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Numerical Simulation of Overburden Breaking Law in Mining Thick Coal Seam with Large Buried Depth and Thin Bedrock

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Abstract: The overburden breaking law of high strength mining in thick and thin coal seam with large buried depth are important to guarantee the safety production in mines. In this paper, the UDEC numerical simulation software is employed to simulate the advancing process of fully mechanized caving mining of working face under the production geological conditions in thin bedrock area of Zhuxianzhuang mine. The vertical displacement and stress changes of overlying strata on the working face are analyzed respectively during the mining process, and the changes of abutment pressure on the overlying strata are extracted to study the subsidence law of overlying strata in the working face during the mining process. The stress variation characteristics of overlying strata in the mining process are defined and the deformation and failure zones of overlying strata after mining are put forward.

Keywords: Numerical simulation, Overburden breaking law, Mining stress, Coal displacement.

I. Introduction

In China, coal seam reserves with the thin bedrock and thick loose bed geological conditions are rich[1,2]. In addition, in order to fully excavate the mine production capacity, some mining areas increase the upper mining limit by reducing the waterproof and sand control coal pillar[3-5], so as to exploit the original off-balance-sheet reserves of coal. Therefore, the bedrock of coal seam becomes thinner and the geological conditions become thin bedrock and thick loose bed. When mining coal seams with such special geological conditions, major accidents such as roof step cutting, shelving, sand collapse and water collapse often occur on the working face, bringing huge economic losses and casualties to the state and enterprises[6].

The thickness of coal seam in Zhuxian zhuang coal mine in Huaibei reaches 10m, while the thickness of bedrock in some areas is less than 40m. Under such conditions, the working face adopts fully mechanized top coal caving mining, without basic roof and key layer in bedrock, and the self-stable bearing structure can not be formed. Besides, the working face support is difficult, and the safe and efficient mining can not be realized. Therefore, it is necessary to study the stability of overburden structure and the factors affecting its stability during fully mechanized caving mining of deep burial, thin bedrock, thick loose layer and thick coal seam[7,8], so as to realize safe and efficient mine production, improve resource recovery, and build a safe production and resource-saving mine. In this paper, the UDEC numerical simulation software is introduced to simulate the advancing process of 871 fully mechanized coal face in Zhuxian zhuang mine. According to the known mechanical properties of engineering materials and the adaptive range of the constitutive model, Mohr-Coulomb constitutive model is selected as the constitutive model, and the joint constitutive model is selected as the Coulomb slip model of face contact.

II. Numeric Simulation Design

The geological conditions of 871 fully mechanized caving face are obtained. The average thickness of the loose sediments in Cenozoic is 247m, and the average thickness of the three compartments is 80m. The distribution is stable and it is a good water-proof layer, completely blocking the hydraulic connection between the first, second and third strata and the fourth strata in the upper strata. The thickness of the lower four strata is 4m, and the contact with the coal measure strata is angular unconformity. The thickness of the bedrock is 20m, and the dip angle of the coal seam is 10°. The roof of the working face is mud-stone, fine sandstone and weathered mud-stone successively from bottom to top, and the floor is fine sandstone. The main physical and mechanical properties of each layer are shown in Table 1.

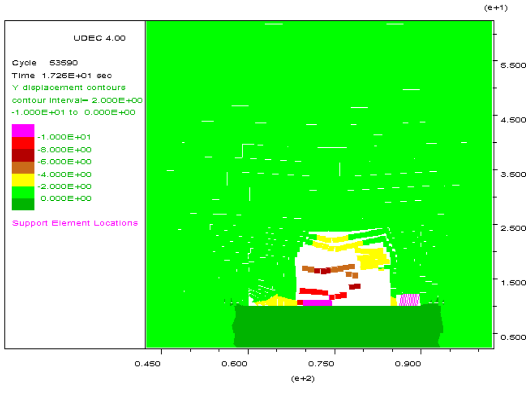
Table 1 Physical and mechanical parameters of rock strata

Lithology	Thickness /m	Bulk Density /kg/m^3	Modulus of Elasticity /GPa	Poisson's Ratio	Tension /MPa	Cohesion /MPa	Friction /°
Sandy Clay	66	1000	0.40	0.36	0.08	0.10	20
Sand	4	1100	0.35	0.35	0.05	0.06	21
Weathered Mudstone	13	2400	1.05	0.33	1.20	0.80	33
Fine Sandstone	2	2640	1.52	0.26	1.92	2.30	37
Mudstone	5	2540	1.23	0.30	0.50	1.20	35
Coal	10	1400	0.80	0.32	0.06	0.50	33
Fine Sandstone	12	2640	2.85	0.26	1.82	2.30	37

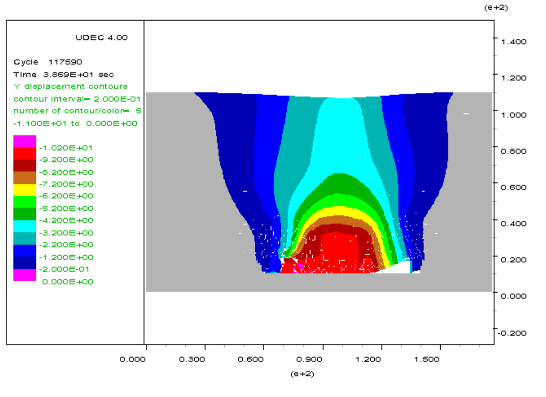
The discrete element model of fully mechanized caving mining is established according to strike mining. The mining height is 2.5m and the top coal is 7.5m. Top coal caving is carried out by the method of one mining and one caving. According to the actual situation, only 2.5m coal seam is mined within 10m of the cut hole, and no top coal is put. The same measures are taken within 10m of the stoppage line. The model considers the influence of the support on top coal caving.

III. Variation Characteristics of Overlying Strata Displacement in Stope

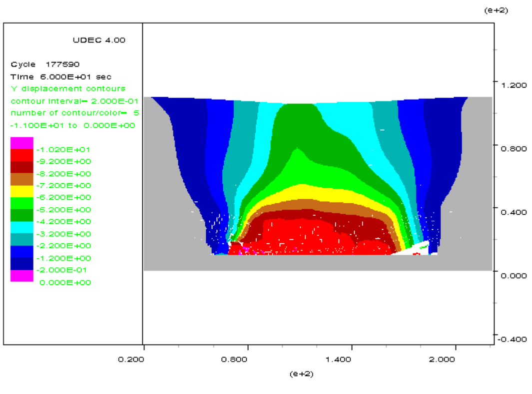
After coal seam mining, the stress is redistributed and the stope roof falls. However, the caving height is limited. When the roof caving falls to a certain height, the rock mass enters a new equilibrium state and forms a natural caving balanced arch, shown in Figure 1.



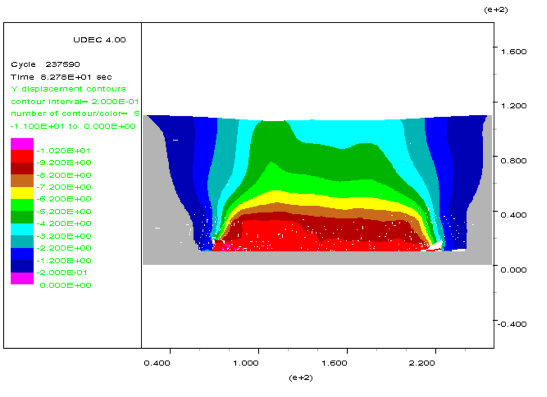
(a) Vertical displacement when the working face advances 30m



(b) Vertical displacement when the working face advances 80m



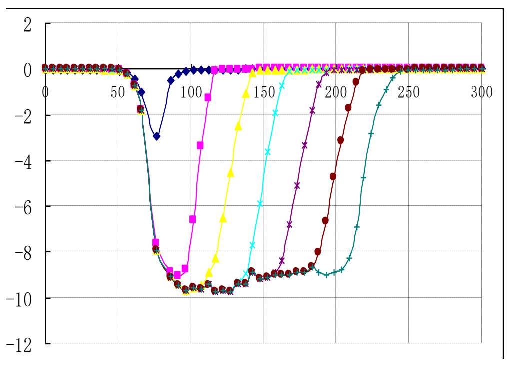
(c) Vertical displacement when the working face advances 130m



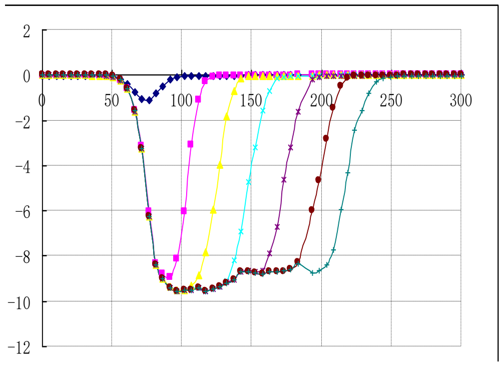
(d) Vertical displacement when the working face advances 180m

Figure 1 Vertical displacement diagram of different advancing distances of working face

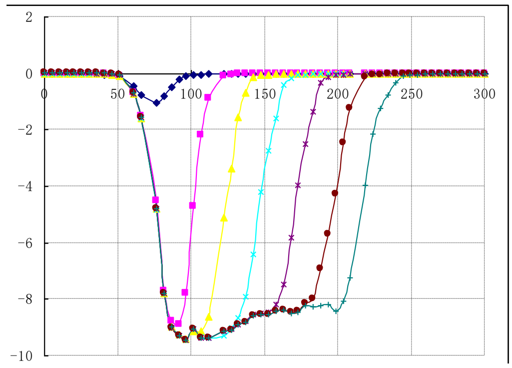
When the model is advanced from the opening hole, four monitoring lines are set on the direct mud-stone roof, fine sandstone basic roof, weathered mud-stone and loose bed respectively to monitor the vertical displacement. 60 monitoring points are selected from each monitoring line, and the vertical displacement change curves of the corresponding four monitoring lines are shown in Figure 2.



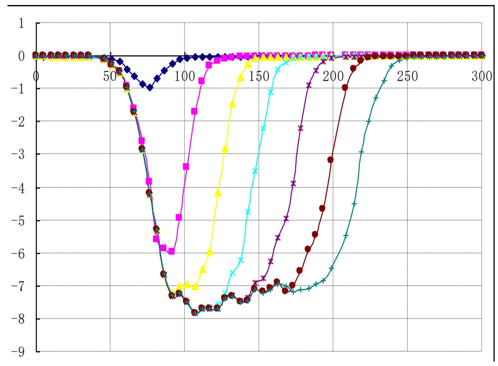
(a) Subsidence curve of direct roof



(b) Subsidence curve of basic roof



(c) Subsidence curve of weatheredmud-stone



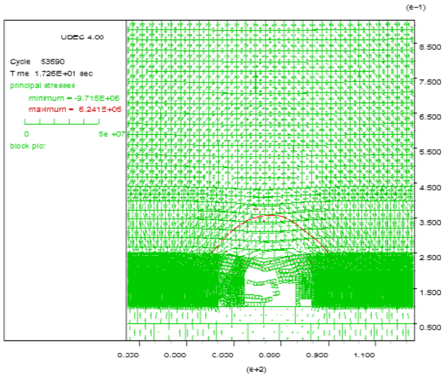
(d) Subsidence curve of loose layer

Figure 2 Dynamic subsidence curves of overlying strata at different levels

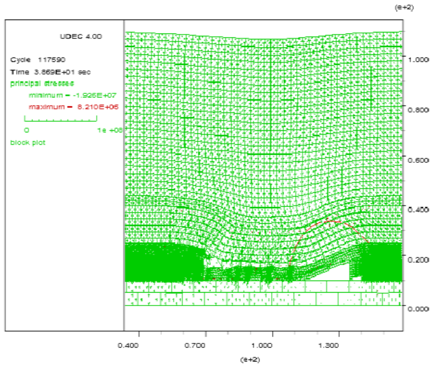
When the working face advances to 8m, the first collapse of the direct roof occurs; when the working face advances to 30m, the initial pressure of the basic roof occurs, and then there are several periodic collapses. The periodic pressure step distance is basically the same, and the periodic pressure step distance is 9~11m. In the process of advancing the working face, the direct top mud-stone is mined along with the rise, and the overlying strata also sinks synchronously. However, the subsidence of the loose strata is slightly smaller than that of the rock strata due to the large thickness of loose strata, which are mostly clay layers. When the working face advances to 55m, the subsidence of overlying rock is close to the maximum subsidence. As the working face continues to advance, the subsidence of overlying rock decreases significantly, and the subsidence range of loose layer is greater than that of overlying rock. This indicates that when the working face advances to 55m, the subsidence of overlying rock is basically stable and in a state of compaction, while the loose layer itself is plastic and has strong creep, and its deformation time is long. Therefore, the movement duration of loose layer is longer than that of the bedrock, which plays a certain role in cushioning the movement of the strata. After 55m advancement of the working face, the surface subsidence is basically in a state of full mining.

IV. Stress Variation Characteristics of Overlying Strata in Stope

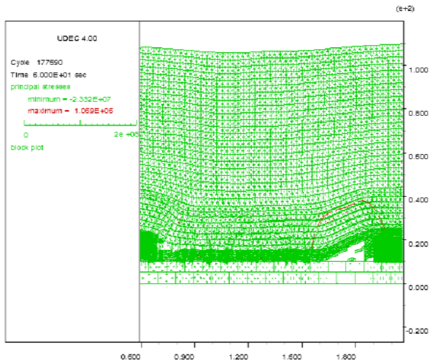
Figure 3 shows the stress vector distribution diagram of overlying strata in different mining stages. The stress vector after mining presents obvious zoning characteristics. A certain area above the gob is the stress release area, while the outside of the gob is the stress concentration area. If the block stress vector lines with the same direction of the front and rear stress vectors of the gob are connected, the stress curve, namely the stress arch is formed. The characteristic of stress arch is that it starts from the coal body at the back of the gob and stops in the controlling roof area or in front of the coal wall. The stress under the arch relaxes due to the caving of rock strata, forming a low stress area, and there is stress concentration at the foot of the arch, which is consistent with the mechanical characteristics of natural caving balanced arch analyzed above. With the advance of the working face, the span and height of the arch continue to increase. After the gangue in the rear gob is compacted, the rear arch foot moves forward. When the arch height reaches the bottom of the unconsolidated layer, the fracture arch no longer expands upward, but advances gradually with the working face. At this time, the fracture arch arch is an approximate horizontal line.



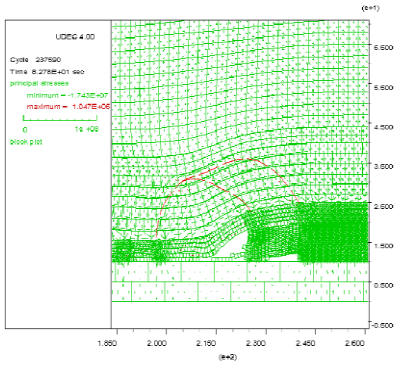
(a) Vector diagram of principal stress of 30m advancing on working face



(b) Vector diagram of principal stress of 80m advancing on working face



(c) Vector diagram of principal stress of 130m advancing on working face



(d) Vector diagram of principal stress of 180m advancing on working face

Figure 3 Principal stress vector diagram of different advancing distance of working face

According to the calculation results, the post-mining overburden is divided into five deformation zones from top to bottom.

1. Undamaged zone (i.e., elastic zone). No rock mass damage occurs under the influence of mining.
2. Plastic deformation zone. Ductile rock formation occurs plastic deformation, brittle rock formation occurs shear failure.
3. Tensile fracture zone. Tensile stress in a certain direction exceeds the tensile strength of rock mass, resulting in tensile cracks in a certain direction. The density and penetration of these tensile cracks are different, and the damage degree to the permeability and integrity of rock mass is different. When they are connected with each other and the density is large, the water-conducting fracture zone is formed. When their density is small or disconnected, they have little influence on the permeability of rock mass.
4. Tensile failure zone. Under the action of two-way tensile stress, rock strata are pulled off and pulled apart to produce large deformation (at this time, rock strata mainly fall).
5. Local stretching area. Because the overburden sinks to the gob as a whole, tensile stress appears at the edge of the subsidence range, resulting in different degrees of tensile cracks in the rock mass. Generally, tensile cracks do not communicate with the tensile fracture area, and there are undamaged areas and plastic deformation areas between them, so water filling channels do not form.

According to the stress discrimination method, the tensile fissure zone appears 15m~18m above the coal seam, and the bottom rock is in the low stress zone, indicating that the range of the fall zone is within 15m above the coal seam.

V. Conclusion

(1).In the fully mechanized caving mining of thin bedrock and thick coal seam, the direct top mud-stone rises along with mining, and the overlying strata also sinks synchronously. However, the subsidence of the loose strata is slightly smaller than that of the rock strata due to the large thickness of the loose strata, which are mostly clay layers. The overburden subsidence is basically stable and in a compacted state, while the loose layer itself has large plasticity and strong creep, and its deformation time is longer. The movement duration of the loose layer is longer than that of the bedrock, which plays a certain role in cushioning the movement of the strata.

(2).The stress vector after mining presents obvious zoning. A certain area above the gob is a stress release area, while the outside of the gob is a stress concentration area. Stress arch is formed in front and back of gob after mining. With the advance of the working face, the span and height of the arch continue to increase. After the gangue in the rear gob is compacted, the rear arch foot moves forward. When the arch height reaches the bottom of the unconsolidated layer, the fracture arch no longer expands upward, but advances gradually with the working face. At this time, the fracture arch arch is an approximate horizontal line.

(3).According to the calculation results, the overburden after mining can be divided into five deformation zones from top to bottom, namely, undamaged zone (i.e., elastic zone), plastic deformation zone, tensile fracture zone, tensile failure zone and local tensile zone. According to the stress discrimination method, the tensile fissure zone appears 15m~18m above the coal seam, and the bottom rock is in the low stress zone, indicating that the range of the fall zone is within 15m above the coal seam.

VI. Acknowledgements

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