top coal and the main roof deformation movement. So, increasing the setting force and working resistance of the support is positive for improving the structural state of the working face roof and maintaining the stability of the lower coal.

3.3 Change of supporting pressure in front of coal wall of working face

Based on the FLAC3D numerical simulation results and the stress variation values calculated by each element, along with advancing distance of the working face under the support strength of 1.17mpa, the change curve of the peak pressure in front of the working face can be obtained (as shown in FIG.6 square curve). It can be seen from the figure that the peak value of abutment pressure gradually increases with the working face advancing from 0 m to 48 m, and when the working face advances to
54 m, the change of peak value of abutment pressure tends to be moderate and gradually stable, with the maximum peak value is around 8.1Mpa to 9.8Mpa and the stress concentration coefficient at peak point is around 1.3 to 1.7.

According to abutment pressure at the recording point after the working face under the support strength of 1.17mpa is advanced at different distances, the change curve of abutment pressure varies with the advancing distance. It can be seen that the abutment pressure presents a parabolic distribution, with the peak value is from 4m to 8m ahead of the mining line, and the distribution range is from 0m to 42m. The peak value increases with the advancing of the working face. When the working face is pushed forward by 12m, the recording point is in the stable pressure zone. At this time, the coal seam at the recording point is less affected by the mining of the working face, and the abutment pressure changes little. As the working face continues to push forward, the recording point enters the pressurized area, and the abutment pressure starts to increase and reaches the peak value after the working face is pushed forward by 54m. At this time, the recording point is about 4m ahead of the working face. It can be seen that the coal seam at the recording point starts to enter the plastic zone and produce shear failure. As the working face continues to push ahead, the plastic zone in front of the coal wall expands continuously, and the bearing pressure of the coal seam at the recording point decreases rapidly.

![Fig 7 Vertical stress diagram of coal seam](image1)

![Fig 8 Abutment pressure range](image2)

Because of top-caving working face, relatively softness (F =2) and 11.8m thick of NO. 9 coal seam, the abutment pressure has a large distribution range and the peak point is more forward. It can be seen from Fig.8 and Fig.9 that the vertical stress along the advancing direction of the working face starts to increase rapidly within the range of 2m, and reaches the peak value at about 6m ahead of working face. The peak value of the stress is 1.3 ~ 1.7 times of the original rock stress, and the distribution range of the abutment pressure is within 42m from the working face. In general, the surrounding rock stress on the working face is reasonable when the supporting strength of the support is 1.17mpa, which is in line with the reasonable value under the relation between surrounding rock and the support.

3.4. Changing of plastic zone at working face

![Fig 9 Plastic zone distribution at work face along the strike](image3)

It shows that the distribution diagram of plastic area in the middle of the working face along the strike section after the working face is pushed forward for 12 m, 30 m, and 54 m respectively. It can be seen that with the advance of the working face, plastic zone failure in front coal, top coal and main roof increases continuously. Shear failure is mainly produced in top coal ahead of working face while shear composite failure in the top coal above the support. Before the old roof caved in, the plastic failure is concentrated at 0 ~ 2.0m ahead of the working face, and the plastic failure is concentrated in the range of 1.0 ~ 4.0m. After advancing 54 m, the primary collapse of the main roof is coming and plastic zone
gradually increases to 0 ~ 4 m, the plastic failure of the top coal is in the range of 6.0m ~ 8.0m, and the plastic failure of the top coal expands deep ahead of working face, while upward in the main roof. The fracture position of the main roof extends to the depth of the coal gradually and the abutment pressure influence range increases.

3.5. Top coal displacement change
It turns out that the top coal at 12m ahead of working face begins to move, and the accumulative displacement increases rapidly as it gets closer to the working face. The maximum displacement is 68.3cm, and the accumulative displacement in the upper top coal is greater than that in the lower top coal. The higher the top coal position is, the farther the distance of the starting point ahead of the working face is, and the larger the accumulated displacement is. In the early movement stage of the top-coal, horizontal movement is the main movement. With the advance of the working face, the vertical displacement increases gradually, and the vertical displacement of the top-coal at 1~2m behind the coal wall exceeds the horizontal displacement.

4. conclusion
(1) The load of support at the working face is mainly the deformation pressure generated by the deformation movement of the top coal and the main roof, so improving the initial support force and working resistance has a positive effect on improving the structural state of the working face roof and maintaining the stability of the bottom top coal.

(2) The abutment pressure in front of working face presents a parabolic distribution, and the peak value is located at 4m ~ 8m ahead, and the distribution range is 0m ~ 42m. As the working face continues to advance, the plastic zone expands continuously. When the coal seam at the recording point starts to enter the plastic zone and produces shear failure, the abutment pressure at the recording point rapidly decreases.

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