A study on the acoustic emission characteristics of the coal rock on different bedding direction

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Abstract

The rock mechanics servo system (MTS815) and the acoustic emission testing system (PCI-2) were selected in this paper to conduct the uniaxial compression test and the acoustic emission test from two different direction of the coal and to clarify the acoustic emission feature during the process compression deformation of the coal. The results show that there is an obvious difference on the characteristic parameter of acoustic emission and the spatial distribution during the process of uniaxial compression, which is from different directions. On the initial compression phase, the stress growth rate of the coal from the vertical direction is greater than that from parallel bedding coal and the acoustic parameters. Acoustic emission ringing, energy and event count rate are less than the coal rocks from parallel bedding. The acoustic emission count will increase with arise stress, the coal from the parallel direction is more stable than the coal from the vertical direction; the coal acoustic emission has significantly reduced which from the vertical direction when after the peak stress and there is a little change with the parallel coal rock; The acoustic emission event of the coal which is from the vertical direction and the parallel coal usually concentrates in the lower part of the coal.

Keywords: Coal Rock, Acoustic Emission, Spatial Distribution of Events, Bedding Direction, AE Characteristic Parameters

1 Introduction

In the process of the mining, the stress of the coal may has changed due to the original stress balanced state was destroyed. The phenomenon which can rapidly release the strain energy is called acoustic emission, AE. The acoustic emission technology is an acoustic method to analyse the mechanic of the rock.

The acoustic technology can reflect the internal defects by means of the acoustic emission signal with the different conditions and infer the behaviour variation within the coal rock. These technologies can also back analyse the failure mechanism of the coal rock. For recent years, with increasingly testified the exploitation intensity and the depth of the coal in China, the acoustic technology will be more and more widely applied. The research on acoustic emission characteristics has made a lot of achievements in recent years. Yang Yong-jie discovered that the maximum Lyapunov index for the energy counting rate which can be used for predicting the coal fracture [1]. Zuo Jian-ping has combined the single rock, the single coal and the coal rock together, the single axis acoustic emission testing was conducted on this compound in order to analyse the temporal and spatial evolution mechanism during the compound crack process [2]. Ning Chao found that there is a variation curve relationship between the stress of the coal and the acoustic emission parameters [3]. Qin Hu found that the moisture content in the coal rock will have an obvious influence on the intensity and the acoustic emission of the coal rock [4]. Voznesenskii found that the relative coefficient of the acoustic emission is a constant [5]. Majewska considered that there are some differences with the emission and the strain characteristics during the process of carbon dioxide adsorption [6]. Cao Shu-gang found that the acoustic emission characteristic may be different under the impact of the uniaxial compression and confining pressure [7]. Ai Ting has located the acoustic emission under the different confining pressures and considered that the acoustic phenomenon mainly comes from mid-prophase [8]. Gao Bao-bin has researched the acoustic emission and found out the comparative rules of the fractal characteristics between the acoustic emission count and the cumulative count [9]. Su Cheng-dong found that the deformation and destruction process of the coal might be different under the different stress path [10].

There is a certain relationship between the heterogeneity and the mechanical property of the coal rock [11]. As mentioned before, the researches on the acoustic emission characteristic were mainly concentrated on the uniaxial compression and the confining pressure of the coal. However, few researches focused on the acoustic emission characteristic concerning the bedding direction. The rock mechanics servo system (MTS815) and the acoustic emission system (PCI-2) were selected to test the uniaxial compression. Furthermore, we will

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conduct the synchronization sound emission research and analyze the acoustic emission feature in the process of the deformation and fracture of the coal.

2 The basic theory of the coal rock acoustic emission

In continuous damage mechanics, the damage can be defined as variable D and calculated as follow [12]:

$$D = \frac{S_n}{S}, \quad (1)$$

where S is the material section surface without damage; S_n is the damage area; D is the damage variables, where $0 \le D \le 1$.

It is considered that the material is entirely damaged when the variable D equals to 1, the material is in completely non-invasive state when D equals to 0. The coal material is the infinitesimal which has a defective, the destroy essence of the coal is the inherent defect which suffers a stretch and extend, like the microcosmic breakage. So the flaw may be activated when the stress is greater than the limit fracture strength and releases the strain elastic energy to motivate the acoustic emission, two-parameter Weibull distribution is often used in the coal defective distribution:

$$n(\varepsilon) = k\varepsilon^m; \quad (2)$$

$$n'(\varepsilon) = km\varepsilon^{m-1}, \quad (3)$$

where strain $n(\varepsilon)$ is the number of activated flaw; The constants k and m representative the material property of the breakage; $n'(\varepsilon)$ is the gradient rate between the flaw and the strain.

When the strain adds an increment ($d\varepsilon$), the number of defects, which join the breakage activity is:

$$dn = n'(\varepsilon)d\varepsilon. \quad (4)$$

Due to the damage, the stress in the materials was released, it is assumed that there is a corresponding relationship between the active damage destroys and the acoustic emission count, where the acoustic emission counts can be expressed as follow:

$$dN = (1-D)n'(\varepsilon)d\varepsilon. \quad (5)$$

We add the formula (3) into (5) and get:

$$dN = km(1-D)\varepsilon^{m-1}d\varepsilon. \quad (6)$$

The random factor $r(\varepsilon)$ was considered the flaw distribution of the coal rock, the total acoustic emission count (N) can be elicited as formula (7):

$$N = r(\varepsilon)\int_{\varepsilon_0}^{\varepsilon} km(1-D)\varepsilon^{m-1}d\varepsilon, \quad (7)$$

where the strain of the materials initial damage is ε_0, $r(\varepsilon)$ is the random factor and the value can range from 0 to 1.

The sound emission gradient is:

$$N'(t) = \frac{dN}{dt} = r(\varepsilon)km(1-D)\varepsilon^{m-1}\frac{d\varepsilon}{dt}. \quad (8)$$

The acoustic emission of the uniaxial compression and damaged process can be described as formula (7) and formula (8) [13].

We conclude from the formula that the value of the acoustic emission and the acoustic gradient depends on the damage factor, the transient strain and the strain rate. The value also has close relations to the defectiveness amount, dimension, bedding distribution and the homogeneity.

3 The preparation of the coal rock

The coal sample is from Furongbaijiao colliery, the fault age in the mine has fully development and has a clearly stratum distribution. Accordance with the rule "the physical and mechanical property assay method of the coal and rock (GB/T 23561.7-2009)", the coal rock can be made up a standard sample ($\phi 50 \times L100mm$) according to the vertical and the parallel direction, shown in Figure 1.

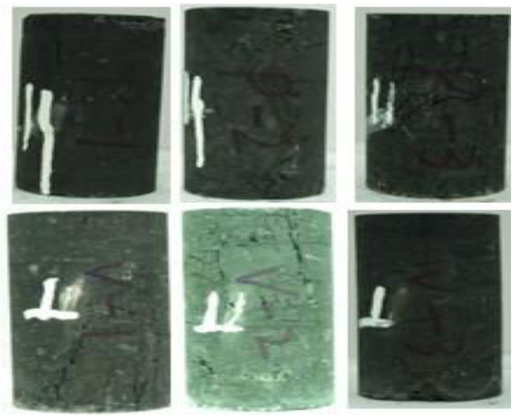


FIGURE 1 Pictures of coal rock

During the process of sample preparation, we must guarantee the two end face of the sample is less than the 0.05mm and the axial direction is less than 0.25. The basic parameter of the coal rock is described in Table 1.

TABLE 1 The basis parameters of the coal rock

Bedding direction	Coal Number	Diameter/*mm*	Height /*mm*	Volume /*cm*^{3}	Weight/*g*	Density *kg/m*^{3}	Crush intensity/*MPa*	Elasticity modulus/*MPa*
Parallel	P-1	`50.33	81.86	162.78	233.50	1434.47	6.571	1914
	P-2	50.07	100.18	197.15	304.00	1541.94	8.986	1201
	P-3	50.43	90.19	180.06	258.54	1435.89	12.596	1710
	mean	50.28	90.74	180.00	265.35	1470.77	9.384	1608
Vertical	V-1	50.06	101.93	200.52	293.11	1461.76	14.618	1761
	V-2	49.86	100.32	195.78	291.46	1488.73	9.582	1413
	V-3	49.72	100.09	194.23	293.77	1512.46	15.624	1921
	mean	49.88	100.78	196.84	292.78	1487.65	13.275	1698

4 Experimental facilities

The experimental facilities are provided by the geotechnical engineering key laboratory, Si Chuan University. The mechanics-practical system of the rock (MTS815 Flex Text GT) is used in this research，the maximum axial direction is 4600kN and the crosswise range is from -4 to +4mm, the axial direction is from 0 to 100mm.

In order to guarantee the synchronism of the system, the acoustic emission and the loading systems are selected to monitor the experiment. The PCI-2 acoustic emission system is provided by PAC Company and this system has several advantages which include the ultrafast processing speed, the low threshold value and the reliable stability. The main parameter of the sound emission will be recorded automatically in the process of the experiment. The experiment equipment is shown in Figure 2.

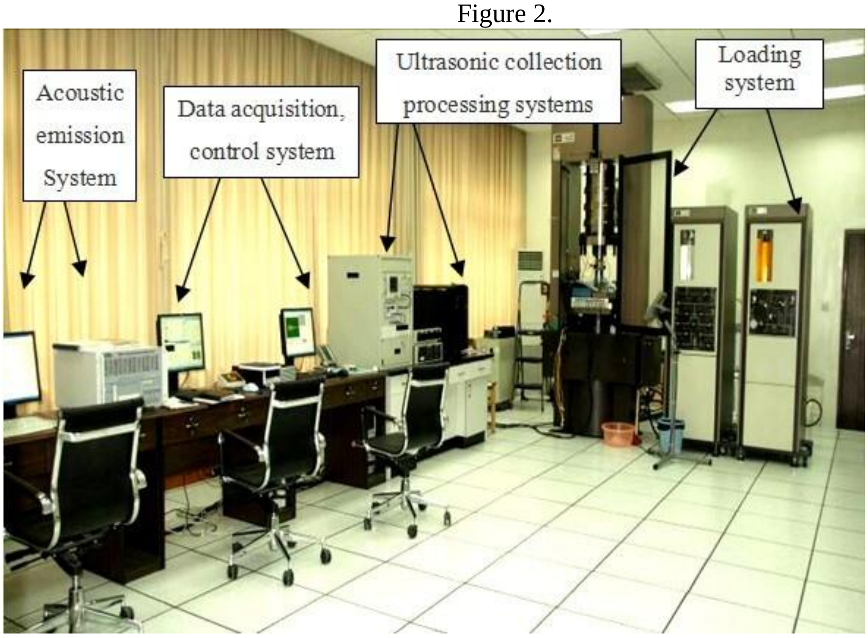


FIGURE 2 MTS hydraulic servo-control testing machine

5 Results and analysis

5.1 THE ACOUSTIC EMISSION ANALYSIS

After the uniaxial compression test, we find the acoustic emission counting rate should correspond to each time quantum, the homotaxial press process is considered in two directions (the vertical and the parallel direction). The relationship between the acoustic emission parameters and the time are shown in Figure 3 and Figure 4.

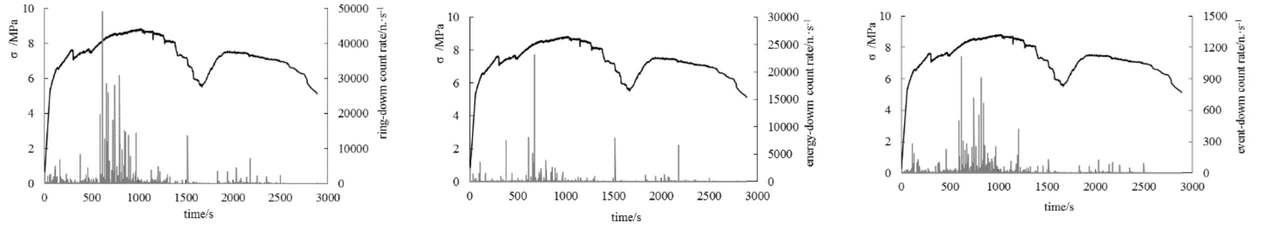
1) When comparing the two figures, we find that the growth rate of the bedding coal from the vertical direction is larger than that from the parallel direction at the initial loading stage; The stress value of the coal from the vertical direction will appear minimum value at the 1500s before arise. The stress value of the coal bedding in the parallel direction will decline around 800s and before decline.

2) Figures 3a and 4a represents the variable curve, the curve can describe the ringing counting rate of the coal which can be changed over time. Form the figure we can see that the ringing counting rate from the parallel direction is greater than that from the vertical direction and this may explain that the acoustic emission feature is determined by the layer property; with the increasing the stress value, the ringing counting rate can reach maximum value when in vicinity of the peak value. The ringing counting rate of the vertical direction ranges from

600s to 1000s and belongs to fracture [14]. But the ringing count rate is uniform when at the process of the rock pressure and belongs to stable type.

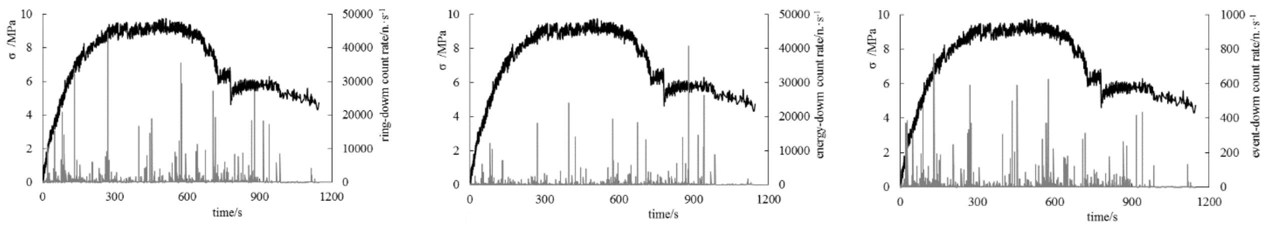
3) Figures 3b and 4b represent the energy counting rate curve over time. As can be seen from the figure, the maximum value of the energy counting rate from the vertical direction appears nearby peak value, but the maximum from the parallel present to late peak and has a more uniformity distribution than the vertical's. This phenomenon clarifies that the acoustic emission may be different at the different direction of the coal.

4) Figures 3c and 4c represent that the incident counting rate has changed with the time. Figures 3c and 4c have similarities with Figures 3a and 4a correspondingly, the maximum counting rate of the coal from the vertical direction equals to the raining counting rate, but the incident counting rate is different.



(a) Ring-down count rate (b) Energy count rate (c) Event count rate

FIGURE 3 AE characteristic parameters and stress-time curve for the vertical bedding coal rock (P-2)



(a) Ring-down count rate (b) Energy count rate (c) Event count rate

FIGURE 4 AE characteristic parameters and stress-time curve for the parallel bedding coal rock (V-2)

5.2 THE DISTRIBUTION OF THE ACOUSTIC EMISSION

Figures 5 and 6 represent the acoustic emission from the vertical and the parallel direction respectively. Figures 5a and 6a are spatial incident distribution map in the increment stage of the AE and Figures 5b and 6b are the stress accumulative incident of the AE.

1) From Figures 5a and 6a we can see that there is a larger difference between the spatial distribution of the acoustic emission from the vertical direction and the parallel direction. In the initial stage of the press, the micro-crack and the micro-structure may cause the acoustic emission incident. The acoustic emission incident appears on the coal sample uniformly, but the firing point from the parallel direction usually focuses on the middle section of the coal; the initial micro-crack will close alone with the stress increasingly grown. The acoustic emission incident has reduced to the range from 40% to 50% and formed a failure mode. The acoustic emission incident will drop off with the increasing stress.

2) From Figures 5b and 6b we find that along with the increasing stress, the coal rock will experience from initial crack closure to new micro-crack extend, cut-through and then destroy. The acoustic emission of the coal from the vertical direction spreads all over the coal rock, but the acoustic emission from the parallel direction mainly concentrates upon the bottom section of the coal and destruction of the coal is mainly the separation.

6 Conclusions

1) This paper applies the coal rock damage theory and the inherent defect distribution of the coal rock to clarify that there is a relationship between the acoustic emission characteristics and the bedding of the coal.

2) There is a big difference between the acoustic emission in the uniaxial compression test over different direction and the incident spatial distribution. The results prove that it is feasible using the acoustic emission technology to analyse the mechanical properties with different directions.

3) In the initial stress stage, the stress of coal from the vertical direction has increased rapidly and the coal has a lower acoustic emission; Along with the increasing stress, the acoustic emission level has increased.

4) In the initial stress stage of the parallel direction, the stress growth rate from the vertical direction changes slowly, but the sound emission, energy and the incident counting rate are high. The acoustic emission events usually distribute in the lower part of the coal rock and have an obvious acoustic emission concentration area, which corresponds to split.

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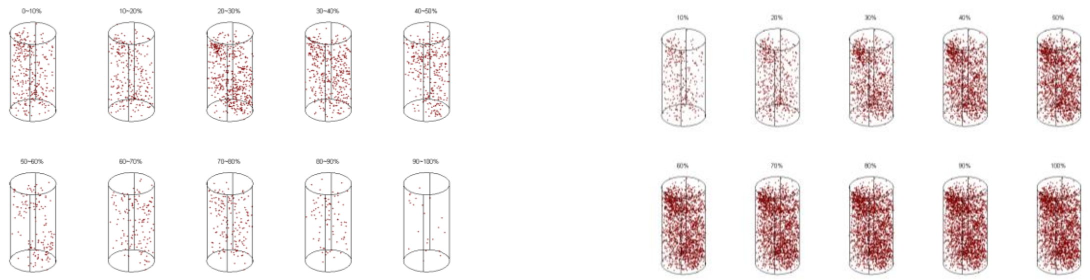
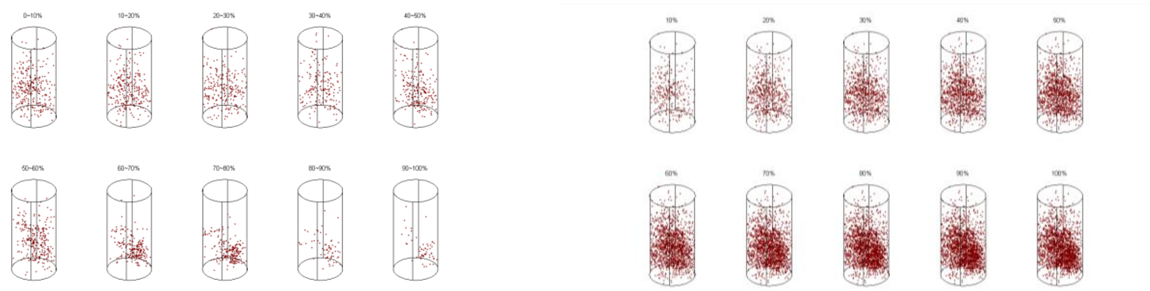


(a) Different stages of the stress increment (b) Stress the cumulative

FIGURE 5 AE event space distribution for the vertical bedding coal rock (P-2)



(a) Different stages of the stress increment (b) Stress the cumulative

FIGURE 6 AE event space distribution for the parallel bedding coal rock (V-2)

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