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Classification of mine blasts and microseismic events using starting-up features in seismograms

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Abstract: To find discriminating features in seismograms for the classification of mine seismic events, signal databases of blasts and microseismic events were established based on manual identification. Criteria including the repetition of waveforms, tail decreasing, dominant frequency and occurrence time of day were considered in the establishment of the databases. Signals from databases of different types were drawn into a unified coordinate system. It is noticed that the starting-up angles of the two types tend to be concentrated into two different intervals. However, it is difficult to calculate the starting-up angle directly due to the inaccuracy of the P-wave arrival's picking. The slope value of the starting-up trend line, which was obtained by linear regression, was proposed to substitute the angle. Two slope values associated with the coordinates of the first peak and the maximum peak were extracted as the characteristic parameters. A statistical model with correct discrimination rate of greater than 97.1% was established by applying the Fisher discriminant analysis.

Key words: microseismic event; mine blast; starting-up feature; Fisher discriminant analysis

1 Introduction

Microseismic events, with Richter magnitude from −3 to 3, refer to rockmass vibrations generated by fracturing or fluid disturbance. The microseismic monitoring technology, a geophysical approach, is used to monitor the status of underground structures. The distribution and its evolution of internal micro-cracking and deformations of the adjacent rock can be obtained by inversion analysis of the systems [1−3]. Microseismic monitoring technology has been rapidly developed in recent twenty years in the field of engineering geology, including tunneling, oil and gas exploration with hydraulic fracturing, nuclear waste disposal, as well as underground excavations existing potential hazards of room-and-pillar collapses and rockbursts. Applications of microseismic monitoring in China with their purposes are summarized in Table 1. Microseismic events, induced by the failure and deformation of rocks, can be located by developed methods [22−27]. On the other hand, from the micromechanical point of view, the particle simulation method [28−32] can be used to investigate the microseismic events in mines for monitoring its safety and stability.

Generally, there are always some problems existing in the applications of microseismic monitoring systems because of the complex mining systems, including background noise, useless data, and blasting signals admixture. As a result, providing intuitive monitoring data accurately becomes impossible. The daily summary of the Yongshaba Mine's monitoring data signifies that more than half are rejected data. And the total number of blasts is nearly one third of the accepted microseismic events. Noise signals existing obvious characteristics can be easily discharged, the most difficult task to identify microseismic events from blasts. Since they share a large scale of intersection in the frequency distribution, to achieve recognition of the two types of events via simple spectral analysis is quite difficult.

Currently, some relatively effective identification methods are mainly dependent on the source parameters [33,34]. MALOVICHKO [35] selected the time of day, the repetition of waveforms, the high-frequency vs the low-frequency radiation and the radiation pattern as the discriminant features, then established the Gaussian maximum likelihood classification method for the classification. This method

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Table 1 Some sites with microseismic monitoring system in China

No.	Site	Time	Purpose	Reference
1	Fankou Lead Mine	2003	Rockbursts monitoring and risk assessment	[4]
2	Hongtoushan Copper Mine	2004	Rockbursts monitoring and risk assessment	[5]
3	Huafeng Coal Mine	2004	Stress field inversion analysis	[6]
4	Dongguashan Copper Mine	2005	Rockbursts monitoring and risk assessment	[7]
5	Huize Lead and Zinc Mine	2006	Geostress monitoring and early warning	[8]
6	Zhangmatun Iron Mine	2006	Rockbursts monitoring and risk assessment	[9]
7	Yuejin Coal Mine	2008	Potential risks assessment of gas outburst	[10]
8	Sanshandao Gold Mine	2008	Hazards control of water inrush applied undersea	[11]
9	Shirengou Iron Mine	2008	Slope stability monitoring with open pit	[12]
10	Shizhuyuan Polymetallic	2008	Stability monitoring of goaf areas	[13]
11	Qianqiu Coal Mine	2008	Potential risks assessment of gas outburst	[14]
12	Xinzhuangmu Coal Mine	2008	Potential risks assessment of gas outburst	[15]
13	Wangfenggang Coal Mine	2008	Potential risks assessment of gas outburst	[16]
14	Jinping Slope	2009	Stability monitoring of bank slope	[17]
15	Taoshan Coal Mine	2009	Potential risks assessment of rockburst	[18]
16	Jinshandian Iron Mine	2009	Geological disaster monitoring	[19]
17	Dagangshan Slope	2010	Stability monitoring of active faults	[20]
18	Xianglushan Tungsten Mine	2010	Stability analysis of large goaf	[13]
19	Yongshaba Phosphate	2012	Hazards control within multi-level mining	[21]

provides a way to identify signals of different types, but great amount of computation leads to low efficiency. VALLEJOS and MCKINNON [36] proposed the identification of seismic records in seismically active mines by considering the logistic regression and the neural network classification techniques. An efficient methodology was presented for applying these approaches to the classification of seismic records [36]. However, seismic parameters (local magnitude, corner frequency, seismic moment, moment magnitude, seismic energy, static stress drop, apparent stress, etc.) provided by the full-waveform systems require precise P and S-wave hand-picking, scilicet, expertise and time.

To determine discriminating features that are physically independent of each other, a blast signal database is established by field tests firstly and then a microseismic event database identified manually is built. Based on the two databases, six characteristic parameters from waveform starting-up analysis are extracted. By applying the Fisher discriminant analysis (FDA) to the characteristic parameters, a mathematical model that is able to correctly classify more than 97.1% blasts and microseismic events is established.

2 Database

2.1 Source of data

Seismic records from the site of Yongshaba Mine are used to identify the proposed method in this work. The Yongshaba orebody is a phosphate deposit, located in Guizhou, China. The mining method of blasthole with delayed backfill is used to extract the ore underground. The studied region covering a volume of approximately 3000 m × 300 m × 750 m, between 300 m and 700 m below the surface. Excavating multi-level simultaneously beneath the Jinyang Road is the principal situation nowadays. Potential hazards including landslides on the steeper surface, instability of the highway foundation and stope collapse are threating the safety to workers and residents. The underground microseismic monitoring system, used to inform the evolution of magnitude, temporal and spatial of the micro-fracture behavior, consists of 26 uniaxial and 2 triaxial velocimeters (Fig. 1).

2.2 Samples

The sample databases contain a total of 103 seismic records, from which 56 are labeled as normal events and the others are tagged as blasts. All of these seismic records are labeled manually. The usual practice of processing seismic data includes a qualitative or semi-quantitative classification of seismic events [35]. Four approaches to eliminate blasts from the seismic catalogue are applied in this study.

2.2.1 Repetition of waveforms

Blasts, especially stope firings, have multiple delays, which are expressed in the seismogram as similar signals repeating closely within a short time interval. The practice of decides whether an event is a blast or a microseismic event is based on the repetition feature. An