Acta Technica 62 (2017), No. 4A, 745–752

Study on working face layout in underlying coal seam in mining close distance coal seams

J.Z. Li[2,3,5], H.Hu[2], M.Zhang[2],Z.H.Jiao[2],Z.Q. Zhang[4], A.Y. Yuan[2]

Abstract. This study is aimed to explore the generation mechanism of 3D stress field for repeated mining of coal seams and determine its multiple working face spatial layout. The mechanical model of spatial distribution of working face of close distance coal seams was established using elastic-plastic mechanics theory. On this basis, it used numerical simulation to make comparative analysis for mechanical characteristic of surrounding rock under different working face layout conditions. Finally, the selection and determination method for working face spatial location of underlying coal seams were proposed. Research results show that: when upper and underlying coal seams are in perpendicular layout, the coal loss is minimized; when the regional stress is concentrated on working face of underlying coal seam and stoping roadway, the construction is faced with the greatest challenge. If the working face of underlying coal seam is situated within the reduced stress-induced area of the upper coal seam, there is minimum stress, displacement and destruction area of surrounding rock for working face and roadway. It is beneficial for roadway maintenance and safe mining for working face. If the working face and roadway of underlying coal seams are under the coal pillar left by upper coal seams, due to its support pressure, the pressure of surrounding rock is relatively bigger for working face and roadway. It is not good for stability control of the surrounding rock. The study achievement has important guidance for mine pressure law in mining close distance coal seams and dynamic control of disaster formation conditions.

Key words. Close distance coal seams, mechanical characteristic,underlying coal seams,coal face,layout.

[1]Acknowledgment-This research is supported by State Key Research Development Program of China (2017YFC0804202).

[2]Workshop 1 - Anhui Province Key Laboratory of Mining Response and Disaster Prevention and Control in Deep Coal Mine, Anhui Universityof Science and Technology, Huainan, Anhui 232001, China

[3]Workshop 2 - School Energy Resources and Safety, Anhui University of Science and Technology, Huainan, Anhui 232001, China

[4]Workshop 3 - School of Resource and Safety Engineering, China University of Mining and Technology, Beijing, 100083, China

[5]Corresponding author: J.Z. Li ;email:592859929@qq.com

1. Introduction

Coal has presently occupied over 65% of energy production and consumption in placecountry-regionChina and is also the primary energy resource for electricity generation, chemical raw materials and commodity in civil use[1]. Most coalfields in country-regionChina, such as those in Huaibei, CityHuainan, CityXuzhou, Xinwen, PlaceNamePingding PlaceTypeMountain, placeCityDatong, etc[2], are close distance coal seams that less than one third mines have less than five mineable seams; 55.2% mines have 6-15 mineable seams and some other mines have over 20 mineable seams[3-5]. Through great efforts of experts at home and abroad, the fundamental research for the single coal mining has realized great breakthrough. However, the coalfields in placeEast China are faced with coal seams along with expanding mining scale and deeper exploitation. Different from single coal seam exploitation, the mutual influence is intensifying among seams while mining in coal seams. Since there is little research for time-space relationship in exploring coal seams, the difficulty in roadway maintenance, tight mining takeover and serious coal loss have affected on safe and efficient extraction in the mine to certain extent. Among that, reasonable allocation parameters in mining zone of coal seams are the key factor for its efficient mining. The difficulties in present study are complex stress field and displacement field generated in this seam and among seams arising from extraction. Therefore, the key issue for mining coal seams in a safe and efficient manner is to reveal the layout in mining close coal seams.

On the basis of FLAC procedure, this paper has deeply analyzed re-mining effect of three-dimensional stress-induced field coal seams. We studied the laws of surrounding rock displacement, stress and fracture fields in stress-induced process of coal seam face, We also discussed layout parameters of close distance coal seams and the advantages and disadvantages.

2. State of the art

In mining close coal seams, if the distance of two neighboring coal seams was relatively bigger[6], and the upper layer mining exerted minor influence on the underlying layer, the underlying coal seal shared the same rock pressure behavior and mining method in mining the single coal seam under general conditions[7]. However, when two neighboring seams shared a shorter distance, the mining effect was obvious, particularly mining extremely close coal seam. In recent years, many domestic and foreign scholars have obtained many important achievements in stress distribution law of surrounding rock and coal pillar and drift layout and support technology of close distance coal seam mining based on much research and analysis, particularly the fruitful exploration in theoretical research and engineering practice of mine stress. It has provided certain basis for surrounding rock control and lane layout in mining close coal seams. After coal seam recovery, the stress field of working face surrounding rock is re-distributed. The upper overburden rock is divided into “three belts”[8]. Based on “brickwork beam” theory , pressure is relieved from roof floor to generate the fracture . Pressure relief expansion is generated in regular collapse belt and fracture belt in medium and top roof strata to have perpendicular fracture development area. In this area, separation layer fracture and perpendicular broken fracture are developing. They were connected with perpendicular and horizontal fractures and the irregular collapse belt. However, many technical difficulties are still to be urgently solved . Lightfoot and Zhang proposed that, in mining the upper strata of close coal seam, stress is redistributed for surrounding rock of recovery area, It not only results in concentrated stress on coal pillar surrounding the recovery area but also passes into the deep floor strata, making it deformed and destructed.

3. Methodology

3.1. General Information on the Project

The 66207 working face of Xinzhuangzi Coal Mine under Huainan Mining Industry Group starts from 70m in the south of III Line and 25m to the south of Li IX Line. Its upper elevation is 721m and lower elevation is 793m. Stoping is completed for 66107 working face in the upper layer and for TCSC066208 in the upper layer. The stoping is not done for lower overburden layer 6. The development is under the construction near 66206 coal haulage door, 66207 ventilating roadway and northern section of roadway. The incline length of 66207 working face in normal stoping stage is 132m, strike is TCSC0403m long, inclined angle of the mine seam is 27˜34 with the average of 30. The distance between #7 and #8 coal seams is only chmetcnvUnitNamemSourceValue13.1HasSpaceFalseNegativeFalseNumberType1TCSC013.1m.

3.2. Establishment of numerical simulation

FLAC 3D model is established for numerical simulation of force, deformation, movement and destruction of the surrounding rock for each working face in a comprehensive and systematic matter in mining close coal seams. The model is 540m long, 500m inclined wide and 350m high. It includes #1 coal seam, #2 coal seam, roof and floor rocks. With horizontal movement restricted in the side and perpendicular movement restricted at the bottom, perpendicular load is applied on the top of the model to simulate the weight of upper rock.

3.3. Technological parameters for data

Based on the sample at the site and rock mechanics test, when load reaches the ultimate strength, rock may be destructed. Rock residual strength will be decreased along with deformation development during plastic flow process after peak. So, Mohr-Coulomb yield criterion is applied in the calculation to determine rock destruction in Formula (1). Strain softening model is used to reflect the nature of decreasing residual strength along with deformation development after coal mass is destructed.

$$f_s = \sigma_1 - \sigma_3 \frac{1+\sin\varphi}{1-\sin\varphi} - 2c\sqrt{\frac{1+\sin\varphi}{1-\sin\varphi}} \qquad 1$$

Where, σ_1 and σ_3 are the maximum and minimum principal stresses respectively. c and φ are adhesive stress and fractional angle respectively. Where fs>0, shear failure will be occurred to materials. Under usual stress state, the rock has extremely low tensile strength. Therefore, it could be determined whether the rock is destructed or not based on tensile strength principle ($\sigma_3 \geq \sigma_T$).

Working face support applies bar element stimulation. It is perpendicular to roof and floor of coal seam. Parameters of bar element: elasticity modulus E=2.1×106MN, length L=2.77∼ 3.0m.

3.4. Numerical simulation plan and calculation process

Upper roof is fractured due to mining disturbance. The redistribution of produced stress has indirect influence on the working face. The principal stress in upper roof rock is relatively higher than that in upper and lower rocks. The higher shearing stress accumulated in the overburden rock is the main reason resulting in upper roof fracture in advancing the working face. This arch structure together with pressure arch becomes bearing structure to support the upper overburden rock. Based on this, it is proposed three layout ways, namely vertical, bottom slicing and external staggered layout in mining close coal seams. The layout for close coal seams are shown in Fig. 1

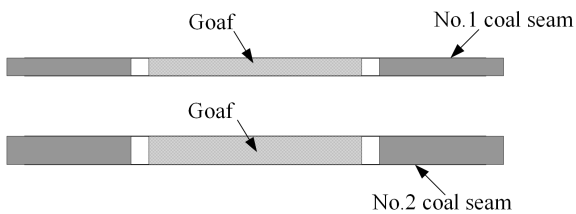

Fig. 1. Working face layout of close coal seams

4. Result analysis and discussion

4.1. Numerical calculation result

Stress distribution of surrounding rock of underlying coal seam working face under different layouts and stress distribution of surrounding rock in the field are shown in Fig. 2 and Fig. 3. The simulation result shows that, the difference for mechanical environment for 66207 working face under vertical, bottom slicing and external staggered layout conditions is obvious. Analyzing from the stress, in perpendicular layout, the stress and side supporting pressure on two sides are overlaid for 66207 and 66208 working faces. The maximum perpendicular stress for 66207 working face is 60.5MPa. In bottom slicing layout, 66207 working face and surrounding rock of roadway are located in the stress reduced area. It has weakened the overlaid stress of underlying coal seam. The maximum perpendicular stress for 66207 working face is 21.5MPa. It has reduced wall caving and roof caving of the underlying coal seam due to bearing oversized pressure. In external staggered layout, influenced by the coal pillar left by the above 66208 working face, the maximum perpendicular stress for 66207 working face is up 41.0 MPa. The law of stress field for surrounding rock under different layout conditions for underlying coal seam working face is shown in Fig. 2.

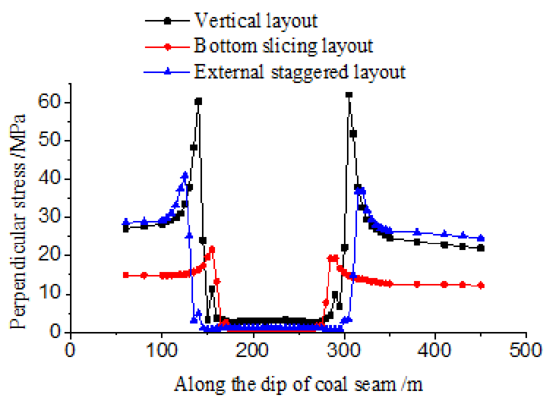

Fig. 2. Displacement field for surrounding rock in the mining field under different layouts

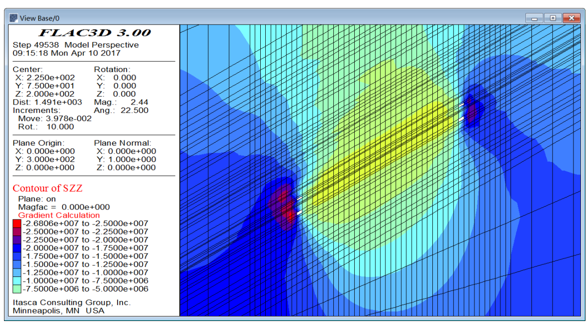

Fig. 3. Stress distribution for surrounding rock

The evolution law of the surrounding rock in the mining field under different layout for underlying coal seam working face is shown in Fig. 6. It could be seen that, after coal seam mining, the tensile stress is primarily left for the rock strata in stress-relived area. Perpendicular fracture will appear when it exceeds the limited tensile strength. So, during the recycled fracture of roof overburden rock, the upward perpendicular fracture will appear in the roof strata in front of coal wall and the downward perpendicular fracture will appear in roof strata rear the coal wall. Along with advancing working face and mining-induced influence, uneven sinking will appear in perpendicular direction and the rock strata with different settlement will develop along with horizontal fracture. So, analyzing from the destruction area size, although destruction is not obvious for surrounding rock in the mining field of 66207 work face under three layouts, compared with other two layouts, due to mutual connection between destruction areas of 66207 working face and 66208 working face, for perpendicular layout, gas could flow along with fracture and the gas is easy to be out of limit which is bad for safe production.

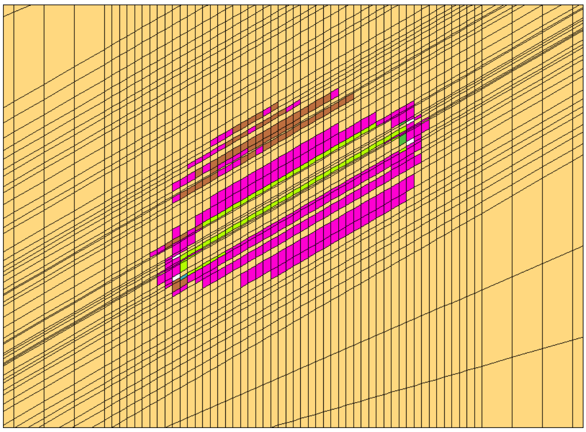

Fig. 4. Destruction area of the surrounding rock for underlying coal seam working face under different layouts

4.2. Field observation result

If bottom slicing is adopted, the haulage roadway and track roadway of 66207 working face are distributed within the pressure relief area of 66208 working face. 66207 working face is located in the low stress area to prevent the influence of high concentration stress after mining the upper coal seam. So, 66207 roadway is adjusted to distribute in the goaf of 66208 working face in chmetcnvUnitNamem-SourceValue10HasSpaceFalseNegativeFalseNumberType1TCSC010m to prevent the concentration stress area generated by coal pillar in #8 coal sector. The field implementation scheme is shown in Fig.5.

Fig.6 is the stress distribution field observation curve of haulage roadway in two working faces. It could be found that, 66207 working face haulage roadway is located in the pressure relief area under 66208 working face. The observed stress value in two observation stations has been always minor without stress concentration in advancing the working face. The concentrated high stress in mining 66208 working face has no obvious influence on underlying 66207 working face, realizing low stress mining under high stress conditions.

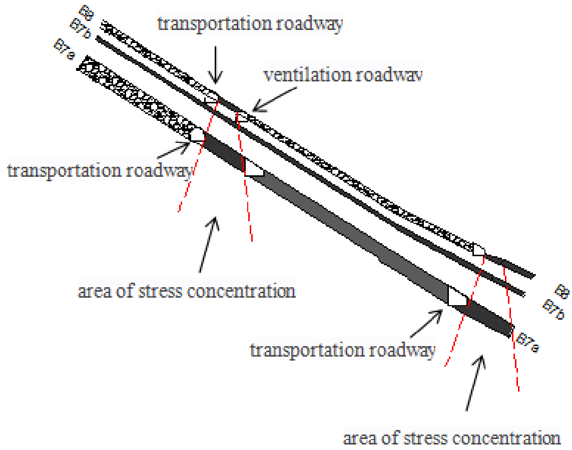

Fig. 5. Optimized mining field structure of close coal seams

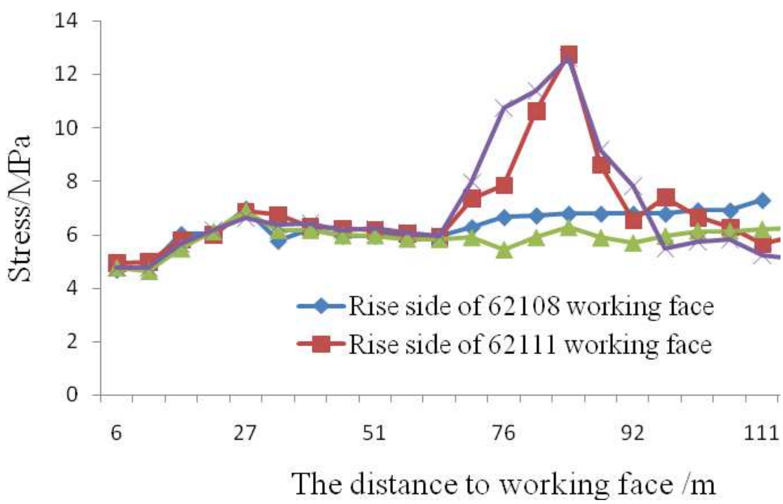

Fig. 6. Distribution curve of haulage drifts on the strike

5. Conclusion

This paper is purposed to determine working face layout in mining close coal seams, reduce the mutual influence of stress fields in mining the upper and underlying coal seams and mine close distance coal seams in a safe and efficient manner. Starting from the mechanical characteristic of surrounding rock under different working face layouts, based on elastic-plastic mechanics and mining theory, it is proposed the method to select and confirm the spatial working face position of underlying coal seams and established working face spatial distribution mechanical model of close distance coal seams.

This paper has studied dual pressure relief law through theoretical calculation and numerical simulation for close coal seams. It also provided spatial distribution mechanical model for working face of close coal seams. The paper also described advantages and disadvantages of different working face spatial layouts. These have provided the basis for studying the law of pressure in mining close coal seams and dynamically controlling disaster formation conditions. However, the study result has only been applied in 66207 and 66208 working faces of Xinzhuangzi Coal Mine and its promotion should be further explored.

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Received November 16, 2016