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Analysis of microseismic activity in rock mass controlled by fault in deep metal mine

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ABSTRACT

Aiming at evaluating the stability of a rock mass near a fault, a microseismic (MS) monitoring system was established in Hongtoushan copper mine. The distribution of displacement and log(*EI*), the relationship between MS activity and the exploitation process, and the stability of the rock mass controlled by a fault were studied. The results obtained from microseismic data showed that MS events were mainly concentrated at the footwall of the fault. When the distance to the fault exceeded 20 m, the rock mass reached a relatively stable state. MS activity is closely related to the mining process. Under the strong disturbance from blasting, the initiation and propagation of cracks is much faster. MS activity belongs in the category of aftershocks after large scale excavation. The displacement and log(*EI*) obtained from MS events can reflect the difference in physical and mechanical behavior of different areas within the rock mass, which is useful in judging the integrity and degradation of the rock mass.

1. Introduction

With the continued rapid development of the national economy and increased demand for mineral resources, deep mineral resources exploitation has gradually become the trend of future mining activity in China. It is anticipated that over thirty mines with depths in excess of 1000 m will be in operation by 2015 and ten of them will be deeper than 1300 m. Deep extraction of minerals creates large volumes of cavities and leads to high stresses surrounding the excavation, which may cause failures in the rock mass in some cases, and the occurrence of dynamic failure. Therefore, it is important to investigate and to understand rock mass behavior in the deep mining environment. The microseismic (MS) monitoring technique, using elastic waves generated by rock damage to evaluate the stability of the rock mass, has been proven to be a useful tool for assessing rock mass stability and for forecasting dynamic hazards, and hence to better manage disastrous rock failures. With the advances in computer technology over past decades, the ability to fast process seismic waves has made MS technology more applicable. It has now become a routine technology in deep mining operations and is widely used in South Africa, Australia, the United States, Canada, Chile, Poland and other countries [1–8]. Additionally, this technology has also gained much attention and was adopted in other applications, e.g. tunneling, hot dry rock power generation, open pit slopes, deep-buried underground powerhouses, etc. [9–12]. Application of the MS monitoring technology in China only commenced after 2000. Li et al. [13] established a 64-channel digital MS monitoring system in Fankou lead–zinc mine with an ESG system. It was used to identify three-dimensional locations of MS events in real-time through on-line monitoring. In 2003, Jiang et al. [14], in collaboration with the Commonwealth Scientific and Industrial Research Organization (CSIRO) of Australia, performed a pilot trial seeking the applicability of MS technology in detecting and preventing coal mine hazards. Following the initial effort, a new explosion-proof MS monitoring system was developed and some meaningful results were obtained. In 2005, Tang [15,16] established an ISS MS monitoring system at Dongguashan copper mine to study stress changes and deformation characteristics in the rock mass due to mining. Other mines such as Shizhuyuan polymetallic mine, Huize lead–zinc mine, Zhangmatun iron mine also established MS monitoring systems successively [17–19].

Hongtoushan copper mine has been in operation since 1958. It is one of the deepest nonferrous metal mines in China. The deepest stope is 1357 m below the ground surface. With continued mining operations, high ground pressures have been causing seismic hazards, e.g. rock bursts and roof collapses, which impact on the safety

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of operators and disrupt production, hence causing financial losses. To enhance the management of seismic hazards, the mine decided to adopt seismic monitoring technology and therefore an ISS MS system was established. This present paper describes the studies carried out on the stability of rock mass near a fault analyzed by microseismic activity.

2. Establishment of a MS monitoring system

The shape of the orebody and the engineering layout of Hongtoushan copper mine below the −467 m level are shown in Fig. 1. The length, dip and thickness of the orebody are about 2000 m, 70° and more than 10 m, respectively. Two diabase veins, whose thickness is about 50 m, divide the orebody into three parts. At present, mining activities are mainly below the −587 m level and the ore near 1# diabase has been depleted. Therefore, the rock mass near 2# diabase was selected for MS monitoring in this study.

A high performance ISS system was adopted for this research project. The hardware system includes sensors, seismic data acquisition unit (GS), DSL 2-wire modem for the GS, server, electric cable, telephone line, optical fiber and photoelectric converter, etc. Through the system, MS wave signals are sensed by the sensors, which convert them into electrical analog signals which are received by the GS data acquisition units, where the signals are further converted to digital signals. A DSL technology-based communication system synchronizes the system and transmits the digital data through a telephone line from GS units to a central server at an underground center at the −707 m level. The digital seismic data can be processed at the server and the results can be downloaded by the central office of the mine and by a remote research center at Northeast University (NEU) via the Internet.

The sensors were installed in either a permanent or temporary installation. The procedure for a permanent installation, Fig. 2a, includes the following steps: (1) Position a sensor and bind with an air-exhausting pipe into the boreholes with a special installation tool. (2) Apply a wooden plug, with a hole in the middle to allow passage of the exhausting pipe, grouting pipe and signal cable, to hold grout at the entrance of the boreholes. (3) Inject grout until it overflows from the exhausting pipe. (4) Block and cut both the injecting and the exhausting pipes. It is worth noting that sensors need to be tied a certain distance from the end of the exhaust pipe to ensure sensors are grouted firmly. The temporarily installed sensors are shown in Fig. 2b and consisted of an inner and an outer sleeve. The outer sleeve was permanently placed at the bottom of the borehole by capsule resin. A sensor was attached to an inner sleeve, which remained in place during the monitoring. Upon completion of the monitoring work, the sensor could be retrieved by withdrawing the inner sleeve using the installation tool so that it could be used elsewhere. A weekly inspection procedure was adopted to ensure it was in a firmly fixed state and was not affected by ground shaking due to blasting operations. Signal testing suggests that the P-wave arrival time could be clearly identified. It was noticeable that coda waves were also present but they have little influence on the location accuracy of MS events.

3. Spatial and temporal characteristics of seismicity

During the period from September 1 to October 10, 2011, there were 244 MS events generated near the fault, with maximum and minimum magnitudes of −1.2 and −3.1, respectively. The distribution of MS magnitude is shown in Fig. 3. It can be seen that the MS magnitude vs. number approximates to a normal distribution. MS events with magnitudes between −2.5 and −1.7 are dominant, accounting for almost 88% of the total number of MS events, while MS events with magnitude smaller than −2.5 and larger than −1.7 are fewer.

The distribution of the MS events can directly reflect the temporal–spatial evolution behavior of the cracks in rock bodies, which is very useful for studying the distribution and migration of the stress field. MS events generated from September 1 to October 10, 2011, were mainly concentrated at the footwall of the contact surface between the orebody and 2# diabase as showed in Fig. 4. It suggests that the damage in the rock mass at the fault footwall is much larger than that at the hanging wall. In addition, most of

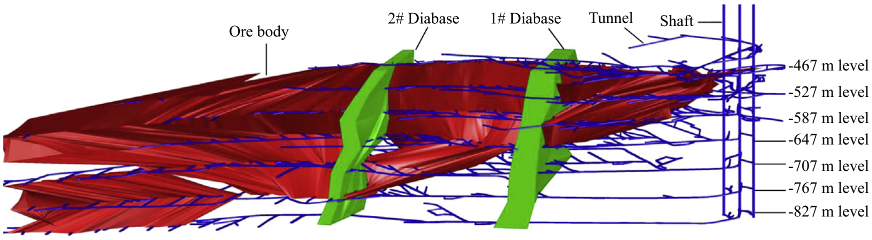
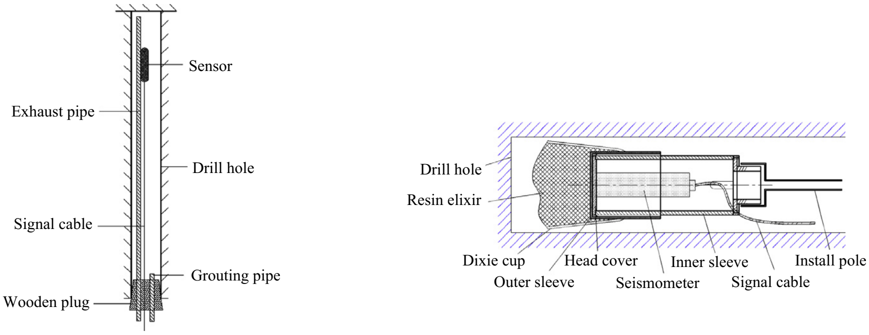


Fig. 1. Orebody and engineering layout below −467 m level in Hongtoushan copper mine.



(a) Sketch of permanently fixed sensors

(b) Sketch of non-fixed sensors

Fig. 2. Installation methods of MS sensors.