Practical Research on Fully Mechanized Caving Face in Extra Thick Coal Seam Based on Cutting Roof Pressure Relief Pre-fracturing Technology

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Abstract. In order to improve the top coal resources at both ends of fully mechanized top coal caving face in Extra-thick seam and the recovery rate of coal resources during the initial caving, reduce the impact of initial weighting on the working face during the initial caving, and reduce the rock pressure appearances during the mining period near the working face, the fracture damage theory is used to analyze the change of the breaking and caving step distance of roof rock girder and the initial pressure strength of fully mechanized top coal caving face after the roof cutting and unloading. It is concluded that the support pressure area of fully mechanized caving face moves forward, which enhances the caving ability of coal seam and the recovery rate of coal resources during the initial caving period. Taking a fully mechanized caving face of a coal mine in Shanxi Province as the research background, this paper compares and analyses the difference between the first weighting step and the first caving step of fully mechanized caving face with or without roof-cutting pre-fracturing before initial mining and at the end of two roadways. The results show that the first weighting step of fully mechanized caving face is shorter than that of non-pre-fracturing after the implementation of roof-cutting pre-fracturing technology. 1.1m, the first caving step is 16 m ahead of the time when the pre-cracking occurs; and by using borehole peeping technology, it is concluded that the top coal suspended in the triangle area of goaf breaks down along the fissures leading by pre-cracking blasting, effectively solving the problem of overhanging roof in the goaf of two roadways, bringing about direct economic and social benefits of 27.5 million yuan, which has broad prospects for popularization.

1. Introduction
Caving mining is the mainstream mining technology in China's coal mining. Compared with the traditional mining technology, it greatly improves the coal mining efficiency, but the caving mining technology is also restricted by the roof lithology. Due to the poor caving property of the top coal during the initial mining, when mining for a period of time, a large area of empty roof will be formed on the side of the goaf, which lays a strict foundation for the safe production of the working face. In the early mining stage of the working face, there is a "first three tail four" non release coal at both ends of the working face, which makes the triangle coal at the end of the working face unable to be effectively...
recovered, resulting in a waste of resources, and greatly reducing the coal recovery rate [1-4]. Domestic scholars have done a lot of research on this kind of problems. He ManChao et al. [5] studied the roof presplitting and pressure relief of goaf and established the mechanical model of "surrounding rock structure roadway side support", which formed the short arm structure of roof cutting and reduced the bearing strength of roadway side support. Zhang Shujun et al. [6] took Jiulishan mine as the research object through theoretical analysis and numerical value The deep hole presplitting blasting technology has been studied by simulation and field practice, and the blasting technology and parameters have been optimized. After the implementation of deep hole blasting, good pressure relief effect has been achieved. Wang Yong'an et al. [7] Based on the research background of Guhanshan mine, aiming at the adverse effect of "arc triangular roof", put forward a new type of "advance strengthening support direction presplitting blasting cutting roof retaining roadway reinforcement support" Pressure relief technology, practice shows that after the implementation of the technology, the roadway roof support is complete and achieves ideal results. In order to reduce the area of the roof at the side of the working face, this paper uses the fracture damage theory to analyze the change of the roof fall distance and the first pressure strength of the fully mechanized caving face after the rock beam fracture According to the geological conditions and mining conditions of 8301 fully mechanized top coal caving face in a certain mine in the west of China, the technology of deep hole presplitting blasting is adopted for the open cut hole and the two ends of the face to increase the caving of top coal, so as to improve the recovery rate of resources during the initial mining period and ensure the safety of the roof and the safe and efficient mining of the working face.

2. Technical principle of pressure relief and presplitting

The technology of roof cutting and pressure relief is widely used in coal mine production. There are two core purposes of roof cutting and pressure relief. First, the coefficient of roof rock block dilatancy increases after roof cutting and pressure relief, which effectively improves the filling area of goaf, increases the supporting capacity of overlying strata, and forms a "simple support beam" bearing structure with the solid coal section [8-13]; second, after roof cutting and pressure relief, the length of roof suspension beam decreases, which makes The "stress triangle" is controlled to some extent [14-16]. After roof cutting and pressure relief in the fully mechanized top coal caving face, there will be a crack above the roof, which makes the mechanical structure of roof rock beam change from "fixed beam at both ends" to "fixed beam at one end and simply supported beam at the other end" in the mining process, and at the same time, the initial falling distance of roof rock beam is greatly reduced, so as to effectively prevent the working face hurricane effect caused by rock beam fracture and ensure the working face Safe mining [17-18].

According to the theory of mine pressure and strata control and the principle of Coulomb criterion, when the working face is normally mined, the roof of the goaf is collapsed by natural fracture. At this time, the first caving distance is expressed by L.

\[ L = 2h \frac{\sigma}{\eta q} \]  

Where: h-height of roof rock beam, m;  
\( \sigma \) - maximum tensile stress of rock, MPa;  
\( \eta \) - safety factor;  
Q-roof rock beam bearing load, MPa

After roof cutting and pressure relief in fully mechanized top coal caving face, the roof is damaged and destroyed under the joint action of blast wave and secondary gas. According to the fracture damage mechanics theory, the strength of roof rock beam after damage is

\[ [\sigma] = (1 - D_s) [\sigma] \]  

Where: \( D_s \) damage variable (\( D_s = 1 \) for broken area, \( 0 < D_s < 1 \) for damaged area, \( D_s > 1 \) for elastic area);  
[\( \sigma \)] - undamaged rock mass strength
It can be seen from the above formula that the strength of the roof rock mass drops sharply after the roof cutting and pressure relief, thus effectively reducing the caving step distance of the roof rock beam, and at the same time, the first pressure strength of the fully mechanized top coal caving face is also reduced to a certain extent, which makes the support pressure area of the fully mechanized top coal caving face move forward, thus enhancing the caving ability of the coal seam and the recovery rate of coal resources during the initial mining and caving.

3. Research on the technology of pressure relief and presplitting in the roof cutting

3.1 Introduction to working face
The 8301 working face is located in the north side of the return air, belt conveyor and auxiliary transportation of the third mining area, the East is the 8303 working face goaf, and the west is the solid coal area. The average thickness of the coal seam is about 13m, the average dip angle of the coal seam is 6°, the minable length is 2220m, the inclined length is 122m, a total of 72 hydraulic supports, 242m after one extension, a total of 143 hydraulic supports. The working face adopts the method of single strike long wall backward comprehensive mechanization low caving coal mining. The mining height of the working face is 3.8m, and the caving height is 9.2m. There are four or seven end supports at the first three ends of the working face without caving. The roof adopts the total caving method to manage the roof of the goaf.

The lithology of the direct roof is mainly sandy mudstone with a small amount of siltstone, and the thickness of the rock stratum is about 2.4m. The lithology of the basic roof is medium fine sandstone with some coarse sandstone. The rock layer has a Proctor hardness of 6-7 and a rock thickness of about 4.8m. The direct bottom is black mudstone, and there is a layer of coal seam 14 in the middle. The rock layer has a Proctor hardness of 2 and an average thickness of 4.9M. The basic bottom is white medium coarse-grained sandstone, with a Proctor hardness of 6 and an average thickness of 8.3m.

3.2 Pressure relief presplitting process

3.2.1 Presplitting blasting technology of cut hole roof
Before the installation of the support, a row of blastholes shall be constructed every 1.75m in the cutting hole. The blastholes are perpendicular to the roof, and the blastholes shall be arranged 200 mm outward from the cutting line of the support. See Fig. 1 for the layout of open cut blasthole.

![Diagram](image1)

Figure 1. layout of 8301 deep hole presplitting blasting blasthole

3.2.2 Presplitting blasting technology of the working face along the trough roof
A row of blastholes shall be constructed on the vertical roof of the working face at an interval of 800mm from the slot 400mm away from the coal pillar side, and the blastholes shall be perpendicular to the roof. The blast hole layout of the working face is shown in Figure 2.
3.2.3 borehole depth
In order to ensure the effect of roof cutting and pressure relief, the blast hole depth is suitable to drill through the medium and fine-grained sandstone on the basic roof. The average thickness of the top coal of the working face is 9.2m, the average thickness of the direct roof is 2.4m, the average thickness of the basic roof is 4.9m, and the blast hole depth is 17m.

3.2.4 charge structure
- The charging structure is divided into three sections. Each section is filled with 200 mm long loess at one end of the PVC pipe with a diameter of 40 mm × 1500 mm, and then four volumes of gunpowder are loaded from the other end, then one volume of blasting charge is loaded, 300 mm loess is loaded at the end and tamped, and three sections are successively fed into the blasting holes.
- A φ 40mm × 2000mm PVC pipe shall be filled with 0.25m loess first, then 6 bags (1.5m in total) of water cannon mud, and then 0.25m loess, tamped, put the pipe into the blast hole and sent to the end of the previous PVC pipe.
- Put 5m loess into the orifice and tamp it step by step, taking care not to damage the blasting line. See Figure 3 for details.

Fig. 3 Schematic diagram of charging structure of pressure relief blasthole at the top of 8301 two roadways

3.3 research on the practical effect of pressure relief and presplitting Technology
3.3.1 ore pressure analysis during initial mining and drawing
During the initial mining period of 8301 fully mechanized top coal caving face, the initial and periodic weighting step distance, the maximum weighting load and its dynamic load coefficient are shown in Table 1.

| Times of periodic pressure | Weighting step distance / m | Maximum load during pressure /MPa | Dynamic load factor |
|---------------------------|-----------------------------|-----------------------------------|--------------------|
|                           |                             |                                   |                    |
During the initial mining period of 8301 fully mechanized top coal caving face and the adjacent 8312 fully mechanized top coal caving face, the initial and periodic weighting steps, the maximum weighting load and its dynamic load factor value are shown in Table 2.

Table 2. Parameters of 8301 and 8312 fully mechanized top coal caving faces after the occurrence of ore pressure during initial mining

| Coal face | Large area caving distance of top coal /m | Initial pressure step /m | Maximum load during pressure /MPa | Dynamic load factor |
|-----------|------------------------------------------|--------------------------|-----------------------------------|-------------------|
| 8301      | 32                                       | 51.9                     | 42                                | 1.96              |
| 8312      | 6 (initiate)                             | 40.8                     | 36                                | 1.62              |

According to Table 1 and Table 2, the 8301 fully mechanized top coal caving face is presplified by cutting and pressure relief blasting at both ends. After presplitting, the first pressure step of 8301 fully mechanized top coal caving face is 11.1m earlier than that of 8312 fully mechanized top coal caving face, and the dynamic load coefficient is reduced by 0.348301. After the support is pushed out from the cutting hole, the top coal starts to fall, and the top coal starts to fall in large area after the cutting hole is pushed out for 6m at the working face. The working face began to enter the normal circulation operation, and the first coal caving step distance was reduced by 26m.

3.3.2 solve the problem of too large hanging roof in the goaf of two roadways

After adopting the technology of roof cutting, pressure relief and presplitting in 8301 working face, the roof of the gob along the chute collapses closely with the working face, which effectively solves the problem of two roadway hanging roof in the caving working face. After roof cutting and pressure relief, the roof was peeped. From the peeping results, as shown in Figure 4, the analysis shows that:

- In the range of 0-9.7m depth, the joints and fissures in the borehole wall are relatively undeveloped, there is no obvious fracture zone, and the borehole wall is complete.
- In the range of hole depth 9.7-14.35m, the joints and fissures in the hole wall are relatively developed, with obvious fracture zone and relatively complete hole wall.
- In the range of 14.35-16.87m of hole depth, the joints and fissures in the hole wall are very developed, and the hole wall is relatively incomplete.
- In the range of hole depth 16.87-17.88m, the joints and fissures in the hole wall are relatively developed, with obvious fracture zone and relatively complete hole wall.

According to the results of PEEP analysis, after adopting the deep hole blasting with top cutting and pressure relief:

- The blasting effect is the best in the range of hole depth 14.35-16.87m. The joints and fissures in the hole wall are very developed, and the hole wall is relatively incomplete.
- In the range of hole depth 9.7-14.35m and 16.87-17.88m, blasting has a certain effect, there are obvious fracture zones in the hole, but the hole wall is relatively complete.
- There is no obvious crack zone in the hole wall after blasting in the range of 0-9.7m depth, and the hole wall is complete.

Through the peep analysis of the borehole, it can be seen that there is a very obvious fracture zone on the wall of the borehole within a range of 8m from the bottom of the borehole after adopting the deep hole blasting with roof cutting and pressure relief. When these fractures are affected by the mining dynamic pressure, the fractures between the adjacent boreholes are successively connected,
and the suspended top coal in the triangle area of the goaf will collapse along the fracture of the connection.

3.3.3 coal resource recovery at both ends

When the roof cutting and pressure relief are not adopted, the head section is not fully collapsed, and the top coal of the fourth frame of the head is basically unable to be recovered; the tail section is not collapsed in time, and the top coal of the fifth last frame and the sixth last frame of the tail which are supposed to be normal caving supports cannot be fully recovered.

After the roof cutting and pressure relief is adopted, the roof caving performance of both ends is improved, and the top coal resource recovery volume above the fourth, fifth and sixth last stand of the head, tail and tail is increased, and the top coal resource of each stand can be recovered at the head and tail respectively.

![Borescope at 0m-17.88m](image)

Fig. 4 borescope at 0m-17.88m

3.4 economic and social benefits

- After adopting roof cutting and pressure relief technology in 8301 fully mechanized top coal caving face, the recovery of coal resources at the top of the head during the initial mining and at both ends of the face reaches 125000 tons, generating an economic benefit of 37.5 million yuan. At the same time, the problems of large initial pressure step and large initial caving step in the initial mining and initial caving of the face are solved, the recovery rate of top coal during the initial mining and initial caving of the face is improved, and the top coal during the initial mining is ensured Board safety.

- The roof of the gob along the two channels of the working face collapses immediately after the working face, which effectively solves the problem of the hanging roof of the two roadways of the caving working face, reduces the hidden danger of the roof safety, and provides the theoretical basis and reference value for other caving working faces of the mine. It also provides the reference for other coal caving working faces to improve the recovery rate of the top coal and strengthen the safety of the roof through the deep hole blasting and roof cutting and pressure relief Significance.

4. Conclusion

- Based on the theory of fracture damage, the paper analyzes the change of the step distance of fracture collapse of roof rock beam and the strength of the first pressure coming from the fully mechanized top coal caving face after the roof cutting and pressure relief, and concludes that the supporting pressure area of the fully mechanized top coal caving face moves forward, which enhances the caving ability of coal seam and the recovery rate of coal resources during the initial mining.

- Compared with 8301 fully mechanized top coal caving face, 8301 fully mechanized top coal caving face adopts the technology of top cutting, pressure relief and presplitting, which shortens the first step by 11.1m compared with 8312 fully mechanized top coal caving face without presplitting, and the first step by 16m in 8301 fully mechanized top coal caving face. Therefore, the first step of fully mechanized top coal caving face is greatly improved during the initial mining. With the recovery rate of coal resources, a direct economic benefit of 37.5 million yuan can be obtained, which has a broad application prospect.

- By using the drilling peep technology, after the pressure relief and presplitting of the roof, there is a very obvious fracture zone in the hole wall within 8m from the bottom of the hole. Therefore, it
is concluded that the top coal suspended in the triangle area of the goaf collapses along the fracture through the presplitting blasting, which effectively solves the problem of the top suspension in the goaf of the two roadways of the caving face.

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