Journal of Applied Geophysics 132 (2016) 152–163

Contents lists available at ScienceDirect

Journal of Applied Geophysics

journal homepage: www.elsevier.com/locate/jappgeo

Real-time microseismic monitoring and its characteristic analysis in working face with high-intensity mining

Yang Li, Tian-Hong Yang *, Hong-Lei Liu, Hong Wang, Xian-Gang Hou, Peng-Hai Zhang, Pei-Tao Wang

[a] Key Laboratory of Ministry of Education on Safe Mining of Deep Metal Mines, Northeastern University, Shenyang, Liaoning 110819, PR China
[b] School of Resources & Civil Engineering, Northeastern University, Shenyang, Liaoning 110819, PR China

A R T I C L E   I N F O

Article history:
Received 7 July 2015
Received in revised form 11 May 2016
Accepted 13 July 2016
Available online 17 July 2016

Keywords:
Xiaojihan coal mine
High-intensity mining
Microseismic monitoring
Microseismic parameter

A B S T R A C T

Xiaojihan coal mine is a typical high-intensity mining in Western China. The real-time monitoring of deformation and failure for the working face was carried out by using IMS microseismic monitoring system. The change process of microseismic parameters such as microseismic event rate, energy release, apparent volume, energy index, *Schmidt* number, *b* value and coefficient of seismic response and the relationships with the surrounding rock failure were studied. This research indicates that some parameters have obvious precursory characteristics before the large scale failure. The predictive periods were divided by these parameters, and *Schmidt* number has the highest predictive sensitivity, *b* value the second, energy index the third. Coefficient of seismic response and energy release have no direct contact with the excavation volume of ore body, but depend on the mine pressure behavior of working face.

1. Introduction

Microseismic (MS) monitoring is a technical method of monitoring the stability of engineering rock mass using elastic waves generated by rock deformation and failure. By the middle of the last century, MS monitoring has carried out a lot of applications in Poland, South Africa, America, Canada and other major mining country (Gibowicz and Kijko, 1994; Cai et al., 2001; Young and Collins, 2001; Ge, 2005; Li, 2009). With the development of electronic technology and signal processing technology, multi-channel MS monitoring technology began to be applied. China started research work of MS monitoring in some mines to carry out mine pressure activity in the mid 80's. Beijing Mentougou coal mine introduced the SYLOK mine tremer system produced by Poland in 1984 and good results were achieved in the monitoring (Lu and Zhang, 1989). Li et al. established a 16-channel MS monitoring system in Fankou lead-zinc mine, which realized all-weather, digital, informationalized and automatic monitoring of mine disasters (Li et al., 2005). South Africa ISS microseismic monitoring system was introduced to achieve continuous monitoring and real-time forecasting of rock burst in Dongguashan copper mine and studied the law of ground pressure activity in deep mine (Yang et al., 2007; Tang and Xia, 2010). Jiang et al. developed the MS monitoring system with independent intellectual property rights. It had applied in monitoring and forecasting coal mine rock burst and water inrush (Jiang et al., 2006, 2008). A ISS microseismic monitoring system was established in Hongtoushan copper mine to study the prediction of mine dynamic disasters (Zhao et al., 2009; Liu et al., 2013). Xu et al. obtained the MS activity laws of the left bank slope in Jinping first stage hydropower station using ESG microseismic monitoring system (Xu et al., 2011). Some scholars carried out MS monitoring during TBM tunneling in Jinping II hydropower station and discussed the feasibility of rock burst forecasting in TBM tunneling (Tang et al., 2010; Feng et al., 2012; Chen et al., 2011). These studies do a lot of good attempts and explorations on MS monitoring and make some meaningful achievements.

At present, the focus of coal resource development in China has transferred to the West. Because of the unique natural geography, geological structure and ecological environment, there are serious geological disasters and environmental damage caused by the high-intensity mining in Western China. It seriously restricts the development of coal resources and the protection of ecological environment, which has drawn the great attention of the government. According to statistics, roof cutting and water inrush accidents in the Western China mining area occurred 83 times and caused 541 people died since 2000. To achieve safe production, it is urgent and important to carry out the study of rock mass damage and ground pressure activity under the condition of high-intensity mining based on MS monitoring technique. This paper introduces the MS monitoring system in Xiaojihan coal mine, which is a typical high-intensity mining mine in Western China. Through the real-time monitoring, the relationships between the surrounding rock failure and the characteristics of MS activity are studied. Attempt is made to provide field basis for the research on roof instability and disaster control under the condition of high-intensity mining.

* Corresponding author at: Key Laboratory of Ministry of Education on Safe Mining of Deep Metal Mines, Northeastern University, Shenyang, Liaoning 110819, PR China.
E-mail address: yang_tianhong@126.com (T.-H. Yang).

http://dx.doi.org/10.1016/j.jappgeo.2016.07.010
0926-9851/© 2016 Published by Elsevier B.V.

2. Establishment of a MS monitoring system at Xiaojihan coal mine

2.1. Geological and mining conditions of Xiaojihan coal mine

Xiaojihan coal mine is the first modern mine of ten million tons production in Yuheng mining area (north area) of China Northern Shaanxi Jurassic coalfield. The mine is located in Yuyang District, Yulin City, Shaanxi province, 12 km away from west of Yulin City (see Fig. 1). It has mining area of 251.75 km^2, geological reserves of 3.17 billion tons and recoverable reserves of 1.89 billion tons. There are 9 layers of mineable coal seam, among them 2# and 4^{-2}# coal seams are the main mining coal seams. Because coal seams are horizontal and their dip angles are less than 1°, geological structure of the mine is simple. Meanwhile, Xiaojihan coal mine is a low gaseous mine. The mine is using inclined shaft development and panel strip mining method, which has the design production capacity of 10 Mt./a.

Fully mechanized working face 11203 is the first mining face of Xiaojihan coal mine, located in panel 11 of 2^{-2}# coal seam. The floor elevation of coal seam in working face 11203 is 826 to 890 m, and the ground elevation is 1208 to 1225 m. The advance length of working face before retracement is 2651.2 m, and the face width is 240 m. The dip angle of coal seam is 0 to 1°, average 0.7°. The thickness of coal seam is 1.6 m to 2.95 m, average 2.67 m. The immediate roof is gray medium thick bedded medium-grained sandstone and thin bedded siltstone, containing muscovite fragments and dark minerals, which is poor sorting, subangular and medium hardness. The lower part of main roof is gray green medium-grained sandstone, and the upper is gray green thin siltstone, sandwiched gray thick layered coarse sandstone with thickness of 2.7 m. The immediate floor is gray thin bedded fine sandstone with thin layers of sandstone, which is medium hardness. The main floor is gray white thick layered medium-grained sandstone, which is granite and medium hardness. The coal seam roof and floor conditions are shown in Table 1. The mining area terrain is generally flat, relative difference is less than 20 m. The surface area is covered by eolian sand with thickness of 12.1 m to 50.62 m, but most area about 25 m. The bedrock thickness is 290 to 321 m.

Working face 11203 is using inclined longwall retreating all caving fully mechanized mining method and all collapsing method of treatment of mined-out area (see Fig. 2). Every day there are two production shifts and a maintenance shift. The maintenance shift need to ensure that the coal cutting 2 knives, and the rest time for maintenance. Two production shifts are mining all the time, and each shift cut coal 5 knives. Every knife cutting depth of the coal mining machine is 865 mm. Thus mining speed of working face 11,023 can reach 8 to 10 m/d, which is a typical high-intensity mining working face.

2.2. MS monitoring system

According to the high-intensity mining characteristics of coal cutting height, the length of the working face and the mining speed, South African IMS microseismic monitoring system with good real-time and high sensitivity was adopted as the monitor method. The hardware of this system is mainly divided into three parts, namely, sensors, data acquisition (NetADC) and data communication (NetSP) (see Figs. 3 and 4). The sensor is used to convert the ground motion (ground speed or acceleration) into a measurable electronic signal. Analog signals from the sensor are converted into digital signals by data acquisition. The data can be collected by continuous recording, or use the trigger mode through a special algorithm to determine whether the MS event data is recorded or not. MS data is transmitted to a central computer or local disk storing or processing. The system can use a variety of data communication to meet the needs of different system environments.

2.3. Sensor layout and installation

According to the characteristics of working face mining, it was appropriate to select the speed sensor with natural frequency of 14 Hz, monitoring range of 9 Hz–2000 Hz and response range of hundreds of meters. Considering the spatial characteristics of rock mass fracture and the convenience of MS sensor installation, the sensor layout had been optimized. For eight channels data acquisition, it was reasonable to adopt five uniaxial geophones and one triaxial geophone. Due to

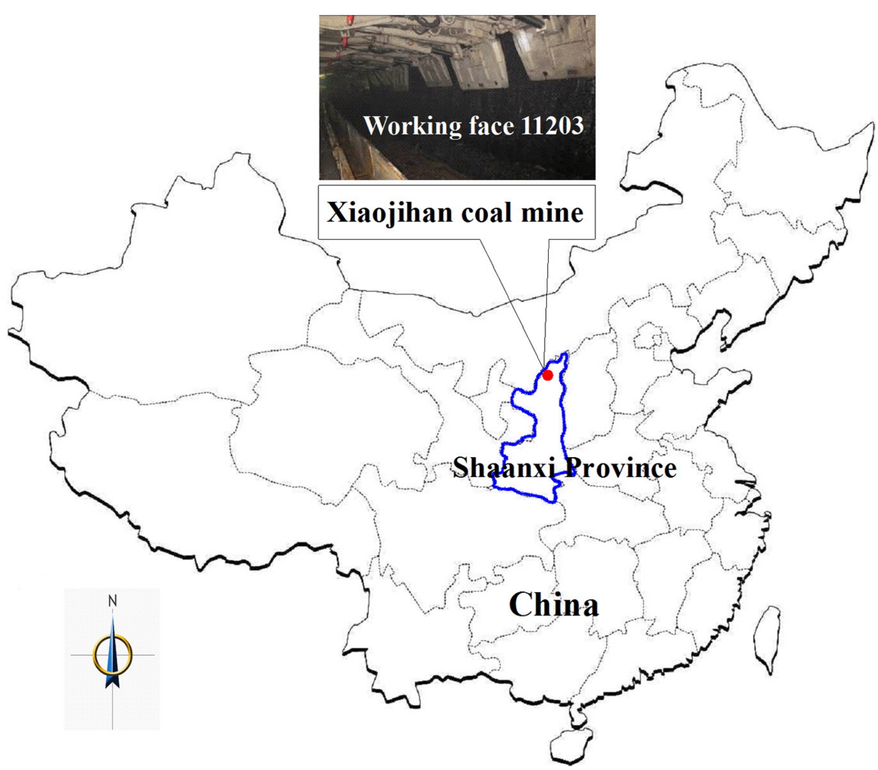

Fig. 1. Regional map of the Xiaojihan coal mine.