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Dynamic destabilization analysis based on AE experiment of deep-seated, steep-inclined and extra-thick coal seam

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Abstract: No. 5 coal seam in Huating Coal Mine is a deep-seated, steep-inclined extra-thick coal seam where excavation disturbance is quite frequent. The maximum and minimum principal stresses differ widely. During mining, dynamical destabilization happens frequently and induce tragedies. Based on the comparison between the acoustic emission (AE) experiment on dynamical destabilization of coal rock and the related *in situ* testing results, this article provides comprehensive analysis on the regular quantificational AE patterns (energy rate, total events) of coal rock destabilization in complex-variable environment. The comparison parameters include dynamic tension energy rate, deformation resistance to compression, and shear stress.

Key words: coal seam; acoustic emission (AE); destabilization; excavation disturbance

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1. Introduction

Owing to several differences in coal-rock fracture and destabilization between deep-mining and shallow-mining, secure mining of deep-seated coal is still a puzzle to the domestic and foreign mining industry [1-2]. Huating Coal Mine is located in the western zone of China with frequent earthquakes. The main parameters of No.5 coal seam are: obliquity = 45º, average thickness = 51.51 m, mining depth = 819.45 m, and rigidity parameter f = 1-3. Roof-caving, collapse, and concussion happen frequently. Around the main faultage of the mine, stress concentration was dynamically and intensively developed in rock mass around the mined-out area and in the remaining coal pillars. Excavation disturbance happens frequently, which is liable to cause dynamical hazards during mining in neighboring areas [3-5]. Based on a comprehensive *in situ* investigation and comparison between indoor rock mechanical experiment with AE measurement and *in situ* investigation, the reasons and mechanical characteristics of dynamical destabilization are discussed in this article, which provides a basis for predicting the possibility (or possible areas) of dynamical hazards during mining and for controlling and eliminating hazards.

2. Anomalous earthquakes and hazards in Huating area

Since 2001, there are obvious phenomena of intensified anomalous earthquakes in Huating area. The primary characteristics are indicated by statistical analysis in Figs. 1 and 2.

(1) The earthquakes converge in space. The earthquakes mainly occur in Huating County and Chongxin County, and most of them occur within a small rectangle area whose longitudinal length is 30 km and latitudinal length is 40 km.

(2) The earthquakes are low in seismic magnitude but are quite frequent. Since October 2001, there have been 717 earthquakes in Huating area, of which 48 had magnitude less than M_L 0.9 (M_L is local magnitude), 243 had the magnitude between M_L 1.0-1.9, 391 had the magnitude between M_L 2.0-2.9, 33 had the

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magnitude between M_L 3.0-3.9, and 1 had the magnitude of M_L 4.1. The strongest earthquake occurred on October 2, 2005, and reached the seismic magnitude of M_L 4.2.

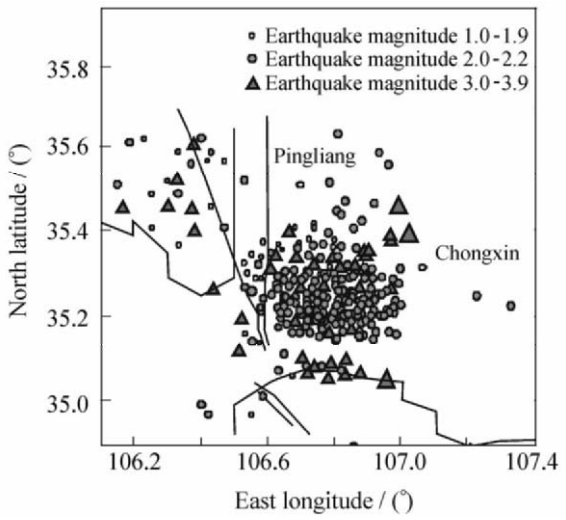

Fig. 1. Location of anomalous earthquakes in Huating area.

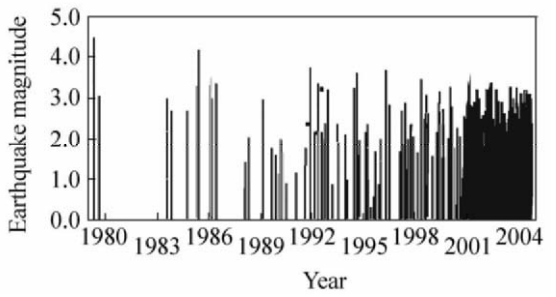

Fig. 2. (M_L-t) distribution of anomalous earthquakes in Huating area.

(3) The earthquakes result in serious damages, although their seismic magnitudes are not high. According to the monitoring data of Municipal Seismological Bureau of Pingliang City, the earthquake of M_L 3.1 on May 30, 2005 twisted the air duct devices fixed in the roadway in No. 603 working face, jammed the roadway of 20 m in Huating Colliery, and resulted in 1 death and 12 injuries. As mentioned above, the strongest earthquake of M_L 4.2 caused a strong quake in Pingliang City and made the roof of No. 603 working faces distorted slightly, in which some roof areas collapsed, and 3 workers were injured.

3. AE-based experiment and analysis on the mechanical characteristics of coal rock media

3.1. AE-based experiment on the fracture and destabilization characteristics of coal rock

The damage and fracture of heterogeneous media is one of the most complicated and challenging puzzles of mechanics. Several basic problems remain unsolved so far. For example, the traditional mechanical theory for homogeneous continuous media is inapplicable because the damage development towards collapse does not follow the steady accumulative pattern. Acoustic emission (AE) is an important tool for studying the damage development in solid materials, which is able to measure and collect real-time continuous information on the inside damage of the materials. A larger size of experimental object indicates higher relative precision of AE location. Therefore, the AE experiment on coal rock damage has become an important way to study the beginning and development of dynamical hazards [6-7].

There have been some successful experimental studies on the deformation, fracture, destabilization, and collapse of coal rock [8-10]. However, there have been few AE studies on the dynamical damages and destabilization of coal rock during deep-seated, steep-inclined, and extra-thick coal mining. Since 2003, coal, rock and roadway fractures have occurred several times during excavation at No. 505, No. 506, No. 507, No. 508, No. 509, No. 601, No. 602, No. 603, and No. 606 working faces in Huating Coal Mine. These fractures have occurred instantaneously, with rapid deformation, loud knocking, and large dynamic stress. These provide the opportunity for AE-based study on the relation between dynamical destabilization and deformation. Based on a comprehensive analysis on the AE characteristics of outside load, deformation, fracture, destabilization, and collapse of coal rock, this experiment explores the dynamical destabilization characteristics and pattern of large-size mined-out area with special geological structure. To provide reliable quantitative parameters for physical and numerical simulation, this experiment applies 5-way SWAES digital whole-spectrum AE device (made by ShengHua Tech. Co.) whose capability parameters are provided in Table 1.

3.2. Comprehensive comparative analysis on the experimental results

A large amount of damage development data has been collected by non-stop AE recording throughout the experiment (Tables 2 and 3). During the experiment, thousands of AE events can be recorded for a single damage. These data provide a foundation for future research and data simulation, helping to improve the preciseness of timing, space, and intensity of dynamical hazards. The roof of No. 5 coal seam mainly consists of mud-rock, where terrain is quite fragmentized. The single-axis stress intensity is about 40 MPa. The coal seam around the roof and the central part has relatively low stress intensity (about 10