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# Identification methods for anomalous stress region in coal roadways based on microseismic information and numerical simulation

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ABSTRACT

It is believed that the microseismicity induced by mining effect and gas gradient disturbance stress is a precursor to the essential characteristics of roadway unstability. In order to effectively identify and evaluate the stability of coal roadways in the process of mine development and extraction, a microseismic monitoring system was deployed for the study of the stress evolution process, damage degree and distribution characteristics in the tailgate and headgate. The mine under study is the 62113 outburst working face of Xin Zhuangzi coalmine in Huainan mining area. The whole process of microfractures initiation, extension, interaction and coalescence mechanisms during the progressive failure processes of the coal rock within the delineated and typical event clusters were investigated by means of a two dimensional realistic failure process analysis code (RFPA2D-Flow). The results show that the microseismic events gradually create different-sized event clusters. The microseismicity of the tailgate is significantly higher than that of the headgate. The study indicates that the greater anomalous stress region matches the area where microfractures continuously develop and finally connect to each other and form a fissure zone. Due to the mine layout and stress concentration, the ruptured area is mainly located on the left shoulder of the tailgate roof. The potential anomalous stress region of the coal roadway obtained by numerical simulation is relatively in good agreement with the trend of spatial macro evolution of coal rock microfractures captured by the microseismic monitoring system. The research results can provide important basis for understanding instability failure mechanism of deep roadway and microseismic activity law in complex geologic conditions, and it ultimately can be used to guide the selection and optimization of reinforcement and protection scheme.



## 1. Introduction

With the continuous increase of depth in mining, a series of problems that impact the production of coal mines are getting more and more serious. One of the major issues is higher ground pressure caused larger roadway deformations, and a higher deformation rate in the surrounding rocks may possibly result in roof fall accidents [1]. Some measures can be implemented to prevent such accidents and guarantee the safety of coal mine production. For example, rational and timely monitoring of the stability of roadways can accurately understand the stress distribution of surrounding rocks as well as its development trend.

At present, there are many research achievements about the methods of monitoring the roadway deformation. Jiang et al. applied mechanical measuring instruments, such as length rod, displacement meter and roof dynamic monitor, to monitor roadway deformation [2,3]. Zhu et al. carried out non-contact measurement of surrounding rocks through the laser ranging method [4,5]. Xi investigated the deformation inside road tunnels with the total station device technology [6]. Wu et al. came up with the idea of applying digital close-range photogrammetry to coal mines safety early warning systems [7]. Sun studied the key technology of precise close-range photogrammetry applied to coal mine deformation monitoring [8]. Zhang et al. studied the characteristics of deformation and damage of surrounding rocks based on the borehole observation technology [9]. Due to the measuring points being limited and the measuring ranges being small, it was hard for the aforementioned methods to achieve large area observation. Apart from that, the duration in a single measurement was long, the interval between two measurements was also long, and the real-time performance was poor. Therefore, studies on roadway discontinuity, sudden deformations, initial positions and turning points of

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deformations, require much further studies and improvements. In addition, some scholars carried out intensive studies on non-damage detection technologies. Su tested the sizes and directions of the main stresses in a measuring station through borehole acoustic wave method [10]. Hu et al. applied the electrical resistivity method to measure the changes in the electrical resistivity of surrounding rocks with the borehole depth [11,12]. Wu et al. obtained the distribution status of roadway loose circle as a whole by utilizing geological radar tests [13,14]. Xu carried out a study on an alerting technology based on machinery visions' real-time monitoring of the roadway deformation [15]. Liu et al. carried out experimental studies on the processes of project disasters caused by coal rock destruction and stress changes by utilizing the microseismic monitoring technology [16–21]. It can be seen that the existing studies on methods for monitoring the "whole process" of the damaged roadway still have much to be improved, especially real-time methods for monitoring the dynamic characteristics of a roadway before it gets damaged due to the mining effect and gas pressure.

In most cases, there are some precursors of geological degradation before a dynamic disaster breaks out. Such precursors are mainly reflected on microseismic activities during the microfracture evolutionary process. Based on the above thoughts, with the strong outburst propensity working face 62113 of Xin Zhuangzi Mine as the project background and a high-precision microseismic monitoring technology as the on-site measuring approach, this paper presents the real-time dynamic monitoring of the evolutionary course of the roadway getting damaged, the degrees of the damage, and the stress distribution status. Meanwhile, a RFPA2D-Flow numerical experiment was used to analyze the real process of coal rocks rupturing. The whole course of microfractures emerging, expanding, interacting and integrating into a potential ruptured surface during the process of coal rocks losing stability was simulated. The microseismic monitoring information and the numerical simulation results agree with each other, which indicate that an effective method for identifying the abnormal stress areas in a roadway. This research outcome can provide a feasible and practical guidance for evaluating the dynamical stability of roadways and informing effective reinforce support strategies.

## 2. Feasibility of identifying areas where the stresses are abnormal

### 2.1. Limitation of conventional stress monitoring

At present, most analyses work on the stability of roadways use apparent information, such as stress and displacement, as the monitoring parameters. However, studies on the natures and characteristics of roadways, which may lose their stability due to microfractures induced by the degradation of coal rocks during the mining process, needs to be studied further. Usually, monitoring methods for apparent deformation indexes can provide the results of coal rocks rupturing in a macroscopic way, but cannot express and describe the evolutionary forming process of a section of fractures inside coal rocks. In addition, monitoring for apparent deformation indexes always targets part of a roadway, thus the results can't reflect the deformation situation of the entire surrounding coal rocks. Therefore, it is challenging for traditional monitoring methods to make a comprehensive macroscopic assessment on the process of the structure of coal rocks rupturing and damaging.

### 2.2. Stress & the emergence of stress

From the mechanism perspective, damage on coal rocks is closely related to the coupling of evolutionary relations between original rock stress field and mining stress field. Therefore, studying the stress field distribution characteristics of coal rocks during a mining process is crucially important for understanding the laws governing the abnormal stresses location in a roadway, and thus evaluating roadway stability. However, at present, methods for determining the stress field in a practical project are either by the calculation using empirical formulae or the measurement using the grid method. Both of them have difficulties in providing the overall information about the stress field of the coal rocks structure. In general, stress movement is inevitable during the mining process, which will result in the accumulation and release of coal rocks stresses and the development of potential microfractures in coal rocks. This phenomenon reflects the response of the coal rocks structure to the stress change which is called the emergence of high stress. Therefore, although it is difficult to obtain the stress field, if the microfractures as the response of the stress can be monitored, the stress distribution can be indirectly acquired through the monitoring of "time-space-magnitude" evolutionary behavior of microfractures.

## 3. Microseismic monitoring system and analysis

### 3.1. Principle of microseismic positioning

During the course of coal rocks bursting in mining, the energy accumulated inside the rocks will release in all directions in the shape of stress wave, with microseismic events coming out. With the help of radio detectors deployed in a certain array, elastic waves can be received and displayed in a 3-dimensional space through conversion of data signals. In this way, the time of coal rocks rupturing, the space and the magnitude can be determined. Based on this, a qualitative or quantitative evaluation on the range of coal rocks rupturing and its development trend, and the stability of the roadways can be analyzed. If a number of sensors are deployed within a certain range in the area to constitute an array of sensors, the 3-dimensional locations where coal rocks rupture can be determined, as shown in Fig. 1.

### 3.2. Geological conditions for the study area

The C13 coal bed of Xin Zhuangzi Mine of Huainnan Mining Group contains rich joints, unstable coal lines, rather matured fragile fractures and many faults. The immediate roof consist of silty sand mudstone, and the upper roof consist of coarse-grain quartz sandstone with a grey-white color and a slightly thick layered shape. The immediate floor is made of gritty mudstone. The thickness of the coal bed is 4.3–14.9 m, with the average thickness being 7.16 m. The 62113 working face has a length of about 860 m; the elevation of the tailgate is −575 m, the elevation of the headgate is −665 m, and the average length deviation is about 120 m. Due to strong outburst propensities, this working face has developed

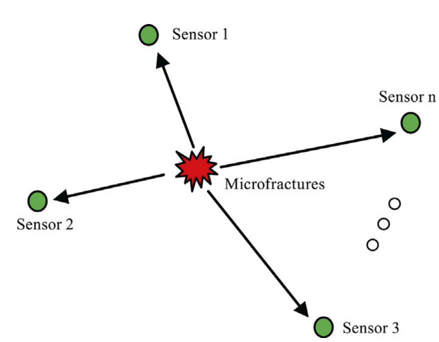


**Fig. 1.** Principle of microseismic location events.