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Study on Optimization of Fully Mechanized Working Face Arrangement Under the Influence of Geological Structure in Shallow Coal Seam

Chen Tian¹*, Yingjie Liu²
¹Shenhua Shendong Coal Group Liu Ta Coal Mine, Inner Mongolia, China
²Shenhua Shendong Coal Group Production Manage Dept., Shan Xi, China

*Corresponding author e-mail: 290783585@qq.com

Abstract. Fold structure and fault exist in fully mechanized mining face of 2-2 seam in Bu’ertai coal mine. The faults encountered in 22101 and 22102 face are many and complex, the density of fault structure is high, and the inclined angle with the working face is between 50° and 60°. During the mining process, the two sides of the roadway are deformed greatly by the influence of geological conditions, and the phenomenon of roof and floor breaking is very serious. Combined with the above problems, this paper analyzes the rationality of length design of 2-2 coal seam working face. The length parameters of the working face are calculated by fitting the control theory of the rock stratum and the measured data, and the following conclusions are obtained. The reasonable working face length of 2-2 coal seam in Bu’ertai coal mine is more reasonable to take 250 meters, and the width of roadway pillar is designed to be 20 m.

1. Introduction

In the process of coal mine production, faults, folds and other geological structures are often encountered, which has a great impact on the safety of mine production. Under the influence of stope pressure, there will be a large amount of deformation along two trenches under the influence of stope pressure, and a serious or large area roof fall from the coal wall. At the same time, the wider the width of the working face, the greater the pressure in the middle of the face. Therefore, the width of the working face is one of the factors affecting the overfold and fault structure [1-7]. Other experts believe that horizontal tectonic stress is one of the important factors affecting the stability of roadway surrounding rock. With the increase of horizontal stress, the tendency of horizontal stress transferring to the depth of roadway roof and floor is obvious, which leads to the destruction of roadway floor heave and fold shape, the roof shear deformation and wedge-shaped caving, and the roof and floor deformation damage is greater than the deformation and failure of the two sides of the roadway [8-11]. From the situation of roadway layout and maintenance of longwall mining face in China, it is rare to see that the rate of roof and bottom movement is 52.7%, that is, the amount of approaching is more than half of the height of roadway. Based on the practice of 2-2 coal mining and the observation of mine pressure, the main reasons of roadway stability and support difficulties can be analyzed and summarized. (1) The influence of geological structure. But the working face mining direction layout has been fixed at present, which can not be changed rapidly; (2) The influence of mining depth and surrounding rock property of roadway is large. The whole quality of surrounding rock is poor, and it
can not be changed; (3) The influence of working face roadway layout. On the basis of mastering the regularity of mine pressure in 2-2 coal seam longwall working face, the adjustment can be improved and the goal of improving the effect of roadway maintenance can be achieved.

2. Study on the geological structure of 2-2 coal seam and the influence on roadway layout of working face

The Bu’ertai minefield is located in the south of the Dongsheng coal field. The Bu’ertai 2-2 coal seam is located at the top of the first, second rock section of the Yan’an formation. The interval between the coal seam and the 2-2 coal seam is 1.40M to 33.48m, with an average of 12.63m. This coal seam is one of the main recoverable coal seams within the scope of the mineral rights. There are 284 coal spots and 276 mining points in the mine field. The thickness of coal seam is 0~5.85 m, and the average thickness is 3.07 m. There are faults and fold structures in Bu’ertai 2-2 coal seam fully mechanized mining face, and the density of faults is high, there are 2.6 faults per 1000m, so the influence on the stability of roadway can not be underestimated.

2.1. Study on geological structure of 2-2 coal

(1) Faults structure

The statistics of fault structures in the mining engineering plan of 2-2 coal seam 22101, 22102 and 22103 working face are shown in Table 1. The coal seam situation of 22101 working face, as shown in Figure 1.

| Name of Working Face NO. | Fault NO. | Throwfall (m) | Extension Length (m) | Distance from Cut Hole (m) | Slope of Fault Plane | Strike Line and Laneway Clamp |
|--------------------------|-----------|---------------|----------------------|---------------------------|----------------------|--------------------------------|
| 22101                    | BF68      | 0~8           | 251                  | 0                         | 55°~60°              | 3°                             |
|                          | BF63      | 0~8           | 202                  | 290                       | 55°~60°              | 77°                            |
|                          | BF65      | 0~6           | 68                   | 310                       | 60°~65°              | 25°                            |
|                          | BF62      | 0~8           | 326                  | 520                       | 55°~60°              | 90°                            |
|                          | BF54      | 0~5           | 200                  | 1180                      | 50°~60°              | 10°                            |
|                          | BF51      | 0~8           | 138                  | 1780                      | 50°~55°              | 19°                            |
|                          | BF45      | 0~8           | 103                  | 2410                      | 55°~60°              | 32°                            |
|                          | BF44      | 0~6           | 208                  | 2570                      | 55°~60°              | 68°                            |
|                          | BF38      | 0~6           | 95                   | 2730                      | 55°~60°              | 25°                            |
|                          | BF31      | 0~8           | 494                  | 4120                      | 35°~40°              | 30°                            |
|                          | BF29      | 0~6           | 59                   | 4480                      | 55°~60°              | 61°                            |
|                          | F17       | 4.8           | 114                  | 4530                      | 60°                  | 60°                            |
| 22102                    | BF58      | 0~6           | 105                  | 630                       | 55°~60°              | 4°                             |
|                          | BF59      | 0~7           | 161                  | 780                       | 50°~55°              | 13°                            |
|                          | BF60      | 0~6           | 130                  | 780                       | 55°~60°              | 77°                            |
|                          | BF50      | 0~10          | 203                  | 1590                      | 55°~60°              | 54°                            |
|                          | BF47      | 0~6           | 255                  | 1990                      | 50°~55°              | 37°                            |
|                          | BF46      | 0~8           | 212                  | 2180                      | 55°~60°              | 0°                             |
|                          | BF44      | 0~6           | 208                  | 2370                      | 55°~60°              | 68°                            |
|                          | BF43      | 0~6           | 180                  | 2420                      | 55°~60°              | 24°                            |
|                          | BF39      | 0~5           | 253                  | 2700                      | 50°~55°              | 31°                            |
|                          | BF41      | 0~6           | 108                  | 2860                      | 55°~60°              | 0°                             |
|                          | BF36      | 0~6           | 84                   | 3110                      | 60°~65°              | 40°                            |
|                          | BF30      | 0~10          | 152                  | 3950                      | 60°~65°              | 24°                            |
|                          | BF29      | 0~6           | 59                   | 4260                      | 55°~60°              | 61°                            |
|                          | F17       | 4.8           | 114                  | 4310                      | 60°                  | 60°                            |
|                          | BF27      | 0~12          | 238                  | 4500                      | 50°~55°              | 34°                            |
|                          | BF11      | 0~9           | 241                  | 4500                      | 50°~55°              | 32°                            |
| 22103                    | BF76      | 0~13          | 866                  | 2670                      | 50°~55°              | 6°                             |
|                          | BF77      | 0~6           | 133                  | 2890                      | 55°~60°              | 13°                            |
From the fault situation encountered in the 22101 working face, there are 12 faults in the range of 4530m propulsion length, the average extension length of the fault is 188.2m, and the dip angle is more than 55°-60°. The average axial angle between fault strike and roadway is 42.4°, in which the smaller angle is only 10°-25°. Because of the small angle, the fault is basically parallel to the axis of roadway in extreme cases.

According to the faults encountered in 22102 working face, there are 16 faults in the range of 4500m propulsive length, and the average extension length of faults is 168.9 m; The drop was 0 ~ 12 m and the inclination angle was 55~60°. The average axial angle between fault strike and roadway is 34.9°, among which there are 6 faults with small angle, which are only 0 ~ 24°, and 4 faults with an angle of 0 ~ 13° with the axis of roadway. Because of its small angle, the fault is basically parallel to the axis of the roadway in extreme cases.

According to the faults encountered in 22103 working face, there are 2 faults in the range of 4530m propulsive length, the extension length of the fault is 133~866m, the drop is 0 ~ 13m, the dip angle is 55~60°. The axial angle between fault strike and roadway is 6°~13°, with an average of 9.50. Because the angle is less than 100, the fault is basically parallel to the axis of roadway.

In general, the faults encountered in the 22101 and 22102 working face are many and complex, and there are also faults that are orthogonal to the roadway, such as BF76 fault and BF35 fault, which indicate that the horizontal stress state of rock strata in the roadway area varies greatly. Although the 22103 working face has few faults, but the extension length is large, that is, the fault scale is large, and the angle between the face and the roadway is the smallest, the average is 9.5°, so the influence on the stability of the roadway can not be underestimated.

(2) Folding structure

From the fold structure, there are 6 folds in the 22101 working face, with the angle between the fold crankshaft and the roadway at 35 ~68°, with an average of 50.40°. There are 2 folds, 1 anticline and 1 syncline in 22102 working face. The angle between fold crankshaft and roadway is 0 35°, with an average of 17.5°.There are 4 folds and Anticline syncline phase in the 22103 working face. The angle between the fold crankshaft and the roadway is 0~66°, with an average of 39°.

In general, the fold crankshaft is parallel to the axis of the roadway and spans the 22102 working face and the 22103 working face, which has a great influence on the stability of the roadway.

2.2. Analysis on the influence of geological structure on working face roadway layout

According to the viewpoint of geomechanics, faults and folds are formed under the action of tectonic stress. From the excavation engineering plan and the foregoing analysis, it can be seen that the
relatively large faults and fold crankshaft lines are basically parallel to the roadway strike. In this case, the horizontal stress of the structure and the layout of the roadway will be formed as shown in Figure 4.

Due to the existence of the structural stress of the basic vertical roadway strike, the deformation of the two sides of the roadway and the fracture of the roof and floor are inevitable. In this case, if the roadway is arranged in or near the fold crankshaft, and meets the syncline structure, the roadway generally occurs floor bulge damage, meets the anticline structure, usually the roof falls off the roof, and is arranged in the vicinity of the fault influence zone, Then the two sides of the roadway and the roof and floor can be deformed and destroyed.

3. Optimization of length parameters in 2-2coal working face

3.1. Judgement of roadway maintenance effect under actual working face length

Roadway maintenance effect under the condition of actual working face length of 2-2 coal, rock pressure and rock layer control theory predict reasonable working face length parameter, analyze reasonable working face length parameter, and finally determine the optimized working face length parameter synthetically.

At present, the length parameters of 22101, 22102 and 22103 working face in 2-2coal seam are 300m. The actual lower working face reuse roadway (return airway) is seriously deformed after being subjected to the influence of single mining, so it is difficult to meet the requirements of maintenance and reuse. Even if the roof and two supports are strengthened, it is difficult to solve the problem of roadway floor heave, Only manual excavate bottom coal can be adopted for governance.

When the coal machine of 22102 working face was pushed to 1170m at the tail, the tail suddenly came under pressure, and a large amount of coal dust rose up 1-6 #, the bottom plate suddenly appeared in the range of lead support, and the height of the bottom drum was 400mm. The chain of the reloader of the front pulling bracket of the 1# leading support pops up, and it is thrown on the drum of the coal machine and is broken by the rotating drum. The violent vibration drops the belt over the front and tail motor to the water tank position, and the inner control module of the tail motor is damaged. Cause the working face to stop production.

By analyzing the reasons for the occurrence of mine pressure, the following points have been obtained..

The inclined length of the working face is large: the inclination length of the working face is 300m. According to the layout of the working face and the pressure analysis of the adjacent disk area of the interconnected coal seam, the difference between the inclination of the 240m and the inclined length of the working face of the 300m is larger than that of the working face. Therefore, there is a great connection between the pressure and the inclined length of the working face.

1. According to the geological data, the direct roof is sandy mudstone with an average thickness of 2.2 m and the main roof is fine sandstone with a thickness of 15.58 m. The roof thickness is large, the structure is relatively complete, and it is not easy to break. During the initial mining period and 17 days in December 12th, the thickness of the direct roof is 10-11m and the thickness of the old roof is 23-24m. When the overlying overburden is very thick, the direct top sand mudstone with mining caving can not completely fill the goaf, which makes it difficult for the basic roof to form the bearing structure and provides the space for the impact pressure to occur.

2. Working face stop time is long: through summing up and analyzing, it is found that the above several large pressure time, the working face is after long downtime. If preventive maintenance or continuous stop time of warehouse full is longer, when cutting 1-3 times after resuming production, it is easy to occur strong rock pressure appearance.

3. Large - structure and small - structure composite breaking: the inclined length of the working face is 309m, and the length is too large. According to the principle of "Seeing square breaking" in the mine pressure, the large structure of the overlying strata will break down when then working face advances to 300m, and there is a large mine pressure when the working face is pushed to 295m, which is basically consistent with the theory.
4. The roof support at the end of the machine is not qualified: it is easy to break the top coal in this working face, which results in poor and full contact with the top beam of the support. By analyzing the data of the hydraulic support in the tail part of the working face, it is found that the working resistance is generally less than the minimum initial support force, and the roof support effect can not be achieved when the working face comes under pressure. That is to say, in addition to looking up from the direction, the main roof forms a cantilever beam after the working face advances a certain length. From the inclination point of view, the initial support force of the 13 supports at the end of the working face is not enough, and the cantilever beam is also formed on the inclination. This repeated superposition of the roof on the tail coal pillar and coal wall pressure.

5. The width of coal pillar: the width of coal pillar is 20m. From the point of view, the coal pillar help drum is serious, some of the anchor cable anchor ends fail, indicating that the deformation plasticity core of the coal pillar has exceeded 6.5m (the anchor length is 6.5m), the coal pillar has poor supporting effect on the top plate, causes the top plate to sink, the top plate sinks and deforms the coal pillar, thereby forming a vicious circle.

6. Large buried depth: Taking 22101 fully mechanized caving face as an example, the burying depth of the cutting hole is 462 m, the present working face is advancing 1170 m, the buried depth is 439 m, and the working face self-cutting advancing 2768 m, the burying depth is less than 400m. Due to the large buried depth of the coal seam, the mine pressure appears violent.

3.2. Prediction of working face length parameters based on stope strata control theory

The mining depth, mining face height and length mainly affect the intensity of stope pressure behavior. The greater the mining depth, the higher the intensity of mine pressure behavior, and the more obvious the influence on mine pressure intensity of roadway is. The higher the mining height, the higher the intensity of roadway pressure, and the longer the length of working face, the stronger the intensity of roadway pressure.\[12\]

When the mining depth and height of 2-2 coal are certain, the longer the length of coal face, the more obvious the influence of mine pressure intensity, especially on the roadway of mining face. In the theory of mine pressure, the influence of flat stope on the supporting pressure of roadway belongs to the influence of large hole on small hole, the length of which is not increased much, but the degree of stress concentration of roadway will be more obvious, so the deformation and destruction of surrounding rock of roadway will be aggravated. As shown in Figure 3.

![Figure 3](image)

Figure 3. Analysis of influence of working face length on roadway maintenance

According to the results of roof test in 2-2 coal seam, the main lithology of roof in 8 joint roadways of return air roadway is medium sandstone and coarse sandstone, and the uniaxial compressive strength is 34.65 MPA on average. The main lithology of the roof of the 12 joint roadway is medium sandstone and coarse sandstone, the local sandstone is sandy shale, and the uniaxial compressive strength is 22.07 MPA, so the roof Pressure-coefficient is 2.2m3.5. It can be calculated according to fl 3.5.

According to Prussian equilibrium arch theory, the paper estimates the strength of rock pressure behavior in the middle of the mine, and selects the reasonable working face length parameters of 2-2 coal seam in Bu’ertai coal mine, that is:

\[ h_g = \frac{L}{2f} \]  (1)
In the formula: \( h_g \) —— the strength of the rock pressure manifestation

\( L \) —— the length of working face, \( m \);

\( f \) —— the Prussian hardness index of roof rocks, the value of the strength of 1/10.

The falling rock of arch roof in stope mining is generally the static load part of the roof, and should also consider the dynamic load. For this reason, the matching relationship between the support and the working face length is selected as follows:

\[
q \geq K \gamma \frac{L}{2f} \tag{2}
\]

In the formula: \( q \) —— Maximum support strength of support, \( 1.16 \text{MPa} \);

\( \gamma \) —— Roof rock weight ratio, we make \( 0.025 \text{MN/m}^3 \);

\( K \) —— The dynamic load coefficient of working face is 1.34 according to the actual measurement.

Therefore, the reasonable working face length is:

\[
L \leq \frac{2f \cdot q}{K \cdot \gamma} \tag{3}
\]

The optimum working face length is 242.4m by replacing the relevant parameters with 3.

It is recommended that the length of the working face be taken as 240m when the 2-2 coal working face is laid out.

According to the above argumentation, the length of working face which affects the stability of roadway in 2-2 coal seam is restricted as follows:

1. The actual mining practice proves that it is difficult to maintain the roadway when the length of the working face is 300m, which affects the use, so the length of the working face should be shortened;

2. The prediction of mine pressure and strata control theory shows that the working face length should be 242.4 m, and the practical value is 240 m;

Considering the above situation, it is considered that 240m~250m is suitable for the length design of mining face.

4. Conclusion

1. Statistical analysis of fault and fold structure in mining engineering plan of 2-2 coal seam 22101, 22102 and 22103. Because the fault and fold are formed under tectonic stress, the bigger fault and fold axis are basically parallel to the direction of the tunnel, so that the deformation of the two sides of the tunnel and the breaking of the roof slab are affected, and the length of the working surface should be shortened.

2. Based on the mining strata control theory, the length parameters of the working face are predicted and calculated. According to the length design of the 2-2 coal working face in the same coal seam and adjacent coal face, the behavior of the coal pressure is obtained. It is more suitable to confirm 240m~250m.

3. Through the measurement and theoretical calculation, it is concluded that the width of coal pillar in 2-2 coal seam roadway is still 20m, and the roof and two side support are strengthened in return air roadway, and the stability is maintained.

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