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Principles of the roof cut short-arm beam mining method (110 method) and its mining-induced stress distribution

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ABSTRACT

Since 1960s, mining science and technology in China has experienced two technical innovations, i.e. the 'Masonry Beam Theory (MBT)' and 'Transfer Rock Beam Theory (TRBT)'. Based on those theories, the conventional mining method (being called as 121 mining method) was established, consisting of excavating two tunnels with a pillar left for mining a working panel. However, with the increase of mining depth, engineering geological disasters in the underground caverns have been frequently encountered. In addition, the usage of the coal-pillar mining results in a large amount of coal resources unexploited. In order to address the problems above, 'Roof Cut Short-arm Beam Theory (RCSBT, being called as 110 mining method)' were proposed by HE Manchao in 2008. The 110 mining method is featured in mining one coal seam panel, excavating necessarily only one roadway tunnel and leaving no pillars. Realization of the 110 mining method include the following steps, i.e. (1) directional pre-splitting roof cutting, (2) supporting the roof by using high constant resistance large deformation bolt/cable (CRLD), and (3) blocking gangue by hydraulic props. This paper presents a panorama of the principles, techniques and application of the 110 mining method. Special emphases were placed on the numerical simulation of the geo-stress distribution found in the mining panel using the 110 method which was compared to that of the 121 method as well; in addition, the stress distribution on the "short beam" left by the roof cutting when performing the 110 method was also investigated using both the numerical simulation and theoretical formulation.

1. Introduction

In the 1960s, QIAN Minggao proposed the 'Masonry beam theory (MBT)' [11–13] for the first time in China, and presented a full discussion on the transmission and equilibrium method of overburden pressure in mined-out areas by using reserved coal pillar. On this basis, the long wall mining method (121 mining method) was established, where one stoping face needs two advanced excavation tunnels and one reserved coal pillar before next mining cycle. The 121 mining method based on the MBT laid a solid foundation for the development of mining science in China. The second mining innovation started in the 1980s, which was featured by the 'transfer rock beam theory (TRBT)' proposed by Song [15–17]. This illustrated a further transition path of stope overburden pressure and its distribution in high-stress area. Then the advanced long wall mining 121 mining method was brought up with smaller coal pillar in terms of inner stress field excavation design, making important contributions to increase the coal recovery rate in that era.

At the beginning of the 21st century, large deformation failure problems in coal mines became more challenging with increasing mining depth. And the accidents in risk-prone gateway and deep gob-side gateway accounted for about 80–90% of total accidents in working face gateways [2–5]. It is basically considered that the traditional 121 mining method was not suitable for the deep mining purpose [20,8,10,1]. In 2008, the theory of 'Roof Cut Short-arm Beam Theory (RCSBT)' was first put forward. In this theory it can be noted that the ground pressure was used for the purpose of advancing the roof caving by precutting to form a cantilever beam above the gob-side gateway. When the precutting was performed on the roof of gateway, the transmission of overburden pressure was cut off, which mitigated the periodic pressure when using the 121 mining method. And part of roof rock mass was driven down, forming one side of the gateway for the next

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stope mining cycle. The RCSBT provides a new basis for the pillarless mining, under which the 'Longwall Mining method (110 mining method)' is developed [6,21,9,14,19,18], namely one stope face, after the first mining cycle, only needs one advanced gateway excavation, while the other one is automatically formed during the last mining cycle with no coal pillars left in the mining area by using this mining technology. The core idea of 110 mining method is that, first, the natural ground pressure is used to help human drive down part of the roof rock, instead of fully resisting it by artificial supporting system and coal pillar; second, the gob roof rock is used to form one side wall of the gob-side gateway; and third, the characteristic of broken expand for gob roof rock is used in gobbing to reduce the surface subsidence. This mining method will reduce 50% of gateway excavation in the stope and fulfill 100% coal pillar recovery, which achieves a significant reduction in mining costs and it is more important that it will reduce the accidents in the stope. It may be used to fulfill the "N00 Mining Method" in the future, which is the optimization and innovation of the 110 mining method. The symbol 'N00' means no matter how many mining cycles and working faces in the district, all the gateways would be formed automatically with RCSBT, suggesting no need for gateways to be excavated in traditional methods. In this paper, China's longwall coal mining associated theories and the 121 mining method will be discussed, and the key technologies of RCSBT will be introduced, and numerical simulation methods have been used to analyze the mining-induced distribution in the application of 110 method. The RCSBT and 110 Mining Method will be considered the basis for China's next-generation mining industry development, from mining giants to mining powers.

Up to now, long wall mining 110 method has been successfully applied in many underground coal mines in some giant coal mining groups across the country, e.g. China national coal group corporation, Shen hua Group, Sichuan coal industry group limited liability company, Sichuan Jiayang Group Co. LTD, etc. The total length of the roadway tunnel created by the 110 method added up to 18,980 m. In the coal mines where the 110 mining method are employed, engineering disasters caused by the roadway excavation and coal pillars along the goaf are complete eliminated, such as roof accidents, rock burst, coal and gas outburst, and other potential dynamical events. At the same time, great economic interests and noticeable social benefits were achieved due to the significant reduction of the roadway tunnel excavation and elimination of the coal pillars, as well as the safety production.

2. Innovation of RCSBT and 110 mining method

For the limits of the traditional 121 mining method, the 110 mining method were proposed in order to address the problems in long wall mining. The RCSBT is verified in field by using advanced roof caving in 2008, and was first applied to No. 2442 working face in Baijiao coal mine, Sichuan, in 2010. In this project, pillarless mining technique was used in the gateway near the goaf formed automatically by advanced pressure relief and roof caving [21]. The RCSBT was established on the basis of interactions of stress fields, supports, and surrounding rocks during the process of advanced pressure release and roof caving. One of the key technologies is the directional cutting in the goaf side roof, which transfers the overburden pressure on the roof, drives part of roof rock mass down, and thus forms a new excavation roadway for stoping. Besides, there are many other key technologies involved to achieve RCSBT. For instance, a new supporting material, the bolt or anchor with constant resistance and large deformation (CRLD), is employed in the gob-side roadway roof supporting to keep the gateway roof stable during the advanced roof caving.

Along the direction of working face, three-dimensional schematic drawing of a coal panel mined by the 110 mining method and 121 mining method were illustrated in Fig. 1. It is shown that in order to mining one coal panel by using the 121 mining method, two roadways were excavated, and one coal pillar was retained. When the coal resources were extracted, the two roadways will be abandoned and destroyed by the periodic pressure as a result of the mechanized for the stoping mining.

In contrast, for mining of a panel using the 110 method, two roadways will be excavated during mining the first panel; in the subsequent stoping process, forming a roadway by cutting a tunnel-length slit beside the next mining panel. It will cancel the coal pillar between the mined two panels, i.e. only one roadway is enough.

3. Key technologies in the 110 mining method

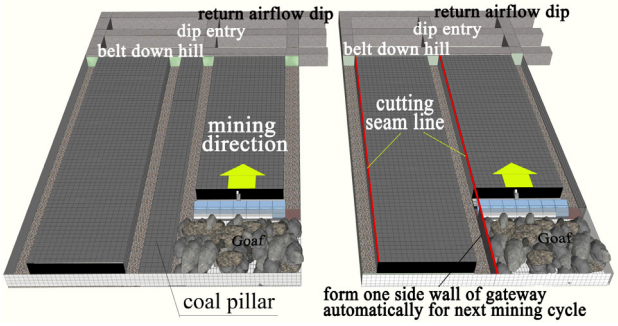
For the fulfillment of long wall mining method (110 mining method), several key technologies are employed, as the 3D-illustration of A-A cross-section in Fig. 1 is illustrated in Fig. 2a, which includes following steps:

(1) Directional pre-splitting roof cutting.
(2) Supporting the roof by using high constant resistance large deformation bolt/cable (CRLD).
(3) Blocking gangue by hydraulic props.

In addition, the characteristics of different projects in different mines are also taken into consideration in this new method. Thus, 110 mining system with pillarless mining and automatic formation of gob-side gateway for the next mining cycle by precutting and advanced roof caving was finally established.

In order to describe the key technologies of 110 mining method in detail, another three-dimensional schematic drawing of 110 mining method is illustrated in Fig. 2b. Firstly, directional pre-splitting roof cutting used to cut down the transmission passage of ground pressure in part of overlying rock strata, and the gob-side pressure is used to drive part of gob roof rock down, instead of totally resisting it. And the roof rock is used to form one side of the gateway wall, and the gob-side gateway is reserved for the next mining cycle.

After the mine resources are excavated in this working face, the upper strata of mine will collapse, although the connection within upper strata is partially separated, but outside the slit depth, both the part above the roadway and the part above the gob-side are still connected and interacted. After the upper strata in gob-side bursts into breaking down, it will have a relatively large shear force



(a) 121 mining method (b) 110 mining method

Fig. 1. 3D-view schematic of two kinds of mining method.

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