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ACOUSTICS OF STRUCTURALLY INHOMOGENEOUS SOLID MEDIA. GEOLOGICAL ACOUSTICS

The Experimental Research on Response Characteristics of Coal Samples Under the Uniaxial Loading Process[1]

Bing Jia[a, b], Jian-Ping Wei[a, b, c, *], Zhi-Hui Wen[a, b], Yun-Gang Wang[a, b], and Lin-Xing Jia[a, b]

[a]*State Key Laboratory Cultivation Base for Gas Geology and Gas Control, Henan Polytechnic University, Jiaozuo, Henan, 454000 China*

[b]*School of Safety Science and Engineering, Henan Polytechnic University, Jiaozuo, Henan, 454000 China*

[c]*Coal Production Safety Collaborative Innovation Center in Henan Province, Jiaozuo, Henan, 454000 China*

**e-mail: 13838910327@163.com*

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Abstract— In order to study the response characteristics of infrasound in coal samples under the uniaxial loading process, coal samples were collected from GengCun mine. Coal rock stress loading device, acoustic emission tested system and infrasound tested system were used to test the infrasonic signal and acoustic emission signal under uniaxial loading process. The tested results were analyzed by the methods of wavelet filter, threshold denoise, time–frequency analysis and so on. The results showed that in the loading process, the change of the infrasonic wave displayed the characteristics of stage, and it could be divided into three stages: initial stage with a certain amount infrasound events, middle stage with few infrasound events, and late stage gradual decrease. It had a good consistency with changing characteristics of acoustic emission. At the same time, the frequency of infrasound was very low. It can propagate over a very long distance with little attenuation, and the characteristics of the infrasound before the destruction of the coal samples were obvious. A method of using the infrasound characteristics to predict the destruction of coal samples was proposed. This is of great significance to guide the prediction of geological hazards in coal mines.

Keywords: rock mechanics, acoustic emission, infrasound, experiment, prediction of geological hazards

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INTRODUCTION

The reason why acoustic characteristics that are monitored in the loading process can be used for researching the deformation and damage characteristics of coal samples is that the strong heterogeneity and difference of stress distribution of coal samples can cause uneven local deformation, and this deformation interacts with air to produce sound waves with different characteristics. These differences of the sound wave are the appearance representation of internal deformation of coal samples, which provides a feasible method for studying the internal damage of coal samples. So, it has attracted many scholars to study the relationship between the responses of sound wave and the deformation of coal samples. In papers [1–3] there are tested the acoustic emission in the loading process with coal samples, rock samples and so on, and studied the relationship between the failure of the samples and acoustic emission characteristics. In papers [4–9] there are studied the response characteristics of acoustic emission in the process of uniaxial loading, three axes loading, cyclic loading, unloading confining pressure loading and so on, and got the response characteristics of acoustic emission at different deformation stages. In papers [10–14] there are tested the characteristics of acoustic emission in different test conditions, such as loading speed and confining pressure, and analyzed the effects of test conditions. In papers [15–19] there are tested the characteristics of acoustic emission in different environmental conditions, such as temperature, water saturation, adsorption capacity, and studied the influence of these factors. In papers [20, 21] there are tested the response rule of infrasonic wave in the loading process with the samples in different lithology, and analyzed the relationship between the acoustic wave and samples destruction. In the past, scholars had made a lot of research results. However, there are few reports on response characteristics or precursor characteristics of the infrasound in different loading stage, and the response characteristics of the infrasound are the bases for the accurate prediction of coal rock failure. Therefore, based on the analysis of the response characteristics of infrasound in the loading process, a method of how to use the infrasound signal to predict the destruction of coal samples is put forward. It is expected to provide guidance for the prediction of geological hazards in coal mines.

[1] The article is published in the original.

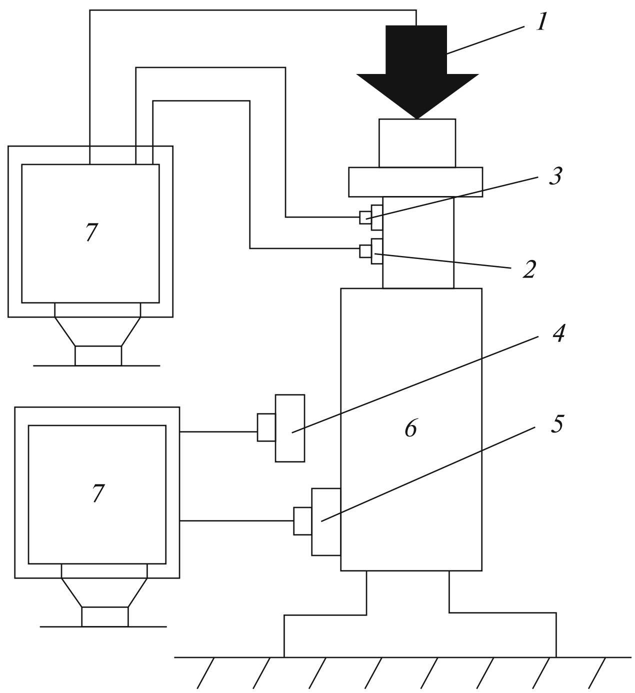

Fig. 1. Schematic diagram of experimental apparatus: *1*—axial compression system, *2*—stress transducer, *3*—strain transducer, *4*—acquisition system of infrasonic wave, *5*—acquisition system of acoustic emission, *6*—sample cylinder, *7*—host computer.

1. EXPERIMENT DESCRIPTIONS

1.1. Experimental Principle and Experimental Device

1.1.1. Experimental principle. In the loading process, the strong heterogeneity and difference of stress distribution of coal samples can cause uneven local deformation, and it interacts with air to produce sound wave with different characteristics. The characteristics of these sound waves are the results of the coupling action of the coal samples properties, loading mode, loading stage and so on. The different characteristics reflect the evolution and damage process of the coal samples. Therefore, on the basis of a large number of tests, the identification method and the recognition feature of damage are established. Then, the damage of coal samples is retrieved and predicted in the loading process according to the characteristic of acoustic wave.

1.1.2. Experimental device. The experimental system includes a self-developed coal rock creep and seepage device, CASI-ISM-2013 high precision capacitive infrasound sensor developed by the Institute of acoustics of the Chinese Academy of Sciences, and a multi-channel fully digital PCI-2 type acoustic emission system developed by the American Physical Acoustics Co. The device mainly includes the axial compression loading system, the stress–strain acquisition system, the infrasonic wave/acoustic emission acquisition and analysis system. The schematic diagram of the experimental principle is shown in Fig. 1.

(1) Stress loading system.

The stress loading device is controlled by a full digital computer program. It can automatically save and display the data. At the same time, it has the advantages of high resolution, high control accuracy, low failure rate, and ensures the reliability of the experimental data. The axial loading stress in the loading system can be realized in the range 1–500 kN; the stress sensor is mainly used to monitor the axial stress, its monitoring range is 0–500 kN, and the test force resolution is less than 2.5 N. The displacement sensors are used to monitor the axial displacement monitoring, their displacement measurement range is 0–150 mm, and the displacement resolution is less than 0.002 mm.

(2) Acoustic emission acquisition system.

The acoustic emission acquisition system transmits the signal collected by an acoustic emission sensor to a pre-amplifier. The pre-amplifier transmits the amplified signal to the signal acquisition and processing card of sound emission. At last, the acoustic emission signal is analyzed by the analysis software, and the characteristic curve of acoustic emission signal is obtained. The acquisition parameters of the system are as follows. The frequency range is 1–3 MHz. The signal amplitude is 17–100 dB. The acquisition frequency is 40 MHz, the input impedance is 50 Ohm, the impact time is 0–104 ms, its resolution power is 1.6 μs, the impact locking time is 0–65 ms, its resolution power is 1 μs.

(3) Infrasonic wave acquisition system.

In the infrasonic wave acquisition system, non-electrical signals are transformed to electrical signals through the infrasound sensor. Then the signals are amplified and transmitted to the digital network transmission collection device. The working principle of the sensor is shown in Fig. 2. A capacitor is formed between the metal diaphragm and the metal plate. The metal diaphragm is affected by sound waves, which causes the change of the distance d between the plates. Thus, the capacitance of the parallel plate capacitor is changed. The conversion of non-electric signals to electric signals is realized by the change of capacitance. The change of capacitance reflects the information about the infrasonic wave.

According to the principle of capacitance, the calculation formula of capacitance is as follows:

$$C = \frac{\varepsilon S}{4\pi \mathrm{k} d}, \tag{1}$$

where ε is the constant of dielectric; S is the area of parallel plate; k is the constant of electrostatic force; d is the spacing of parallel plate. When the change of d is Δd, the change of capacitance is as follows:

$$\Delta C = \frac{\varepsilon S}{4\pi \mathrm{k}(d - \Delta d)} - \frac{\varepsilon S}{4\pi \mathrm{k} d} = C_0 \frac{\Delta d}{d - \Delta d}, \tag{2}$$