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Research on structural evolution characteristics of overburden rock for shallow buried thick coal seam mining

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Abstract: In order to grasp the structural evolution characteristics of overburden rock in shallow buried thick coal seam mining, the mechanism of overburden rock destabilization in the mining of 42106 comprehensive release workings in the 4-2 coal seam of Bultai coal mine was analyzed by using theoretical analysis, similar simulation and numerical simulation. The results show that: with the increase of the workface recovery length, the overburden of the comprehensive release workface experiences a continuous dynamic sinking process; the initial pressure step is about 95m, and the initial breakage position of the key layer is located at the back of the workface, and the periodic pressure step is about 25m, and the breakage position is located in front of the coal wall; when the workface recovery distance is from 65m to 95m, the overburden support stress of the comprehensive release workface appears to rise abruptly at the initial pressure. trend.

1 Introduction

However, with the continuous development of Shendong coalfield, especially after the "10-10" accident of Shendong Daljuta coal mine, many scholars in China have researched the structural evolution characteristics of shallowly buried coal seams in terms of coal seam inventory, mechanical mechanism and mine pressure manifestation, and defined the definition of shallowly buried coal seams. The definition of shallow buried coal seam is summarized as follows: it is difficult for the roof to form a stable mechanical structure[1-3]; it is difficult to form a complete "three belts"; the working face has a large dynamic pressure load and the roof is very easy to cut down.

As the working face advances and the mining height increases, the mine pressure pattern at the working face will be more complicated, and it is very easy to have sudden change of mine pressure such as slice gang, roof rise and pressure frame[4]. In response to this situation, the 4-2 general working face of Shendong Buertai coal mine is used as an example to study the mechanism of overburden destabilization and mine pressure emergence law during the mining of shallow buried thick coal seam, revealing the mechanism of sudden change of dynamic mine pressure, which can provide theoretical basis for the safe production of similar working faces.

2 Project Background

Buertai coal mine is located in the Shenfu Dongsheng coalfield, with a simple geological structure, coal seam dip angle of 1°~5°, no large fault, and the main coal seams are 2-2 and 4-2. The average thickness of 4-2 coal seam can reach 6.6m, the cutting height is 3.6m, the releasing height is 3m, and the mining ratio is 1:1.02. The roof lithology is mostly sandy mudstone, the average thickness is about 14m, and its "step-type" cut-down characteristics are in line with the definition of shallow buried coal seam by related scholars.

In order to accurately grasp the physical parameters of the overburden rock of the 4-2 coal seam, the basic lithological tests such as density, tensile strength, cohesion and friction angle were conducted on the 4-2 coal seam, direct top, key layer and bottom plate respectively, and the results are shown in Table 1.

Table 1. Physical and mechanical parameters of the overburden rock of the 4-2 coal seam of the Buertai Mine

Rock name	density /kg·m-3	tensile strength/MPa	compressive strength/ MPa	cohesion/ MPa	Elastic modulus/ MPa	Friction angle/ (°)
Siltstone	2547	2.30	67.38	6.97	11.68	32
4-2coal	1320	0.94	10.36	1.3	8.36	30
sandy mudstone	2137	1.56	32.58	6.13	6.78	29

3 shallow buried thick coal seam mining overburden destabilization characteristics analysis

Combined with the shallow buried thick coal seam comprehensive release working face site mine pressure revealed characteristics, the basic top breakage form of Burtai coal mine can be simplified as a solid support

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beam mechanical model[5-6], as shown in Figure 1, combined with the mechanics of materials can calculate the basic top initial breakage step.

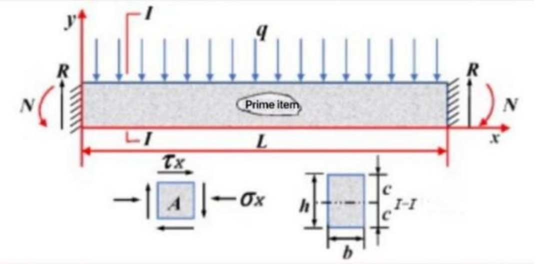


Figure 1 . Mechanical model of the basic top fixed support beam

From the mechanical model, the maximum bending moment calculation formula (1) and the maximum tensile stress calculation formula (2) for the basic top can be obtained.

$$N_{Max} = -\frac{qL^2}{12} \tag{1}$$

$$y(t) + \frac{y(t)}{k_e} y(t) = p\frac{dt_p}{dt} \tag{2}$$

Where, h is the basic top thickness in m; q is the load shown in it in Mpa; N is the bending moment of the section where the point is located in KN.m; y is the distance of the point from the neutral axis of the section in m; R is the reaction force at both ends of the beam in N. When the broken collapsed rock reaches equilibrium, the impact stress on the rock above the heaving working face is obtained by combining the dynamic equilibrium equation after simplification as follows[7-8]:

$$\sigma(t) = \frac{-F}{S} = \frac{M\sqrt{2g\Delta(\alpha^2+\upsilon^2)}}{\alpha S} e^{-vt} \sin \alpha t \tag{3}$$

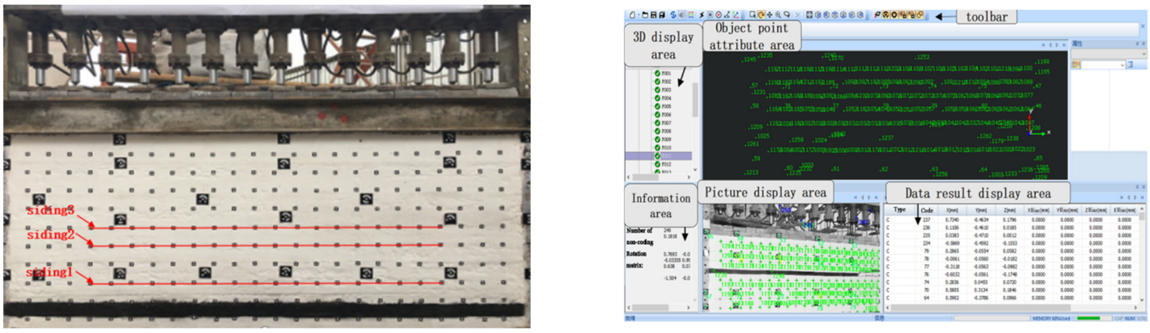
In which, M=m+Q is the weight of its entire broken collapsed overburden rock, kg; S is the area of dynamic load impact surface, m2; α2=k/M is the ratio of vertical spring coefficient to M; υ=C0/2M is the ratio of vertical damping coefficient to 2M.

The average density of the collapsed rock in the roof of Bultai coal mine is ρ=2547kg/m3, the collapsed rock is approximately rectangular body, the thickness can be obtained from the field measurement with the mean value Δ=51m, the slope length of the working face is b=300m, the length of the collapsed roof is the initial collapse step l=95m, the collapse height H=3.12m, i.e. the elastic modulus of the degree coal body is taken as E=8.36Gpa, Poisson's ratio μ=0.38, the Density ρ=1320kg/m3.

4 Similar simulation test of overburden transport law

4.1 Similar simulation test design

The transport law of overburden rock during the mining of shallow buried thick coal seam was tested by using FLJ two-dimensional similar simulation test bench with simplified plane stress model. 412.9m buried depth, 6.6m thick coal, 1:1.02 mining and releasing ratio, 10m/d average daily advancing speed, and comprehensive mechanized top release coal mining process were used for back mining in Burtai 4-2 coal seam. Meanwhile, in order to reduce the influence of boundary effect on excavation, both sides of the coal seam are tested to keep 40cm without excavation. The displacement monitoring points were placed on the model with 10cm×10cm spacing, and the displacement during the backmining process was processed by XJTUDP 3D optical photographic monitoring system to monitor and analyze the evolution characteristics of the roof displacement during the backmining advance of the comprehensive release working face. The similar model, measuring point arrangement and displacement monitoring system are shown in Figure 2.



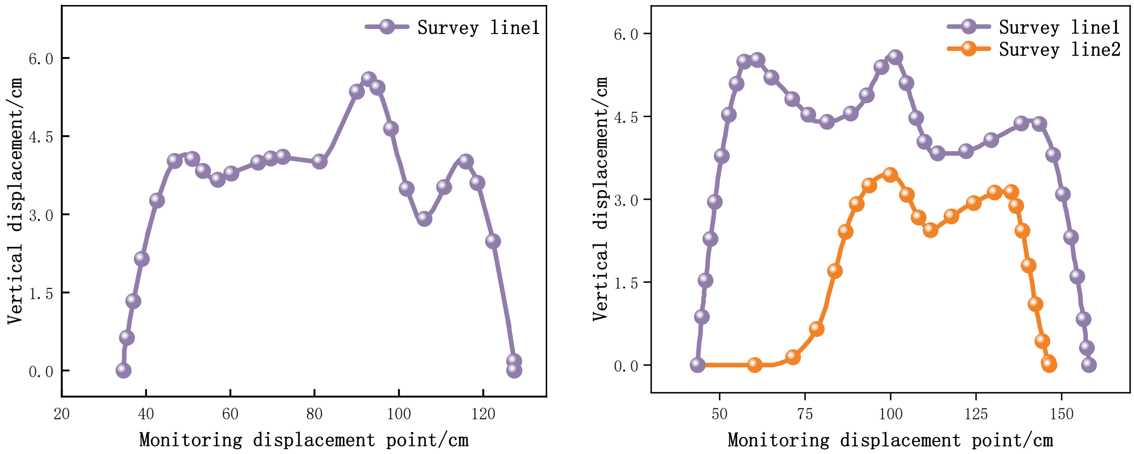
(a) Similar model and measurement point arrangement

(b) XJTUDP 3D optical photographic monitoring system

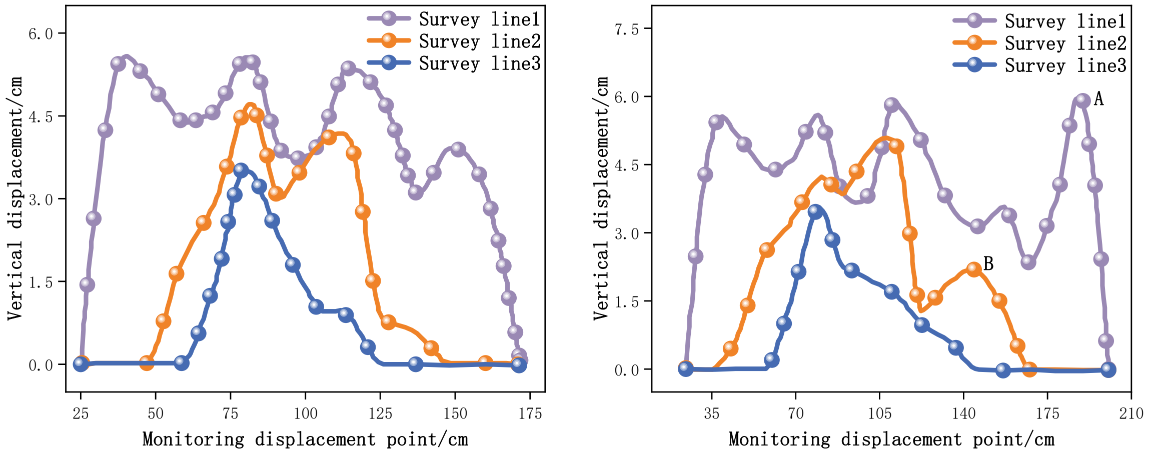
Figure 2. Schematic diagram of the basic situation of the similar simulation test

4.2 Analysis of overburden transport law

When the shallow buried header workface is retrieved to different positions, the changes of vertical displacement at measurement line 1, 2 and 3 are shown in Figure 3.



(a) The working face is mined back to 85m (b)The working face is mined back to95m



(c)The working face is mined back to120m (d)The working face is mined back to150m

Figure 3. Monitoring of vertical displacement of each measurement line of similar model

Through the displacement monitoring curve shown in Figure 3, it can be seen that the shallow buried header working face overburden displacement changes in a continuous dynamic sinking trend.

(1) When the heaving working face advanced to 85m, the top plate of the heaving face bent and sank, at which time the overhanging distance of the top plate of the heaving face reached 85m and a large displacement was generated at measurement line 1, with the displacement amount reaching about 6m.

(2) When the working face of heaving is advanced to 95m, the overburden rock at measuring line 1 and 2 sinks as a whole, and the trend of displacement change is the same, the displacement change of measuring line 1 is in the form of "W" peak, and the displacement change of measuring line 2 is in the form of "V" sinking, at this time the overburden rock at the position of measuring line 2 At this time, the first collapse of the key layer occurs, and the initial pressure is formed on the working face, accompanied by the simultaneous collapse of the direct top and the key layer, and the mineral pressure of the coal body in front of the working face increases sharply, due to the soft lithology of the coal body and the poor bearing capacity, the vertical displacement of the top plate reaches 3m, if the hydraulic support capacity is not enough, it may produce a pressure frame accident.

(3) When the integrated working face advanced to 120m, the measurement line 1 and 2 still maintained the "W" peak type and "V" type synchronous sinking, indicating that the first cycle pressure occurred at the working face, and the rock layer at the measurement line 3 was also displaced, which indicates that after the initial breakage of the key layer, the overlying rock of the key layer will be displaced. This indicates that after the initial breakage of the key layer, the overlying rock layer of the key layer is very easy to bend and break due to its weak stability, and collapse with the key layer simultaneously when the cycle breaks.

(4) When the integrated workface is advanced to 150m, the second cycle pressure occurs at the workface, as shown in Figure 3(d) at A in measurement line 1 and B in measurement line 2, the trend of displacement change and displacement amount of the top plate are similar to the first cycle pressure, at this time, the direct top and key layer produce a new displacement sink peak, the peak is 4.5m.

The initial breakage step of the key layer is about 95 m, and the periodic breakage step is about 25. The test results of the initial breakage step of the key layer and the periodic pressure step are basically consistent with the actual data of the working face, that is, the physical simulation test reproduces the overburden breakage and transportation characteristics during the advance of the shallow buried coal face of Buertai 4-2.

5 Numerical simulation test of overburden structure evolution characteristics

5.1 Numerical model establishment

The 3DEC software is used to study the structural evolution of the overburden of the shallow buried thick coal seam. Taking the Buertai 4-2 coal seam as an example, a mining model is established for the strike section of the header workface, with dimensions of 280m×4m×100.5m, and the Mohr-Coulomb yield criterion is selected as the model ontology. The model is constrained around the boundary, the bottom is fixed, and the top is only compensated by gravity loading. The physical and mechanical parameters of the model seams are shown in Table 2. In order to effectively monitor the evolution characteristics of the overburden stress field of the shallow buried thick coal seam, measurement lines 1 and 2 are arranged above the top coal and direct top of the 4-2 seam, respectively, and the numerical simulation model and lateral lines are arranged as shown in Figure 4.

Table 2 Physical and mechanical parameters of coal seams

classification	depth of stratum /m	unit weight/kg·m-3	Elastic modulus/Gpa	Friction angle/(°)	cohesion/Mpa	compressive strength/Mpa	Poisson's ratio
sandy mudstone	43	2100	6.78	37	6.13	32.58	0.43
Siltstone	8.0	2550	11.68	41	6.97	67.38	0.24
sandy mudstone	12.0	2100	6.78	37	6.13	32.58	0.43
2-2 # coal seam	3.5	1300	5.36	31	1.3	10.78	0.25
sandy mudstone	19.0	2100	6.78	37	6.13	32.58	0.43
Siltstone	22.0	2550	11.68	41	6.97	67.38	0.24
sandy mudstone	10.0	2100	6.78	37	3.6	32.58	0.43
4-2#coal rake	6.5	1300	5.36	31	1.3	10.36	0.25
sandy mudstone	5.0	2100	6.78	37	6.13	32.58	0.43

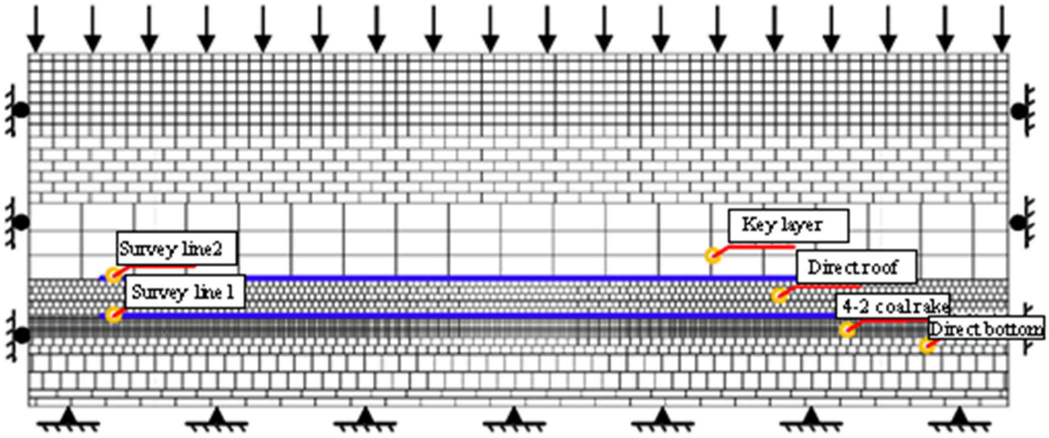
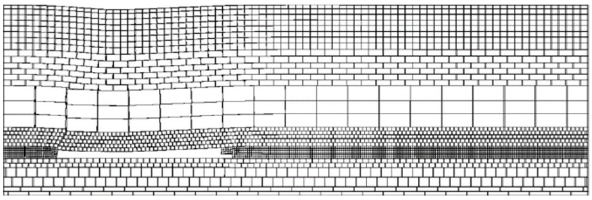


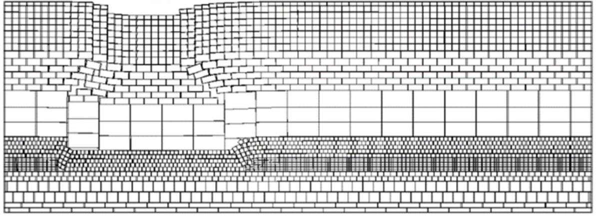
Figure 4 .3DEC numerical simulation model

5.2 Analysis of overburden structure evolution characteristics

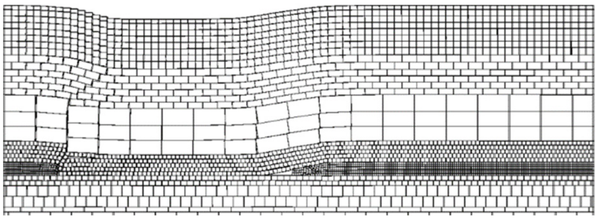
From Fig. 5, it can be seen that when the heaving workface advances to 85m, the direct top bends and sinks substantially, and the key layer starts to deform synchronously, at this time, the vertical fissure at the position of the coal wall of the cuthole develops further upward; when the heaving workface advances to 95m, the overburden rock presents cut-down sinking, and the initial breaking position of the key layer is located at the back of the workface when the initial incoming pressure occurs at the heaving face; when the heaving workface advances to 120m, 150m When the workface is advanced to 120m and 150m, the key layer is broken periodically, and the overburden is broken in front of the coal wall.



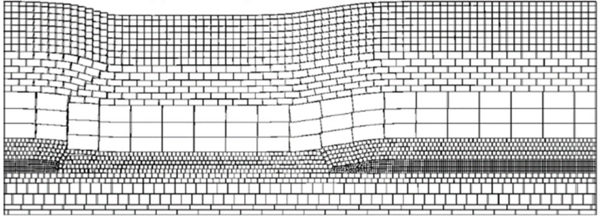
(a)Working face stoping to85m



(b)Working face stoping to95m



(c)Working face stoping to120m



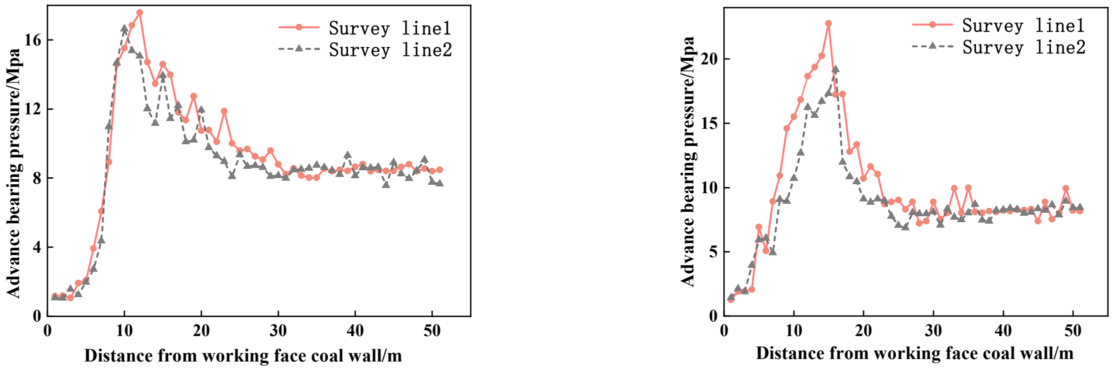
(d)Working face stoping to150m

Figure. 5 .3DEC numerical simulation results of different mining distances

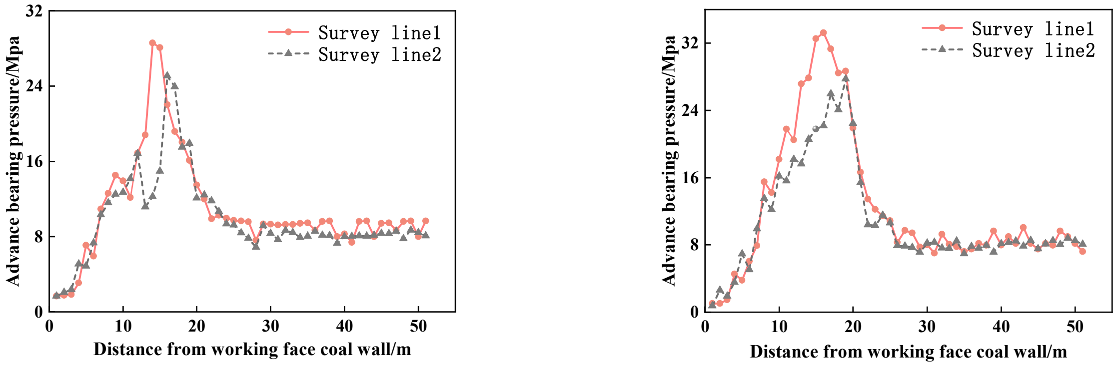
From the above analysis, it can be seen that the numerical simulation and similar simulation results basically agree, that is, the initial incoming pressure step of the comprehensive release working face of the Burtai 4-2 coal seam is about 95m, and the periodic incoming pressure step is about 30m, which is consistent with the mining situation on site. From the above test, it can be seen that during the mining process of shallow buried comprehensive release working face, there is a large mining disturbance in front of the working face and coal wall, and the location of overburden breakage is located in front of the coal wall, and its distance from the coal wall is non-linearly changing.

5.3 Analysis of overburden stress evolution characteristics

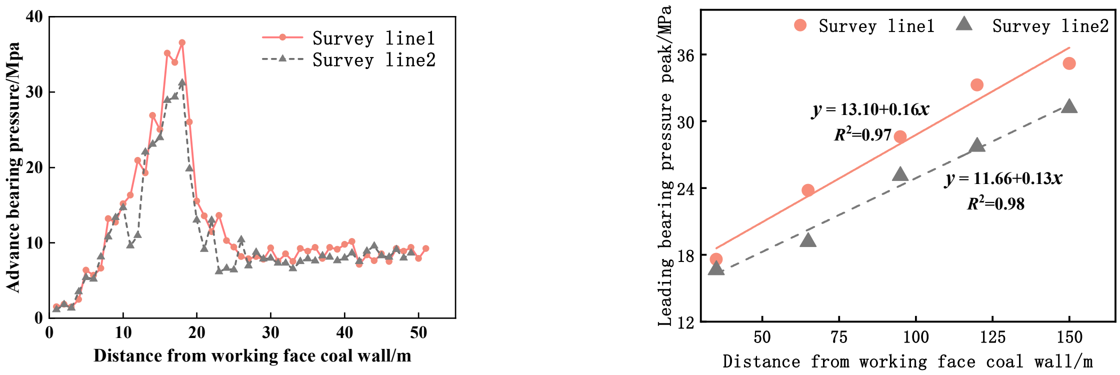
The change of overburden support pressure at measuring line 1 and 2 when the shallow buried comprehensive workings are mined back to different positions is shown in Figure 6.



(a)Working face stoping to35m (b)Working face stoping to65m



(c)Working face stoping to95m (d)Working face stoping to120m



(e)Working face stoping to150m (f)Peak change of leading bearing pressure

Figure 6. Variation of over-support pressure at different retrieval distances on the working face

It can be seen that with the advancement of the integrated workface, the overhead support pressure shows an increasing trend. Since the direct top is closer to the workface, it is more likely to be affected by the disturbance during recovery, so the peak over-supporting pressure in different recovery periods of measurement line 1 is higher than that of measurement line 2, and the monitoring curves of the two measurement lines increase in the same pattern. The peak over-support pressure is linearly correlated with its distance from the coal wall, and the over-support stress of the working face top plate period is greater than the initial pressure, with a peak stress of 33.25MPa and a peak growth rate of 16.30%.

In order to further analyze the intrinsic relationship between the peak over-support pressure and the coal wall at the working face, the linear fitting analysis of the peak over-support pressure and its distance from the coal wall was carried out for measuring lines 1 and 2 at 0-65m, 65-95m, 95-120m and 120-150m of the header face retrieval respectively, as shown in Figure 6(f), with the advancement of the header face, the linear relationship between the peak over-support pressure of measuring lines 1 and 2 and their distance from the coal wall The linear correlation with the distance from the coal wall reaches 0.97 and 0.98 respectively.

6 Conclusion

(1) From the similar simulation test displacement monitoring curve, it can be seen that with the advance of the header workface, the overburden rock of the shallow buried thick coal seam header workface shows a continuous non-linear dynamic sinking trend, the initial pressure step of the key layer is about 95m, and the periodic pressure step is about 25m; after the initial break, the overburden rock of the key layer keeps "W" peak type and "V" peak type during the periodic break. peak type and "V" type and then collapse and sink simultaneously, with the maximum sinkage amount reaching 6m.

(2) From the 3DEC numerical simulation test, the peak growth rate of over-support pressure is 20.53% and 16.30% when the header surface is from 65m-95m and 95m-120m respectively, which indicates that the over-support stress of the header surface rises more when the initial pressure comes.

(3) The first breakage position of key layer is located at the back of working face, according to the law of mine pressure, it is recommended to use ZT9500/30/39D type two-pillar coal release hydraulic support; when the comprehensive release working face is advanced to 120m and 150m, the key layer is broken periodically, and the comprehensive release face is under periodic pressure, the overburden breakage position is located in front of the coal wall, it is recommended to carry out over-support from the coal wall line to 30 m outward.

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