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Key Problems of Fully-Mechanized Continuous Advancing in "Three-Soft" Bifurcation-Combination Coal Seams

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ABSTRACT

The conventional mining method used in "three-soft" bifurcation-combination coal seams (BCCS) brings about problems like low recovery rate and poor efficiency. This paper first proposes the fully-mechanized continuous advancing method in BCCS, i.e., continuous advancing with the same set of large mining height fully-mechanized mining equipment in the lower slice of bifurcation area and combination area. This paper, adopting integrated research methods like theoretical analysis, physical simulation and field measurement, studies intensively the equipment selection on fully-mechanized continuous advancing face in three-soft BCCS, the mining space-time relation of upper and lower seams in bifurcation area, the fully-mechanized continuous advancing technology in bifurcation combined transition zone, mine pressure regulation and other key problems. Field trials indicate that the recovery rate increase around 12% with the adoption of this method and thus providing the reference for mining under same conditions.

KEYWORDS: Three-Soft bifurcation-combination coal seams; Fully-mechanized continuous advancing; Variable height mining; Strata behavior; Recovery rate

INTRODUCTION

Many researches have been conducted on the geological origin [1-3] of BCCS. However, few attention has been paid on the efficient exploitation of BCCS. There are two ways to achieve efficient exploitation of BCCS: first, reducing the number of mining face and increasing the unit yield of mining face; second, further improving the recovery rate of coal resources. Taking the above as a starting point, this paper first proposes the fully-mechanized continuous advancing method for mining in the lower slice of bifurcation area and combination area with the same set of large mining height fully-mechanized mining equipment. Taking Xutuan mine in Huaibei as engineering background, this paper studies systematically the key problems in fully-mechanized continuous advancing process under situation of three-soft BCCS, which provides reference for the efficient exploitation of coal seams under similar conditions.

PROJECT OVERVIEW

The relationship between coal seam 71 and seam 72 of one mining face in Xutuan Mine is characterized by bifurcation and combination, with the general trend of combined at the ends and

bifurcated in the middle, with the seam spacing of 0～12.75m and the average seam spacing of 7.66m. The thickness of coal seam 71 is 0.8～3.4m with the average thickness of 1.82m; the thickness of coal seam 72 is 3.09～4.21m with the average thickness of 3.71m. The inclined angel of coal seam is 10° ～14° with the average of 12° . The immediate roof is composed of thick mudstone with thickness of 3.66m; the main roof is composed of fine sandstone with thickness of 5.58m. The immediate floor is composed of thick mudstone with thickness of 2m; the main floor is sandstone with thickness of 3.91m. So they are three-soft bifurcation-combination coal seams under typical geological conditions.

FULLY-MECHANIZED CONTINUOUS ADVANCING METHOD IN BCCS

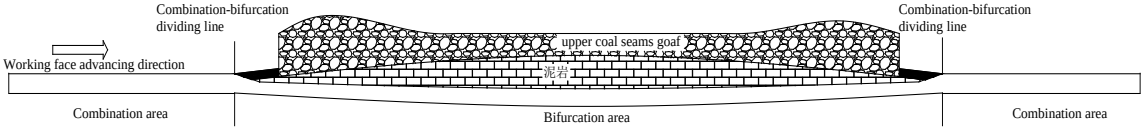


Figure 1: fully-mechanized continuous advancing method in BCCS

Adopting fully-mechanized continuous advancing method in BCCS is to realize the continuous advancing in the lower slice of bifurcation area and combination area. The exploitation order is to first explore the upper coal seams in bifurcation area, followed by combination area and the lower coal seams in bifurcation area, as shown in Fig. 1. The technical difficulty lies in smoothly advancing of mining face under conditions of large stress, broken roof and variable mining height.

KEY PROBLEMS IN FULLY-MECHANIZED CONTINUOUS ADVANCING METHOD IN THREE-SOFT BCCS

Equipment sets in mining face

Fully-mechanized continuous advancing in three-soft BCCS requires that the support has large adjustable height, great guarding capacity and anti-drilling function [4]. Through theoretical calculation and analysis, ZY11000/28/63 support and other equipment can meet the needs of efficient exploitation of mining face. The main technical parameters of mining face equipment are shown in Table 1.

Table 1: Main equipment sets of working face

Equipment name	Equipment type	Main technical characters
Shearer	MG750/1815-WD	Mining height: 3～6.3m, cutting depth: 0.8m, traction speed: 0～17.1m/min, adapted coal seam≦30°
Hydraulic support	ZY11000/28/63	Support height: 2.8～6.3m, center distance: 1.75m, weight42.6t， secondary guard structure, maximum guarding length: 2.3m, bottom-lifting jack force:485kN, working resistance:10627~11207kN, adapted coal seam≤15°
Scraper conveyor	SGZ－1000/1400	Conveyed capacity: 2000t/h, chain speed: 1.2m/s, power: 1400kW

The space-time relations in mining the upper and lower working face of bifurcation area

(1) The layout of upper and lower coal seams in bifurcation area

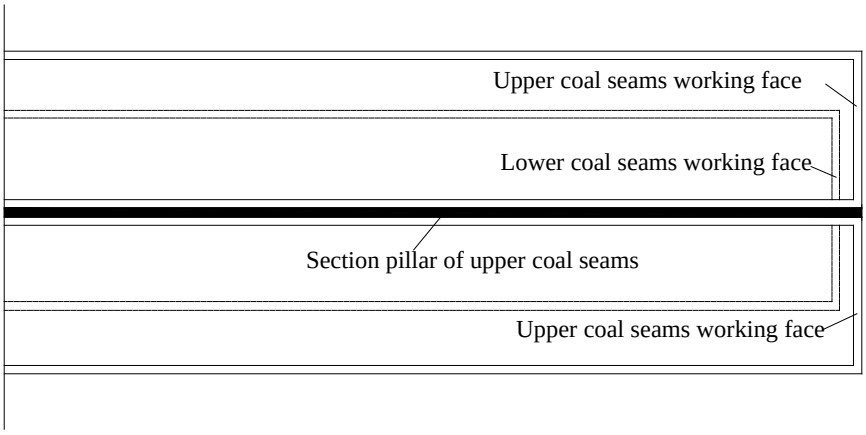


Figure 2: The staggered layout of upper and lower coal seam working face

To avoid the mutual interference in mining the working face of upper and lower coal seams and to maximize the recovery rate of coal resources, staggered arrangement is adopted in the layout of upper and lower coal seams as shown in Fig.2. For exploitation of the upper coal seam, a small coal pillar is remained in the middle of lower coal seam working face. The stopping roadway of lower coal seam working face is located in the middle of two empty adjacent working face of the upper coal seam. As the small coal pillar remained in mining the upper coal seam has been damaged in mining the lower coal seam duo to the soft characteristic of coal seam [5], it has little impact on mining the lower coal seam.

(2) Reasonable time interval in mining the upper and lower working face in bifurcation area

It is necessary to start mining the lower coal seam of bifurcation area after the rock movement caused by mining the upper coal seam being stable. Based on technical experiences in upward coal mining, the reasonable time interval T in mining the upper and lower working face can be calculated through the following formula[6]:

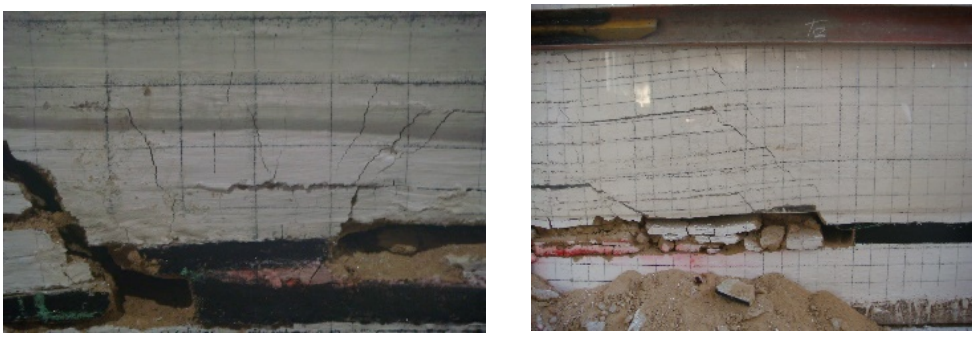
$$T = 0.01\frac{H}{M} + 3 \tag{1}$$

Where: H—mining depth, 535m; M—thickness of the upper coal seam, 1.82m; through calculation, T=5.94 month. That is, after ending the upper coal seam exploitation for more than 0.5a, the lower coal seam exploitation can start; after ending the exploitation of two working faces in 71 coal seams for about 1a, the exploitation of the lower coal seam in bifurcation area can start.

Continuous mining technology in the transition zone of bifurcation-combination areas (TZOBCA)

There are two phases in continuous mining the TZOBCA: first, the transition from the height-reducing mining in combination area to mining the lower coal seam in bifurcation area; second, the transition from the height-increasing mining of the lower coal seam in bifurcation area to mining the combination area.

(1) Roof cracking mechanism in the TZOBCA



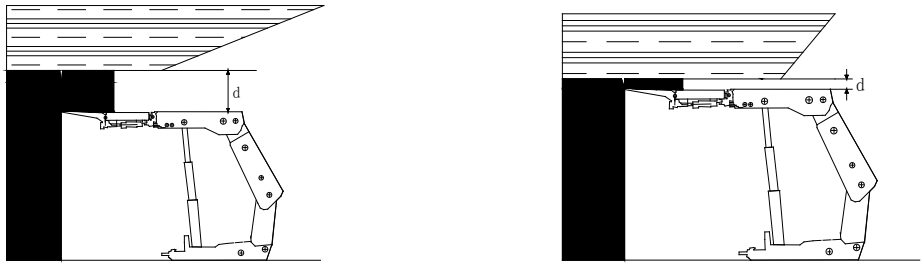
(a)height-reducing mining (b)height-increasing mining

Figure 3: Roof cracking situation in mining with variable height in the TZOBCA

As shown in Fig.3, being subject to the coupling action of the abutment pressure in mining the upper coal seam and advanced abutment pressure in mining the present coal seam, the roof is broken in mining with variable height. In height-reducing mining, because the upper part of the roof has been exploited, the roof damage degree is more serious than that in height-increasing mining.

(2) Mining method with variable height in the TZOBCA

There are two ways for height-reducing mining: first, mining height reduces to the desired height directly; second, mining height being reduced for many times until the given height is achieved, as shown in Fig.4. The height-increasing mining can be carried out in similar ways.



(a)mining height being reduced once (b)mining height being reduced for many times and in circulation

Figure 4: Sketch map of height-reducing mining

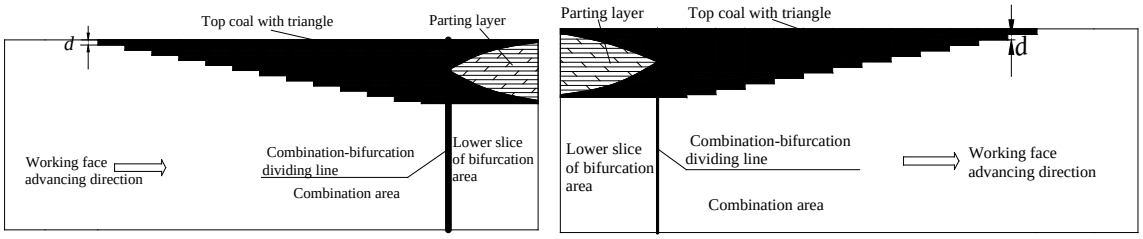
For direct reduction method, the support should be dropped down for 1.9m and thus covering rock in the roof has large impact force on the support; the support is away from the roof with poor stability [7]. After comprehensive comparison, the method of mining height being reduced for many times is considered to be the better option. The reducing height of each time can be calculated through the roof broken degree [8], as shown in formula (2):

$$(d+h)(1+k) \geq md + h \tag{2}$$

where h refers to the height of the broken roof; m; d refers to the support reducing height for one time; m; k refers to roof broken coefficient; m refers to the ratio of roof beam length on the cutting depth of the shearer. Supposing h=2.8m，k=1.2，m=3.12/0.8=3.9, then d<0.21m, that is, the support

reducing height for once should be no more than 0.21m and d=0.15m. The height-reducing mining should start from the bifurcation-combination line, with support lowering height of 0.15m of each time. Through height-reducing mining for many times and in circulation, the coal exploitation is transited to the lower coal seam in the bifurcation area.

Similarly, the height-increasing mining should adopt the method of increasing the mining height for many times until reaches the desired height. That is, the height-increasing mining should start from the bifurcation-combination line, with support increasing height of 0.15m of each time. With the adoption of successive height increasing, the coal exploitation is transited to the coal seam in the combination area, as shown in Fig.5.



(*a*) support-dropping method (*b*) support-lifting method

Figure 5: Sketch map of mining with variable height

(3) Roof control technology in mining with variable height in the bifurcation-combination transition zone

During coal exploitation with variable height in bifurcation-combination area, subject to the broken roof and support's incomplete touching with roof, it is necessary to adopt roof control technology. According to the situation in Xutuan mine, measures are made as follows:

① Grouting the "top coal with triangle" area to ensure the integrity of "top coal with triangle";

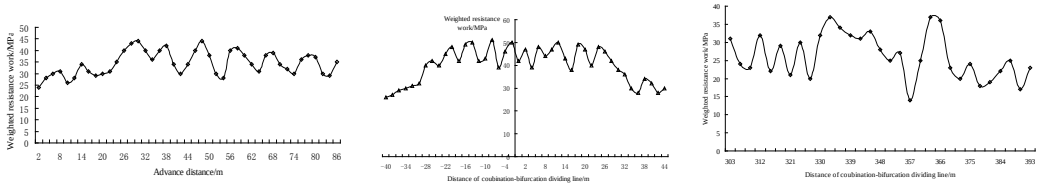
② Inclining the working face, mining the working face by gradually increasing the height from the bottom of the working face to the top to reduce the support number under the condition of broken roof and incomplete touching with the roof;

③ Reducing the mining height in advance. The less the mining height difference (referred to as the height difference) of coal seam in combination area and the lower coal seam in bifurcation area becomes, the more easily to continuously advance the bifurcation-combination coal seams. Gradually reducing the mining height from a certain distance is helpful for reducing the height difference and for mining safety.

④ Ensuring enough setting load of the support. Researches indicate that: better control effect on roof can be achieved by large setting load. When lifting the support, the setting load should be kept more than 25MPa.

Mine pressure regularity on the continuous advancing fully-mechanized mining face

During the backstopping period, the mine pressure of the working face is as shown in Fig.6.



(a)combined section (b)bifurcation-combination transition section (c)mining section of lower coal seam in bifurcation area

Figure 6: Resistance distribution of weighted support along the working face of different stages

From Fig.6, we can get that: ①The support resistance distribution on the working face has characteristic of segmentation. With different mining height and different roof condition, the support resistance distribution on the working face has different characteristics; ②When the roof is integrate in large mining height fully mechanized mining in combination area; the initial weighting step is about 26～28m, the periodic weighting step is about 8 ~ 10m; the maximum working resistance is 43MPa; dynamic load coefficient is about 1.5; the pressure-affecting time is generally 1 ~ 2d; ③In the bifurcation-combination transition zone, under condition of broken roof with high-stress and mining with variable height, due to the coupling action of abutment pressure from the upper coal seam's working face and advanced abutment pressure on present mining face, the support pressure is significantly increased. The highest value of working resistance is 52MPa; the dynamic stress centralized coefficient is 3; the high stress area is within 30m before and after the bifurcation-combination line; ④When the upper coal seam is exploited, the weighted support resistance in mining the lower coal seam is 20～35MPa with the average of 27MPa. The pressure regulation is not obvious because of the broken roof.

CONCLUSIONS

(1) From perspective of reducing the number of working faces and improving the coal recovery rate of coal seams, this paper first proposes the fully-mechanized continuous advancing method in BCCS. The practice and application in three-soft bifurcation-combination coal seams of Xutuan mine shows that compared with conventional method, this method can increase recovery rate by 12%, increase stuff work efficiency by 120% and improve the economic benefit by 110 million yuan.

(2) Through remaining the small coal pillars in the upper coal seam and the staggered layout of working faces in upper and lower coal seams, the mutual interference in mining short-distance working faces of upper and lower coal seams can be reduced, and the recovery rate of coal seams can be maximized.

(3) Under the condition of broken roof with high-stress, the bifurcation-combination line is adopted as the starting point, and the support-dropping or support-lifting height of each time is decided to be 0.15m. Then the continuous advance in transition zone of bifurcation-combination areas can be realized through the mining with changing height

(4) Subject to different roof conditions and mining heights, mining pressure of fully-mechanized continuous advancing face in three-soft bifurcation-combination coal seams has characteristics of segmentation.

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