



Design of Ground Pressure Monitoring System in Fully Mechanized Mining Face

Shuhao Yang^{1,2}

¹ CCTEG Changzhou Research Institute, Changzhou 213015, China;

² Tiandi (Changzhou) Automation CO LTD. Changzhou 213015, China

Tel: 17864286107, E-mail: 978603367@qq.com.

Abstract. A stable mine pressure monitoring system in fully mechanized coal mining face is an important guarantee for safe mining in the working face. In order to effectively monitor the change of roof pressure, roadway surrounding rock displacement, roof separation, bolt (cable) stress and advance stress in the mining process, a set of fully mechanized mining face ground pressure monitoring system is designed based on the existing ground pressure observation equipment, aiming at the weighting behavior phenomenon during the mining period of fully mechanized mining face, which can monitor the ground pressure behavior law during the mining period in real time, judge the ground pressure change law and ensure the safe production of the working face.

Keywords: Fully mechanized coal mining face; Support pressure; Lateral stress; Roof separation; Anchor (cable) stress

1 Introduction

With the continuous development of coal engineering, the mining of coal resources is gradually moving towards the deep^[1-2]. However, under the stress condition of "three highs and one disturbance" in the deep, the complex diversity of strata behavior in the working face has caused great difficulties to the safe mining of the working face and hindered the efficient mining of deep coal resources^[3-6]. It is particularly important to design different ground pressure monitoring systems according to different surrounding rock movement states.

At present, scholars at home and abroad have designed various types of mine pressure monitoring systems according to different geological conditions in different mining areas. Li Yonggang^[7] evaluated the adaptive relationship between support and surrounding rock according to the strata behavior law during the initial weighting and periodic weighting of the working face, and determined the control parameters of support and surrounding rock to ensure the safe production of the working face. Zhang Junyi^[8] et al. monitored and analyzed the mine pressure of the roadway according to the mine pressure behavior characteristics of isolated island working face in extra-thick coal seam, designed the mine pressure monitoring mode, and predicted the development pattern of mine pressure behavior. Yang Gui^[9] optimized the design of fully

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mechanized coal mining face in mining area, reduced the moving times of the face and improved the working efficiency of the face through the experiment and research of crossing roadway, crossing joint roadway and rotating mining in fully mechanized coal mining face. Li Binsheng^[10] designed the mine pressure monitoring system for the first small coal pillar working face in a mine, and studied the design rationality of coal pillar size and roadway support parameters by adopting various mine pressure monitoring methods.

Based on the research results of the fully mechanized coal mining face under different conditions, this paper takes the fully mechanized coal mining face of a mine in the northern part of Shendong mining area as the engineering background, and designs a set of fully mechanized coal mining face ground pressure monitoring system by adopting various ground pressure monitoring methods. The research results are of great significance to guide the safety production of the working face.

2 Engineering background

2.1 Geological survey

The northern landform of Shendong mining area belongs to the transition zone from Loess Plateau to Maowusu Desert, which is a typical ridge terrain. The northeast is mostly covered by aeolian sand, and the coal-bearing stratum of the mine is Jurassic extension. At present, the mining depth of mine is generally between 320~475m, and the coal seam is mainly fine-grained sandstone with an average thickness of about 14m, which belongs to hard roof. The thickness of coal seam is 3.5~7.9m, with an average of about 6m, and the dip angle of coal seam is 3~9.

2.2 Status of Top and Bottom Plates

Sandy mudstone, fine-grained and siltstone are the main floor of the main mining seam in the northern mine of Shendong mining area, and mudstone and sandstone are the main roof. The direct bottom and top are sandy mudstone, and the basic top is fine-grained sandstone about 14m. See Table 1 for roof and floor strata and thickness

Table 1. Roof and Floor Strata of Coal Seam

Top and bottom plate	Thickness/m	Rock stratum
Basic top	$\frac{6\sim39}{14}$	Fine-grained sandstone
Direct top	$\frac{2\sim27}{9}$	Sandy mudstone
Direct bottom	$\frac{1\sim5}{3}$	Sandy mudstone

2.3 Roadway layout

(1) Belt groove in working face.

The belt is arranged along the coal seam roof along the gateway, and the roadway adopts rectangular section, with specifications: clear width \times clear height = 4.6 m \times 2.6 m, S net = 12.08 m, barren width \times barren height = 4.8 m \times 2.7 m, S barren = 13.08 m, and the right side is arranged with clear width \times clear depth = 300mm \times 400mm ditch. Conveyor, crusher and belt conveyor are installed in the belt groove.

(2) Track gateway of working face.

The track gateway is arranged along the coal seam roof, and the roadway adopts rectangular section. The section specifications are: wastage width \times wastage height = 3.2 m \times 2.6m, S wastage = 8.41 m, clear width \times clear height = 3 m \times 2.5m, S net = 7.59 m, and the right side is arranged with clear width \times clear depth = 300mm \times 300mm ditch.

(3) Coal mining method.

The working face adopts inclined longwall backward coal mining method, comprehensive mechanized coal mining, double-drum electric haulage shearer for bidirectional coal cutting, front drum for top coal cutting, back drum for bottom coal cutting, full height mining at one time, advancing degree of 0.8 m per cycle, and all caving method for roof management.

3 Contents of ground pressure observation and corresponding instruments

(1) Contents of ground pressure observation.

Affected by mining or tunneling, the surrounding rock in the working environment is in an unstable state of stress, and the main content of underground ground pressure observation is the stress change of surrounding rock during the working face advancing or roadway tunneling. The main contents of mine pressure monitoring are: roadway roof separation, bolt (cable) stress change, roadway lateral support stress change, working face roof pressure change.

(2) Related instruments and equipment.

The monitoring equipment of mine pressure monitoring system mainly involves: support pressure monitoring sensor, borehole stress meter, roof separation meter and bolt (cable) stress meter.

Technical route

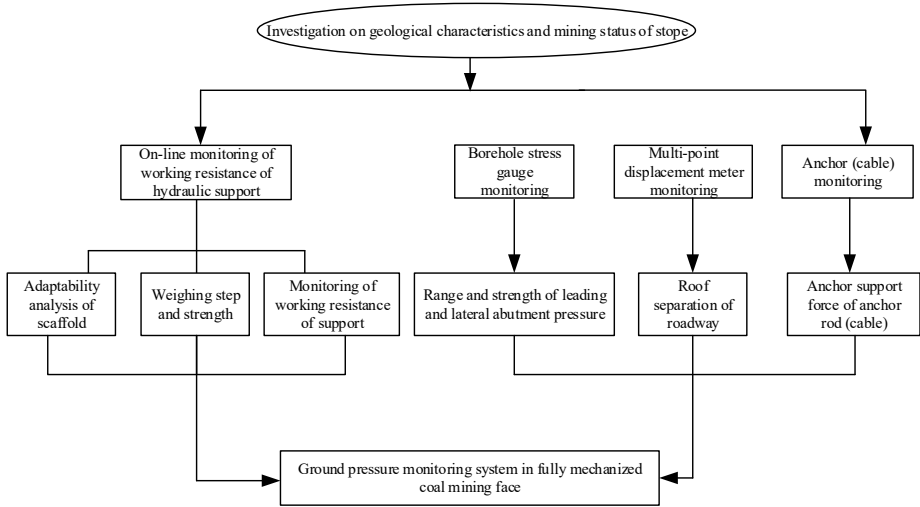


Fig. 1. Technology Roadmap

4 Design of mine pressure monitoring scheme

4.1 Working resistance monitoring of hydraulic support in working face



Fig. 2. Support Pressure Sensor

There are 65 hydraulic supports arranged in the working face, and 6 stations are arranged at both ends of the working face and the middle part of the working face. Each station selects 2 groups of hydraulic supports for monitoring (1 # station is No.7 and No.8 supports; 2 # station is No.17 and No.18 supports; 3 # station is No.27 and No.28 supports; 4 # station is No.37 and No.38 supports; 5 # station is No.47 and No.48 supports; 6 # station is No.57 support). Among them, 1 # station and 6 # station monitor the roof pressure change at the end of the working face, and other stations monitor the roof pressure change at the middle part of the working face. In the monitoring work, the support pressure sensor is used to collect the working resistance of the hydraulic sup-

port, and the field equipment installation is shown in Figure 2. When the working face starts mining, the working resistance of hydraulic support is collected in real time, and the daily footage of the working face is recorded in detail, including the number of coal cutting cycles and the footage of each cycle.

4.2 On-site monitoring scheme of leading and lateral abutment pressure in working face

The advance abutment pressure and lateral abutment pressure of working face are monitored by borehole stress meter. Three stations A, B and C are set up in front of the working face, and the distance between the two stations is 40m. Among them, Station A is 225m away from the cutting hole of the working face, as shown in Figure 3. There are 2 boreholes in each station, the distance between each borehole is 3m, and the depth of each borehole in the station is 5m and 7m respectively. Install hydraulic sleeper, with drilling diameter of 54mm and 1.5 m away from roadway floor. Observe the influence range and distribution characteristics of supporting stress along with the advance of working face.

Two stations D and E are set up in the non-production side of the belt gateway, and the distance between the two stations is 40m. Among them, D station is 225m away from the cutting hole of the working face, as shown in Figure 3. Four boreholes are set in each station, among which four boreholes are set in the borehole of station D, with depths of 5m, 7m, 9m and 11m respectively; There are 5 boreholes in the E borehole of the survey station, with depths of 4m, 6m, 8m, 10m and 12m respectively. Observe the influence range and distribution characteristics of lateral support stress along the working face. The equipment site is shown in Figure 3.

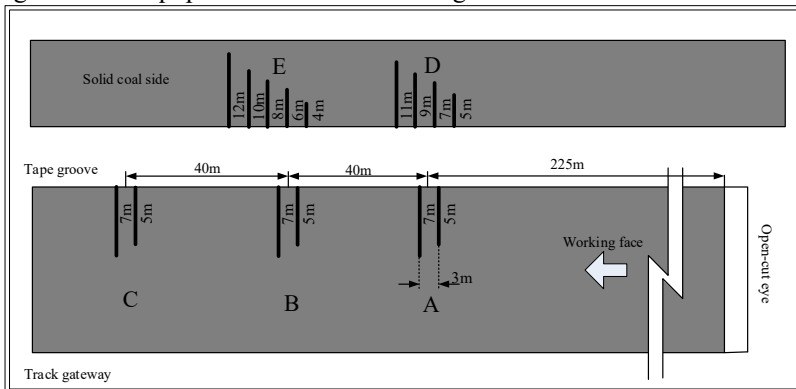


Fig. 3. Monitoring Scheme Diagram of Borehole Stress Meter

4.3 Design of on-site monitoring scheme for roadway strata behavior law

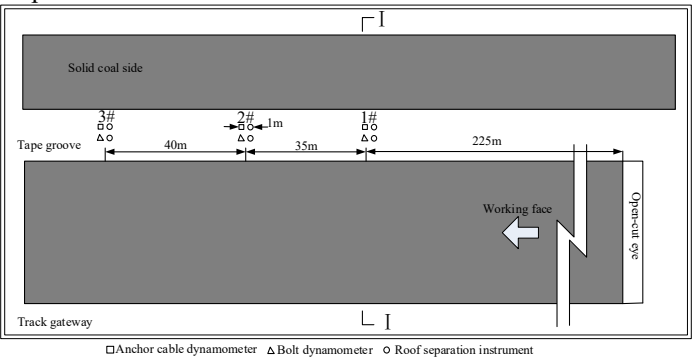
The mine pressure monitoring of belt gateway includes: monitoring the supporting force of roof anchor rod, anchor cable and side anchor rod; Deep displacement monitoring of roof coal and rock mass. The specific form is shown in Figure 4.

(1) Monitoring of anchoring force of roof anchor rod, anchor cable and side anchor rod.

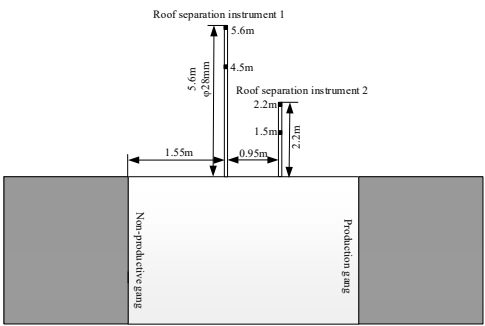
Anchor rod and anchor cable dynamometer are installed at the exposed end of anchor rod and anchor cable respectively to monitor the stress at the end of anchor rod.

(2) Deep displacement monitoring of roof coal and rock mass.

Boreholes are arranged in the surrounding rock of roadway roof, and multi-point displacement meters are installed to monitor the displacement data of surrounding rock in different depths of roof.



(a) Station layout plan



(b) Roof separation meter section surface

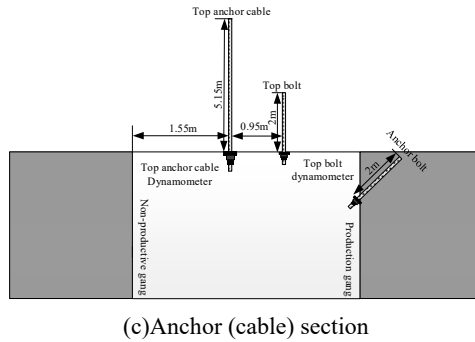


Fig. 4. Contents of mine pressure monitoring in roadway

(3) Design of monitoring mode.

① Monitoring of anchoring force of roof anchor rod, anchor cable and side anchor rod

The purpose of using bolt (cable) dynamometer to monitor the working resistance of bolt (cable) is to understand the real stress state of bolt (cable) in the whole use process, evaluate the existing support effect of roadway, and provide basis for support design. Anchor (cable) dynamometer is selected.

Installation of instrument: Re-install the bolt (cable) in the middle of the roadway and the side of the roadway. When installing the bolt (cable) dynamometer, first put the dynamometer between the bolt (cable) tray and the nut of the outer bolt head, then tighten the nut, apply prestress to the bolt, and record the initial value indicated by the dynamometer.

Deep displacement monitoring of roof coal and rock mass

Multi-point displacement meter is used to observe strata separation at different positions in roadway surrounding rock, to determine the relationship between roadway surrounding rock movement and support parameters, to evaluate the existing support effect, and to provide a basis for reasonable selection of bolt support parameters, such as bolt length.

Installation of multi-point displacement meter: at each measuring point, use anchor cable drilling rig to drill test holes to determine the thickness H of roadway roof. According to the thickness h determined on site, the length h of the roof multi-point displacement meter hole is determined on site. A multi-point displacement meter with a diameter of 42mm is selected. The deep base point (anchor claw) of the multi-point displacement meter is located h_m above the roof, and the other base points (anchor claw) are 1 ~ 2m apart in turn.

5 Study on the Law of Ground Pressure Behavior in Working Face

5.1 Field monitoring data analysis

According to the data monitoring results of hydraulic pressure in a mining face, the stress of hydraulic support is analyzed and the periodic weighting and strata behavior law under the influence of mining are judged.

(1) Cyclic end resistance of hydraulic support.

End-of-cycle resistance (P_m) refers to the working resistance before moving the end-of-cycle support. Under normal circumstances, the resistance at the end of the cycle is the maximum working resistance in the cycle. It is an important index to reflect the strength of strata behavior and evaluate whether the rated working resistance of support is reasonable. According to the variation law of working resistance of hydraulic support in working face and the footage of each knife in working face, the circulating end pressure of hydraulic support is obtained, and then the circulating end total resistance of support column is calculated by formula 1 [11-15].

The calculation process is as follows:

$$P_m = \frac{\pi D^2 \sum_{i=1}^z Q_{mi}}{2 \times 10} \quad (1)$$

Where, Q_{mi} —Measured working pressure of hydraulic support column at the end of circulation, unit: MPa;

D —Inside diameter of hydraulic support column, unit: m.

(2) Weighting step of working face.

The roof weighting step is inferred by using the relationship curve between the measured support resistance and the advancing step. The sum of the average cyclic end resistance of support and its mean square deviation is taken as the main index to judge the roof weighting. The formula for calculating the mean square error of the resistance at the end of the cycle is:

$$\sigma_p = \sqrt{\frac{1}{n} \sum_{i=1}^n (P_{ti} - \bar{P}_t)^2}$$

Where, σ_p —Mean square deviation of average resistance at the end of cycle;

n —Measured cycle number

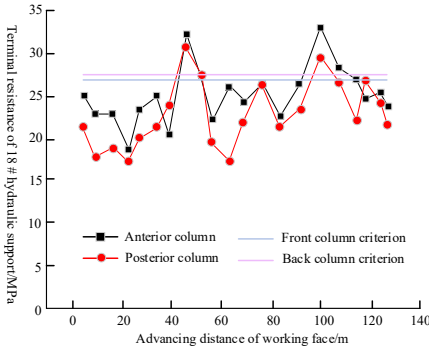
P_{ti} —The measured end-of-cycle resistance of each cycle;

$$\overline{P_t} \text{—Average value of resistance at the end of cycle, } \overline{P_t} = \frac{1}{n} \sum_{i=1}^n P_{ti}.$$

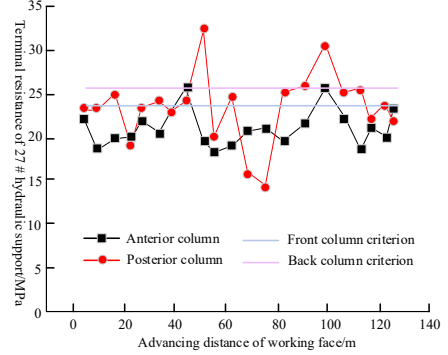
$$\text{Criterion of roof weighting: } P'_t = \overline{P_t} + \sigma_p$$

5.2 Data analysis of monitoring results of hydraulic support

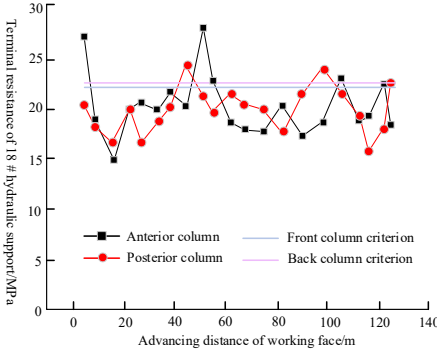
In order to simplify the analysis, only 18 #, 28 #, 38 # and 48 # bracket data were selected for analysis.



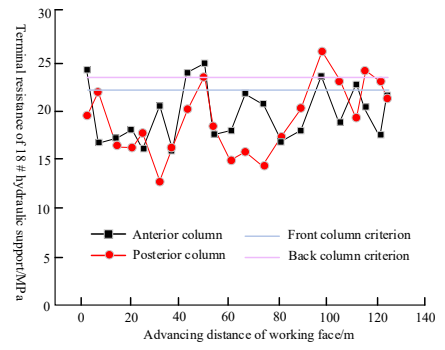
(a) 18 # Hydraulic Support



(b) 27 # Hydraulic Support



(c) 38 # Hydraulic Support



(d) 48 # Hydraulic Support

Fig. 5. Variation of circulating end resistance of hydraulic support with advancing working face

When the working face of 18 # hydraulic support is pushed to 44.6 m, the resistance of the front column and the back column of the support all exceed the weighting criterion line at this time, which shows that the roof is broken at this time, which leads to the periodic weighting behavior of the roof; When the working face is pushed to 99.1 m, the resistance of the front column and the back column of the support all exceed the weighting criterion line at this time, which shows that the roof breaking leads to the periodic weighting appearance of the roof at this time, and the working face is pushed 54.5 m from the last weighting, which shows that the periodic weighting step moni-

tored by the 18 # support is 54.5 m. When the 28 # hydraulic support is pushed to 51.3 m, the resistance of the front column and the back column of the support all exceed the weighting criterion line at this time, which shows that the roof is broken at this time, which leads to the periodic weighting behavior of the roof; When the working face is pushed to 99.1 m, the resistance of the front column and the back column of the support exceeds the weighting criterion line at this time, which shows that the roof is broken at this time, which leads to the periodic weighting appearance of the roof. At this time, the working face is pushed 47.8 m from the last weighting, which shows that the periodic weighting step monitored by 28 # support is 47.8 m. On the day of monitoring, the support resistance of 38 # and 48 # hydraulic supports exceeds the weighting criterion line at this time. Because there is no data to analyze before, it is roughly analyzed and judged that it is a weighting phenomenon at this time. When the working face is advanced to 51.3 m, the resistance of the front column and the back column of the supports all exceed the weighting criterion line at this time, which shows that the roof breaking at this time leads to the periodic weighting phenomenon of the roof; When the working face is pushed to 106.6 m, the resistance of the front column and the back column of the support exceeds the weighting criterion line at this time, and the working face is pushed 55.3 m from the last weighting, which shows that the periodic weighting step monitored by 38 # and 48 # supports is 55.3 m.

To sum up, study the weighting behavior law of different hydraulic supports in the process of advancing in the direction of the working face, and get the periodic weighting step is about 50m. It can be seen from the working resistance diagram of the support that the overlying roof pressure presents a certain periodic law, that is, the roof periodic weighting occurs, and the breaking distance is about 50m; The roof pressure in the upper, middle and lower parts of the working face is constantly shifting and changing, so it is necessary to adjust the initial supporting force of the support and other necessary safety measures in time according to the actual conditions on site.

6 Conclusion

Through various means to monitor the surrounding rock pressure of the working face and roadway, the monitoring schemes together constitute the monitoring system of the ground pressure of a fully mechanized mining face in a mine. Through the comprehensive analysis of the monitoring results of the ground pressure of each part, the stress change of the surrounding rock during the mining period can be grasped in real time, and according to the analysis results, the reasonable basis can be provided for the supporting design of the surrounding rock of the mining in the continuous working face.

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