

# Stability of Support and Surrounding Rock in Fully Mechanized Top Caving Face with Large Dip Angle

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**Abstract:** Under the combined action of the strike angle and dip angle of coal seam, the coal wall failure, top coal migration, support stress and roof control of double inclined FMT-CCF (fully mechanized top-coal caving face) are special. In order to solve the difficult problem of stability control of support-surrounding rock system in FMT-CCF with LDA (large dip angle) in coal seam, the stability of support-surrounding rock system in FMT-CCF with LDA in transition area of angle change was studied by comprehensive research methods such as simulation experiment, theoretical analysis and field ground pressure observation, and the sub-regional characteristics of deformation and failure of surrounding rock and support stability in FMT-CCF with LDA and variable angle were analyzed. Successful experience has been gained in controlling the stability of support and surrounding rock in FMT-CCF with LDA, and the safety in production has been guaranteed.

## 1. Introduction

The coal seam with LDA (large dip angle) refers to the coal seam with buried dip angle of  $35^\circ \sim 55^\circ$ , which is recognized as a difficult coal seam by the international mining community. At present, the research on FMT-CCF (fully mechanized top-coal caving face) is mostly focused on gently inclined coal seam, while the research on FMT-CCF with LDA is less [1-2]. Therefore, it is necessary to carry out in-depth research on the related problems of FMT-CCF with LDA.

Roof water drenching disaster is one of the many factors that affect the safe and efficient mining of large inclined face. Due to the lack of water control experience of fully mechanized coal mining personnel, sudden roof water drenching accidents in some mines with relatively simple hydrological conditions often make the miners unprepared. The joint effects caused by roof drenching, such as large-scale roof caving and violent support dumping, often seriously affect the normal progress of the working face. The relationship between support and surrounding rock of FMT-CCF with LDA is an organic whole. Good support position and working condition of FMT-CCF with LDA is beneficial to the control of surrounding rock of end face, and good surrounding rock condition of end face will react on support of FMT-CCF with LDA, so that support of FMT-CCF with LDA can keep good position and working condition [3-4]. Based on the relationship between support and surrounding rock of FMT-CCF with LDA, this paper studies the stability of support of FMT-CCF with LDA, and formulates feasible control measures to improve the support reliability of working face.

## 2. Relationship between support and surrounding rock in FMT-CCF with LDA

The relationship between fully mechanized top-coal caving support and surrounding rock is the key to affect the safe and efficient production of working face. Good support surrounding rock relationship is characterized by good working condition of the support and good control effect on top coal at the end face, which is conducive to the rapid advancement of the working face and high yield and efficiency.

The core of the relationship between support and surrounding rock depends on the mutual influence range among support, direct roof and basic roof [5]. Especially in the surrounding rock

system of basic roof-direct roof-support, the interaction between support and basic roof takes the direct roof as the medium. Therefore, whether the support can support the basic roof and whether the support is affected by the rotation deformation of the basic roof depends on the mechanical characteristics and deformation and failure status of the direct roof.

When the dip angle of coal seam is greater than  $35^\circ$  and the long wall mining face is adopted, the uneven filling and restraint of roof caving rock along the inclined direction of the working face makes the distribution law of abutment pressure and the deformation and collapse of surrounding rock have obvious asymmetry and timing, and at the same time, it leads to the destruction and sliding of the floor, the sliding and falling of the support and equipment, and the resulting support-surrounding rock system is prone to dynamic instability and sudden change of surrounding rock during the working face advancing, resulting in safety accidents.

The change of the direct roof caving height  $\sum h$  along the inclined direction of the working face after the mining of large inclined seam is mainly influenced by the coal seam inclination  $\alpha$ , coal seam mining height  $M$ , the strength  $R^*$  and integrity coefficient  $W_z$  of the direct roof rock mass, the filling degree  $C_m$  of the caving gangue to the goaf, the caving position  $x$  and other factors:

$$\sum h = f(\alpha, R^*, W_z, C_m, M, x) = kx^2 - 2\alpha kx = kx(x - 2\alpha) \quad (1)$$

Among them,  $k$  is the location coefficient of roof caving, which depends on factors such as the dip angle of working face, mining height, direct roof lithology and so on.

### 3. Deformation and failure process of roof when mining large dip seam

In the free state, the support is mainly affected by its own weight, and the mechanical model of the support in the unstable state of inclined slip is established [6-7], as shown in Figure 1.

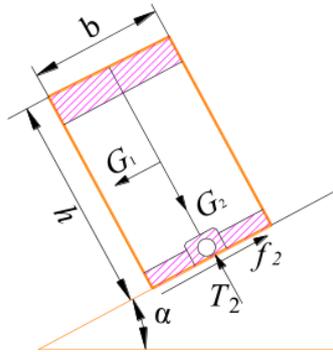


Figure 1 Inclined slip model of support in roof caving area

Under the action of self-weight, the inclined beam at an angle to the horizontal plane is subjected to the combined action of bending and stretching-compression [8]. According to the additive principle of acting force, the stress of a beam can be expressed by the sum of the stresses formed by various acting forces such as bending, stretching-compression, so the inclined beam can be divided into bending beam and stretching-compression beam.

The combined stresses of the upper and lower parts of the inclined beam neutral surface are:

$$\delta_{\text{upper}} = \frac{3ql^2}{h^2} \left( \frac{1}{6} - \frac{x}{l} + \frac{x^2}{l^2} \right) \cos \alpha + \frac{q(2x-l)}{2h} \sin \alpha \quad (2)$$

$$\delta_{\text{under}} = \frac{q \cos \alpha (6lx - 6x^2 - l^2)}{2h^2} - \frac{q \sin \alpha \left( x - \frac{l}{2} \right)}{h} \quad (3)$$

The existence of additional force reduces the tensile stress on the upper surface of the lower end of the beam, but increases the compressive stress on the lower surface. At the upper end of the beam, the upper surface tensile stress increases, while the lower surface compressive stress decreases. Considering that brittle failure is the main failure of the rock stratum, it will inevitably increase the failure uncertainty of the roof along the inclined direction of the rock stratum.

When the strike angle is constant, the critical working resistance gradually increases with the increase of the support inclination angle. When the inclination angle is less than 30°, the critical working resistance of the support increases with the increase of the inclination angle. However, when the inclination angle is greater than 30°, there is no obvious regularity between the working resistance of the support and the inclination angle.

Compared with the critical working resistance of the support in the working face under the conditions of up-mining and down-mining, it is found that the critical working resistance of the support under the condition of down-mining is larger, which indicates that the support under the condition of down-mining is easier to twist.

#### 4. Stability analysis of support-surrounding rock in fully mechanized face with LDA

##### 4.1. Influence of inclination angle on ground pressure of fully-mechanized coal face with double inclination and large inclination angle

In order to analyze the law of ground pressure in the face with LDA, especially the distribution characteristics in the dip direction, the initial support force and working resistance of supports at different times are selected to draw curves, as shown in Figure 2.

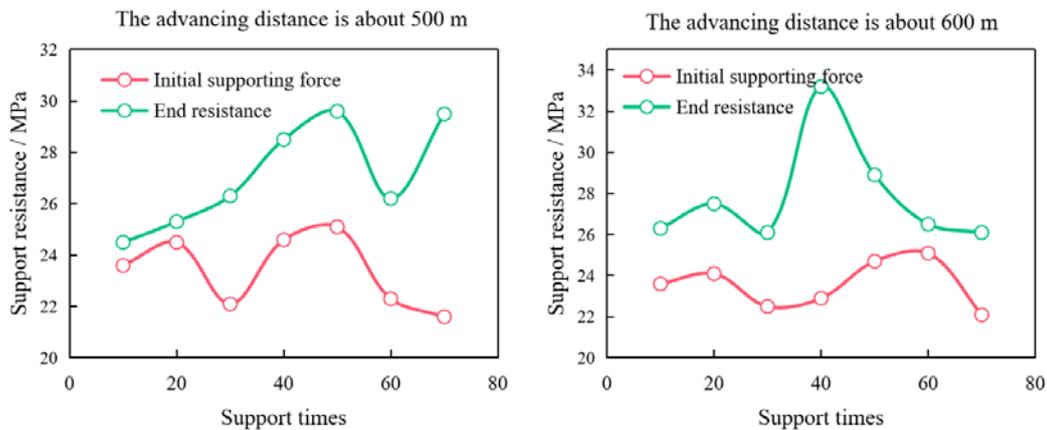


Figure 2 Distribution of initial supporting force and final resistance of working face inclination

It can be seen from the analysis that the working resistance of the inclined support along the working face is generally the largest in the middle, the second in the upper part and the smaller in the lower part. Due to the angle along the inclination of the large inclination working face, the gangue with backward roof collapse can not accumulate and stay in place, and will slide down to the lower part of the large inclination working face along the inclination of the working face.

As a result, there are more gangue piles in the lower part of the face with LDA, but less gangue piles in the upper part. The roof of the lower part of the working face with LDA is supported by the accumulated gangue, and the roof is not easy to collapse. Therefore, the tendency of periodic weighting in the face with LDA has obvious time series, that is, the upper part of the face is weighted first, followed by the lower part.

##### 4.2. Cause analysis of collapse of working face support

According to the field practice and theoretical analysis, it can be known that the reason for the collapse of the support in the FMT-CCF with LDA is the comprehensive effect of many factors, and the main influencing factors are as follows:

Under the normal working condition of the support in FMT-CCF with LDA, the friction

generated by the effective contact between the support and the top coal and floor is an important constraint condition for the support to remain stable. The initial support force of the support is of great significance to slow down the early subsidence of the roof, increase the stability of the roof and reduce the appearance of mine pressure in the working face, and it is the key to maintain the overall rigidity of the direct roof-support-floor in the FMT-CCF with LDA.

Roof leakage causes false roof connection of the support, and the bottom plate is soaked and softened by drenching water, which causes the support base to sink. The combination of the two results in low rigidity of the support system and low working resistance.

Under the condition of LDA, the side guard plate of FMT-CCF with LDA plays a more important role in adjusting the support besides the support seam. When the frame cannot be adjusted after the failure of the lower side guard plate, the upper side guard plate will adjust the bracket upside down [9].

In addition, the working face supports all lack the connecting lugs, pull rings for the supports, and the pillar sockets for the diagonal supports, which makes the supports extremely inconvenient after the supports are toppled.

### **4.3. Stability control countermeasures of support in FMT-CCF with LDA**

Based on the coupling characteristics of support and surrounding rock in FMT-CCF with LDA, the stability control countermeasures of support are analyzed. In daily work, the support quality, support management, special anti-sliding measures and other aspects are emphasized to ensure the support reliability, support stability and production safety.

For the double-inclined working face with LDA, the influence of coal seam dip angle and working face strike angle will lead to the inconsistent movement of "roof-support-floor", especially in the special situations such as basic roof breaking pressure, coal wall spalling, working face crossing fault and so on, which will generate large lateral stress on the working face support, posing a great threat to the stability of the support. Therefore, corresponding anti-falling and anti-skid control measures should be taken in the field practical application.

Improve the quality of coal and rock support at the end face. First, to ensure that the initial supporting force reaches the standard and the supporting strength; Second, control the end face distance not to exceed 0.3m to prevent end face leakage and roof caving; The third is to ensure that the top beam and front beam of FMT-CCF support with LDA are tightly connected, and control the roof clutch.

Control the abnormal position of support in FMT-CCF with LDA. Strictly control the parameters such as support moving step, roof beam step, support spacing, roof beam pitch angle, etc., so as to avoid the abnormal position of support in FMT-CCF with large inclination angle and prevent the instability of support caused by the continuous deterioration of a certain parameter.

For the empty roof area of the support in the working face, lay the plank or semi-log on the top of the support to wring the roof, so that the support can effectively connect the roof. Due to the soaking in drenching water, the soft floor of the working face softened and deformed, which made the support base of the working face sink, aggravated the degree of the support leaning forward and backward, and to a certain extent, also caused the false roof connection of the support. Therefore, in the process of moving the support, firstly, the support base should be lifted by the support bottom lifting device, and the support should be lowered and quickly pulled to wipe the top moving frame, so as to ensure the stability of the support to the greatest extent from the moving operation.

## **5. Conclusions**

In the mining process of FMT-CCF with LDA and variable angle, the spatial collapse of overlying strata takes the form of asymmetric arch shell, and the characteristics of overlying strata movement zoning in different areas tend to be obvious. It is easy to form a curved beam structure composed of cantilever beams and inclined masonry, and the stress peak appears at the angle transition position, which leads to sudden change of roof displacement at this position. Under the condition of end coal caving, the working resistance of the end support is smaller than that of the

support in the middle part of the working face, and the pillar pressure before and after coal caving does not change much. The roof above the end bracket is broken, and it is not easy to form a supporting structure. In order to ensure the stability of the end roof, the initial supporting force of the end bracket should be improved. Mastering the characteristics and activity rules of surrounding rock can realize the effective control of the selected support to the corresponding surrounding rock to the greatest extent.

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