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Research on Distribution Law of Advanced Support Pressure in Narrow Coal Pillar Working Face

DU Feng[1,2,3], CHEN Bo[1], LI Zhen[4], LIU Shuai[1], REN Zhuli[1],
CAO Zhengzheng[1,2,3](Corresponding author)
[1]*School of Energy Science and Engineering, Henan Polytechnic University, Jiaozuo 454003, Henan, China*
[2]*Henan Mine Water Disaster Prevention and Control and Water Resources Utilization Engineering Technology Research Center, Henan Polytechnic University, Jiaozuo 454003, Henan, China*
[3]*Collaborative Innovation Center of Coal Work Safety and Clean High Efficiency Utilization, Jiaozuo 454003, Henan, China*
[4]*School of Safety and Emergency Management Engineering, Taiyuan University of Technology, Taiyuan 030024, Shanxi, China*

Abstract: In order to solve the problem of imbalanced distribution of advance support pressure during narrow coal pillar mining under large burial depth conditions, this paper takes the coal pillar working face on the inner side of the second panel of Zhaogu Mine as the research object, and studies the stress distribution characteristics of coal pillar mining. By combining numerical simulation and on-site measurement methods, the distribution law of advance support pressure in the direction of working face advancement is revealed. The drilling stress at different depths inside the coal pillar is measured using a stress meter. The results show that during the mining process of the working face, the pressure of the support in front of the work face will experience an increase in stress, but the stress will decrease until it reaches the initial stress value. The peak stress of advanced support is approximately 5-10m away from the coal wall side, with a significant impact range of 30-35m. The maximum impact range of advanced stress can reach 90m away from the coal wall. The stress concentration coefficient ranges from 1 to 2.44. The coal pillar working face is affected by the excavation disturbance on both sides of the working face, and the stress inside the coal pillar shows a distribution trend of high, medium, and low on both sides, forming high concentrated stress at the positions of the tunnels on both sides of the coal pillar.
Keywords: section coal column; numerical simulation; field measurement; drilling stress

I. Introduction

Coal is the most economic and reliable resource in China's primary energy. It is the energy that can realize clean and efficient use. It is the ballastof China's energy security [1-2] .In actual production of mines, in order to ensure safe and efficient mining of the working face, it is usually necessary to leave coal pillars [3,4] (mainly referring to section coal pillars) to support the overlying strata and maintain the stability of the surrounding rock of the roadway. However, this also results in a large amount of high-quality coal resources remaining, and the sustainable mining of coal will be seriously threatened [5,6]. The remaining coal carbon resources on the inner side of the second panel of Zhaogu Mine have considerable reserves and excellent quality. If safe, green, and high recovery mining can be achieved, it will undoubtedly promote the sustainable development of the mine, meet the urgent demand of the regional economy for high-quality coal resources, and promote the advancement of science and technology in the coal industry.

This article takes the recovery of coal pillars in the remaining section of Zhaogu No.2 Mine as the background, and comprehensively uses two research methods of on-site measurement and numerical simulation to reveal the distribution law of advance support pressure in the direction of working face advancement. By using a stress meter to measure the drilling stress at different depths inside the coal pillar, efficient and safe mining of the working face is achieved. The research results provide guidance and reference for the recovery of narrow coal pillar working faces [7,8].

II. Stress Distribution Rule in the Coal Column

After being disturbed by mining on both sides, the internal stress balance of the coal pillar has been disrupted, and the stress has been redistributed. Understanding the stress distribution pattern inside the coal pillar is an important basis for determining whether impact disasters occur during top coal mining. Given the complexity of the historical stress situation of the coal pillar, it is difficult to simulate it through laboratory experiments. Therefore, a numerical model was established to simulate the historical stress situation of the coal pillar after being affected by mining on both sides. In addition, two sets of stress gauges are installed along the groove on the coal pillar working face to test the stress at different depths inside the coal pillar, in order to analyze the distribution pattern of stress inside the coal pillar.

III. Numerical Simulation

In order to simulate the distribution range and law of the advance support stress before the coal wall of the working face, the model is established according to the propulsion direction of the working face. The length of the model is 260m, the thickness of the rock cover on the simulated working face is 57m, 30m boundary coal column is left on both sides, and the propulsion distance of the simulated working face is 200m. Horizontal constraints are set in the left and right directions of the model to ensure that the horizontal tangential displacement of the model is 0; while vertical constraints are set at the bottom of the model, the numerical model is shown in Figure1.

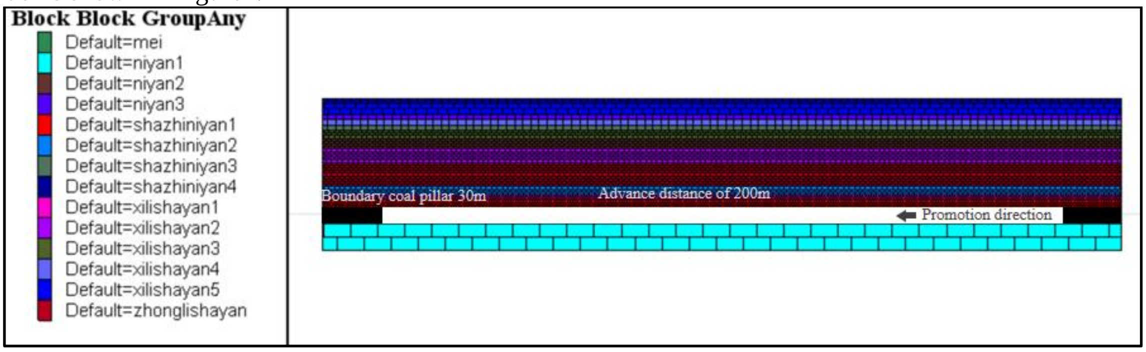
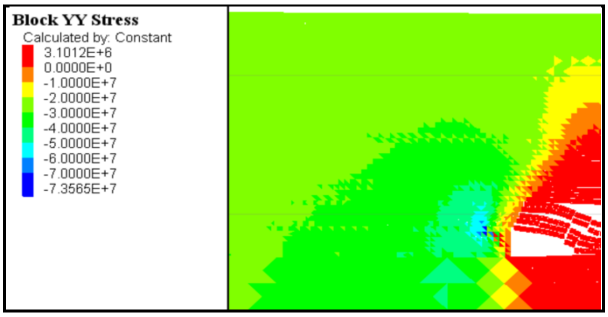
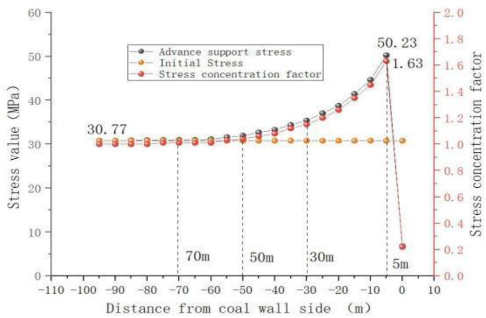


Figure1. Numerical Model

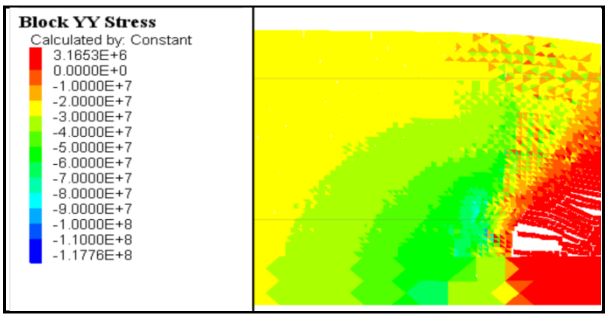
For the excavation of 10m each time, the distribution range and law of advanced supporting stress of the working face are studied through the distribution map of advanced supporting stress of different propulsion distances of the working face. With the advancement of the working face, the stress in the coal rock in front of the coal wall changes by the mining disturbance. In order to further study the distribution characteristics of the pressure in front of the work after mining, draw the distribution of the supporting pressure in front of the work at different propulsion distances. The stress distribution diagram of advanced support is shown in Figure 2



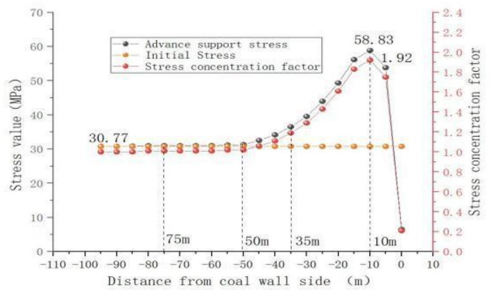
(a) Advance 30m Advance Support Pressure Cloud Map



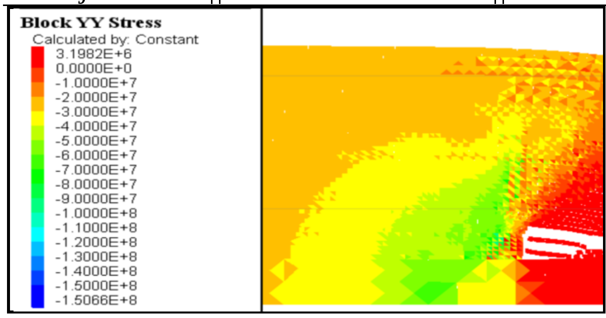
(b)Advance the Pressure Distribution Curve of 30m Advanced Support



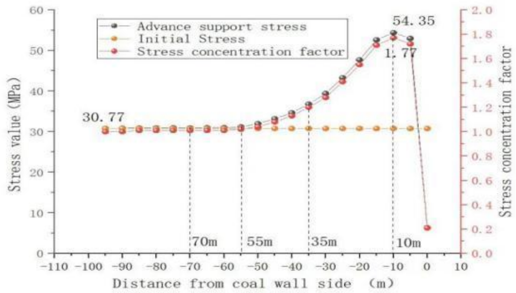
(c) Advance 60m Advance Support Pressure Cloud Map



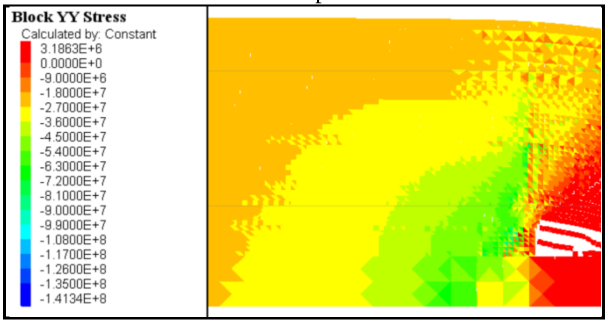
(d) Advance the Pressure Distribution Curve of 60m Advanced Support



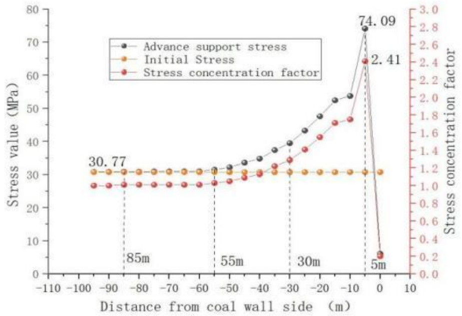
(e) Advance 90m Advance Support Pressure Cloud Map



(f) Advance the Pressure Distribution Curve of 90m Advanced Support



(g) Advance 120m Advance Support Pressure Cloud Map



(h) Advance the Pressure Distribution Curve of 120m Advanced Support

Figure 2.Stress distribution cloud map and stress curve of advanced support

During the mining process of the working face, the support pressure in front of the work face will experience an increase in stress, but the stress will decrease until it reaches the initial stress value. The peak stress of advanced support is approximately 5-10m away from the coal wall side, with a significant impact range of 30-35m. The maximum impact range of advanced stress can reach 90m away from the coal wall. The stress concentration coefficient ranges from 1 to 2.44.

IV. On Site Testing of Internal Stress in Coal Pillars

In order to better grasp the variation law of the support pressure on both sides of the working face that the coal pillar bears, measuring points are reasonably arranged along the groove on the working face of the coal pillar on the inner side of the second panel area. Supporting software is used to monitor and analyze the data, and the stress curve changes are obtained. Two sets of stress measurement points with a total of 8 different depths are arranged along the groove on the working face to monitor the stress distribution inside the coal pillar. The layout position of the stress gauge is shown in Figure 3.

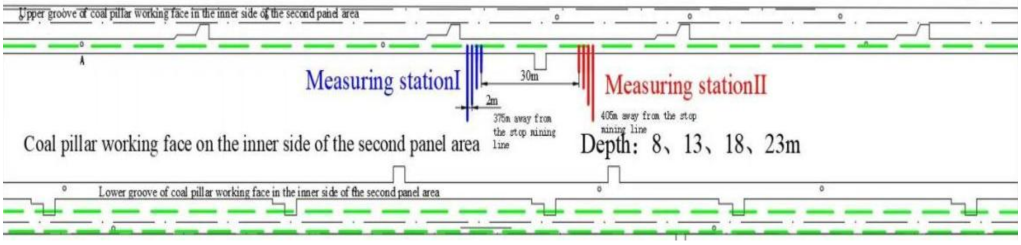


Figure3. Layout of stress gauges for the coal pillar working face inside the second panel area

The construction positions of the three groups of boreholes are all 1.5m away from the bottom plate of the upper groove, with a horizontal angle, and 42 anti protrusion drill rods are used for construction. During the construction and installation process, the construction and installation of stations ① and ② were normal, with final hole depths of 8m and 13m respectively During the construction of drilling hole ③ due to encountering water, the construction was stopped and the final depth of the hole was 17m. During the installation of drilling hole ④ a collapse occurred, and the installation depth of the stress gauge was 16m. The construction and installation of stations ⑤ and ⑥ at station II are normal, with final hole depths of 8m and 13m respectively

During the drilling process, debris was found and construction was stopped. The final depth of the hole was 17m During the drilling process, debris was found and construction was stopped. The final depth of the hole was 19m. The installation depth of each stress gauge is shown in Table 1.

Table 1 Stress Gauge Installation Depth

Observation Station I			Observation Station II		
Stress Gauge Number	Installation Site /m	Installation Depth/m	Stress Count Number	Installation Site /m	Installation Depth/m
①	405	8	⑤	375	8
②	407	13	⑥	373	13
③	409	17	⑦	371	17
④	411	16	⑧	369	19

The installation of the stress gauge is completed. The pressure recorder records the stress values of each borehole stress gauge every six hours and automatically stores the data. The data is collected by the data collector and transmitted to the computer terminal. Considering the large amount of stress meter testing data, only one data is taken per day during stress analysis. During the data selection process, any abnormal data caused by the possible instability of the testing system or other reasons were excluded (the abnormal data of stress meter ⑤ at 375m (stress value of 93.6MPa) has been removed). As shown in the Figure 4, the stress meter test curve is shown in Figure 3 after one month of collection by the stress meter. Except for the stress values of the ⑤ stress gauge installed at a depth of 8m in Station II, which have significantly increased, the data of other stress gauges in Station I and Station II have basically stabilized. From this, it can be seen that the internal stress of the coal pillar has been redistributed after being affected by the excavation disturbance on both sides of the working face.

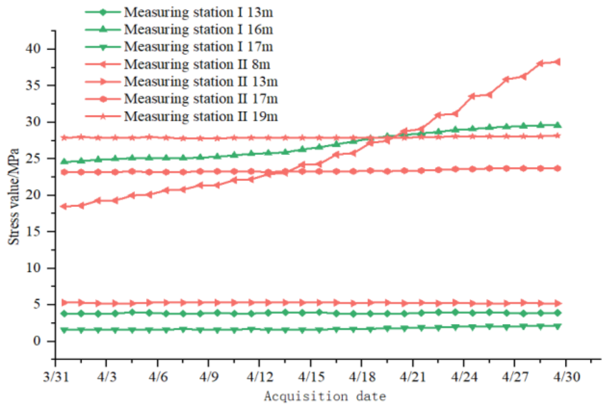


Figure 4. Plot of the stress values of different installation depth varying with date

Considering that the overlying loose layer of the coal seam is a clay layer with a relatively low bulk density compared to the bedrock, the data for calculating the original rock stress of the coal pillar is more accurate. Therefore, the calculation of the original rock stress of the coal pillar will be divided into the original rock stress of the loose layer and the original rock stress of the bedrock layer. The bulk density of the loose layer is taken as 17.00KN/m3, and the average bulk density of the bedrock layer is taken as 26.00KN/m3. After calculation, the original rock stress of the coal pillar is 11.3MPa.

In the test results of the stress meter, three sets of data were lower than the original rock stress value of the coal pillar. The reason may be due to the expansion of the borehole during drilling, which caused the stress meter probe to not be in close contact with the coal seam, resulting in a smaller value of the stress meter test.

The remaining normal data of the stress gauge were analyzed and extracted, and the known data was used for curve fitting. Finally, the stress distribution curve of the coal pillar in the 8-19m section from the roadway was obtained. Based on the numerical simulation results, the stress distribution curve and stress concentration coefficient inside the coal pillar were predicted and supplemented, as shown in Figure 5. Both numerical simulation and stress meter testing show a "saddle shaped" distribution trend of stress inside the coal pillar. The peak point of stress inside the coal pillar is located 6-8 meters away from the roadway on both sides of the coal pillar, and the stress value in the middle of the coal pillar working face is the lowest. The stress concentration coefficient inside the coal pillar is between 1.4 and 2.72.

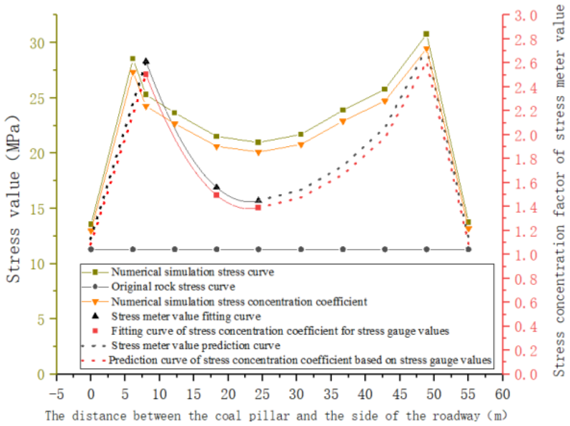


Figure 5. Fitting curve of stress and stress coefficient distribution inside coal pillars

In summary, the coal pillar working face is affected by the excavation disturbance on both sides of the working face, resulting in the concentration of stress inside the coal pillar. Overall, the stress inside the coal pillar shows a distribution trend of high, medium, and low on both sides, forming high concentration stress at the positions of the tunnels on both sides of the coal pillar. Therefore, during the mining process of the working face, attention should be paid to strengthening and supporting the tunnels. Measures such as advanced grouting of the tunnel roof or reinforcement and support with anchor rods and cables can be adopted to enhance the stability of the tunnels during the mining process.

V. Conclusions

(1) By combining numerical models with on-site testing data of internal stress in coal pillars, it is analyzed that the internal stress of coal pillars shows a distribution trend of high, medium, and low on both sides, with the peak stress located at a distance of 6-8 meters from the roadway on both sides of the coal pillar. The stress concentration coefficient inside the coal pillar is between 1.2 and 2.7. Monitor and prevent the high concentration stress of coal pillars during the mining process of the working face.

(2) According to the simulation results of numerical simulation software, the peak stress of the advanced support during the mining face is approximately 5-10m away from the front of the coal wall, with a significant impact range of 30-35m. The maximum impact range of the advanced stress can reach 90m away from the coal wall. The stress concentration coefficient ranges from 1 to 2.44.

VI. Acknowledgement

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