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Activation characteristics analysis on concealed fault in the excavating coal roadway based on microseismic monitoring technique

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ABSTRACT

In order to effectively monitor the concealed fault activation process in excavation activities, based on the actual condition of a working face containing faults with high outburst danger in Xin Zhuangzi mine in Huainan, China, we carried out all-side tracking and monitoring on the fault activation process and development trend in excavation activities by establishing a microseismic monitoring system. The results show that excavation activities have a rather great influence on the fault activation. With the working face approaching the fault, the fault activation builds up and the outburst danger increases; when the excavation activities finishes, the fault activation tends to be stable. The number of microseismic events are corresponding to the intensity of fault activation, and the distribution rules of microseismic events can effectively determine the fault occurrence in the mine. Microseismic monitoring technique is accurate in terms of detecting geologic tectonic activities, such as fault activations lying ahead during excavation activities. By utilizing this technique, we can determine outburst danger in excavation activities in time and accordingly take effective countermeasures to prevent and reduce the occurrence of outburst accidents.

1. Introduction

Most gas disasters in excavation activities, cross-cut mine uncovering, mining-face excavation and other projects under the influence of geologic tectonic belts, are closely related to heading faces or mining faces. Especially when there is a geologic structure, such as fault and fold lying ahead, the structure will inevitably affect the continuality of the coal seam in forms of thinning or discontinuing the coal seam, blocking the passage of gas flow, and raising the gas pressure and increasing the risk of gas dynamic disasters to some extent. Therefore, it is crucial to carry out research on the rules of concealed fault activation in excavation activities.

At present, fruitful achievements have been obtained in terms of research on the rules of concealed fault activation in excavation activities. Zhao conducted experiments on the characteristics of thrust fault activation influenced by mining operation [1]. Li et al. studied the fault slide destabilization induced by coal mining [2,3]. Mao et al. studied fault activation rules influenced by mining and prevention measures against rock-burst [4]. Lai et al. performed influential range assessments of dynamic pressure in the fault zone with broken rock masses [5]. Huang et al. conducted simulation experiments on the development characteristics of water conductive fissures in the concealed and reversed fault [6]. Qiao et al. explained the transition process from seepage to massive flow of water inrush induced by fault activation in mining operation by establishing a similarity experimental model [7]. Wang et al. studied the influence of fault activation in mining floor on mining operation through numerical simulation analysis [8]. Jiang et al. studied the characteristics of mining stress evolution of reversed fault below hard-thick strata and the activation rules through 3D numerical simulation [9]. Hu and Chen et al. conducted an in-depth study on fault activation and water-inrush and its control by establishing a mining-floor concealed fault activation mechanical model and a fault water-conductive expansion model [10–13]. By using a simplified fracture mechanical model for the study of water-inrush caused by a concealed fault in the mining floor, Chen et al. studied the influential factors and the critical water pressure causing water-conductive fault rapture [14]. However, due to the limitations of these models, the aforementioned studies that analyzed the rules of fault activation by establishing a model could not conduct real-time dynamic monitoring on fault activation. At present, in the mining industry, geophysical exploration methods such as the seismic reflection method and the 2D/3D seismic method are used to detect the tectonic situations

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of faults. These methods have high accuracies up to 90% in detecting faults with drops more than 10 m and over 70% accuracy in detecting faults with drops more than 5 m. Moreover, 3D seismic method is simple, reliable, economical and effective. It targets geophysical exploration, with low costs, short working time, accurate and reliable geological results, and plays a crucial role in safe coal production. But for some small faults, especially faults with drops less than 3 m, the accuracy of the 3D seismic method is less satisfactory. Outbursts tend to occur near tectonic zones that have been confirmed to have faults or concealed faults [15–17]. Du et al. detected faults with a geophysical exploration technique [18]. Zhu et al. studied fault activation rules in extra-thick coal seams of deep mines by adopting the microseismic technique [19]. Guo and Wang et al. studied the microseismic rules of fault activation induced by coal mining [20,21]. Yu et al. detected the structures of concealed faults during excavation activities by adopting the advanced detection technique [22]. Microseismic monitoring technique can achieve real-time monitoring on the activation process of small concealed faults influenced by coal mining, and track the development directions. Therefore, the monitoring results have significant guidance in formulating fault passing measurements, carrying out geological borehole projects and optimizing parameters of gas drainage boreholes.

By combining the geographic and mining conditions of the working face containing faults with high outburst danger in the Xin Zhuangzi mine in Huainan, and by using the microseismic monitoring technique, we carried out an on-site survey to get the real-time evolutional process of rock destabilization and its distribution status in excavation activities, and studied the rules of fault activation of the working face. This study aims to provide some engineering guidance for head development projects where faults are contained.

2. Geographic and mining conditions

The B10 coal seam in Huainan's Xin Zhuangzi mine produces dark coal. The coal seam has irregular fractures and has a thickness of 0.6–1.9 m with average thickness of 1.0 m. It has 1–3 layers of mudstone with dirt, contains high ash content, and breaks easily into pieces or lumps. The immediate roof with a thickness of 2.0–3.0 m, is made of a thin layer of grey silty mudstone and breaks easily. The main roof with a quite high hardness and a thickness of 3.0–5.0 m, is made of a medium-thick layer of grey medium-grain sandstone and develops a layer of unstable coal streak with a thickness of 0.2–0.5 m at its bottom part. The immediate floor with a thickness of 1.0–3.5 m, is made of dark grey fine-grain sandstone and breaks easily.

The working face 62110 is the first panel of the 62 mining area, with its south end at 126 m south of the 52 cross-cut and its north end at the F10-8 (8) fault. This face is 780 m long and 120–160 m wide. The elevation for the intake and the return airflow roadway are −600 m and −662 m, respectively. The coal seam has a dip angle of about 25°. This working face is within the coal seam with outburst danger, and the B11b coal seam above it and the B8 coal seam beneath it (in the equal-elevation section) haven't entered actual mining process. It is adjacent to the F10-8 (8) fault and the F10-8 (11) fault, and has developed small structures and varied coal production situations in its rock strata. The surrounding rocks break easily and it has relatively concentrated ground stress. According to analysis based on the development progress, the actual mining will be influenced by 14 faults which have fault throw of 0.5–5 m. Among these faults, three of them have fault throw of more than 3.0 m. In this working face, the intake airflow roadway and the open-off cut have been excavated, while about 100 m of the floor roadway and about 500 m of the return airflow roadway are unexcavated, as shown in Fig. 1.

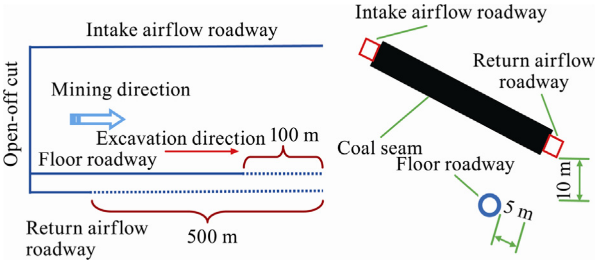

Fig. 1. Mining conditions of monitoring area in working face 62110.

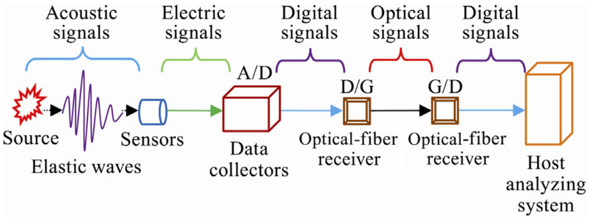

Fig. 2. Pathways and types of signals.

3. Design of the monitoring scheme and the construction

Considering the network structure of the system and the characteristics of the microseismic experiment, the designed monitoring system prefers an optical fiber transmission based bus network transmission mode. In general, in regard to the structure of such a network, the system consists of three parts: the sensor, the data collector and the host analyzing system. The signal transmission routes among these three parts and the transmission types are shown as follows: a sensor consists of detective elements, a pre-measuring-and-switching circuit and a power supply. It receives elastic sound waves in coal and rock masses. The detective elements make direct contact with the coal and rock masses under detection, and the pre-measuring-and-switching circuit converts the electric signals output by the detective elements to standard electric signals for display convenience. The signals are then recorded, controlled, processed, and amplified. The amplified signals are transmitted to the data collector through signal cables. The data collector amplifies, filters, samples, quantifies and codes the electric signals. Through the A/D conversion process, the signals are converted into digital signals for convenient digital transmission, analysis and processing. Afterwards, the digital signals are converted into optical signals through D/G conversion, and converted back to digital signals through G/D conversion, both by the optical-fiber receiver. Finally, the signals are transmitted to the host analyzing system through a twisted-pair cable, as shown in Fig. 2.

During the process of constructing the systemic network, there are mainly two kinds of cables involved: the electric cable and the optical cable, as shown in Fig. 3a. Electric cables are mainly used for connecting the sensor and the data collector, and optical cables and used for connecting the data collector and the host. Specific arrangements for the layout and connection of these two kinds of cables are shown as follows: (1) For electric cables, 20 AWG (American Wire Gauge) copper-conductor shielding electric cables are used in this experiment, with the number being 30 and the total length being 1.3 km. Moreover, electric cables should be arranged as far away from power cables and lighting cables as possible, as shown in Fig. 3b; (2) For optical cables, 4-conductor single-mode optical fiber is used in this experiment with the number being 1 and the total length being 0.5 km. Different from electric cables, optical cables are hardly disturbed by power cables, but they are