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The Impact of Different Mining and Releasing Ratios on the Over-Support Pressure of Header Working Face

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Abstract

Through the theoretical analysis of overburden destabilization mechanism, FLAC 3D simplified plane numerical simulation method and field measurement method, we compared the relationship of overburden support pressure at 35 m of workface recovery, and the peak overburden support pressure decreased from 13.85 Mpa to 11.97 Mpa from 1:1 to 1:3. With the increase of mining ratio, the peak over-supporting pressure decreases: with the increase of top coal recovery thickness, the peak over-supporting pressure and the influence range will be further expanded, and the distance between the peak over-supporting pressure and the coal wall of the working face will be further increased and the high stress zone of the peak area will be expanded simultaneously.

Keywords

Different Extraction and Release Ratios, Overburden Support Pressure, Overburden Destabilization Mechanism

1. Introduction

The factors influencing the overrunning support pressure have been studied by many scholars, and for the earliest by analyzing the whole process of support pressure formation and development at the working face before and after the basic roof fracture, it is concluded that the location of overrunning roof fracture and its support pressure formation mechanism are intrinsically related [1] [2] [3]. By constructing the elastic foundation beam mechanics model [4] [5] [6], it is analyzed that: the roof slab fracture occurs mainly by excessive bending moment [7] [8], which makes the tensile stress at the edge of the roof slab exceed the ultimate tensile strength that its rock can withstand [9]. In this paper, the relationship between the thickness of the top coal and the peak overhead support pressure is revealed by studying the intrinsic correlation between different mining and releasing ratios and the peak overhead support pressure using the 4-2 working face of the Burtai coal mine as the research object.

2. Project Background

Buertai coal mine is located in Shenfu Dongsheng coalfield, Ordos city, Inner Mongolia Autonomous Region, China. Currently, there are 9 coal seams in Buertai coal mine, among which the main coal seams are 2-2 and 4-2.

This paper takes the 4-2 working face of Burtai coal mine as the research object, the working face of 4-2 coal seam 42106 adopts partial "Y" type ventilation, its auxiliary transport chute is the main inlet road, the thickness of coal mining is 3.6m, the height of coal release is 3 m, the ratio of mining release is 1:1.02, the average thickness of coal seam can reach 6 m, the roof lithology is mostly sandpaper mudstone The average thickness of the coal seam is about 14 m, and the average depth of the coal seam is about 365.7 m.

3. Different Mining and Releasing Ratios on the Theoretical Analysis of the Top Plate Breakage Position

In the case of coal rock seam stiffness value is large, the maximum bending moment in front of the hard roof working will exceed the span bending moment in its roof mining area, and then derive its theoretical formula of the maximum bending moment in front of the coal wall [10], the formula is shown in the following equation (1).

$$x_i = \tan^{-1}\left\{ \frac{\left[(3as - ar) M_i + \gamma Q_i + \frac{q_1 s}{br} \right] \beta}{\left(\gamma^2 + \gamma\beta^2 - s\beta^2 \right) M_i + \alpha\gamma Q_i + \frac{asq_1}{br}} \right\} * \beta^{-1} \tag{1}$$

where, M_i Q_i is the internal force of the beam section corresponding to the location of the coal wall in the same mining area, respectively bending moment and shear force; q_1 is the increment of lateral load caused by mining; b is the influence range of over-support pressure; $s = N/EI$, $r^2 = k/EI$, where E is the top plate elastic modulus, when in plane strain conditions, E is taken $E/\left(1-u^2\right)$, k is the foundation stiffness, I is the moment of inertia per unit width of the basic top, $I = bh^3/12$, b, h are the width and thickness of the basic top; $\alpha = \left(r/2 - s/4\right)^{0.5}$, $\beta = \left(r/2 + s/4\right)^{0.5}$.

Based on the working conditions of the working face, the foundation coefficient Mpa; basic top elastic modulus Gpa; basic fixed flexural modulus; basic top flexural stiffness is taken. Accordingly, we can calculate the local load value of 0.57 Mpa at the overhanging part, and the length of the initial broken overhanging roof at the working face is 90 m, which is calculated as:

$$Q_1 = q_1 L + Q_1' = 0.57 \times 90 + 213 = 264.3MN;$$

$$
\begin{aligned}
M &= 0.5 \times q_1 L^2 + Q'L + N'\left(h/2 + \Delta s_1\right) \\
&= 0.57 \times 90 \times 90 + 213 \times 90 + 99.07 \times 2.46 \\
&= 24030.71\ \text{N·m}
\end{aligned}
$$

Matlab was used to process the function data and draw the distribution curves of the top plate bending moment under different mining thicknesses (**Figure 1**), and the evolution characteristic curves of the maximum bending moment of the rock beam and the corresponding position (**Figure 2**).

4. Numerical Simulation Analysis of the Effect of Different Extraction and Release Ratios on the Overrun Support Pressure

This subsection analyzes the impact of overburden support pressure under different mining and release ratios by using FLAC 3D numerical simulation method, whose model size is 240 m × 1 m × 58.15 m, and the overburden rock of 30 m is

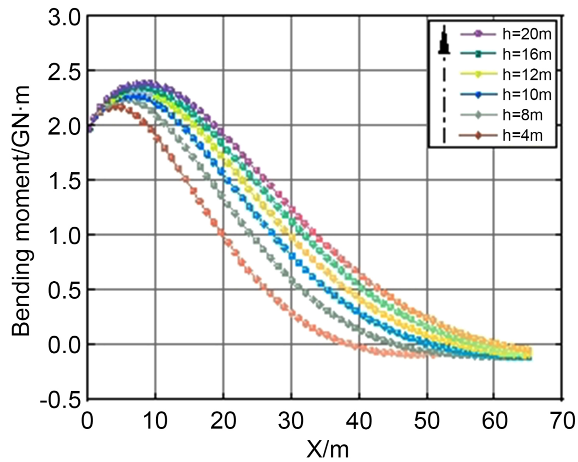


Figure 1. Distribution of bending moment of the top plate under different mining thickness.

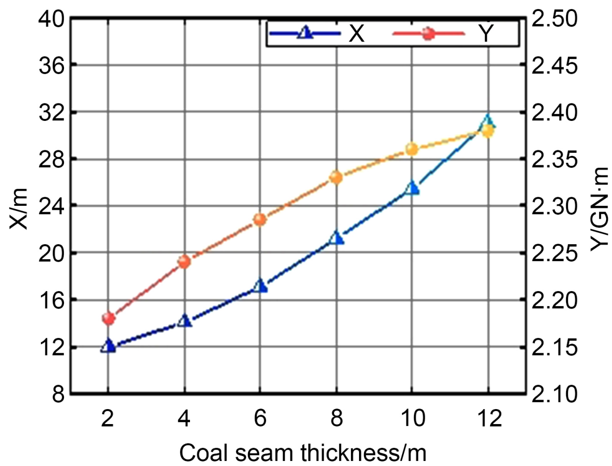


Figure 2. Evolutionary characteristics of the maximum bending moment (Y) and corresponding position of the rock beam.

constructed above the Burdai 4-2 coal seam, which is 10 m sandy mudstone and 22 m key layer siltstone, respectively, and the upper boundary of the model is used as the upper boundary of the model by applying 9.20 Mpa vertical stress to the compensation force of the overburden rock at the surface, constructed by using near-horizontal coal seams, which are constrained to the left and right, and the boundary is fixed at the bottom, and the model is shown in Figure 3 below. The model adopts the Mohr-Coulomb criterion as the coal-rock material ontogenetic relationship [11], as the following Equation (2):

$$f_s = \sigma_1 - \sigma_2 \frac{1+\sin\varphi}{1-\sin\varphi} - 2C\sqrt{\frac{1+\sin\varphi}{1-\sin\varphi}} \tag{2}$$

where σ_1—maximum principal stress; σ_3—minimum principal stress; C—cohesion; φ—angle of internal friction.

Two measurement lines are laid out, one of which varies according to the simulation scheme of the coal cutting and release line position, *i.e.*, measurement line 1; the other measurement line is located at 6.0 m of the coal seam, *i.e.*, measurement line 2, as shown in Figure 3 below, for different mining and release ratios of 1:1, 1:1.5, 1:2, 1:2.5 and 1:3, respectively. After the model is calculated and balanced, the initial state is saved; the stress and displacement of the initial state of the model are cleared to zero; an excavation is carried out by cutting an eye at 20 m on the left side of the model, each excavation is 5 m and the calculation is run and saved, and the excavation is cycled for 120 m in turn;

Based on the results of the similar simulation tests and 3DEC numerical simulations above, the initial pressure step and the periodic pressure step of the 42106 heaving face in the Burtai 4-2 seam were determined, and the data of 35 m, 65 m, 95 m and 120 m of measurement line 1 in the FLAC 3D numerical simulation results were processed and analyzed.

Through the analysis of the curve in Figure 4 below, it can be seen that the peak over-support pressure of different mining and releasing ratios increases with the increase of the recovery distance of 42106 comprehensive workface. But with the increase of mining and releasing ratio, the peak over-supporting pressure decreases, such as when the working face is retrieved 35 m, the mining

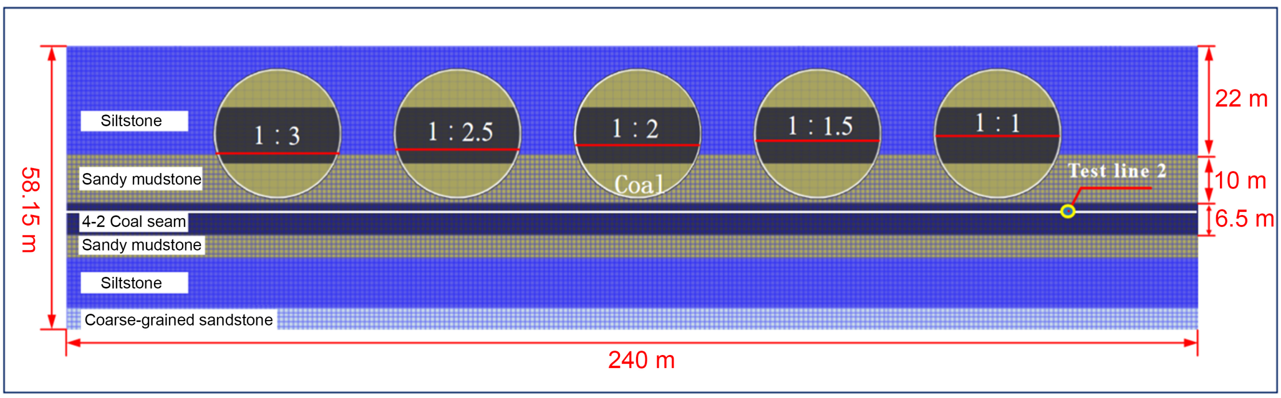


Figure 3. Numerical simulation model of FlAC 3D under different extraction and release ratios.

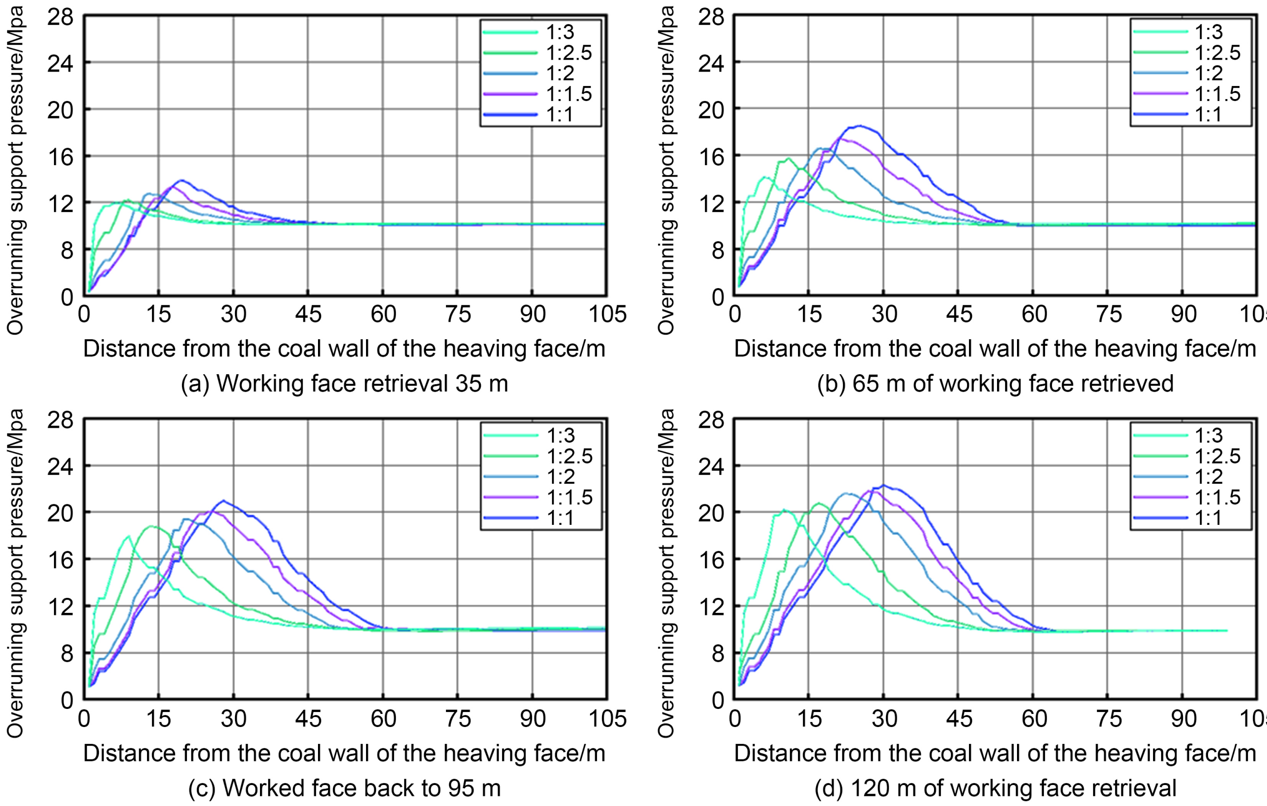


Figure 4. Relationship between each retrieval distance and overrun support pressure under different extraction and release ratios.

and releasing ratio increases from 1:1 to 1:3, and the peak over-supporting pressure decreases from 13.85 Mpa to 11.97 Mpa, and the working face retrieval distance of 65 m, 95 m and 120 m also shows this law.

5. Field Test Analysis of the Evolution of Over-Support Pressure of Top Coal at Different Seams

5.1. Top Coal Stress Field Actual Measurement Program

The top coal stress field test is arranged in 42106 auxiliary transport chute and 42107 auxiliary transport chute from bottom to top with 4 observation lines, of which the hole depth of I and II observation lines is 35 m, and the hole depth of III and IV observation lines is 15 m, so that 6 measurement points are set at 5 m intervals along the direction of back mining advancement of the working face, and the arrangement of measurement points is as follows Figure 5.

5.2. Field Monitoring Analysis of Top Coal Stress at Different Levels

The site monitoring and analysis of stress on the top coal at different levels in the site construction factors led to the failure to install measurement point I-4, while measurement points II-4 and IV-1 failed to monitor the stress data acquisition due to equipment failure after installation, so the monitoring data of these two measurement points were missing. The residual stress observation lines I, II, III and IV are shown in Figure 6.

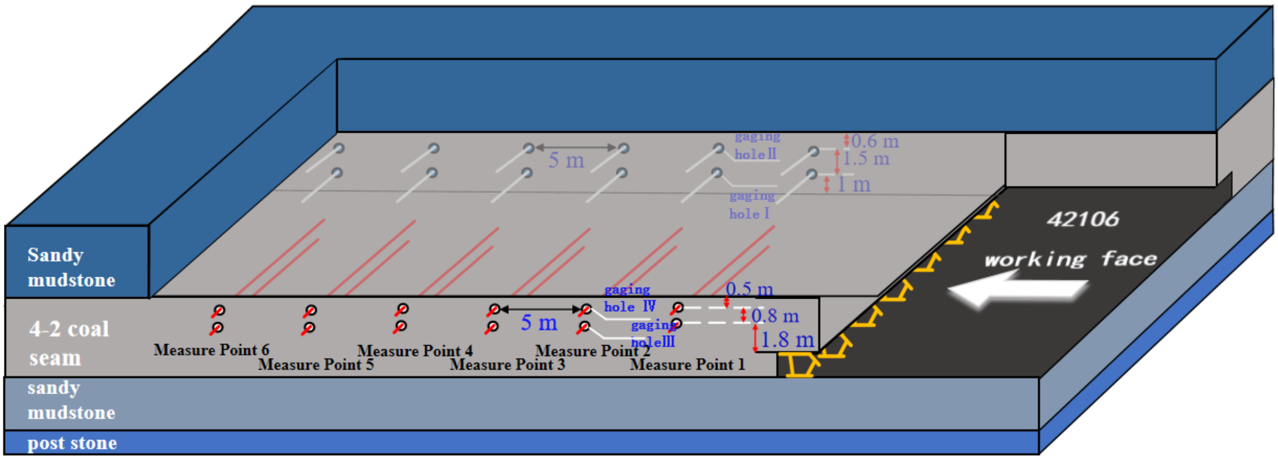
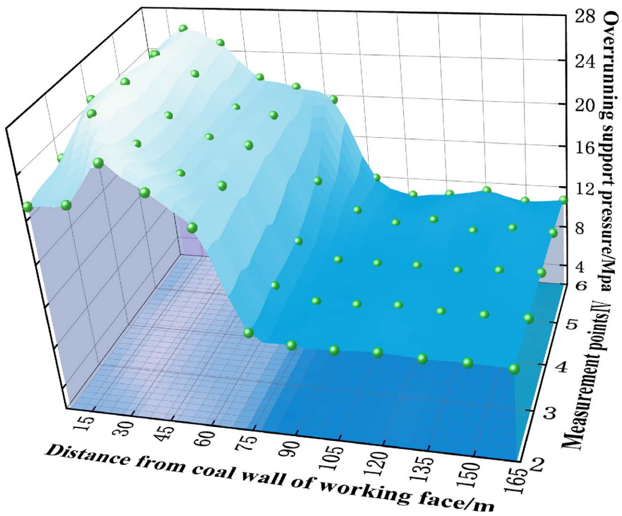
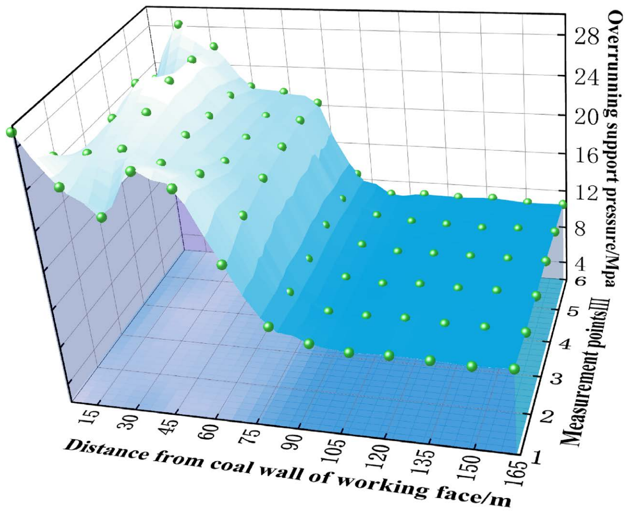


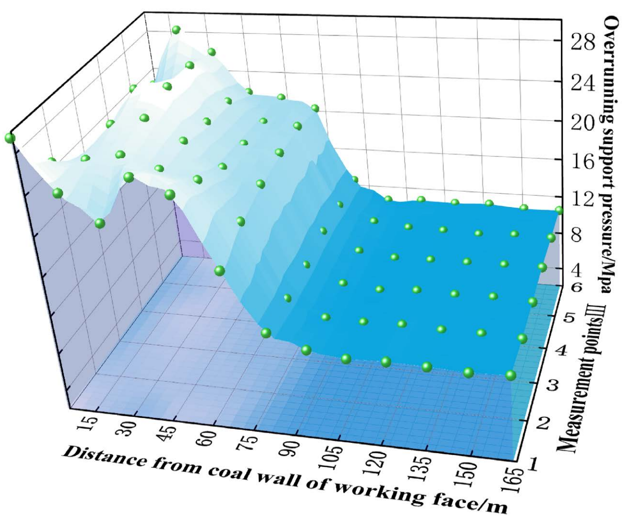
Figure 5. YHY60 mining intrinsically safe borehole stress test diagram.



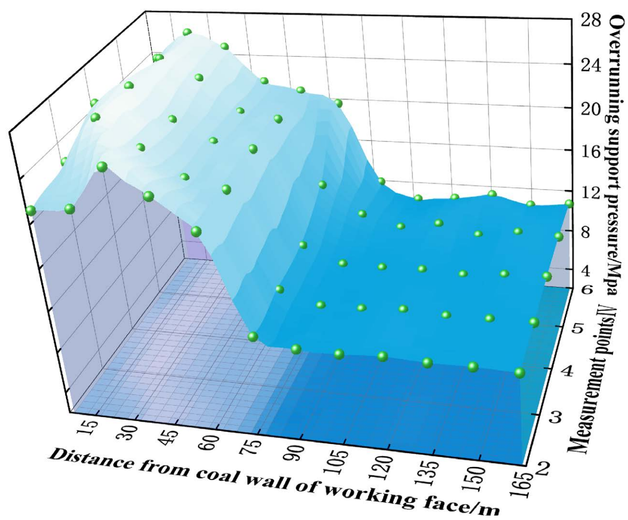
(a) Stress observation line I



(b) Stress observation line II



(c) Stress observation line III



(d) Stress observation line IV

Figure 6. Relationship between the stresses and the distance from the coal wall of the working face between each stress observation line.

Based on (a) and (d) in **Figure 6** above, it can be seen that the over-supporting position of the coal seam consolidation workface of Buertai 4-2 starts to occur at 85m in front of the consolidation workface, and the over-supporting pressure increases rapidly in the range of 40 Mpa to 50 Mpa in front of the workface, while the peak over-supporting pressure appears in the range of 20 - 45 m in front of the workface, and the peak can reach 26 Mpa, and the over-supporting pressure in front of the consolidation workface is about 10.8 Mpa. The stress is about 10.8 Mpa, and the stress concentration coefficient of the working face is about 2.6.

Based on the stress monitoring data of the top coal at different levels, the distance between different measurement points and the coal wall is plotted by the matrix method, as shown in **Figure 7**.

By comparing the peak overhead support pressure and the average stress curve of each measurement point in **Figure 7**, it can be seen that the peak stresses in the top coal of different layers at the same distance in front of the comprehensive discharge work are different, and the stresses in the top coal above are greater than the stresses in the top coal below, for example, at 40 m in front of the work, the average values of the I - IV measurement lines are 22.8 Mpa, 23.6 Mpa, 25.4 Mpa and 25.9 Mpa.

Through the monitoring results of over-supporting stress at different levels, it can be seen that the peak over-supporting pressure and the influence range will be further expanded as the thickness of the top coal recovery increases, *i.e.*, when the ratio of mining and releasing decreases, the over-supporting pressure stress concentration coefficient will be smaller than that of comprehensive mechanized

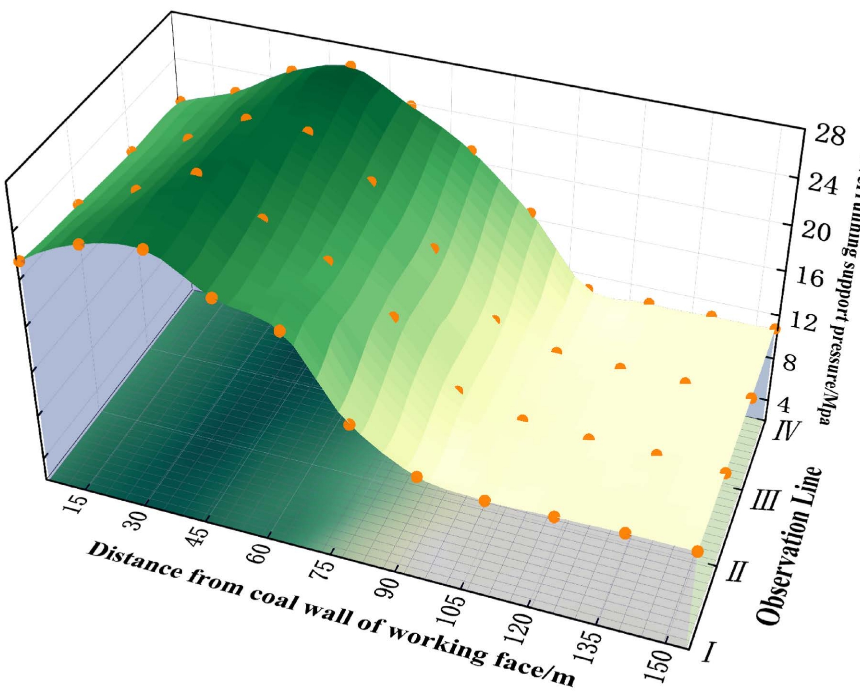


Figure 7. Relationship between the average value of stress and distance from the coal wall of the working face for each measurement observation point.

mining at full height, and the distance of the peak over-supporting pressure zone from the coal wall of the working face will be further increased and the high stress zone in the peak zone will be expanded simultaneously. Simultaneously, expansion will also occur.

As the coal body in front of the working face wall is subjected to one-way pressure breakage during the workface retrieval process, its over-front support stress peak will be transferred to the coal body in the deep two-way and three-way stress state, which then constitutes the transient equilibrium of the structure in front of the coal wall, according to which related scholars adopt the continuity medium limit equilibrium theory and deduce the horizontal distance between its over-front support pressure peak position and the coal wall of the working face η_0 [12]:

$$\eta_0 = \frac{L\beta}{2\tan\theta} \times \left(\rho\gamma H + \frac{k}{\tan\theta}\right) \times \left(\frac{k}{\tan\theta} + \frac{P_t}{\beta}\right)^{-1} \tag{3}$$

In the above equation, η_0 is the horizontal distance from the peak overhead support pressure to the coal wall of the working face, m; L is the thickness of the coal seam, m; β is the pressure measurement coefficient; θ is the internal friction angle of the coal and rock body, ˚; ρ is the stress concentration coefficient of the peak overhead support pressure; H is the mining depth of the coal seam, m; γ is the average capacity of the overlying rock seam, 106 N/m^2; k is the cohesive force of the coal body, Mpa; p_t is the support strength formed by the support reaction force of the support to the coal wall of the working face, Mpa.

Based on the production technology and conditions of the 4-2 coal mine in Burtai and the results of the mechanical lithology test of the coal rock body, the values in the table are taken and brought into the above Equation (3) respectively, The parameters are as follows (**Table 1**).

The calculation formula and results after bringing in the parameters are as follows:

$$y = \frac{x \times 0.48}{2 \times \tan 26.2} \times \left(1.3 \times 0.042 \times 412 + \frac{4.2}{\tan 20.2}\right) \times \left(\frac{4.2}{\tan 26.2} + \frac{0.041}{0.48}\right)^{-1} = 15.98\ \text{m}$$

This result is very similar to the field actual measurement line I test result of 16 m, thus indicating the feasibility of the relationship between the peak over-support pressure and its peak distance from the coal wall by the field over-support pressure of different layers. For observation line II - IV, the horizontal distance between the peak over-support pressure and the coal wall of the working face are 17.5, 28 m and 32 m respectively, so the relationship between the over-support pressure and the horizontal distance from the working face for different seams of the top coal of the thick coal seam is fitted by the non-linear regression method, as shown in **Figure 8** below. The correlation coefficient reaches 0.998, which indicates that the different mining and release ratios have some intrinsic relationship to the size of support pressure and breakage position.

Table 1. List of parameter values.

L (m)	β	θ (˚)	ρ (m)	γ (N/m²)	H (m)	C	P_t (MN)
6.5	0.48	26.2	1.3	0.022	412	4.2	0.041

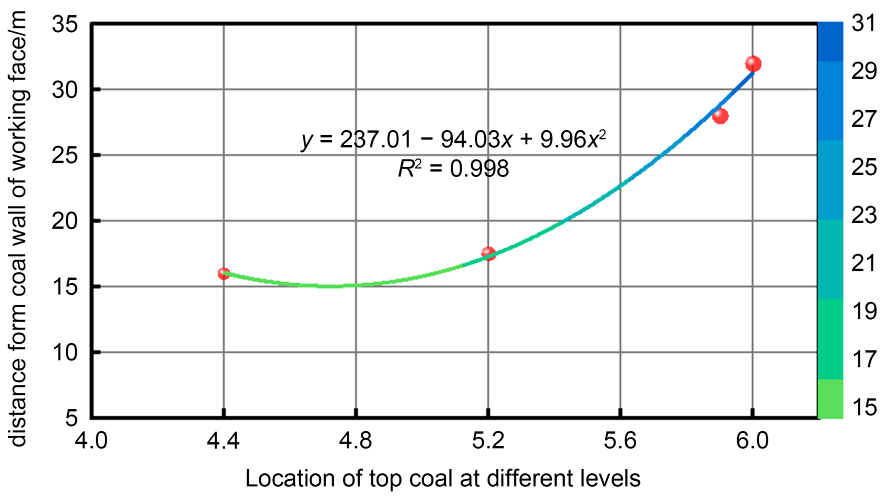


Figure 8. Relationship between the peak support pressure of coal body at different levels and the horizontal distance from the working face coal wall.

6. Conclusions

1) The finite element numerical simulation software FLAC 3D is used to construct corresponding simulation schemes for different mining and releasing ratios, and the analysis shows that the peak over-support pressure shows a decreasing trend with the increase of mining and releasing ratio, and this conclusion has certain guiding significance for the over-support of the roadway.

2) For the stress zone in front of the coal wall of the comprehensive working face, the high stress zone shows a simultaneous expansion trend with the increase of the working face distance; however, with the increase of the mining and releasing ratio, the high stress zone shows a reduction trend under the same working face distance, which has certain significance for the engineering support of the working face.

3) Through the non-linear fitting of the peak over-support pressure and the distance from the working face coal wall at different mining and releasing ratios, the correlation coefficients are 0.945 and 0.993 respectively, which reveals the intrinsic correlation between the peakover-support pressure and its peak distance from the coal wall at different mining and releasing ratios.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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