Research on the dynamic effect of mineral-pressure in coal and gas outburst working face

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Abstract

The mining pressure of the working face of the fully inclined coal seam is large, but the research is rare and lacks theoretical guidance. In this paper, the theoretical analysis of overlying strata structure and motion law, working surface appearance law and supporting pressure distribution law in large dip angle coal seam is carried out, and the characteristics of roof movement in longwall fully mechanized mining face with large dip angle coal seam are obtained. The time series characteristics of roof collapse and mine pressure appearing in the coal seam face and the motion characteristics of the direct roof in the inclined direction of the working face provide a theoretical basis for the future large-angle fully mechanized mining.

Keywords

Coal and gas outburst, Mineral-pressure, Dynamic effect, Working face.

1. Foreword

Some basic laws for the development of mine pressure during the mining of large dip angle coal seams are the same as those for mining gently inclined coal seams [1-2]. For example, because the coal seam is produced, it will cause the movement, destruction and fall of the rock layer around the mining space, and the stress in the surrounding rock will be redistributed, and the deformation and damage of the roadway will be caused accordingly, and the support will be crushed and damaged. However, when the large dip angle coal seam is mined, the angle between the gravity direction of the rock and the direction of the rock bedding plane becomes smaller due to the larger dip angle, so the force of the gravity along the layer direction is greatly increased [3]. This causes the movement of the surrounding rock, the shape of the roof to fall, and the characteristics of the load on the support, which produce a series of characteristics different from those of the mining of the gently inclined coal seam [4-6]. In this paper, the systematic analysis of the overlying strata structure and motion law, the working surface appearance law and the distribution pressure distribution law of the large dip angle coal seam is carried out.

2. Analysis of rock movement law of roof in large dip angle and longwall fully mechanized mining face

2.1. Movement law of overburden strata on the roof of mining face with large dip angle coal seam

(1) Direct top motion law. After the large dip angle coal seam is mined, the direct top rock movement is mainly broken and caving. Due to the influence of the dip angle and the stability characteristics of the rock stratum in the oblique direction, the caving height of the direct top

rock stratum in the inclined direction of the stope is different. Due to the better filling of the lower part of the stope, these "masonry arches" have a certain supporting effect on the large structure of the overlying strata, so that the instability of the stope has a greater impact on the stope than the upper and middle sections of the stope. Smaller, when the rock formation above the fallen belt is larger than the falling space, the rock mass will sink smoothly. These "masonry arch" small structures in the direct roof are large deformation regions, which can be called "lower rock formations". The stability of these structures can prevent the deformation of the overburden and the overburden expansion.

The limit equilibrium condition for the structural slip instability is:

$$T = \frac{(Lh_z\gamma - P_G)(L\cos\theta + h_z\sin\theta)}{2\tan\beta(L\cos\theta + h_z\sin\theta) + L\sin 2\theta - 2h_z}$$

Where: T-the horizontal pressing force when the direct top small structure is formed, KN; L-the length of the direct top rock block, m; hz-the direct top thickness, m; γ-the direct top rock layer bulk density, KN/m^3; PG - the lower part of the structure is supported by the meteorite, KN; θ - the sinking angle of the rock, °; β - the internal friction angle of the top rock, °.

(2) Basic top motion law. As the working face continues to advance and the inclined rock stratum reaches the ultimate span, the broken plate continues to fall into the goaf, and the rock block forms a falling zone in the mining area, which can be called the "lower rock formation" and the "factory" type. The inclined rock layer on the left side of the "factory" type moving arch forms an overall curved moving belt under the action of the horizontal beam support and the basic top self-gravity, which is called "upper rock formation". The upper rock layer is prone to deformation and overall bending. However, compared with the lower rock layer, the deformation degree of the rock formation is obviously small, belonging to the small deformation zone, and the stratification characteristics and integrity of the upper rock formation remain intact. The mechanical properties between the layers are different, and belong to the small deformation zone. Each layer can be regarded as the "superposition" of the small disturbance plate, as shown in Fig.1.
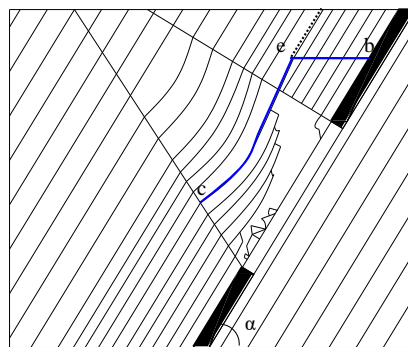

Fig.1 "Factory" type moving pattern of rock formation in large dip angle coal seam mining

In the roof rock strata of the large dip angle coal seam, it is easy to form the "large structure" of the basic top rock stratum and the small structure of the direct top part of the rock stratum. The key block of the large structure is in the upper section of the stope, and there is no direct top "small structure" underneath, at the middle and lower sections. The large structure maintains balance under the support of the lower direct top rock layer and the stability of the structure itself, and protects the small structure during non-pressure. The destruction and instability of the small structure inevitably cause disturbance to the large structure. During non-pressure, this disturbance has certain influence on the supporting condition of the large structure at the corresponding position, but does not cause the instability of the large structure. In the process of large structural instability, this disturbance will inevitably accelerate the instability of the large structure. At the same time, it will inevitably cause the relationship between the stopway

and the surrounding rock to be re-adjusted to a certain extent and extent, thus causing changes in the mining ground pressure.

2.2. Fracture mechanism and determination of breaking parameters of roof rock strata in large dip angle coal seam mining

In the theory of elastic mechanics, for a four-sided or three-sided supported plate, when the ratio of spans in two directions is $\frac{1}{2} \leq \frac{L_x}{L_y} \leq 2$, the load on the plate can no longer be considered to be transmitted only to the support boundary in the short span direction, but the actual load transfer route should be considered, that is, the load on the plate is transmitted to the boundary in both the long span and the short span. Such boards are often referred to as two-way boards. The span ratio is outside the above agreed range and is called a single board.

The top plate of the large dip angle coal seam has different restraint states with the working face advancing and mining. The working face is just installed, the initial working face is just formed, the top plate is in the four-sided fixed state, and the exposed area of the top plate is very small, only Open the top area of the eye. When the working face starts to advance, the top plate is still in the four-sided fixed state before the basic top is broken and pressed, but the top plate is generally at the maximum exposed area. As the working surface continues to advance, the basic top breaks and the first pressure occurs. At this time, there are two kinds of constraints on the top surface of the working face: one is three-sided solid support and one side is free. The other is fixed on both sides, hinged on one side, and free on one side.

(1) Direct top limit span. The ultimate span of the direct roof is the maximum span of the direct top rock. Before the initial collapse of the basic top, the span is the distance from the coal wall of the open cut to the coal wall of the working face; after the initial fall, it can be regarded as the maximum overhang of the working face. The falling step of the direct top differs from its ultimate span by the length of a controlled top distance. The ultimate span of the direct top is generally less than half the length of the working face, which is approximately one third of the working face inclined length.

(2) Basic top initial fracture step. The phenomenon of the initial fracture of the basic top rock layer on the working face support is called the basic top initial pressure. The initial pressure of the basic top seriously affects the support strength and stability of the working face support system. Especially under the condition of hard roof, if the working resistance of the bracket or the choice of the frame type is improper, it will often cause a large roof accident.

The top plate mechanical model before the initial pressure of the basic top is a sloping plate model with four sides fixed, Fig.2.
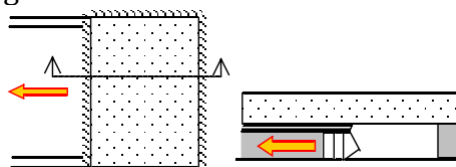

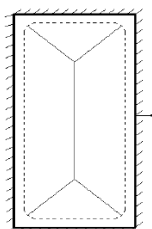**Fig.2** The mechanical model of the roof before the initial fracture of the basic top

Fig.3 Broken form when the basic top is first pressed

When calculating the model of the plate, according to the support condition of the plate and the elastic theory, it is simplified into an elastic two-way plate, which is calculated in two directions, one is the direction along the working surface and the other is the inclined direction along the working surface. The broken form of the basic top when it is first pressed is shown in Fig.3. Calculated according to the elastic thin plate, if the basic top breaks the step distance L. When it is less than half of the length of the working surface Ly, the basic top breaking step is basically. Can be calculated by one-way board. In the short span direction, when the basic top is first broken, the front end support point is located above the coal wall of the working face, and the rear end support point is located above the coal wall of the open face of the working face, so it can be regarded as the fixed support plate at both ends, and Simplified to solve the fixed beam at both ends, that is, the basic top fracture step under the condition of the one-way plate is:

$$l = H\sqrt{\frac{2KR}{q}}$$

Where: l - the initial top step of the basic top rock layer, m; H - the basic top thickness, m; R - the basic top rock layer tensile strength, KN; K - the basic top tensile strength coefficient; q - Basic top uniform load, MPa.

The range in which the rock plate breaks along the inclined direction of the working surface is:

$$\frac{2q\cos\alpha(3l+2h) - \sqrt{[2q\cos\alpha(3l+2h)]^2 - 24q\cos\alpha[q\cos\alpha(l^2+hl) - 2bh^2\sigma_t]}}{12q\cos\alpha} \leq x$$

$$\frac{2q\cos\alpha(3l+2h) - \sqrt{[2q\cos\alpha(3l+2h)]^2 - 24q\cos\alpha[q\cos\alpha(l^2+hl) - 2bh^2\sigma_t]}}{12q\cos\alpha} \geq x$$

Where: q - the load on the basic top, MPa; α - the dip angle of the coal seam, °; L - the initial fracture step in the middle direction of the strike direction, m.

3. Distribution law of bearing pressure in longwall fully mechanized mining face with large dip angle coal seam

The coal and rock mass before the mining operation are not disturbed by humans, and the stress is in equilibrium. At this time, the measured rock mass stress is the original rock stress; after the coal seam is mined, the mining stress field is formed, and the surrounding rock stress is redistributed. Within the scope, the vertical pressure acting on coal seams, rock formations and vermiculite is called the supporting pressure.

(1) Working surface tends to support pressure distribution law. There is a pressure peak in the range of the bearing pressure distribution, and the bearing pressure distribution is divided into a plastic zone and an elastic zone by the pressure peak. Establish the structural mechanics model as shown in Fig.4.
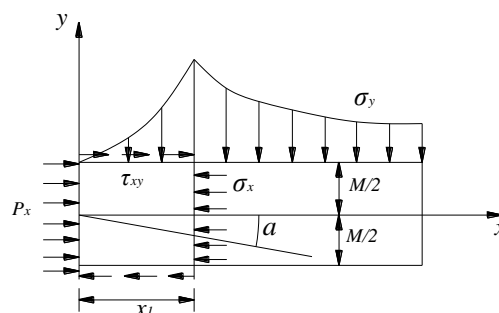

Fig.4 Mechanical model of the propensity bearing pressure structure

Establishing the equation gives the working surface a tendency to support the pressure plastic zone range:

$$\begin{cases} x_1 = \dfrac{M\beta}{2\tan\varphi_0}\ln[\dfrac{\beta(\sigma_{y1}\cos\alpha\tan\varphi_0 + 2c_0 - M\gamma_0\sin\alpha)}{\beta(2c_0 - M\gamma_0\sin\alpha) + 2P_x\tan\varphi_0}] \\[4mm] x_2 = \dfrac{M\beta}{2\tan\varphi_0}\ln[\dfrac{\beta(\sigma_{y1}\cos\alpha\tan\varphi_0 + 2c_0 + M\gamma_0\sin\alpha)}{\beta(2c_0 + M\gamma_0\sin\alpha) + 2P_x\tan\varphi_0}] \end{cases}$$

Where: x_1-the upper side of the stope tends to support the pressure plastic zone range; M-the thickness of the mined coal seam, m; β-the lateral pressure coefficient of the surface where the ultimate strength is located; c_0 - the interface between the coal seam and the top and bottom plates Friction angle, °; σ_{y1}—support pressure peak, MPa; α—coal dip angle, °; c_0—cohesion at the interface between coal seam and top and bottom plate, MPa; γ_0—average volume force of coal body, MPa; Px —the binding force of the roadway support on the coal wall in the x direction, MPa.

(2) Working surface distribution pressure distribution law. The movement and stress redistribution of the surrounding rock mass caused by the coal seam mining process has a great impact on the deformation and damage of the surrounding rock of the large dip angle coal seam. When the working face is recovered, the irregular fault zone is loose, and most of the overburden is suspended. The weight of the suspended rock is transferred to the coal in front of the working face. At this time, the goaf is lower than the original rock. In the region of reduced stress, the coal in front of the working face exhibits a much greater bearing pressure than the original rock stress.

4. Conclusion

(1) The movement law of overburden strata on the roof of the large inclined angle longwall fully mechanized mining face is analyzed. Combined with the theory of masonry arch, the mechanical model of the direct top "small structure" of the large inclined coal seam stope is proposed, and the large dip angle is determined. The limit equilibrium condition of the direct roof structure sliding instability of coal seam stope.

(2) Based on the theory of elastic mechanics, the fracture mechanism and breaking parameters of the roof rock strata in the large dip angle coal seam are discussed by using the two-way plate theory of elastic thin plates. The calculation formula of the basic top cycle fracture step of the working face with large dip angle coal seam is proposed.

Acknowledgments

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