Study on the Law of Earth's Surface Movement on Ultra-long Working Face

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Abstract

The problem of stoping on ultra-long working face is one of challenges for making coal mining safe and efficient. The strong mining effect of surrounding rock induced by long working face mining causes a number of coal or rock dynamic disasters to safe and efficient coal mining. For the purpose of in-depth study of the law of earth's surface movement on ultra-long working face, this paper, with FLAC3D (numerical simulation software) used to build a numerical model of ultra-long working face, analyzes the law of roof-to-floor strata behaviors in coal bed during mining, and studies the weakening of roof-to-floor parameters in coal bed, bearing pressure and the law of roof caving and rock strata movement; Analyzes the face length effect resulted from the difference in face lengths. It has been recognized that the sphere of influence of bearing pressure changes from small to large and then to small, and changes in distribution of arch bottom and arch height at the plastic failure zone are further intensified over advancing of the working face, moreover, the movement of rock strata is subject to the cumulative influence of the advancing direction of the working face and the face length effect. The above-mentioned research results can serve as a theoretical basis for practical engineering.

Introduction

Double-length working face mainly refers to the working face with ultra-long advance and super face length. The distance of ultra-long advance of working face is generally more than 3000m, and the length of working face is generally more than 300m. A working face can only be called double-length working face when its above two indexes meet the above standards. The deployment of double-length working face can effectively improve the mining efficiency and reduce costs of coal mines, and increase the utilization rate of equipment. It is particularly conducive to the construction of high-output and high-efficiency mines.

In the context where coal mining machinery and equipment have become more reliable, double-length working face, especially ultra-long working face layout, has gradually become the mainstream trend of coal mining in the world. At present, China is playing an increasingly significant role in leading the trend of coal mining. Yang (2020), by means of theoretical analysis, data simulation and field test, showed that the surrounding rock stress of the withdrawal channel in the working face before mining would transfer from the stoping fall to the stander fall. Fu (2019) analyzed the stoping technology of ultra-long working face in terms of rib fall of coal wall, large-scale roof instability, and uneven gas emission. Guo (2018), by virtue of FLAC3D, explored the causes of deformation by analyzing the behavior law of mine pressure during gob-side entry driving, and proposed a targeted reinforced timbering technology for roadway. Wang (2017; 2017; 2018), out of the purpose to solve the problems of disability for skip-mining in actual engineering background, great coal losses and difficulty in roadway maintenance, studied how to realize sequential mining along the goaf with a double-lane arrangement of ultra-long driving distance. Kang (2020) applied the roadway surrounding rock support-modification-pressure relief coordinated control technology to reducing roadway deformation and the rupture rate of bolts and cables, with large deformation of roadway caused by intensive mining in cases of kilometer well depth and soft rock reduced significantly, as mining stress of working face is significantly reduced. Wang Jiachen (2020) focused on analyzing the characteristics of mining stress rotation in the ultra-long working face of kilometer-deep well and its driving

effect on the damage of surrounding rock, and proposed the principle of applying mining-induced stress rotation in surrounding rock control. Wang (2018) studied and summarized the behavior law of mine pressure and the law of overlying strata movement based on the law of initial mining pressure in working faces of different length. Yao (2017) found that the application of lateral large-aperture water injection fracturing roof pressure relief technology in the final mining pass-through stage of fully mechanized coal mining face can significantly reduce the probability of jammed support accidents caused by dynamic load ground pressure. Fan (2017) analyzed the structural characteristics of overlying rock caving in deep-seated ultra-long island working face. Wang (2019) built a theoretical analysis model based on the study of roof strata rupture regulation of ultra-long well working face and determined the roof break criterion. Ding (2021) by means of various methods such as theoretical calculation of rock pressure, site state real-time monitoring and analysis via KJ21 software, analyzed the rule of changes in the working resistance of hydraulic supports, the periodic weighting on working face and lead abutment pressure, checked the working strength of hydraulic support at the existing working face and proposed reasonable working resistance range of hydraulic support under similar coal seam occurrence conditions in the Inner-Mongolia-Shaanxi Area. According to the theory of clamped beam and cantilever beam, Jin (2019) by means of 3DEC numerical simulation and on-site measurement, analyzed the behavior law of underground pressure after ultra-long fully mechanized caving face in ultra-thick coal seams is mined. Liu (2019) based on the geological occurrence conditions of ultra-long fully mechanized caving face, analyzed the transportation of mining equipment, support strength, rock pressure and coal wall stability on ultra-long fully mechanized caving face. Yu (2019; 2019) conducted indoor analog simulation experiments to analyze the impact of high stress on roadway stability. Shi (2020) studied the characteristics of surrounding rock deformation and support by means of numerical simulation.

The problem of stoping on ultra-long working face is one of challenges for making coal mining safe and efficient. The strong mining effect of surrounding rock induced by long working face mining causes a number of coal or rock dynamic disasters to safe and efficient coal mining, such as gas outburst, rock burst, as the distribution of supporting pressure on roof and floor of coal seam is concentrated in addition to roof falling and severe floor bulge and rock strata movement. In view of the problem, it is necessary to study ultra-long working face and analyze the distribution law of roof and floor support pressure induced by face length effect, the height of caving zone and the law of rock movement. For the purpose of in-depth study of the law of earth's surface movement on ultra-long working face, this paper, with FLAC3D (numerical simulation software) used to build a numerical model of ultra-long working face, analyzes the law of roof-to-floor strata behaviors in coal bed during mining, and studies the weakening of roof-to-floor parameters in coal bed, bearing pressure and the law of roof caving and rock strata movement. This paper also analyzes the face length effect resulted from the difference in face lengths. The above-mentioned research results can serve as a theoretical basis for practical engineering.

Project Profile

The No.9105 working face above the ground is located about 200m north of Beili Village and Dongshi Village. In terms of its underground location, there is a no-mining reservoir area in the east, unmined areas

in the south and north, and No.540 belt roadway in the west. The ground elevation is 903~932m, and the working face elevation is 377-520m. The 3# coal seam in which this faced is mined occurs in the middle and lower parts of Shanxi Formation of the Permian System. The seam is a continental lacustrine deposit. Within the scope of this working face, the thickness of the coal seam (6.6m) is stable, and the thickest layer of dirt band is 0.1m. The designed length of No.9105 haulageway is 3650m, the air way is 3580m, the strike length is 340m, and the stope length is 3432m. The coal bulk density is 1.45m³/t, and the recovery rate is 95%.

The No.9105 working face currently adopts the top-coal caving design with the layout of “U+high pumping lane”, and the coal seam has low permeability. Regarding design parameters, the No.9105 working face is the most special one encountered since the mining of Wangzhuang Mine. Its major distinctive features include: high gassy mine, low permeability coal seam, the longest working face, the longest working face advancement, and simultaneous use of top coal caving, called double-length working face. Due to the superposition of the above factors, the mining of the No.9105 working face suffers from numerous uncertain challenges, such as evaluation of reliability of the ventilation system and the production system of the working face, the law of earth’s surface movement on the working face, gas emission and distribution law of high-intensity mining, etc. Therefore, the project studies the actual situation of the No.9105 working face and meets the technical requirements of coal mine safety production.

According to the on-site geological data, the No.9105 working face currently adopts the top-coal caving design with the layout of “U+high pumping lane”, and the coal seam has low permeability. The working face’s design length is 340m, and its advance length is 2819m. The designed production capacity is 3 million t/a. The histogram of the strata in the No.9105 working face of Wangzhuang Coal Mine is shown in Fig.1 below.

Regarding design parameters, the No.9105 working face is the most special one encountered since the mining of Wangzhuang Mine. Its major distinctive features include: high gassy mine, low permeability coal seam, the longest working face, the longest working face advancement, and simultaneous use of top coal caving. Due to the superposition of the above factors, the mining of the No.9105 working face suffers from numerous uncertain challenges, such as evaluation of reliability of the ventilation system and the production system of the working face, the law of earth’s surface movement on the working face, gas emission and distribution law of high-intensity mining, etc.. Concerning the problem, a special project of technical research on the No.9105 working face is necessary for safe and efficient mining of the No.9105 working face of Wangzhuang Mine.

Wangzhuang Coal Mine is a supergiant modern production mine of Lu'an Group. During the construction and production of the mine, scientific research institutes measured the uniaxial compressive strength, elastic modulus and Poisson’s ratio of coal and conducted related experiments. The measurement results are shown in Table 1.

Table 1 Physical Mechanics Parameter Value Table of Soil-Rock Engineering

No.	Lithology	Layer Thickness (m)	volume-weight d [kg/m ³]	Elastic Modulus E(MPa)	Poisson's ratio μ	Cohesive Force c (MPa)	Internal Friction Angle ϕ (°)	Extension Strength σ_t (MPa)
1	Loess	104.5	1960	15	0.42	0.125	18	0.0125
2	Mudstone	6.85	2300	2000	0.25	0.4	38	0.04
3	Siltstone	19.5	2600	4800	0.32	5.0	38	0.5
4	Mudstone	2.9	2300	2000	0.25	0.4	38	0.04
5	Siltstone	10.59	2600	4800	0.32	5.0	38	0.5
6	Mudstone	6.11	2300	2000	0.25	0.4	38	0.04
7	Siltstone	8.99	2600	4800	0.32	5.0	38	0.5
8	Mudstone	19.6	2300	2000	0.25	0.4	38	0.04
9	Medium Sandstone	17.41	2500	4300	0.32	3.1	39	0.05
10	Mudstone	17.1	2300	2000	0.25	0.4	38	0.04
11	Packsand	11.2	2500	4000	0.33	3.2	40	0.32
12	Siltstone	10.69	2600	4800	0.32	5.0	38	0.5
13	Mudstone	6.43	2300	2000	0.25	0.4	38	0.04
14	Medium Sandstone	14	2500	4300	0.32	3.1	39	0.05
15	Mudstone	22.96	2300	2000	0.25	0.4	38	0.04
16	Siltstone	15.2	2600	4800	0.32	5.0	38	0.5
17	Mudstone	7.82	2300	2000	0.25	0.4	38	0.04
18	Shed Coal	0.15	1350	1000	0.38	1.62	36	0.295
19	Packsand	11.95	2500	4000	0.33	3.2	40	0.32
20	Mudstone	11.12	2300	2000	0.25	0.4	38	0.04
21	3# Coal Seam	7.44	1350	1000	0.38	1.62	36	0.295
22	Mudstone	8.24	2300	2000	0.25	0.4	38	0.04
23	(Medium) Sandstone	14.92	2500	4300	0.32	3.1	39	0.05

Determination of Numeric Simulation Scheme

Based on the analysis of a numerical model of the roof and floor during coal mining, the weakening of roof and floor parameters, the size of abutment pressure, and the laws of roof caving and rock strata movement

are studied. In addition, the face length effect resulted from the difference in working face lengths is analyzed to study the law of rock strata movement on ultra-long working faces.

1. 1. The width of limit equilibrium area of working face strike abutment pressure changes from small to large, and then to small; the range of influence of abutment pressure also changes from small → big → small. The essential characteristics of the distribution of lead abutment pressure in the middle part of the lengthened working face changes. The limit equilibrium zone of abutment pressure on the top-coal seam is wider, and its peak value is higher. The abutment pressure of the top-coal seam near the coal wall is higher.
2. 2. With advancing of working face, the arch bottom distribution in the plastic failure zone and changes in arch height are obvious, as the height increases by about 3m. The face length effect has a significant impact on roof caving, and the maximum sphere of influence is about 5m.
3. 3. The study on rock strata movement is subject to the superimposed influence of working face advance and face length effect. To be specific, face length effect has a greater influence, as the maximum movement of rock strata increases by 30cm in the context of mining advancement of 20m. Rock strata movement triggered by the increase of face length effect increases by 47cm. In particular, rock strata movement reaches the peak when the face length is 340m.
4. 4. According to simulation, the initial roof weighting step of working face is about 40m, and periodic roof weighting step is about 20m.
5. 5. The height of roof caving after ultra-long working face mining is larger than that of ordinary working faces. The height of caving zone usually reaches 15.5m when No.9105 working face is weighted for the first time, and the height of the caving zone is about 13.3m during periodic roof weighting step.

Numerical Calculation Modeling

Numerical calculation modeling is conducted with relevant simulation parameters set. As the average inclination of the working face is 5°, a near-horizontal model is built as shown in Fig.3. In its coordinate system, the roadway axis serves as the Z axis, the X axis is horizontal, and the Y axis is vertical. Length*width*height=420m*380m *91.5m. The working face is 340m long, and the reserved boundary coal pillar is 20m. There are 6 groups of similar lithology in a top-down order, including sandstone (its material strength is slightly lower than packsand), packsand, mudstone, coal, mudstone, medium sandstone, and argiloid (its material strength is slightly higher than mudstone); In the x direction, the width of every grid near the roadway wall is every 1.35m, and that of every grid far away from the roadway wall is 5m. In the model, except for the irregular 8-node hexahedral element near the roadway wall, the rest elements are all regularly hexahedral. The total number of elements in the final model is 241,350 and the total number of nodes is 252776. The three-dimensional space model of the ultra-long working face is shown in Fig.2a below, and its three-dimensional schematic diagram is shown in Fig.2b below. The side surface of the model is of normal constraint, the top surface is of free boundary of stress and displacement, and the bottom surface is of horizontal and vertical constraint. The main rock layer is composed of coal and mud. Softening-expansion model and the Mohr-Coulomb Failure Criterion are selected, to be specific, the physical and mechanical parameters are set according to the results of the indoor rock mechanics test listed in Table 1.

Determination of Numeric Simulation Scheme

In the simulation, parameters such as length of the working face and mining advancement distance are changed to explore the distribution characteristics of the stope fissure zone and behavior law of mine pressure on the working face under different conditions. The specific simulation scheme covers the following three stages:

The first stage: Analysis of the law of initial and periodic weighting on the working face under the influence of face length effect.

The second stage: Analysis of the characteristics and distribution law of roof caving of working faces with different face lengths.

The third stage: Research on the relationship between the length of the working face and strata pressure behavior.

To be specific, the following approach is adopted to simulate the face length effect caused by mining the ultra-long working face:

Staged excavation is carried out for different face-length models. The excavation length in the first step is 20m, and the advancing distance of the working face is displayed in cross-sectional view, as shown in Figs.3a, 4a, 5a. The excavation length in the second step is 40m, and the advancing distance of the working face is displayed in cross-sectional view, as shown in Figs. 3b, 4b, 5b.

Routines of Activity of Pressure on the Roof of Working Face under the Influence of Face Length Effect

In reference to the distribution law of lead abutment pressure on working face under the influence of effect of face length during normal advancing period, the change law of stress field of the overlying strata of the main roof can be preliminarily determined according to past experience. It is found that there are two peaks of lead abutment pressure on the working face in the main roof stratum. There is a peak area in the middle of back abutment pressure on working face in the direction of face length. The area between these two is of low abutment pressure. Compared with the mechanical mining horizon, the abutment pressure peak of the top-coal seam horizon is greater, but the impact range of abutment pressure is smaller, and the limit equilibrium zone of top-coal seam is wider. In addition, the limit equilibrium zone of abutment pressure on working face of great face length is wider during normal advancing period.

The following research is carried out to analyze the distribution of roof abutment pressure on working faces of different face lengths during advancing: First, the law of distribution of overlying rock abutment pressure on working faces during normal advancing is analyzed, and the specific points are excavation at 20m and 40m; finally, the influence of face length effect on routines of activity of pressure on the roof of working face is analyzed. To be specific, for the same mining advance distance, the difference in the roof

pressure distribution corresponding to working faces of face length of 260m, 300m, and 340m is analyzed, as shown in Figs.6-8 below.

Routines of Activity of Pressure on the Roof of Working Face During Normal Advance. During normal advance, the old roof strata is carried in the form of floor. With the increase of advance, the surrounding bearing reaction of the old roof strata structure gradually increases. As far as the elastic foundation effect of top coal and immediate roof are concerned, the resultant force point of bearing reaction of the simply supported edge moves forward; the peak value of the abutment pressure is increasing, namely, the peak coefficient is increasing; the distance from the two peaks to belt transporter tunnel and air way decreases, implying that the peak area moves closer to the two roadways. When the old roof structure is broken for the first time, the supporting reaction force acting on the periphery of the original plate structure decreases. In sum, the width of limit equilibrium area of working face strike abutment pressure changes from small to large, and then to small; the range of influence of abutment pressure also changes from small → big → small.

Routines of Activity of Pressure on the Roof of Working Faces of Different Face Length. The distribution of lead abutment pressure on the middle of the forked working face in the direction of face length in the influence range of abutment pressure along the 260m working face under the superimposed influence of the lateral abutment pressure of working face is shown in Fig.6. At the position of 20m, the abutment pressure on the overlying strata and the two sides is 15.624MPa, and the distribution height of abutment pressure is 8.0m. At the position of 40m, the abutment pressure on the overlying strata and the two sides is 19.160MPa, and the distribution height of abutment pressure is 8.8; the changes in the essential characteristics of the distribution of lead abutment pressure in the middle part of the lengthened working face are shown in Fig.7. The limit equilibrium zone of abutment pressure on the top-coal seam is wider than that of the mining layer, and the top-coal seam's peak value is higher. The abutment pressure of the top-coal seam near the coal wall is lower than that of the mechanical mining layer. The abutment pressure of the mechanical coal mining body at the coal wall of the 300m working face and the top-coal seam is greater than the 260m working face. It is related to the superimposed influence of the lateral abutment pressure of the working face and the broken structure of the overlying strata main roof of the coal seam. In sum, ultra-length working face wall is subject to wall caving, but is conducive to op-coal crushing and improvement of top-coal caving properties. At the position of 20m, the abutment pressure on the overlying strata and the two sides is 16.324MPa, and the distribution height of abutment pressure is 10.3m. At the position of 40m, the abutment pressure on the overlying strata and the two sides is 20.763MPa, and the distribution height of abutment pressure is 12.5m; the distribution of lead abutment pressure on the middle of working face in the direction of face length in the influence range of abutment pressure along the 340m working face is shown in Fig.8. At the position of 20m, the abutment pressure on the overlying strata and the two sides is 21.036MPa, and the distribution height of abutment pressure is 13.3m. At the position of 40m, the abutment pressure on the overlying strata and the two sides is 23.329MPa, and the distribution height of abutment pressure is 15.5m.

Analysis of Roof Caving Features of Working Faces of Different Face Lengths and Regularities of Distribution

The working face length effect of the macroscopic caving features of surrounding rock is identified by means of systematical analysis and study on the mechanical characteristics of surrounding rock with different working face lengths, with numerical simulation conducted. According to previous empirical studies, changes in working face length have a significant impact on caving characteristics of overlying strata. With the increase of working face length, overlying strata caving of working face is intensified in the vicinity of the coal wall margin in front of the working face and areas near upper and lower roadways. In addition, the caving height gradually rises and the flatness rate keeps increasing. Working face is the focus of roof fracture development; the vertical displacement of the surrounding rock decreases, while the horizontal displacement increases. It indicates that reasonable adjustment of working face length can improve the dynamic balance of surrounding rock caving and plays a positive role in protecting the stope and reducing pressure on the mine.

The following research is carried out to analyze the distribution of roof fracture in working faces of different face lengths during advancing, so as to infer the scope of roof caving: firstly, the regularities of distribution of overlying strata fracture during normal advance of the working face are analyzed. To be specific, at the positions of 20m and 40m of the mined coal seam, the regularities of distribution of overlying strata abutment pressure during normal advance of the working face are analyzed; and then the influence of face length effect on the regularities of overlying strata roof caving is analyzed. To be specific, the difference in fracture distribution corresponding to working faces of face length of 260m, 300m, and 340m is analyzed for the same mining advance distance, as shown in Figs.9-11 below.

Features of Development of Roof Fracture and Caving Zone Height of Working Face During Normal Advancing. The overall contour of the plastic failure zone is approximately arched. The arch bottom falls on the coal wall and at the side, and the inside is dominated by shear failure. Tensile failure occurs in some areas at the junction of rock strata. When the working face advances to 300m, the arch bottom distribution in the plastic failure zone and changes in arch height are obvious, as the height increases by about 2m; when the working face advances to 340m, the arch bottom distribution in the plastic failure zone and changes in arch height are intensified, as the height increases by about 3m.

Routines of Activity of Pressure on the Roof of Working Faces of Different Face Lengths. The sphere of mining influence of working face with length of 260m under the superimposed influence of roof fracture development is shown in Fig.9. The height of the roof caving zone at the position of 20m is 6.0m, and the height at the position of 40m increases to 6.8m with an insignificant increase; the increase of the height of the roof caving zone in lengthened working faces is significant, as shown in Fig.10. The height of roof caving at the position of 20m in the working face of 300m is 6.3m, and the height increases to 8.5m at the position of 40m; according to Fig.11, the height of coal seam roof caving at the position of 20m in the working face of 340m is 21.036m, and the height increases to 15.5m at the position of 40m.

Study on the Relationship between Working Face Length and Strata Pressure Behavior

According to information of on-site monitoring and numerical simulation, strata pressure behavior of the working face, in which the midpoint serves as the symcenter, is distributed in quadratic function. The

mining pressure at the upper end of the support in the simulation is studied on, and the working surface effect of the fracture zone and strata pressure behavior is analyzed. The results are shown in Figs.12-14. To be specific, for the convenience of research, only the vertical movement law of the rock strata at the working face roof is presented here. Firstly, the law of overlying strata movement during normal advancing of the working face is studied, namely, the vertical displacement distribution of the overlying strata during normal advancing of the working face at the positions of 20m and 40m is analyzed; secondly, the influence of face length effect on rock strata movement in the overlying strata roof is analyzed. To be specific, the difference in displacement distribution corresponding to working faces with face lengths of 260m, 300m, and 340m is analyzed for the same mining advance distance.

The law of roof movement of the working face with face length of 260m under the superimposed influence of working face advance and face length effect is shown in Fig.12. The maximum movement of roof rock strata at the position of 20m is 2.198cm, and it increases to 5.582cm at the position of 40m with an insignificant increase; the increase of movement of roof rock strata in lengthened working faces is significant, as shown in Fig.13. The maximum movement of roof at the position of 20m in the working face of 300m is 10.615cm and the movement increases to 11.821cm at the position of 40m; according to Fig.14, the movement of coal seam roof at the position of 20m in the working face of 340m increases further to 17.832cm, and the movement increases tremendously to 49.186cm at the position of 40m.

Conclusion

Based on the analysis of a numerical model of the roof and floor during coal mining, the weakening of roof and floor parameters, the size of abutment pressure, and the laws of roof caving and rock strata movement are studied. In addition, the face length effect resulted from the difference in working face lengths is analyzed to study the law of rock strata movement on ultra-long working faces.

1. The width of limit equilibrium area of working face strike abutment pressure changes from small to large, and then to small; the range of influence of abutment pressure also changes from small → big → small. The essential characteristics of the distribution of lead abutment pressure in the middle part of the lengthened working face changes. The limit equilibrium zone of abutment pressure on the top-coal seam is wider, and its peak value is higher. The abutment pressure of the top-coal seam near the coal wall is higher.
2. With advancing of working face, the arch bottom distribution in the plastic failure zone and changes in arch height are obvious, as the height increases by about 3m. The face length effect has a significant impact on roof caving, and the maximum sphere of influence is about 5m.
3. The study on rock strata movement is subject to the superimposed influence of working face advance and face length effect. To be specific, face length effect has a greater influence, as the maximum movement of rock strata increases by 30cm in the context of mining advancement of 20m. Rock strata movement triggered by the increase of face length effect increases by 47cm. In particular, rock strata movement reaches the peak when the face length is 340m.

4. According to simulation, the initial roof weighting step of working face is about 40m, and periodic roof weighting step is about 20m.
5. The height of roof caving after ultra-long working face mining is larger than that of ordinary working faces. The height of caving zone usually reaches 15.5m when No.9105 working face is weighted for the first time, and the height of the caving zone is about 13.3m during periodic roof weighting step.

Declarations

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Data Availability statement

Readers can easily access some datum supporting the corresponding conclusions of the study in Tables. 1. In a word, research datum made available to all interested researchers upon request.

References

- Yang Z., Xu D., Gao M.S., Xue X.Q., Zhang D.X., 2020. Research on the Key Technology of Pressure Adjustment for Final Mining Backout Caving in Fully Mechanized Coal Mining Face of Ultra-Long-Large Mining Height. *Coal Engineering*. 52(08): 77- 83.
- Fu S.J., Fan Z.Z., Zhang X.F., Pan L.M., Zhao J., 2019. Study on the Relationship between Abnormal Strata Pressure Behaviors and Gas Emission in Ultra-Long Working Face. *Coal Engineering*. 51(05): 139-142.
- Guo Z.B., Yang S., 2018. The Law of Strata Pressure Behaviors in Gob-side Entry Driving of Ultra-Long Island Working Face and Reason Analysis. *Coal Mining Technology*. 23(05): 91-94+47.
- Wang Z.Q., Wang J.M., Guo L., Xu J., 2017. Study on the Technology of Gob-Side Two-Entry Mining in Working Face with Ultra-long Advance. *Journal of Mining Science*. 2(04): 364-370.
- Wang Z.Q., Wang H.H., Shi L., Su Y., 2017. The Mechanism of Two-Entry Layout Gob-Side Entry Driving in High-Strength Working Face with Ultra-long Advance. *Journal of China Coal Society*. 42(S2): 302-310.
- Wang Z.Q., Su Y., Song Z.Y., Shi L., Sun Z.W., 2018. Two-Entry Layout Gob-Side Entry Driving Technology in Working Face with Ultra-long Advance and Analysis of Application Effect. *Chinese Journal of Rock Mechanics and Engineering*. 37(S2): 4170-4176.
- Kang H.P., Jiang P.F., Huang B.X., Guan X.M., Wang Z.G., Wu Y.Z., Gao F.Q., Yang J.W., Cheng L.X., Zheng Y.F., Li J.Z., 2020. Collaborative Control Technology of Support-Modification-Pressure Relief of Wall Rock around Thousand-meter Deep Tunnel in Coal Mine. *Journal of China Coal Society*. 45(03): 845-864.

- Wang J.C., Wang Z.H., Yang J., Tang Y.S., Li B.B., Meng Q.B., 2020. Features and Application of Mining Stress Rotation on Ultra-long Working Face in Thousand-meter Deep Mine. *Journal of China Coal Society*.45(03): 876-888.
- Wang S.B., Huang Q.X., 2018. Research on Strata Behavior Regularity of 400m Ultra-long Fully Mechanized Mining Face in Shallow Coal Seam. *Coal Science and Technology*. 46(S1): 75-80.
- Yao H., Jia X., 2017. Analysis on the Cut-Through Crushing Accident of Ultra-Long Fully-Mechanized Mining Face in Shallow Thick Coal Seam. *Coal Science and Technology*. 45(S2): 77-81.
- Fan Z.Z., Fu S.J., Pan L.M., 2020. Research on Structural Characteristics of Overlying Rock Caving in Deep Ultra-long Island Working Face. *Coal Engineering*. 52(02): 86-90.
- Wang J.C., Yang S.L., Yang B.B., Li Y., Wang Z.H., Yang Y., Ma Y.Y., 2019. Main Roof Zonal Rapture Model and Support Resistance Distribution Characteristics of Ultra-Long Working Face in Deep Mine. *Journal of China Coal Society*, 44(01) :54-63.
- Ding G.L., Lu X.H., Wu S.G., Liu Y.Q., 2021. Research on Strata Behavior Regularity and Support Adaptability of Deep Ultra-long Fully Mechanized Mining Face. *Coal Science and Technology*. 1-6.
- Jin B.S., Wang A.W., Huang Z.D., Zhang J., 2019. Research on Behavior Law of Mine Behavior in Ultra-Long Fully Mechanized Caving Face in the Ultra-Thick Coal Seam of Shuonan Mining Area. *Coal Mine Safety*.50(12): 203-206+211.
- Liu W.T., 2019. Research on Key Technologies for Ultra-Long Fully Mechanized Caving Working Face in Soft and Thick Coal Seam. *Coal Engineering*. 51(12): 38-43.
- Yu W.J., Pan B., Zang F., Yao S.F., Liu F.F., 2019a. Deformation characteristics and determination of optimum supporting time of alteration rock mass in deep mine. *KSCE J Civil Eng*. 23(11):4921.
- Yu W.J., Wu G.S., An B.F., Wang P., Wu B.S., 2019b. Experimental study on the brittle-ductile response of a heterogeneous soft coal rock mass under multifactor coupling. *Geofluids*.
- Shi J.J., Feng J.C., Peng R., Zhu Q.J., 2020. Analysis of Deformation Damage in Deep Well Roadway and Supporting Countermeasures. *Geotechnical and Geological Engineering*.

Figures

No	Roof & floor	Thick- ness	Columnar	Rock name	Lithology description

1	Old roof	5.20		Fine sand- stone	Gray, fine grain
2	Direct roof	7.47		Mud- stone	Black contains a lot of plant fossils
3	Coal	7.14		3#coal	4.9(0.3)1.3
4	Direct floor	4.23		Mud- stone	Black, uniform and dense quality
5	Old floor	6.66		Medium sandstone	Gray, fine grain

Figure 1

Histogram of the Strata in the No.9105 Working Face

(a) 3D Diagram Numerical Calculation Model

(b) 3D Diagram of Ultra-long Working Face

Figure 2

3D Modeling of Numerical Calculation

(a) Excavation at 20m in the 3D Model of Face Length 260m

(b) Excavation at 40m in the 3D Model of Face Length 260m

Figure 3

Length of Main Mining Face of 3# Coal Seam: 260m

(a) Excavation at 20m in the 3D Model of Face Length 300m

(b) Excavation at 40m in the 3D Model of Face Length 300m

Figure 4

Length of Main Mining Face of 3# Coal Seam: 300m

(a) Excavation at 20m in the 3D Model of Face Length 340m

(b) Excavation at 40m in the 3D Model of Face Length 340m

Figure 5

Length of Main Mining Face of 3# Coal Seam: 300m.

(a) Distribution of Pressure on Roof of Working Face Length 260m, Excavation at 20m

(b) Distribution of Pressure on Roof of Working Face Length 260m, Excavation at 40m

Figure 6

Distribution of Pressure on the Roof of Working Face with Face Length 260m During Mining

(a) Distribution of Pressure on the Roof of Working Face with Face Length 300m, Excavation at 20m

(b) Distribution of Pressure on the Roof of Working Face with Face Length 300m, Excavation at 40m

Figure 7

Distribution of Pressure on the Roof of Working Face with Face Length 300m During Mining

(a) Distribution of Pressure on the Roof of Working Face with Face Length 300m, Excavation at 20m

(b) Distribution of Pressure on the Roof of Working Face with Face Length 300m, Excavation at 20m

Figure 8

Distribution of Pressure on the Roof of Working Face with Face Length 300m During Mining

(a) Distribution of Shuttered Zone in Roof of Working Face with Face Length 260m, Excavation at 20m

(b) Distribution of Shuttered Zone in Roof of Working Face with Face Length 260m, Excavation at 40m

Figure 9

Influence of 260m Working Face Length on Roof Fracture Development

Block State

- None
- shear-n
- shear-n shear-p
- shear-n tension-n shear-p
- shear-p

(a) Distribution of Shattered Zone in the Roof of Working Face at 20m of 3D Model of 300m Face Length

Block State

- None
- shear-n
- shear-n shear-p
- shear-p
- shear-p tension-p

(b) Distribution of Shattered Zone in the Roof of Working Face at 40m of 3D Model of 300m Face Length

Figure 10

Influence of 300m Working Face Length on Roof Fracture Development

Block State

None
shear-n shear-p
shear-p
shear-p tension-p

(a) Distribution of Shattered Zone in the Roof of Working Face at 20m of 3D Model of 340m Face Length

Block State

None
shear-n shear-p
shear-p

(b) Distribution of Shattered Zone in the Roof of Working Face at 40m of 3D Model of 340m Face Length

Figure 11

Influence of 340m Working Face Length on Roof Fracture Development

(a) Rock Strata Movement on the Working Face at 20m of 3D Model of 260m Face Length

(b) Rock Strata Movement on the Working Face at 40m of 3D Model of 260m Face Length

Figure 12

Influence of 260m Working Face Length on Roof Fracture Development

(a) Rock Strata Movement on the Working Face at 20m of 3D Model of 300m Face Length

(b) Rock Strata Movement on the Working Face at 40m of 3D Model of 300m Face Length

Figure 13

Influence of 300m Working Face Length on Roof Fracture Development

(a) Rock Strata Movement on the Working Face at 20m of 3D Model of 340m Face Length

(b) Rock Strata Movement on the Working Face at 40m of 3D Model of 340m Face Length

Figure 14

Influence of 340m Working Face Length on Roof Fracture Development