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Numerical Simulation Study on the Influence of Roof-Cutting Angle on the Stability of Gob-Side Entry Retaining Without Coal Pillars

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ABSTRACT

For the gob-side entry retaining of the 21311 auxiliary intake airway in Xiangshan Mine, a numerical calculation model for automatic entry formation through roof cutting and pressure relief in the fully-mechanized mining face of Xiangshan Mine was established using numerical simulation software. The model simulated the stress and displacement distribution characteristics of the surrounding rock when the roof-cutting height was 6 m and the slit angles were 0°, 5°, 10° and 15°. It also analyzed the impact of the roof-cutting angle on the pressure relief effect. The research results indicate that increasing the roof-cutting angle is conducive to pressure relief on the roadway roof, but the effect becomes less pronounced once the angle increases to a certain extent. Through numerical simulation, it was determined that when the reasonable roof-cutting height in Xiangshan Mine is 6 m, the reasonable roof-cutting angle is 10°.

KEYWORDS

Gob-side entry retaining without coal pillars; Cutting the top; Stress; Displacement; Pressure relief effect.

1. INTRODUCTION

The pillarless gob-side entry retaining can improve the coal recovery rate and reduce the roadway driving rate [1-2]. However, its stability is influenced by multiple factors, with the roof-cutting angle being one of the key factors [3-4]. Numerous previous studies centered around this have found that changes in the roof-cutting angle can alter the caving pattern of the roof in the goaf, the stress distribution on the roadway roof, and the deformation characteristics [5]. A reasonable roof-cutting angle can promote the timely caving of the goaf roof, expand the pressure relief zone of the roadway, and ensure the stability of the retained entry; whereas an improper angle may exacerbate stress concentration, cause abnormal roof subsidence, and threaten the safety of the retained entry [6-8]. Therefore, clarifying the influence pattern of the roof-cutting angle on the stability of the pillarless gob-side entry retaining is of great significance for guiding practical production.

The 21311 fully-mechanized mining face in Xiangshan Mine is located in the middle and lower part of the South No.1 Dip Mining District and belongs to the No.3 coal seam. The mining method employed at the face is the fully-mechanized, full-seam height, strike longwall mining method, with the roof managed using the caving method. The roadways are arranged along the strike of the coal seam, with the main intake airway sharing the same airway as the auxiliary intake airway of 21310. The strike length (average) of the mining face is 1,309.2 m, with a dip width of 205 m and an area of

268,386 m2. To the east, it is adjacent to the goaf of the 21310 fully-mechanized mining face. To the south, a 753.7 m protective coal pillar is left between the open-off cut and the South No.1 3# coal boundary return air dip. To the west, it is adjacent to the designed 21312 fully-mechanized mining face (solid coal seam). To the north, an 118.9 m protective coal pillar is left between the stopping line and the South No.1 5# coal track dip. The floor elevation of the coal seam in the target roadway ranges from +106 m to +144 m, corresponding to a surface elevation of +616 m to +789.1 m, with an overburden thickness of 472 m to 683.1 m. The specific conditions of its roof and floor are as follows: (1) False roof: The false roof has a thickness ranging from 0.10 m to 0.20 m, with an average thickness of approximately 0.15 m. It consists of gray-black mudstone, which is blocky and easily fractured, and caves with the coal seam during mining. (2) Direct roof: It is composed of silty mudstone, siltstone, and fine sandstone, which are black, gray-black, or gray in color, with medium-thick bedding, calcareous-mud cementation, and containing a small amount of mica flakes. The thickness ranges from 2.5 m to 4.5 m and includes a coal seam layer. It is relatively dense and hard, with well-developed roof fissures (1-2 fissures per meter), classified as a Type 2, moderately stable roof. (3) Main roof: It consists of interbedded siltstone, fine sandstone, and medium sandstone, which are dense and relatively hard, with mud cementation, horizontal bedding, and extremely thick bedding. It contains a small amount of mica flakes and complete plant leaf fossils in the lower part. The rock stratum thickness ranges from 4.5 m to 6.0 m, with an average of 5.0 m, classified as a Grade II clearly defined type roof. The saturated compressive strength ranges from 22.8 to 73.8 MPa, and with moderate rock mass integrity and good quality. (4) Floor: The false floor in this mining face is not well-developed. The direct floor is composed of gray silty sandstone with mud cementation and medium-thick bedding, containing plant root and stem fossils. The thickness ranges from 3.8 m to 5.2 m, with an average of approximately 4.2 m.

Therefore, using numerical simulation software to analyze the influence of top cutting angle on the pressure relief effect of the auxiliary air intake roadway along the goaf of Xiangshan Mine 21311.

2. CONSTRUCTION OF NUMERICAL SIMULATION MODEL

Taking the roadway with roof cutting and gateway retention in Xiangshan Mine as the geological background, a numerical simulation model is established. The model size is 100 m × 300 m × 50 m, with a simulated length of 300 m, width of 100 m, and height of 50 m. The coal seam is buried at a depth of approximately 500 m, and an in-situ stress of about 12.5 MPa is applied. Within a 50 m range of the coal seam where the roof cutting and gateway retention is implemented, the impacts of various factors on the gob-side entry retaining are analyzed. The physical and mechanical parameters of the roof and floor, as well as the numerical calculation model, are presented in Table 1 and Figure 1, respectively.

Table 1 Physical and mechanical parameters of roof and floor

Lithology	Density/ (kg/m3)	Bulk modulus/ GPa	Shear modulus/ GPa	Internal friction angle/°	Cohesion /MPa	Tensile strength /MPa
Medium grained sandstone	2720	14.5	12.5	37	5.2	4.2
Fine sandstone	2640	15.6	10.8	34	4.3	2.4
Siltstone	2520	9.15	4.21	33	2.4	1.3
Coal seam	1500	0.79	0.71	28	0.9	0.5
Sandy mudstone	2500	8.75	4.02	36	4.5	1.1

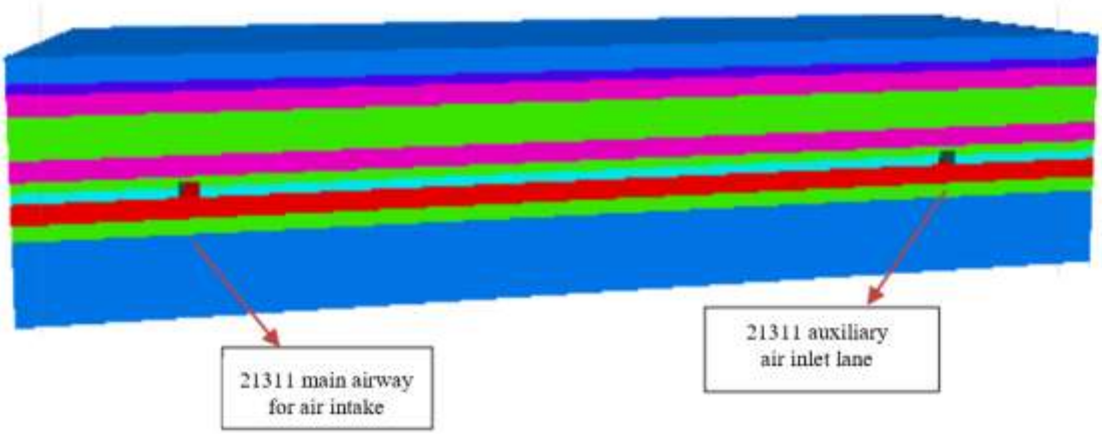


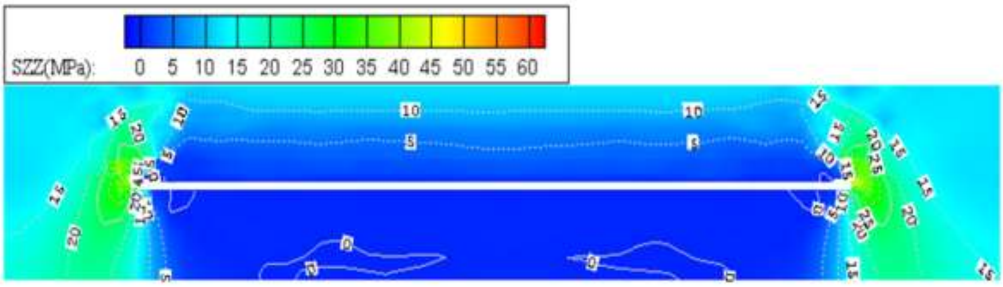
Figure 1 Numerical simulation model

According to the theory of strata control, after roof cutting is carried out on the roadway roof, the rock mass above the goaf sinks under the action of the self-weight stress of the overlying strata. During the sinking process, it interacts with the roadway roof to varying degrees, resulting in significant deformation of the roadway roof. Based on past construction experience in roof cutting for pressure relief and gob-side entry retaining, deflecting the cutting seam by a certain angle towards the goaf side facilitates roof caving and reduces the pressure exerted by the overlying strata on the roadway roof. To investigate the influence law of roof cutting angles on mine pressure manifestation and determine a reasonable cutting seam angle, simulations were conducted with a roof cutting height of 6 m, examining the stress distribution characteristics of the surrounding rock at cutting seam angles of 0°, 5°, 10°, and 15°. The study also analyzed the stress variations in the roof and floor of the 21311 auxiliary intake airway, as well as the impact of cutting seam angles on stress contour plots and peak stress values.

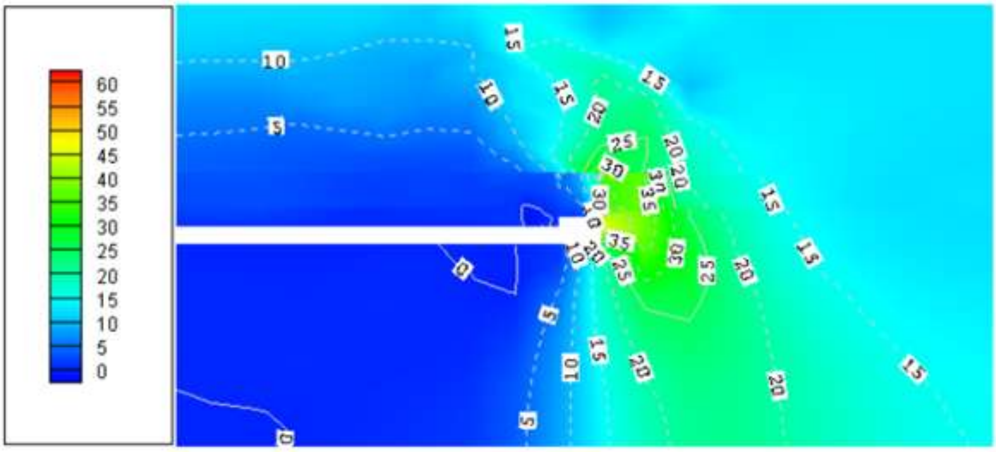
3. SIMULATION RESULTS

3.1. Stress change

When the cutting height is 6m and the cutting angles are 0°, 5°, 10°and 15°, the stress cloud maps are shown in Figure 2 and Figure 3.



(a) Stress cloud map of uncut roof mining



(b)Stress cloud map of auxiliary air intake roadway without cutting top 21311

Figure 2 Stress cloud map without cutting top

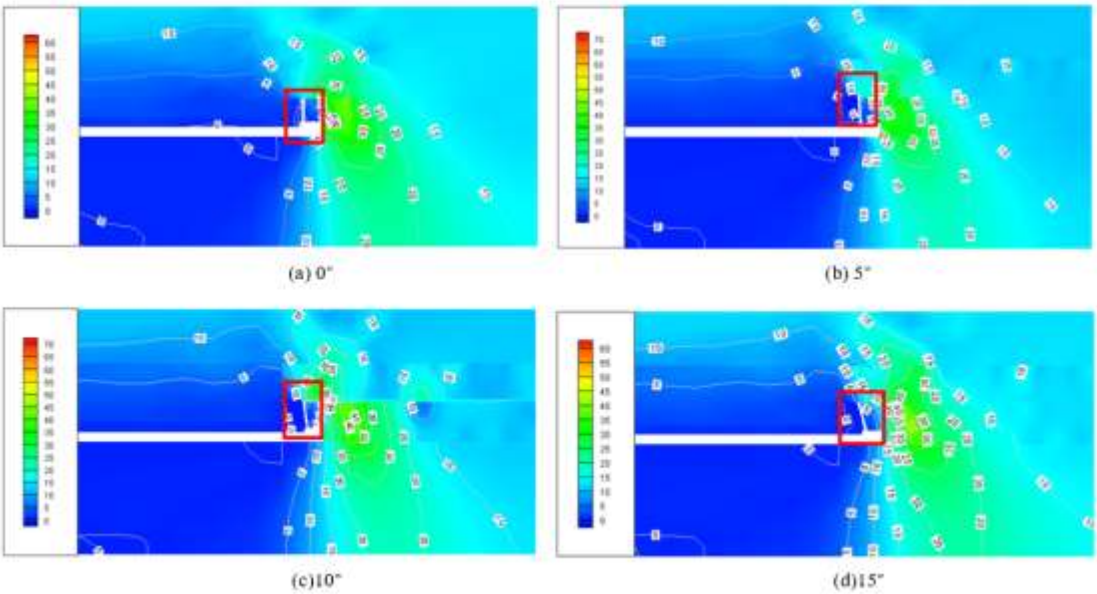


Figure 3 Stress cloud map of auxiliary air intake roadway at different cutting angles (depth 6m)

A comparison based on Figure 2 and Figure 3 reveals that, under the non-roof-cutting condition, the stress contour lines near the 21311 auxiliary intake airway are densely distributed, with a high stress peak. The maximum vertical stress reaches up to 40 MPa, which is 3.2 times the in-situ rock stress. When the roof cutting angle ranges from 0° to 15°, there is no significant change in the stress curves around the 21311 gob-side entry retaining. The area around the roof cutting line falls within a pressure relief zone, and the stress around the roadway and near the roof cutting line decreases markedly.

Within the roof cutting angle range of 0° to 15°, the maximum vertical stress in the surrounding rock of the 21311 auxiliary intake airway is 25 MPa to 30 MPa, indicating a notable pressure relief compared to the non-roof-cutting scenario. When the angle is between 0° and 10°, the stress contour values around the auxiliary side (solid coal side) of the roadway decrease, with a minimum value of 15 MPa. Between 10° and 15°, the region of increased stress around the auxiliary side gradually shifts towards the auxiliary side. As the roof cutting angle increases, the stress in the floor of the 21311 auxiliary intake airway gradually decreases, and the area of increased stress gradually extends towards the auxiliary side, although the magnitude of the stress increase is minimal and nearly negligible.

3.2. Displacement change

When the cutting height is 6m and the cutting angles are 0°, 5°, 10°and 15°, the displacement cloud maps are shown in Figure 4 and Figure 5.

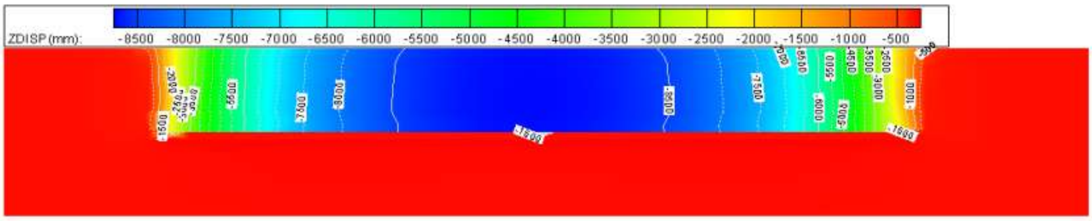


Figure 4 Displacement cloud map without cutting top

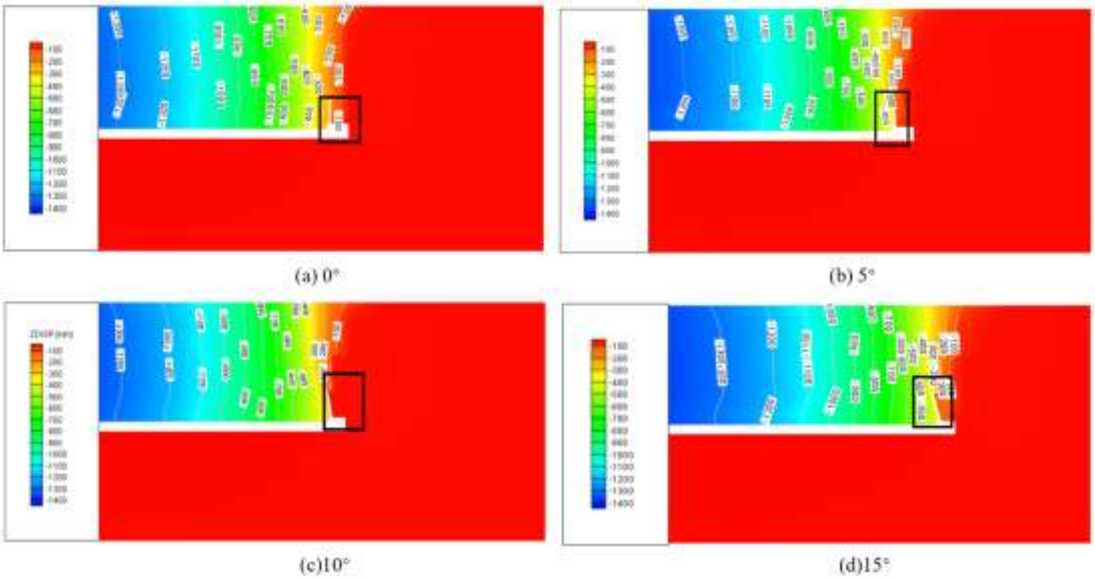


Figure 5 Displacement cloud map of auxiliary air intake roadway at different cutting angles (depth 6m)

A comparison based on Figure 4 and Figure 5 reveals that,, under both the roof-cutting and non-roof-cutting conditions, the displacement in the upper part of the roadway roof significantly decreases. In the non-roof-cutting state, the subsidence near the roof ranges from 1000 mm to 1600 mm. In the roof-cutting state, the roof subsidence sharply decreases to approximately 100 mm to 300 mm on the right side of the roof-cutting line and in the vicinity of its extension at the top of the roadway. The area where subsidence accumulates and rises continues to shift inward toward the coal mass, but the amount of subsidence does not increase. Under the roof-cutting condition, the maximum roof subsidence at the working face is about 1300 mm, which is a reduction of 300 mm compared to the maximum roof subsidence in the non-roof-cutting state. When the roof-cutting angle ranges from 0° to 10°, the roof subsidence in the 21311 auxiliary intake air roadway continues to decrease, and the area where subsidence accumulates shifts inward toward the roof of the working face, while the extent of the pressure relief zone increases. Near the extension line of the roof-cutting line, the subsidence continues to decrease. When the roof-cutting angle is 10°, the roof subsidence in the auxiliary intake air roadway is 200 mm. When the roof-cutting angle is 15°, there is a slight increase in subsidence near the roof-cutting line, with the subsidence ranging from 300 mm to 400 mm.

4. DISCUSSION AND CONCLUSION

Through comparative research, the following findings have been obtained:

(1) As the roof-cutting angle increases, the extent of the low-stress zone on the roof of the goaf side expands, indicating that increasing the roof-cutting angle facilitates the caving of the roof in the goaf and reduces the unsupported roof span in the goaf. However, when the roof-cutting angle increases to a certain extent, the expansion of the low-stress zone on the goaf side becomes less pronounced.

(2) A larger roof-cutting angle results in a wider pressure relief zone on the roadway roof, suggesting that increasing the roof-cutting angle is beneficial for pressure relief on the roadway roof. However, when the roof-cutting angle reaches 15°, the expansion of the pressure relief zone on the roadway roof becomes less significant.

(3) When the roof-cutting angle is 0°, the maximum vertical stress within the solid coal rib is 30 MPa, which is 2.4 times the in-situ rock stress. When the roof-cutting angle is 10°, the maximum vertical stress is 22 MPa, which is 1.76 times the in-situ rock stress. When the roof-cutting angle is 15°, the maximum vertical stress is 26 MPa, which is 2.1 times the in-situ rock stress. These findings indicate that as the roof-cutting angle increases, the degree of stress concentration also increases, but the stress concentration zone shifts towards the deeper part of the coal mass, the upper part of the roof, and the far end of the solid coal rib.

(4) When the roof-cutting angle ranges from 0° to 10°, the subsidence near the roof-cutting line continuously decreases. When the angle ranges from 10° to 15°, there is a slight increase in subsidence, and the area with concentrated subsidence shifts towards the deeper part of the coal mass and the upper part of the roof. And the reasonable roof-cutting height for Xiangshan Mine is 6 meters, and the reasonable roof-cutting angle is 10 degrees.

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REFERENCES

[1] Wang Yufeng. Research on Comprehensive Gas Control Technology in Gob-Side Retaining Roadway Without Coal Pillar Mining[J]. Coal Technology, 2025, 44(02): 139-142.

[2] Zhao Mengye, Huang Qingxiang, Huang Kejun, et al. Strata Behavior Law of Gob-Side Entry Retaining by Roof Cutting Without Coal Pillar[J]. Journal of Xi'an University of Science and Technology, 2019, 39(04): 597-602.

[3] Xue Weifeng, Hou Enke, Wang Sujian. Floor Failure Law of Gob-Side Entry Retaining by Roof Cutting Without Coal Pillar[J]. Journal of Xi'an University of Science and Technology, 2022, 42(06): 1133-1139.

[4] Lyu Guangpeng. Study on Roof Cutting and Pressure Relief Parameters of Gob-Side Retaining Roadway in Fully Mechanized Mining[J]. Shandong Coal Science and Technology, 2025, 43(03): 12-17.

[5] Yin Helin. Simulation Analysis of Key Roof Cutting Parameters and Filling Body Width in Gob-Side Entry Retaining[J]. Shanxi Metallurgy, 2024, 47(06): 107-109.

[6] Liu Yaoyue, Wen Daoyi, Wang Chao. Research on Key Technical Parameters of Roof Cutting and Pressure Relief in Gob-Side Entry Retaining Under High Ground Stress Conditions[J]. Energy and Energy Conservation, 2024, (03): 212-215.

[7] Du Xianchi, Guo Lipeng. Research on Key Parameters of Roof Cutting and Pressure Relief Mining in Gob-Side Entry Retaining at Shandong Hongyang Mining[J]. Shandong Coal Science and Technology, 2023, 41(10): 1-4+8.

[8] Zhang Junhu, Nian Jun, Zhao Bo, et al. Influence of Roof Cutting Parameters on Surrounding Rock Stability Under Dual Roof Cutting and Gob-Side Entry Retaining Conditions[J]. Safety in Coal Mines, 2024, 55(06): 134-140.