Investigation on rock mass stability monitoring system and activity characteristic in deep mining

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Abstract. The monitoring system of rock mass stability and activity characteristic was established using the microseismic monitoring technology in view of the problem that the dynamic disaster of ground pressure was easy to occur in the process of deep mining. The monitoring network was set up according to the actual characteristics of the mine and the wave velocity was corrected by the method of fixed-point blasting. A monitoring network with a positioning error of 10 m was established finally. The waveform of the monitoring data was picked up and the temporal-spatial evolution characteristics of microseismic events were analyzed, the microseismic events increased greatly and in a high level, the spatial distribution was concentrated highly, the potential dangerous areas were delineated. The research results can provide references for the investigation of rock mass stability monitoring in underground engineering.

1 Introduction

The internal strain energy of rock mass will be transformed into elastic wave released to the outside under the action of stress disturbance. Microseismic monitoring technology can receive the elastic wave signal in real time, and then inverse the internal crack growth, damage and stress state of rock mass[1]. Qi et al.[2] showed the backfill body can reduce the energy released by mining rock, so as to realize mine seismic management and sustainable deep mining by using microseismic monitoring technology effectively. Tang et al.[3] showed that the microseismic events *b*-value of rock mass had obvious change characteristics before large-scale fracture. Jiang et al.[4] realized the monitoring and early-warning of coal mine water inrush based on the microseismic events positioning results. Chen et al.[5] obtained the microseismic information of rock engineering disaster evolution process through microseismic technology, and identified the microseismic information of rock fracture, and located the location of rock fracture automatically. Li et al.[6] inversed the focal mechanism solution of the precursory microseismic source location event for the

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failure of the overlying rock mass in the goaf using the moment tensor theory. The stress state of rock mass was evaluated, and the stability of rock mass was analysed according to the rock mass failure information contained in microseismic signal. Lu et al.[7] studied the evolution characteristic of microseismic energy and concluded that the necessary condition for the occurrence of rockburst was the aggregation of high-energy microseismic events.

The rock mass stability monitoring system was established in the deep mining on a gold mine in China using microseismic monitoring technology in this paper. The monitoring data were screened and the temporal and spatial evolution characteristics of microseismic events were analysed. The rock characteristic was analysed based on monitored data. This investigation provides technical support for mining and rock support.

2 Mine overview

The mine adopts horizontal slicing upward full tailings cemented backfilling mining method. The backfilling work begins after the completion of slicing mining and ore drawing. The backfilling pipeline is introduced from the ramp to each section roadway for backfilling. The height of layered backfilling is 3 m. The stoping and backfilling of footwall orebody will be carried out after the backfilling body is cured. Two stopes can be used alternately in order to eliminate or reduce the interaction and restriction between stoping and backfilling. When one stope is filled, the other stope is mined to improve the production efficiency.

The mining depth reached 600 m and the exploitation depth reached 1000 m. The problems of the pressure of the slope and roof fall caused by the stress concentration induced by deep mining are prominent. It is urgent to establish a monitoring system for rock mass stability.

3 Stability monitoring of deep rock mass

3.1 Microseismic monitoring systems

IMS microseismic monitoring system was selected to monitor the stability of rock mass. The high-precision microseismic monitoring system was a set of digital, intelligent and visual rock stability monitoring equipment with online microseismic data acquisition and human-computer interaction analysis. It had outstanding advantages in spatiotemporal monitoring and early warning in addition, and the system structure is shown in Figure 1.

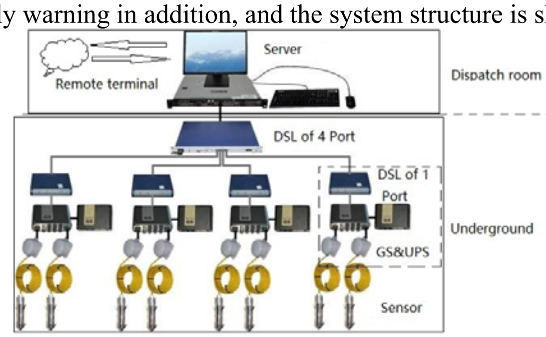

Fig. 1. Structure of microseismic monitoring system.

Through the sensors distributed in the surrounding rock to collect the underground microseismic events, the collected signals were sent to the nearby GS data acquisition connected with the sensors, and then transmitted to the four port DSL modem through the single port DSL modem, and converted into standard ethernet signals finally, which were stored in the microseismic database.

This paper focused on the monitoring of the fracture and development characteristic of the rock mass in the main mining areas of 725 m, 675 m, 625 m and 575 m. There were 4 sensors in 725 m middle section, 8 sensors in 675 m middle section, 8 sensors in 625 m middle section and 4 sensors in 575 m middle section. The positioning error and sensitivity of the network layout were analysed, and the positioning error was about 10 m as shown in Figure 2, which can meet the needs of rock mass stability monitoring in deep mining.

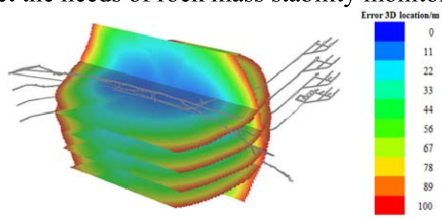

Fig. 2. The positioning error.

3.2 The wave velocity correction

The rock mass of the mine is heterogeneous because of its specificity and difference. It will produce some errors if the P-wave and S-wave velocities recommended by the monitoring system were used for positioning. Therefore, the fixed-point blasting method was adopted in the 675m middle section, and the wave velocity field was corrected by comparing the actual blasting coordinates with the measured coordinates. The fixed-point blasting was carried out again in order to test the positioning accuracy of microseismic monitoring after wave velocity correction, the results are shown in Table 1.

Table 1. Validation of positioning results.

Number	Coordinate	Measured coordinates /m	Location coordinates/m	Error/m		
				coordinate	straight line	Line averaging
1	x	5019	5024	5	10.34	10.58
	y	5667	5666	1		
	z	677	668	9		
2	x	4587	4579	8	10.82	
	y	5832	5830	2		
	z	677	670	7		

4 Investigation on microseismic activity characteristics of deep mining

4.1 Time evolution characteristics of microseismic events

The change of the number of microseismic events was related to the energy accumulation and release in the rock mass closely. The microseismic events number was at a high level generally or rising sharply when the rock mass was damaged in a large range. Therefore the time series of microseismic events can analyze the stability of rock mass better. The monitoring system operates from January 2019 to June 2019 normally, and detected 3843 effective microseismic events. Figure 3 shows the evolution of the microseisms number with a statistical period of one week, the average number of events was 250 per week. The lower level was less than 10 per week, which was caused by mine shutdown and system failure. There will be a small increase in the last ten days of February 2019, and then the event decreased. The number of event rose sharply at the beginning of May 2019. There were 600 microseismic events in the period from May 20 to 26; the microseismic events were at a high level. The events rise and fall alternately from May to June in 2019, that was the energy inside the rock mass was released and accumulated continuously, and the microseismic events were at a high level.

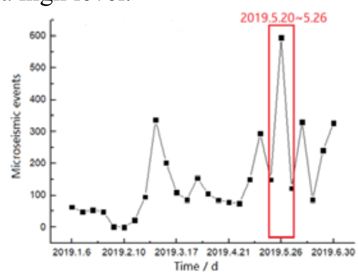

Fig. 3. Time evolution of microseismic events.

4.2 Spatial evolution characteristics of microseismic events

The spatial distribution characteristics of microseismic events can reveal the stress state of rock mass. Figure 4 shows the microseismic events spatial distribution in the monitoring period. The color of the event sphere indicated the occurrence time and the size of the sphere indicated the magnitude. The events were distributed in the west side of the stope and concentrated in the middle section of 675 m and 625 m mainly, accounting for 80% of the total monitoring events. Microseismic events can represent the fracture activity of rock mass, and there was a great possibility of ground pressure disaster in the area where microseismic events were concentrated. The key analysis module was established for the concentrated area of microseismic events, and the potential danger area was determined between 14-18 lines in the middle section of 725 m, 675 m and 625 m.

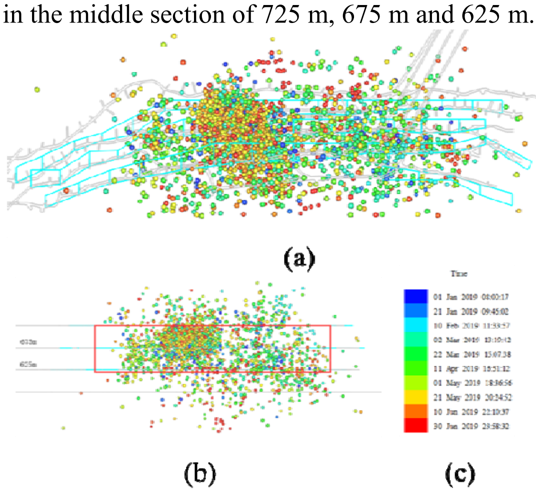

Fig. 4. Spatial distribution of microseismic events. (a) The top view. (b) The main view. (c) The legend.

5 Conclusions

A set of 24 channels monitoring system for rock mass stability in deep mine was established, and the network was optimized. The final positioning error was about 10 m. The wave velocity was corrected by fixed-point blasting to ensure the microseismic positioning accuracy and meet the needs of mine safety monitoring.

The microseismic activity can reflect the stability of rock mass. The microseismic events rised sharply in early May 2019, and the 14 ~ 18 line in the middle section of 725 m, 675 m and 625 m appeared spatial aggregation. The area was designated as a potential dangerous area, which was consistent with the on-site appearance.

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