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Research Article

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Research on mine pressure law of working face passing through the boundary of overlying goaf

Zihan Yang

College of Safety Science and Engineering, Henan Polytechnic University, Jiaozuo, China, 454003
Email: 1592618547@qq.com

Abstract In order to study the safety production problem of the fully mechanized mining face passing through the boundary coal pillar of the upper goaf in a mine in Inner Mongolia, the similar material simulation and Flac 3 d numerical simulation were used to study the variation law of mine pressure in the process of advancing the fully mechanized mining face below. The results show that when the lower working face is 50 m away from the upper working face, the advance support pressure of the working face and the support pressure of the boundary coal pillar of the upper goaf begin to overlap. When the working face advances to 5m from the upper open-off cut, the stress superposition peak appears, and a crack running through the interlayer rock stratum appears in front of the working face. When the working face pushes through the upper cut 20 m, the influence range of the two stresses has been basically separated.

Keywords Downward mining; numerical simulation ; over mined-out area

1. Introduction

With the improvement of mechanization of coal resources mining and the gradual exhaustion of shallow coal resources, the mining depth of coal mines continues to extend [1]. With the increase of mining depth of coal mine, the influence of goaf on working face is becoming more and more serious [2]. When the working face passes through the boundary coal pillar of the goaf above, the advanced support pressure in the coal pillar and the support pressure in the boundary coal pillar of the goaf above are superimposed to become a high stress concentration area, and the frequency and intensity of coal and rock dynamic phenomena in coal mine are increasing. Many scholars have done a lot of research on the law rate of mine pressure when the downward mining face of close distance coal seam passes through the overlying coal pillar area. Liu Zhaoxing et al. [3], combined with the actual situation of Haoda Coal Mine, put forward the optimization design and improvement of the support of the fully mechanized mining face, and measured the support quality of the empty roadway through the working resistance of the hydraulic support and the subsidence of the empty roadway roof. Xiao Jianru [4] proposed that measures should be taken in advance from the design and mining process to enable early detection of potential hazards to be avoided. Li Haodang et al. [5] think that the overlying strata structure of the fully mechanized mining face in the downward mining of shallow buried close-distance coal seams is certainly unstable in the coal pillar stage, and the roof dynamic pressure disaster will inevitably occur. By analyzing the causes of the roof dynamic pressure disaster and the movement state of the overlying strata, the treatment scheme of using blasting means to deal with coal pillars in advance is proposed.

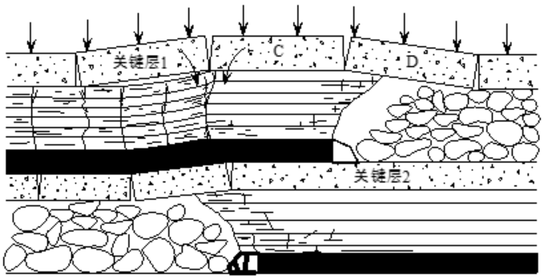
Most of the existing researches on the boundary of the goaf above the working face put forward pressure relief and support schemes for the whole area of stress concentration. As a strong mine pressure phenomenon, the internal mine pressure changes with the advance of the working face. Through similar material simulation, the movement law of overlying strata in the mine is understood. Combined with numerical simulation, the internal stress variation law in the process of working face advancing is studied, which can effectively avoid the stress peak area and provide a new scheme for the mine pressure control of the working face passing through the upper goaf boundary.

2.Project Profile

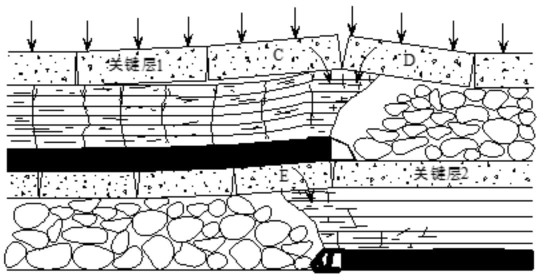
The mine is located in Ordos City, Inner Mongolia Autonomous Region. The designed recoverable reserves of the mine are about 180,000 tons, and the designed production capacity is 10 million tons / year. The mine belongs to the weak impact tendency mine, which has the prerequisite for the occurrence of rock burst. At present, the roof and floor of the 31 mining area of No.3 coal seam have weak impact tendency, and the mining area begins to enter the upper 2 coal goaf from the 315 working face. The mining practice shows that the mining pressure of the fully mechanized mining face is relatively strong when passing through the open-off cut in the upper goaf, which is mainly manifested in the coal wall spalling, roof caving and obvious shrinkage of the support movable column of the 315 working face in the area below the open-off cut. The working face is prone to the phenomenon of dynamic load mine pressure, which has a certain impact on the safety production of the mine.

3.Mechanism of Working Face Crossing Goaf Boundary

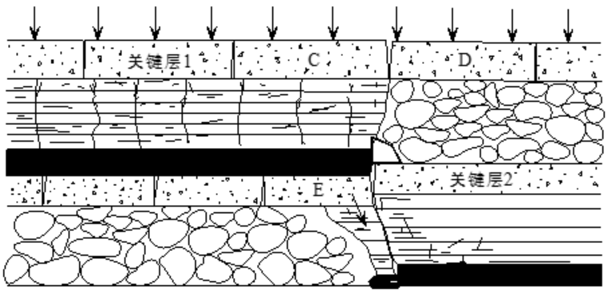
After the upper coal is mined, the overlying strata near the open-off cut is a hinged structure, as shown in Figure 1, and this structure bears the load of the part of the rock strata it controls[6]. In the process of pushing the lower coal seam working face through the open-off cut, the fractured rock block of the structure will inevitably produce further rotational movement, and the huge force generated by it will further lead to the sliding instability of the lower coal seam roof structure, and finally cause the occurrence of dynamic load mine pressure accident in the lower coal seam working face [7].



(a)



(b)



(c)

Figure 1: Schematic diagram of key block movement in coal pillar stage of working face

As the 315 working face gradually advances to the boundary of the goaf, the key strata above the 315 working face will gradually undergo periodic breaking and rotary motion, and the rock blocks are hinged with each other. Finally, the three-hinged arch hinge structure shown in figure 1 (a) will be formed near the boundary cut of the goaf. When the working face is about to advance to the boundary of the goaf, the broken block C has not yet rotated. As the working face continues to advance, the rock layer below the block will gradually move down with the fracture rotation, which provides a rotating space for the block C.Finally, the block will bite with the broken block D to form an arched lap structure, showing the state shown in Fig.1 (b). Theoretical analysis and field practice show that when the working face pushes out the boundary of the goaf, the sliding instability of the key block structure above the coal pillar is inevitable, which causes the dynamic load pressure problem of the working face in the boundary stage of the goaf.

It can be seen from the borehole histogram near the 315 working face that there is a thick sandstone or sandy mudstone above the coal seam. It can be seen from the existing test results that the compressive strength of the coal seam roof is mostly about 30 MPa, but in view of its large thickness, there is a hinged structure near the boundary of the upper goaf. After the mining of the 315 working face, it will lead to the instability of the overlying hinged structure, which in turn will cause the phenomenon of strong dynamic pressure on the working face.

4. Similar Material Simulation Experiment

A. Experimental Design of Similar Material Simulation Method

According to the research purpose of this subject, a plane simulation test bench was used. The specifications (length, width and height) of the plane simulation test bench were 4200mm × 250mm × 1800mm, and the effective experimental heights were 1700mm, respectively. A total of one test was designed to simulate the failure law of overburden rock on the strike section

The similar material is composed of a binder and a filler [8]. The binder is gypsum, calcium carbonate is added at the same time, and the filler is sand. The different proportions of similar objects and models can be achieved by similar materials with different proportions. According to the selected simulation material characteristics and ratio experiments, the bulk density similarity constant is: ar = rm / rp = 0.6. According to the similarity principle and dimensional analysis, aσ = 0.003, at = 0.07 can be calculated.

The model test uses a similar material of gypsum and filler, and calcium carbonate is added. The filler is sand, and the mica powder is scattered among the layers to play a layered role. According to the above similar constants, the bulk density and mechanical strength of the model rock layer laying can be determined, and then the material ratio can be determined, the material consumption of each layer can be calculated, and the model can be made. After the model is made, the rock strata movement measuring points are arranged and the model is dried for about 3 days, and the model is depressurized and stabilized for 1 day in advance before mining

The working face of the test model adopts the whole caving method to manage the working face of the whole high mining in the partition section of the roof. The simulation experiment first mines the upper coal, and the mining is completed. After the upper rock layer is stable, the 315 coal is mined upward. During the whole test process, photographs were taken after each mining, and then the next mining was continued until all the working faces were mined. Finally, the overall movement and deformation of the overlying coal strata were observed after the movement was stable, the material model is shown in Fig. 2.

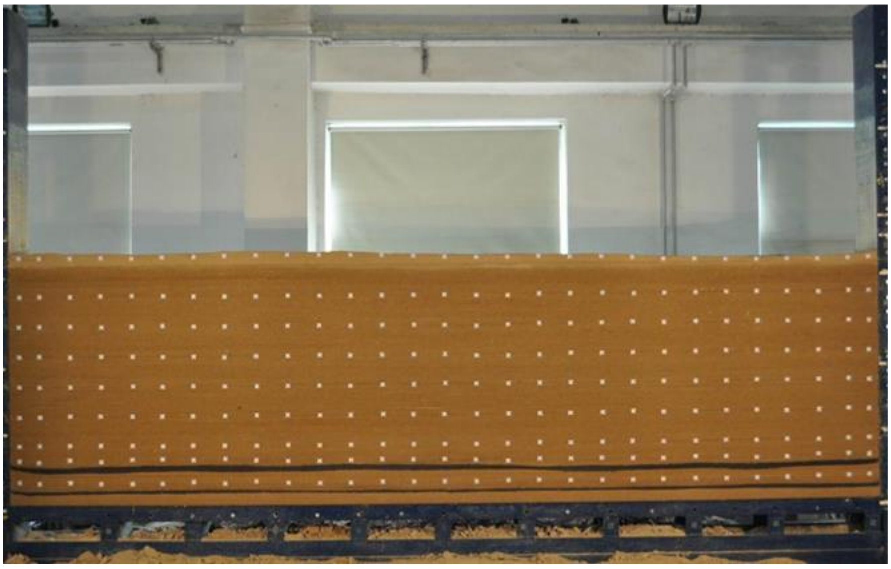
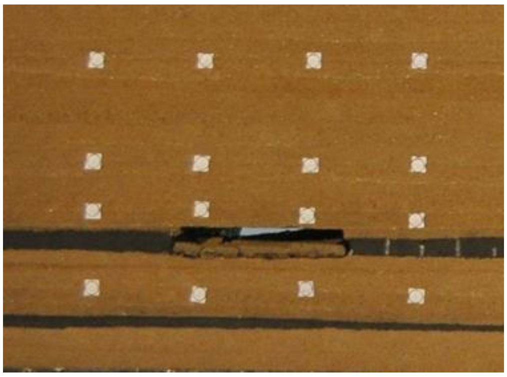


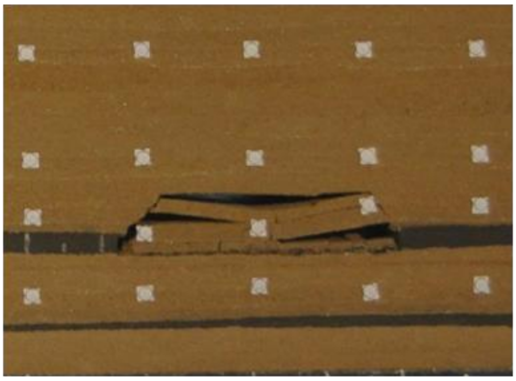
Figure 2: Equivalent material model

B. Analysis of Overlying Rock Movement Law

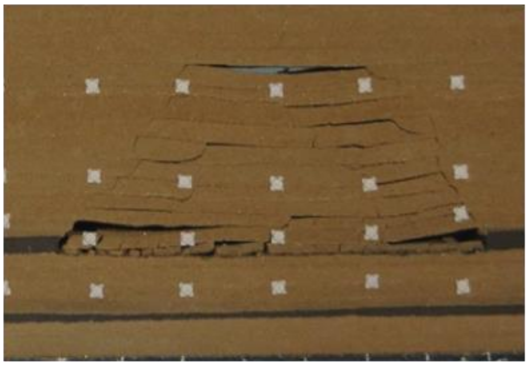
The working face begins to be mined from the open-off cut. With the continuous advancement of the working face, the overlying strata are damaged to varying degrees, and the roof strata are caving, breaking, bending and interlayer separation. After the mining of the working face is stable, the middle rock layer is basically compacted, and the cantilever beam and cavity structure are caused by the support of the boundary coal pillar at the boundary of the cut hole. The length of the cavity development interval is about 5cm (10m), and the position is generated at the interface between the immediate roof and the main roof, as shown in the figure 2.



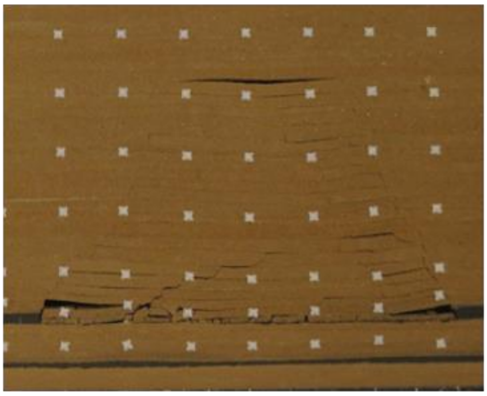
(a) The working face is advanced by 25 cm



(b) The working face is advanced by 38 cm



(c) The working face is advanced by 70 cm

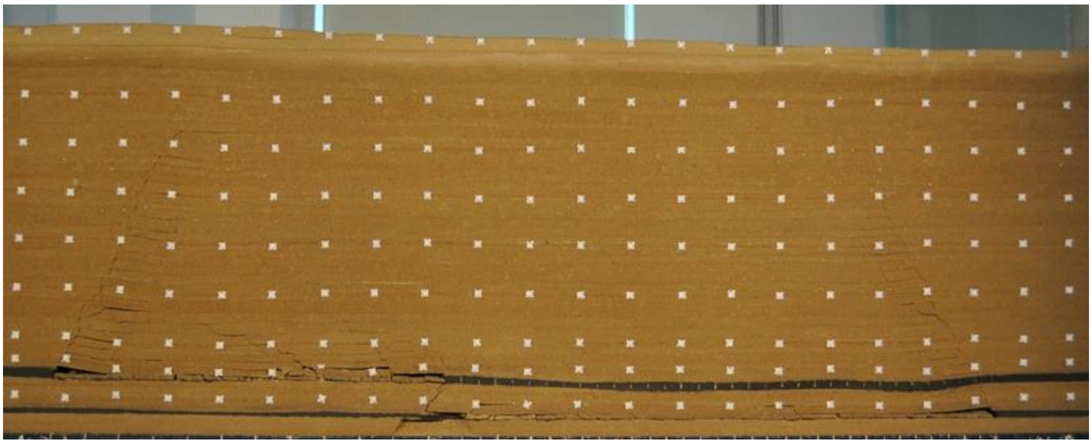


(d) The working face is advanced by 100 cm

Figure 3: Overburden strata movement during upper coal seam mining

When the 315 working face is mined to 15 cm from the boundary of the goaf above, the interlayer rock and roof rock near the boundary of the goaf appear obvious subsidence, which makes the cracks and cavities existing before the area further compacted, and a crack through the interlayer rock layer appears. The crack dip angle is about 56 °, as shown in figure 4

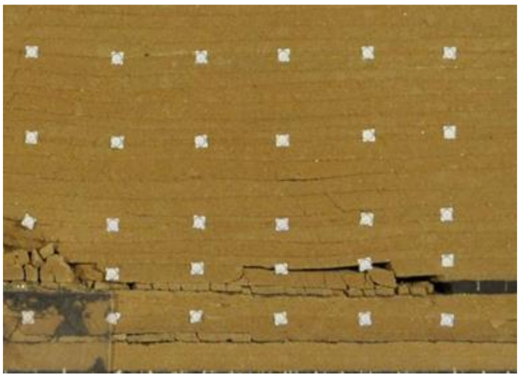
During the mining process of the 315 working face, the working face passes through the upper goaf boundary stage (transition stage), which is slightly affected by the residual abutment pressure. Occasionally, the roof suddenly collapses, and other sections are basically normal. The roof and floor strata are basically stable.



(a) The 315 working face is close to the boundary of the goaf above

(b) Working face is ready to enter 31201 open-off cut (local enlargement map)

(c) The working face is located directly below the boundary of the goaf (local amplification map)



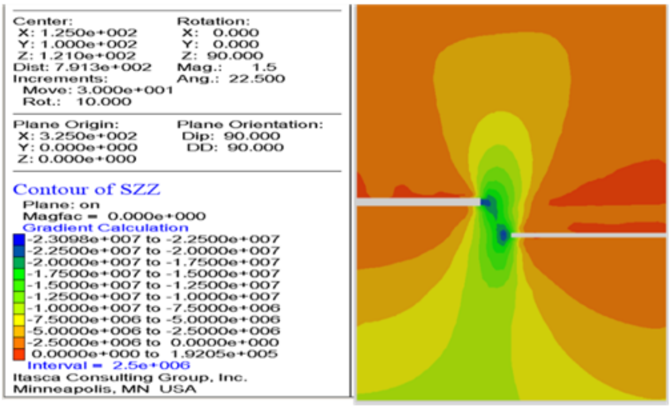
(d) Working face into the goaf 40cm

Figure 4: Working face through the upper goaf boundary overlying strata movement

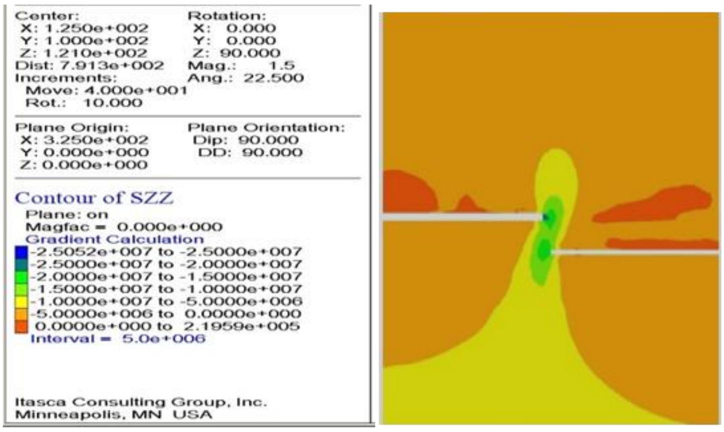
C. Numerical simulation

In order to predict the mine pressure characteristics of the subsequent working face passing through the boundary of the upper goaf, based on the occurrence conditions of the coal seam, the FLAC 3D numerical simulation software was used to construct the FLAC 3D three-dimensional numerical model. The vertical stress of the stope at different distances from the boundary of the upper goaf during the mining process of the 315 working face is shown in Fig. 5. It can be seen from the figure that when the 315 working face advances to about 50 m in front of the upper goaf boundary, the advance support pressure in front of the working face and the lateral support pressure of the upper goaf boundary begin to have a superposition trend. As the working face continues to advance, the superposition effect of the two becomes more obvious. When the 315 working face advances to about 5m in front of the upper goaf boundary, the advance support pressure in front of the 315 working face is completely superimposed with the lateral support pressure of the upper goaf boundary.

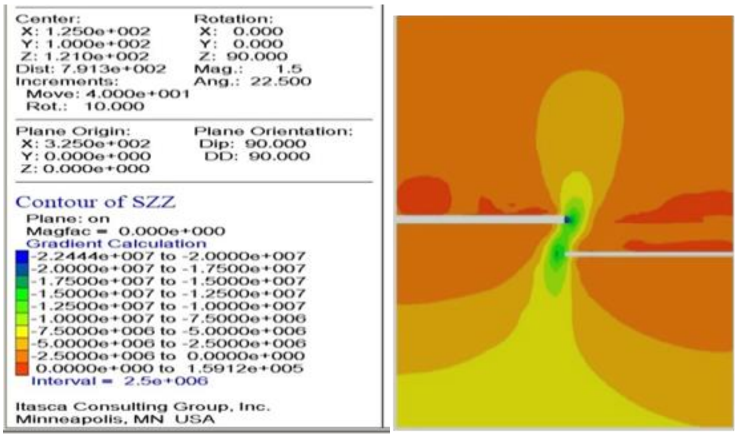
Since then, with the continuous advancement of the working face, the superposition effect of the two has gradually weakened. When the working face advances to about 20 m behind the open-off cut in the upper goaf, the advanced support pressure in front of the working face is completely separated from the lateral support pressure at the boundary of the upper goaf. In addition, it is worth noting that the stress values of both are significantly reduced at this time. The reason is that the goafs of the two coal seams are mined as each other 's protective layers at this time, that is, the pressure relief effect has begun to appear.



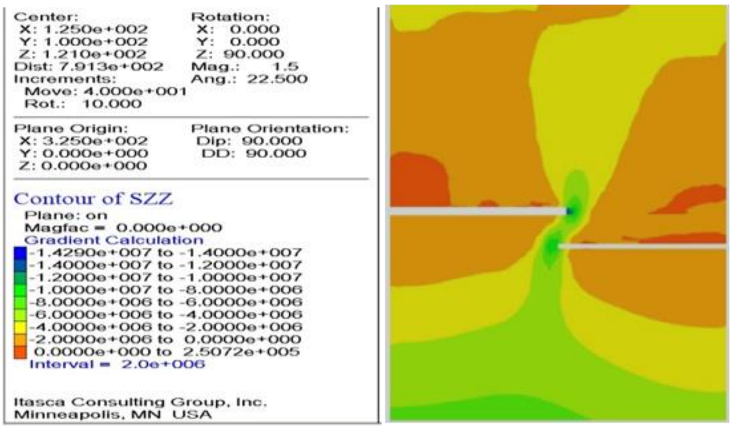
（a）*The working face is 20 m away from the boundary of the upper goaf.*



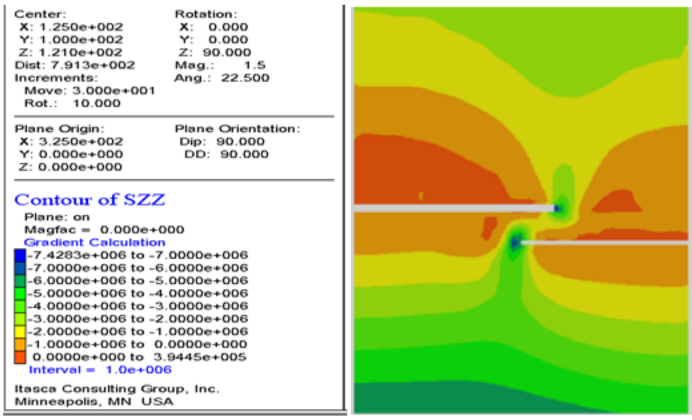
（b）*The working face is 5 m away from the boundary of the upper goaf.*



（c）*The working face is located directly below the boundary of the upper goaf.*



(d) The working face passes the boundary of the upper goaf by 5 m.



(e) The working face passes the boundary of the upper goaf by 20 m.

Figure 5: The stress distribution when the working face passes through the upper goaf boundary at different distances

5. Conclusion

In summary, during the mining period of the 315 working face, the largest hazard source will be the secondary instability of the ' suspended structure ' at the boundary of the upper goaf under the action of multiple mining-induced stresses. Based on this, the mining process of the working face can be divided into three stages as shown in the following figure.

(1) The first stage is that the 315 working face starts from the open-off cut of the working face to 40 m before the boundary of the upper goaf.

(2) The second stage is the 315 working face from the upper goaf boundary 40 m, to push the upper goaf boundary 20 m.

(3) In the third stage, the 315 working face passes through the upper goaf boundary by 20 m to the end of mining. The first stage of the three stages is the normal mining stage, and the risk degree of the mining stage is the smallest.

the second stage is the stage of cutting through the lower goaf, which is the most dangerous stage. It is considered that the whole working face area of this stage is a dangerous area, and the danger of this area is mainly the sudden instability of the ' suspension structure ' at the upper goaf.The working face is 5m away from the upper goaf boundary, and the stress superposition peak appears. At this time, the stress in the coal rock mass reaches the maximum value. Therefore, the working face should quickly push through the position and the nearby area during the mining process to avoid long-term stay.

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