Research on Roof Management Technology of Mining in Shallow Buried Coal Seam use Continuous Miner

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Abstract. For the difficulty in managing the roof of mining under the shallow buried coal seams by continuous miner, the technical principles and effects of roof management technologies such as coal pillar support, artificial forced roofing and mining with backfilling were systematically analyzed. This paper has studied the advantages and disadvantages of different roof management methods. The results show that the reasonable reservation of coal pillars can effectively manage the roof, but the mining face has a low recovery rate; effective manual forced roofing can reasonably control the roof cave and increase the mining face recovery rate; mining with backfilling can effectively prevent the large area of the roof from caving, significantly increase the recovery rate of the working face, and can reduce or even avoid surface subsidence.

1. Introduction
With the continuous application of the continuous miner mining technology in the Shanxi, Shaanxi & Inner Mongolia mining area, especially the Shenfu coalfield, it has shown great advantages in the mining of side coals, mining of residual coal pillars, etc., effectively improving the mine recovery rate. Shallow burial depth is a common feature of the occurrence of coal seams in this area [1]. As the top priority of safe and efficient production work at the working face, this paper analysis different roof management technologies and explores the advantages and disadvantages of related technology applications, with a view to providing some reference for coal mine site production safety.

2. Coal pillar support
When the continuous coal mining machine is mining in shallow and deep coal seams, the roof is supported by retaining coal pillars with different functions. Through the stable yielding of coal pillars where located among splitting, branch roads, branch entries, and block gates, the problem of dynamic disasters caused by large-area caving of thin bedrock roofs in shallow coal seams can be reduced or eliminated [2]. Then ensure the safety of the continuous miner mining face, while maximizing the coal recovery rate.

For shallow buried coal seams, roof management focuses on the stability of the thin bedrock roof as a key layer. On the basis of ensuring the safety of the "thin bedrock-coal pillar yielding" system [3], the branch road layout, mining sequence, and branch road width were analyzed systematically. With the goal of increasing the block mining area and coal recovery rate, mining designers can determine the type and quantity of coal pillars, and the parameters of coal pillar width. As shown in Figure 1 below, a common coal pillar retention method is provided. A small coal pillar of a certain width is left between each splitting, which plays a certain role in supporting the roof when mining by continuous
miner. After the mining of the branch road is completed, a coal pillar is left at the branch gate to avoid the danger of the roof caving suddenly in the branch mining area. Once the mining of all the branch of one block are completed, a big coal pillar is left to control the overhanging area of the block to avoid the impact of the large-scale collapse on the adjacent working face, and it is beneficial to the control of coal seam spontaneous ignition.

![Figure 1. Schematic diagram of coal pillar support](image)

3. Forced roof caving

The roofs of shallow buried coal seams are generally more integrated, and joint fractures are less developed. In the continuous miner mining process, it is difficult for the roof to cave follow with the mining, and it is easy to form a large area suspended roof. After the suspended roof reaches a certain area, the roof of the working face forms a strong pressure area, which can easily collapse suddenly and form a hurricane impact, which will seriously damage production and even cause casualties. By forced roof caving, the stress concentration is reduced, the number, length and depth of cracks in the roof rock layer are increased, and the control mode of small step pitch natural collapse is realized to ensure the safety of the working face.

3.1. Breaking the roof by strengthening the support

By adopting crawler walking hydraulic support to strengthen the support of the gate of splitting [4], two walking supports are used as a group to achieve the control of the roof by the stepping lifting rack with pressure, so that the working face roof can caving follow the mining, which can be avoid the formation of a large area suspended roof. In the case where the roof is relatively hard and cannot fall in time, it can be treated by means of pre-split of the roof to ensure that the suspended roof collapses in time. The crawler walking hydraulic support shown as Figure 2(a), and the common arrange method shown as Figure 2(b).
3.2. Ground pressure relief by blasting

This method is an anti-danger measure to reduce the stress concentration of the roof through manual intervention by blasting the roof that has formed a strong mine pressure danger. Through blasting, the elastic modulus of the roof and the strength are reduced, and the mechanical properties are changed [5], so that the length and density of the cracks in the roof are increased, and the roof can be partially collapsed in a small area to prevent the occurrence of strong mineral pressure. The implementation effect is shown in Figure 3 below.

The application focus of pressure relief by blasting is to determine the limit collapse area of the roof. Implementing blasting before the suspended roof area reaches the limit area can not only effectively avoid the large area collapse of the roof, but also minimize the number of blasts and improve the blasting effectiveness.

3.3. Hydraulic pre-splitting

Drilling in a hard roof for (directional) hydraulic fracturing, resulting in hydraulic main cracks and airfoil branch cracks. Use it to modify the structure of the roof to form a weak surface that is conducive to roof fracture and collapse. At the same time, the roof rock formation absorbs moisture and softens [6, 7]. Based on the structural transformation and softening of the roof, the roof fully falls in time under the action of the ground pressure.

When hydraulic pre-splitting is applied in site, a high-pressure pumping station connected to a hole sealer is usually used to inject water into the pre-splitting hole and maintain a certain pressure and time to complete it. The continuous high-pressure water injection promotes the expansion of
hydraulically induced cracks to the surface of the rock mass, thereby forming pre-splitting cracks and fissures, and further induces the roof to fall in time. The effect of cracks formation after water injection is shown in Figure 4(a) & (b) below.

![Figure 4. Generate new cracks after injection of high-pressure water](image)

4. Continuous miner mining with backfilling

Backfill mining technology is an important part of the current green mining technology of coal mines. As an effective way to solve the environmental problems of coal mining and the "three under" (under buildings, railways, and water bodies) coal mining problems [8, 9], it has little disturbance to rock formations, and has the effect of controlling rock formation movement and surface subsidence. The current coal mine filling technology in China is mainly divided into dry filling, paste filling and super high-water material filling according to the filling medium.

The continuous miner mining technology has the characteristics of fast driving speed, flexible equipment movement, and small space occupied during mining. This technology can meet the technical requirements of backfilling in terms of mining process and equipment operation space. When combined with backfilling technology, it can achieve parallel mining and filling operations. Backfilling and mining are not affected by each other, and it can maximize the advantages of continuous miner mining and backfilling technology. While improving mining efficiency and ensuring filling effect, it can effectively control surface subsidence and rock movement.

According to the technical characteristics of continuous miner mining, as per the protection requirements of the mine surface buildings and the mining conditions, two main mining and filling schemes are considered.

Option I: Mining first and then filling, filling while mining, and partially fill. The process is shown in Figure 5.

![Figure 5. Partially fill mining process](image)

Option II: Mining first and then filling, filling while mining, and completely fill. The process is shown in Figure 6.
5. Conclusions
When a continuous miner is mining under conditions of shallow buried coal seams, it is necessary to select a suitable and effective roof management method through a detailed analysis of the geological conditions of the coal seam and combined with mining process design, to ensure safe and efficient mining.

- Setting reasonable coal pillars can effectively manage the roof and avoid roof fall, which will not cause surface subsidence, but the mining face recovery rate is low.
- Hydraulic pre-splitting technology can effectively promote the development of cracks in the roof and induce the roof to fully and timely collapse. Pressure relief by blasting can timely and effectively reduce the stress concentration of the roof and prevent the occurrence of strong mine pressure, which is an effective way to relieve danger. Compared with the two, hydraulic pre-splitting focuses on prevention and can reduce the use of pyrotechnic products, which is beneficial to mine safety management.
- The combination of continuous miner mining and backfill mining can effectively prevent the roof from falling down, giving full play to the advantages of both technologies, significantly improving the recovery rate of the working face, and reducing or even avoiding surface subsidence.

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