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Research on Roof Cutting and Pressure Relief Technology of Deep Hole Pre-cracking Blasting

Jilong Qin, Peng Zhu *

Kuqa County Yushuling Coal Mine Co. LTD, Aksu Prefecture, Xinjiang, China

*** Corresponding author:** Peng Zhu

Abstract: The dynamic pressure gob-side entry is affected by the whole mining process of the working face, and the cause of the large deformation is the additional stress generated during the rotary sinking process of the key block. Therefore, in order to alleviate the deformation of surrounding rock of roadway along goaf. The deep hole pre-splitting blasting roof cutting pressure relief method is used to relieve the pressure of the test roadway. In this study, finite element and discrete element models were established by means of numerical simulation and theoretical analysis, and the law of influence of cutting top height and Angle on roof cutting effect is studied. The optimal cutting height and angle are 15 m and 10° towards the gob, respectively. The industrial test results show that the deformation of surrounding rock of the test roadway is controlled within a reasonable range after pressure relief, and the roadway section meets the production demand.

Keywords: Dynamic Pressure Gob-side Entry; Deep Hole Pre- cracking Blasting; Numerical Simulation; Parameter Optimization.

1. Introduction

In order to improve the confining stress condition of roadway and increase the recovery rate of coal resources, experts and scholars have invented the layout of goaf roadway. However, the traditional goaf excavation needs to be carried out after the goaf is completely stable, which causes problems such as tight excavation succession [1]. Therefore, based on the traditional goaf excavation, some scholars put forward the new layout of goaf excavation and small pillar excavation under constant dynamic pressure [2]. However, the goaf roadway under dynamic pressure needs to experience the whole process of mining influence near the working face, resulting in large deformation of the surrounding rock of the roadway, which will also induce mine pressure and associated disasters in serious cases. It is found that the power source of large deformation of goaf roadway under dynamic pressure is mainly from the "given deformation pressure" formed by the rotation and subsidence of the key block at the end of the adjacent surface. Therefore, the research on the key block cantilever beam structure has certain practical significance for the maintenance of goaf roadway under dynamic pressure [3].

Experts and scholars have carried out a lot of research on the stability control technology of surrounding rock of goaf roadway under dynamic pressure, and achieved a lot of results. Zha Wenhua et al [4] used theoretical analysis methods to analyze the deformation characteristics of surrounding rock in narrow coal pillar excavation, and put forward reasonable coal pillar size and excavation time, providing reference for similar engineering conditions. He Fulian et al [5] used theoretical analysis methods to analyze the deformation characteristics of surrounding rock in narrow coal pillar excavation, and put forward reasonable coal pillar size and excavation time, providing reference for similar engineering conditions. Fan Kegong et al [6] analyzed the deformation characteristics of coal pillar in goaf roadway under dynamic pressure and proposed an asymmetric deformation control method for goaf roadway to improve the stress environment of surrounding rock of roadway. He Manchao et al [7] proposed a long and short cantilever beam structure model in view of the excessive additional stress caused by excessive cantilever structure in surrounding rock of goaf roadway under dynamic pressure, and realized the purpose of transforming a long cantilever beam into a short cantilever beam by using the top-cutting pressure relief technology. Wang Meng et al [8] based on the masonry beam theory, analyzed the stability characteristics of roadway and coal pillar in the process of overburden rotation and subsidence of gob roadway, and proposed the coordinated control technology of top-cutting pressure relief and asymmetric support.

The above experts and scholars respectively use different research methods to put forward reasonable suggestions for the maintenance of dynamic pressure gob roadway from the aspects of stress, support and pressure relief, among which the application of top-cutting pressure relief technology effectively controls the "given deformation pressure" exerted by the subsidence of key blocks. However, most scholars have studied the principle of pressure relief by cutting the top, but few have studied the design of technical parameters of pressure relief by cutting the top of gob roadway. Therefore, this study carried out research on top cutting and pressure relief technology to determine key top cutting and pressure relief parameters such as top cutting depth, Angle and drill row spacing under specific engineering conditions, and the research results provided a basis for the design of top cutting and pressure relief schemes under similar engineering conditions.

2. Engineering Background

There are three working faces arranged in the first mining area of Yushuling Coal mine, of which 110501 working faces has been mined and 110503 working face is being arranged at present. When the mine plans to arrange the 110503 working face, the 110505 track transportation chute will be dug out by leaving small coal pillars, that is, after the 110503 working face is mined, the 110505 track transportation chute will be retained as the 110505 working face return air chute. The 110505 rail transportation channelling needs to experience the mining influence of 110503 working face, which is a typical dynamic pressure goaf roadway. The excavation engineering plane is shown in Figure 1.

The top coal is about 5.77 m thick. The direct top of the coal seam is dominated by siltstone, and the lithology exposed upward includes fine sandstone, medium sandstone and gravelly sandstone. The basic top is fine sandstone with a thickness of 9.95 m. The column information of the borehole near the test roadway is shown in Table 1.

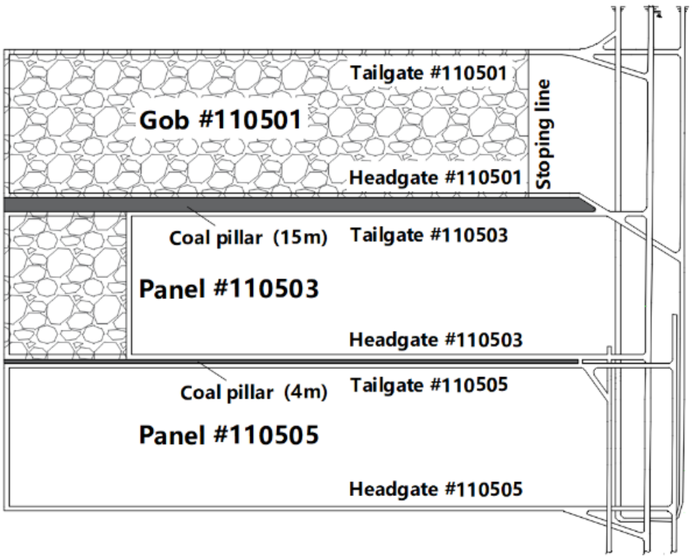
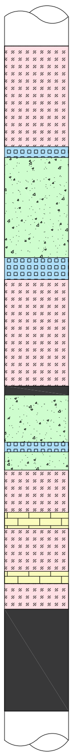


Fig 1. Excavation engineering plane

Table 1. Columnar information of coal and rock

	Number	Lithology	Thickness/m
	14	fine sandstone	9.40
	13	medium sandstone	1.00
	12	siltstone	9.35
	11	medium sandstone	2.05
	10	fine sandstone	9.95
	9	coal streak	0.85
	8	siltstone	4.40
	7	medium sandstone	0.90
	6	siltstone	1.70
	5	fine sandstone	3.95
	4	gritstone	1.50
	3	fine sandstone	4.00
	2	gritstone	1.15
	1	fine sandstone	2.40
	0	5# coal seam	9.50

3. Research on Pressure Relief Parameters of Goaf Roadway Roof Cutting

Reasonable selection of parameters such as cutting height and Angle is an important guarantee for good pre-cracking effect. Therefore, when determining the parameters, it is necessary to carry out research on the influence law of top cutting effect and check the key parameters, so as to provide a basis for the implementation of on-site engineering.

3.1. Research on Cutting Height

Numerical calculation method was used to establish the cutting top model, and the influence law of cutting top height on surrounding rock stress was calculated. Post-processing software was used to conduct post-processing on the simulation results, and the post-processing results after simulation calculation were shown in Figure 2.

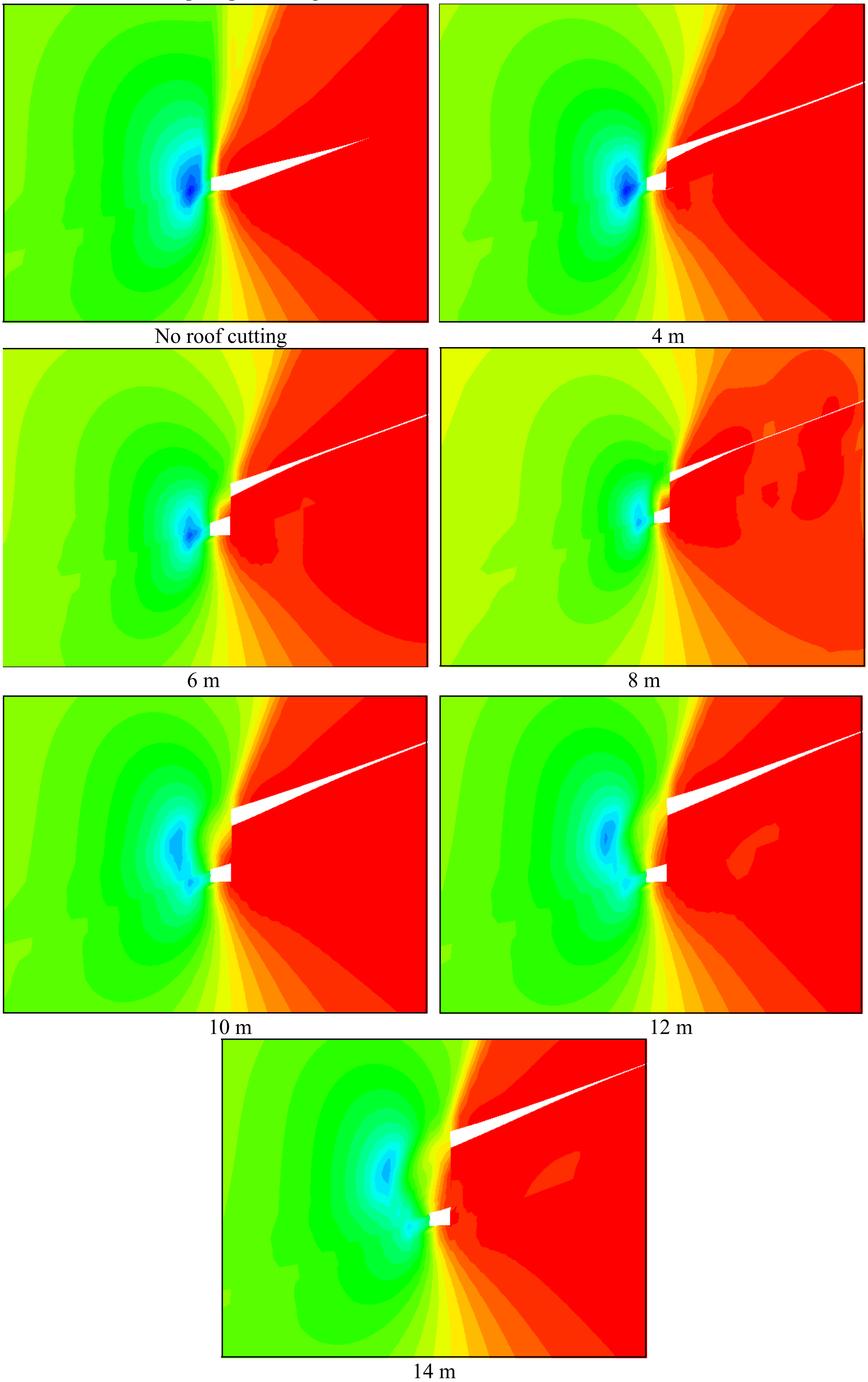


Fig 2. Influence law of cutting top height on stress of wall rock of working face

It can be seen from Figure 2 that the cutting height has different influences on the stress evolution of the surrounding rock of the roadway working face. The peak value of the internal stress in coal body is about 22.4 MPa without cutting the top, and the internal stress concentration in coal body is obviously weakened after cutting the top, and the concentrated stress in the surrounding rock of the working face continues to decrease with the increase of the cutting height. When the top cutting height is 4 m, the peak stress of the coal body is about 21.6 MPa, and the peak stress decreases about 3.5%; with the increase of the top cutting height, the peak stress in the coal body decreases to 18.4 MPa and the peak stress decreases about 18% when the top cutting height is 8 m, and the peak stress in the coal wall is about 17.2 MPa when the top cutting height is 12 m. The peak stress is reduced by about 23.2%, the peak stress on the side of the cutting height of 14 m is about 17 MPa, and the peak stress is reduced by about 24%. When the cutting top height exceeds 12 m, the stress concentration in the coal body at the edge of the goaf decreases.

The cutting height can be calculated as follows from the Angle of gangue filled gob [9]:

$$H_0 = \frac{H - \Delta H_1 - \Delta H_2}{K - 1} \tag{1}$$

Where, H is the mining height and m; ΔH_1 is roof subsidence, m; ΔH_2 is the floor heave, m; K is the overburden dilatancy coefficient, which is generally 1.2 ~ 1.8.

The actual mining height H is 8.43 m, and the initial crushing coefficient of roof strata K=1.8, so it can be calculated that the cutting height required to fill the goaf is about 10.5 m, that is, the actual site needs to cut at least 10.5 m thick roof strata. Considering the coal and rock conditions of the test roadway roof, the vertical height of the pre-split borehole is determined to be 15 m.

3.2. Research on the Angle of Cutting Hole

The cutting Angle is the Angle between the drilling hole and the vertical direction, which has a certain influence on the structural length and other parameters of the cantilever beam of the key block. With the reduction of the cutting Angle, the length of the cantilever beam will be reduced, and then the additional stress generated when the key block turns and subsides will be reduced, which will promote the maintenance of the goaf roadway to a certain extent [10]. In order to determine the influence law of cutting Angle on cutting effect, a numerical model of cutting roof of goaf roadway is established, and the pressure relief effect of different cutting Angle on roadway and coal pillar is obtained by calculating the model.

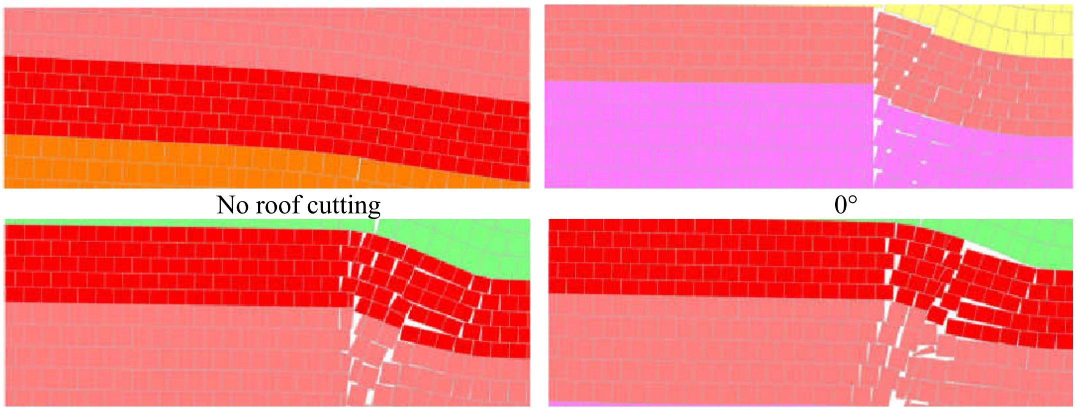


Fig 3. Influence rule of cutting Angle on overburden caving degree

The numerical calculation results of the influence of cutting top Angle on overlying rock caving on the working face are shown in Figure 3, which shows the caving conditions of overlying rock without cutting top, cutting top Angle 0°, cutting top Angle 10° and cutting top Angle 20°. As can be seen from the figure, when the roof is not cut, a triangular block hanging roof will be formed at the end of the working face, and the given deformation pressure generated by the rotation and subsidence of the triangular block will cause great damage to the coal pillar, which is not conducive to the stable maintenance of the surrounding rock of the roadway. When the top cutting Angle is 0°, although the overlying rock hanging beam above the roadway can be effectively cut, the fractured rock block will have friction with the cantilever beam structure above the coal pillar during the sinking process, forming an additional force to prevent the subsidence of the fractured rock block, which is not conducive to roof collapse. Meanwhile, the vertical drilling of the roof in the field construction is difficult, and there are problems such as difficulty in charging; When the drilling Angle along the goaf direction is 10° and 20°, the roof falls into the goaf smoothly under the action of mining stress and self-weight stress, and the roof caving effect is better. However, it is worth noting that the larger the construction Angle of the borehole along the goaf, the longer the length of the cantilever beam, the greater the load of overlying rock acting on the goaf roadway and coal pillar, and the top-cutting effect will gradually weaken.

According to the results of numerical calculation, combined with the site construction conditions and experience, it is determined that the pre-split blasting top-cutting pressure relief borehole along the goaf axial direction of the goaf is constructed at a 10° Angle.

4. Industrial Test

According to the research results of key parameters of pressure relief by deep hole precleavage, the technology of pressure relief by cutting top is implemented in the field. In order to verify the effect of pressure relief, the deformation characteristics of the surrounding rock of the test roadway were monitored at the test roadway layout test point. The monitoring results show that when the roadway experiences the working face disturbance, the deformation of surrounding rock begins to accumulate. The floor displacement of the roadway is the largest, while the displacement of the solid coal side is the smallest. About 60 m in front of the working face, the deformation of the floor, roof, coal pillar and solid coal side are 20.20 mm, 12.40 mm, 5.94 mm and 8.91 mm, respectively. As the influence time of mining stress on the working face continues to increase, the measuring point changes from the front of the working face to the rear of the working face. At about 120 m behind the working face, the deformation of the bottom plate, the top plate, the coal pillar wall and the solid coal body wall are 162.78mm, 105.25mm, 41.75mm and 63.25mm, respectively. The results show that the deformation of roadway surrounding rock is small, and the roadway section meets the production demand.

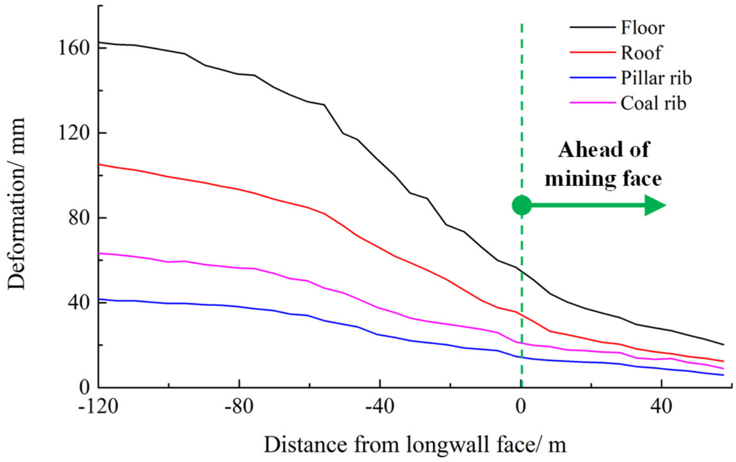


Fig 4. Displacement of t roadway surrounding rock

5. Conclusion

(1) Numerical simulation and theoretical analysis were used to study the influence law of the cutting height and Angle on the stress of surrounding rock and the caving degree of overburden rock in goaf roadway. The cutting height and Angle were optimized to be 15 m and 10° towards goaf, respectively.

(2) The optimized key parameters of deep hole pre-splitting blasting are used to conduct industrial tests in the test roadway. The mine pressure monitoring data show that the maximum deformation of roof, floor, pillar wall and solid coal wall of the goaf roadway is 162.78 mm, 105.25 mm, 41.75 mm and 63.25 mm, respectively, and the pressure relief effect is good.

References

[1] G.C. Zhang, C.W. Zang, M. Chen, et al. Ground response of entries driven adjacent to a retreating longwall panel, International Journal of Rock Mechanics and Mining Sciences, Vol. 138 (2021), 104630.

[2] Q. L. Chang, S. G. Ge, X. Y. Shi, et al. Determination of narrow coal pillar width and roadway surrounding rock support technology in gob driving roadway, Sustainability, Vol. 14 (2022), No.8, 4848.

[3] D.M. Zuev, D.D. Makarov, K.G. Okhotkin. Experimental and analytical study of geometric nonlinear bending of a cantilever beam under a transverse load, Journal of Applied Mechanics and Technical Physics, Vol. 63 (2022), p.365-371.

[4] W. H. Zha, S. Hao, S. Liu, et al. Surrounding rock control of gob-side entry driving with narrow coal pillar and roadway side sealing technology in Yangliu Coal Mine, International Journal of Mining Science and Technology, Vol. 27 (2017), No.5, p.819-823.

[5] F. L. He, X. H. Xu, B. B. Qin, et al. Study on deformation mechanism and control technology of surrounding rock during reuse of gob side entry retaining by roof pre-splitting, Engineering Failure Analysis, Vol. 137 (2022), 106271.

[6] K. G. Fan, H. G. Liang, C. S. Ma, et al. Non-harmonious deformation controlling of gob-side entry in thin coal seam under dynamic pressure, Journal of Rock Mechanics and Geotechnical Engineering, Vol. 6 (2014), No.3, p.269-274.

[7] J. Zhang, M. C. He, G. Yang, et al. N00 method with double-sided roof cutting for protecting roadways and surface strata, Rock Mechanics and Rock Engineering, Vol. 57 (2024), p.1629-1651.

[8] M. Wang, Y. L. Xu, Q. Y. Xu, et al. Stability control of overburden and coal pillars in the gob-side entry under dynamic pressure, International Journal of Rock Mechanics and Mining Sciences, Vol. 170 (2023), 105490.

[9] D. Y. Li, P. K. Chen, J. Z. Liu, et al. Risk field assessment of longwall working face by the double-sided roof cutting along the gob, Geohazard Mechanics, Vol. 1 (2023), No.4, p. 277-287.

[10] Q. Zhang, M. C. He, S. Guo, et al. Investigation on the key techniques and application of the new-generation automatically formed roadway without coal pillars by roof cutting, International Journal of Rock Mechanics and Mining Sciences, Vol. 152 (2022), 105058.