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Support-surrounding rock relationship and top-coal movement laws in large dip angle fully-mechanized caving face

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A B S T R A C T

When mining the fully-mechanized longwall caving face along strike, the unstable equipment, the low top-coal recovery ratio and the difficulty in controlling surrounding rock may occur due to large dip angle. Considering the effects of strike angle on support stability, the "support-surrounding rock" mechanical models of support topple and support slip were established in this paper. On the basis, the influencing factors of support stability were analyzed and the technical measures of controlling support and surrounding rock stability were put forward. Then the loose particles simulation experiment was conducted to analyze the impacts of caving directions and methods on the top-coal recovery in large dip angle fully-mechanized caving face. Finally, the "upward sequence and double-openings double-rounds" caving technology was determined. The research results are of great scientific significance and practical values to improve large dip thick seam mining technology.

1. Introduction

Abundant thick seams with large dip angles under 15 m can be found in West China. Due to the relatively small thickness of seam, inclined sectional or horizontal sectional mechanized top-coal caving method is not available [1,2]. In addition, the low top-coal recovery ratio and the unstable surrounding rocks (including the top-coal) and equipment (particularly the hydraulic support) are caused by asymmetric movement of large overlying strata space in the process of fully-mechanized longwall caving face mining, which has seriously restricted the safe and efficient production of the working face.

Some scholars have conducted researches on large dip seams, including mining methods, strata movement, equipment development, etc. Kulakov has systematically studied the stress distribution in large dip seam mining area and analyzed the effects of buried depth and dip angle on stress distribution laws [3,4]. Díez et al. have studied the subsidence due to large dip (steep dip) seam mining and established mining subsidence prediction model [5]. Mikhalitsyn et al. have proposed that the mining equipment of large dip seam should be developed towards systematization, automation and high reliability [6]. However, the studies on the "support-surrounding rock" stability control with large dip angles are relatively rare. There are many limitations on fully-mechanized caving mining technology of thick seam in some countries and areas. The instability mechanism of the hydraulic support in large dip thick seam and top-coal movement laws haven't been studied in detail.

Thick seams are the main seams which could be mined with high production and high efficiency methods in China. Many Chinese scholars have conducted studies on the mining technologies of large dip thick seams, the instability of hydraulic support and the top-coal movement laws. Wu et al. have established the "Roof-Support-Floor" dynamic equation. They analyzed the factors and dominant parameters that could trigger instability of the system from the view of dynamics and set dynamic control patterns of system stability [7,8]. Lin et al. studied the toppling, slipping and torsion of the support in large dip seams within the framework of static mechanics and analyzed the effects of dip angle, roof pressure, geometric parameters and working status of support on stability of power support [9,10]. Tu et al. proposed to efficiently control the support system stability of fully-mechanized top-coal caving face with large dip by laying out the oblique face, cutting coals in unidirectional way, laying out the supports in groups, increasing the support resistance, controlling the mining height

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and optimizing the conveyor and support [11]. Wang et al. put forward the impact load calculation of roof in fully-mechanized caving mining area with large dip and gave the criteria of equipment stability in the working face. The theoretical equation of top-coal caving shape in large dip thick seam was built and the internal laws of top-coal caving were revealed [12–14].

The support stability of the fully-mechanized longwall caving face is the fundamental guarantee to successfully realize the large dip thick seam mining. The caving laws are key to the fully-mechanized caving mining, but there are lack of mature studies on support stability of large dip thick seams and the caving theories. The "support-surrounding rock" mechanical models of the large dip thick seam were established and the instability mechanism was studied in this paper. The top-coal movement laws were analyzed. The research results were applied for the seam with maximum dip angle of 42° in 10-704 fully-mechanized caving face in Pangpangta Mine. The results are helpful to solve the problems of low top-coal recovery ratio and unstable equipment (support) and realize the safe and efficient production.

2. "Support-surrounding rock mechanical models and support resistance determination

2.1. "Support-surrounding rock" mechanical models

The "support-surrounding rock" mine pressure model in the dip direction of large dip angle fully-mechanized caving face is established, as shown in Fig. 1.

The working face has angles both along the strike and the dip, so the self-weight of the support can be disassembled into G_1 parallel to the dip, G_2 perpendicular to the floor and G_3 parallel to the strike [15–18], as shown in Fig. 2.

The results are as follows:

$$G_1 = G_3 = G \times \sqrt{1 - \cos^2(\alpha)\cos^2(\beta)} \quad (1)$$

$$G_2 = G \times \cos(\alpha)\cos(\beta) \quad (2)$$

where G is the gravity of the support, kN; G_1 the component force of G along the dip, kN; G_2 the component force of G perpendicular to

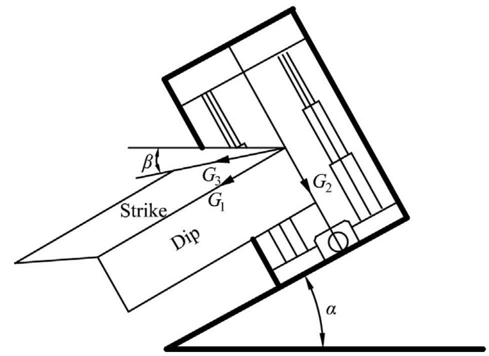

Fig. 2. Detail sketch of support force.

the floor, kN; G_3 the component force of G along the strike, kN; α the dip angle of the working face and β the angle of strike, °.

Considering the effects of strike angle on the support stability in the dip direction, the support toppling and slipping models of large dip angle fully-mechanized caving face are established, as shown in Figs. 3 and 4.

The critical conditions of the support topple model (see Fig. 3) can be seen as follows:

$$\begin{cases} f_{11} + f_{12} + T - F_1 = G_1 \\ R_{11} = G_2 + R_{12} \\ R_{12}b + (T - F_1 + f_{12})h + \frac{G_2 b}{2} - G_1\lambda h = 0 \\ f_{11} = \mu R_{11} \\ f_{12} = \mu R_{12} \end{cases} \quad (3)$$

The critical conditions of the support slip model (see Fig. 4) can be seen as follows:

$$\begin{cases} f_{21} + f_{22} + T - F_1 = G_1 \\ R_{21} = G_2 + R_{22} \\ \frac{R_{22}b}{2} + (T + f_{22} - F_1)h + \frac{G_2 b}{2} - G_1\lambda h - \frac{R_{21}b}{2} = 0 \\ f_{21} = \mu R_{21} \\ f_{22} = \mu R_{22} \end{cases} \quad (4)$$

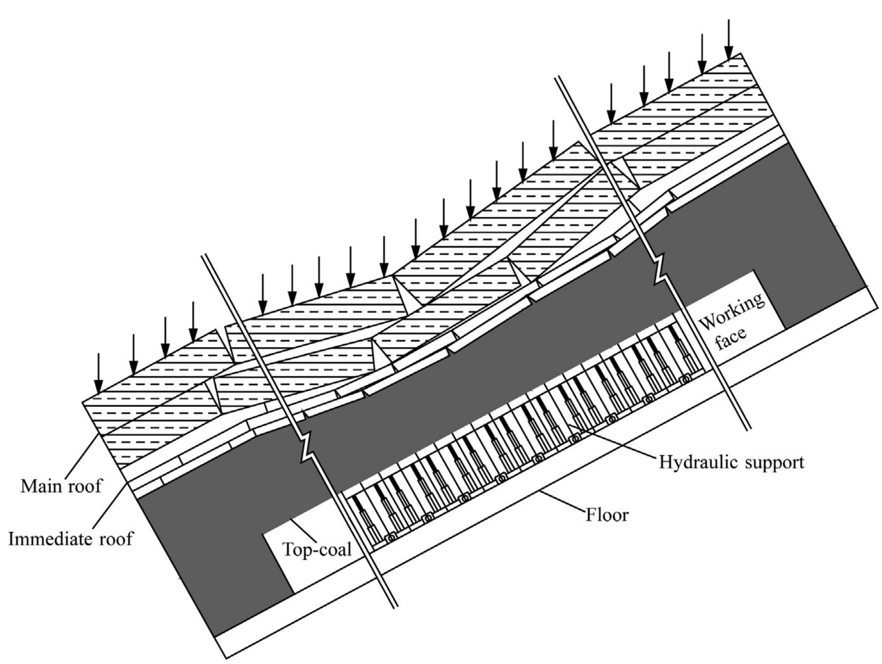

Fig. 1. "Support-surrounding rock" mine pressure model in the dip direction.