The General Characteristics of Electromagnetic Radiation During Coal Fracture and Its Application in Outburst Prediction

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ABSTRACT

Coal and methane outburst are catastrophic in coal mining, their prediction is difficult. In this paper, the electromagnetic radiation (EMR) generated during coal or rock deformation and fracturing is measured and analyzed. The results show that EMR truly exists during the fracture of coal or rock (with or without the presence of gas). It follows the Hurst statistical rule, and it basically exhibits gradually enhancing tendency during the process. The EMR strength and frequency are correlated to the coal or rock fracture process. Based on the experimental and theoretical studies, a new method for coal and methane outburst prediction is proposed –the EMR method. This new method significantly facilitates methane outburst prediction.

KEY WORDS

Electromagnetic Radiation (EMR), Acoustic Emission (AE), Coal Fracture, Coal and Methane Outburst, and Rock Outburst.

INTRODUCTION

Coal is a porous solid and consists of mainly carbon and hydrogen. It also contains different liquids in its pores. In coal layers the coal pores are often filled with gas. The monitoring of the dynamic process of coal or rock containing gas is a very important technology in modern coal mining, especially in the prediction of coal and methane outbursts, rock outbursts, roof falls and abutment pressure displacements. However, the current prediction technology was developed a long time ago, (such as monitoring technology), most of these methods are complex in application and the sensors must be coupled with coal or rock wall during the process of monitoring.

Tests and theoretical analysis show that electromagnetic radiation (EMR) takes place during the deformation and fracturing of coal or rock (He, 1994, 1995). This phenomenon has also been verified by EMR researchers in the research of earthquakes (Gress, 1987). EMR research can be widely used to assess the stress condition of rock, to reveal the mechanism of deformation and fracture, and to predict the catastrophic phenomena of rock or coal. These catastrophes are due to the stress change, which follows the "Rheology Hypothesis" (He, 1992) and surely leads to some characteristic change of EMR, which can be regarded as an omen of rock destabilization. It is obvious that the research and applications of EMR are important, especially in coal mine safety.

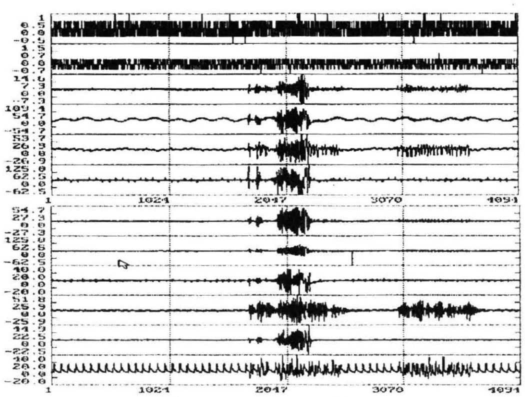
EXPERIMENT STUDY

In the experiment two types of coal were tested. The first is a molded coal specimen, which is molded under the pressure of 135Mpa in a steel model with coal powder (the particle sizes are less than 0.4 mm); the second is molded with original coal. The sizes of tested coal specimen are Φ50×100mm. The experiment system consists of EMR sensors, AE sensors, signal amplification system, load system, electromagnetic wave shield system, coal specimen vacuuming system and gas adsorption system. A total of 22 different coal specimen were tested under the load of axial compressive stress. Some of the original records are shown in Figure 1. The sensor parameters are shown in Table 1.

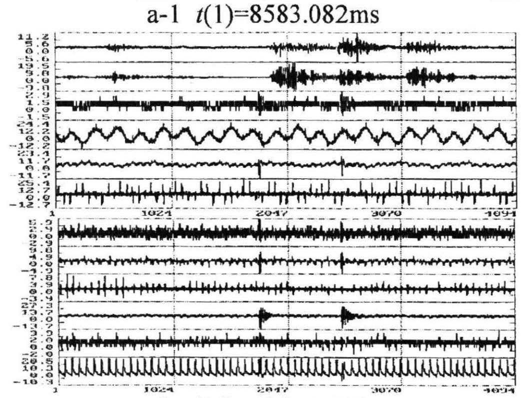
It can be proven that EMR is more sensitive than AE during the fracture of coal. The frequency of EMR signals is in a wide distribution, and some times it is not synchronized with AE. According to the curves of stress and strain plotted against time, the EMR signal number is in some way direct proportional to the load.

Table 1. The sensor parameters used in the test.

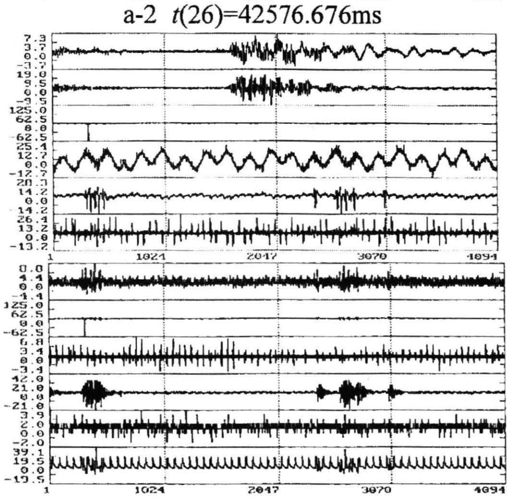
channel	Signal type	frequency
1	AE(P)	
2	AE(S□)	
5	EMR	3kHz
6	EMR	10kHz
7	EMR	81.6k
8	EMR	2.6MHz
9	EMR	814kHz
10	EMR	542kHz
11	EMR	6.9MHz
12	EMR	76kHz
13	EMR	6.9MHz
16	EMR	76kHz



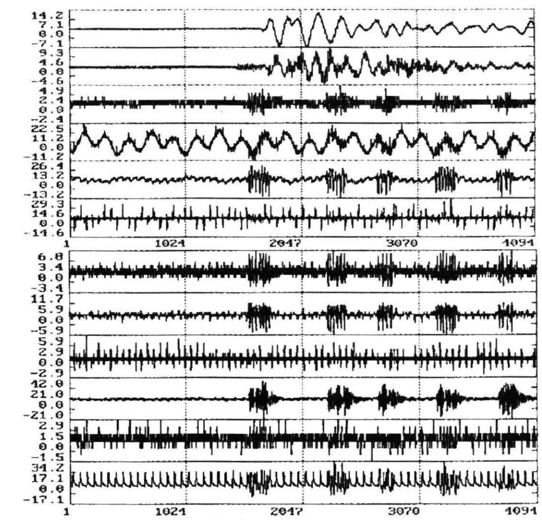
a-1 $t(1)$=8583.082ms



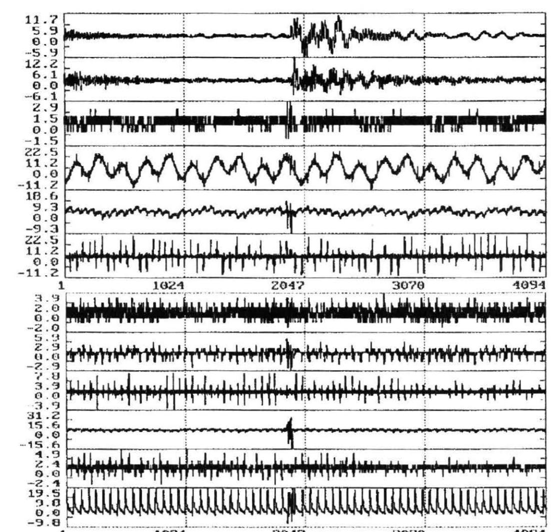
a-2 $t(26)$=42576.676ms



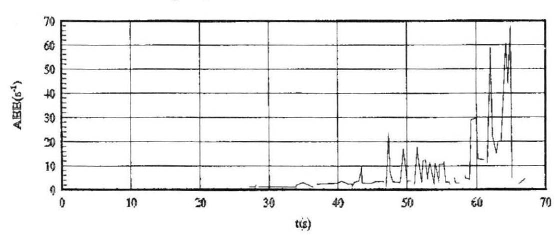
a-3 $t(48)$=55086.945ms



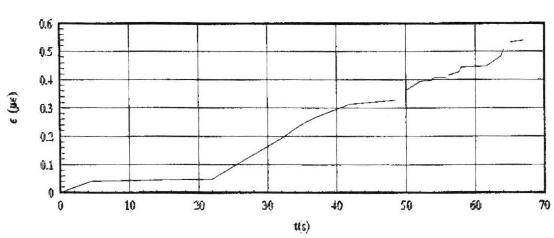
a-4 $t(59)$=61478.369ms



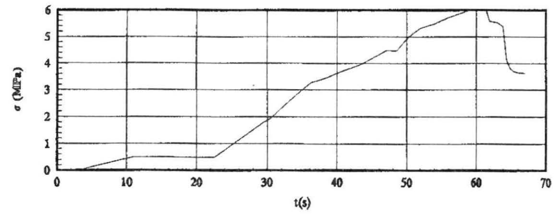
a-5 $t(67)$=65999.99ms



b



c



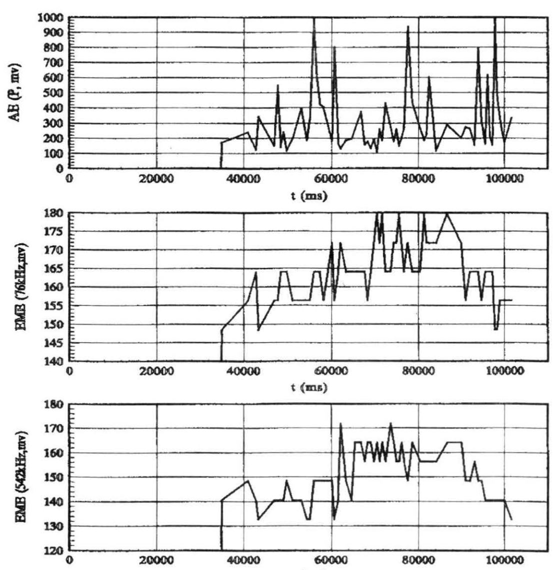
d

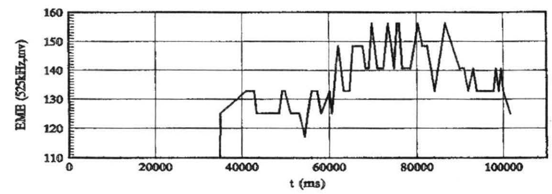
a-1~a-5 Some original events of AE and EMR during the deformation of coal specimen under the axis compressive stress. In every figure, the ordinate is breadth of AE or EMR; the abscissa is time, t(x) is the time to start sampling. This experiment is under the touching off AE signal. In every figure, the first two record lines are AE signals; from the third to the last record lines are EMR signals measured with different frequency sensors as shown in Table 1.
b is the record of total number of AE during the fracture (time/sec).
c is the curve of strain to time.
d is the curve of stress to time.

Figure 1. The AE and EMR records of original coal specimen (from Xuzhou Coal Mining Bureau, Jiangsu province, China) during the process of fracture.

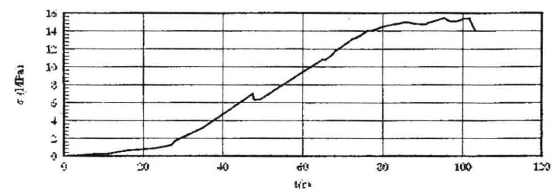
ANALYSIS

Based on test results, a general concept of EMR during the fracture of coal is built up, and it can be found that the frequency is spread across a very wide range. Every micro-fracture or displacement in the coal emits a different frequency signal of EMR. And sometimes it is coupled with the AE of coal fracture, not even homologous to the AE. The general characteristics of EMR and AE during the whole process of coal fracture are shown in Figure 2.





a Time sequence of AE and EMR



b The curve of stress to time

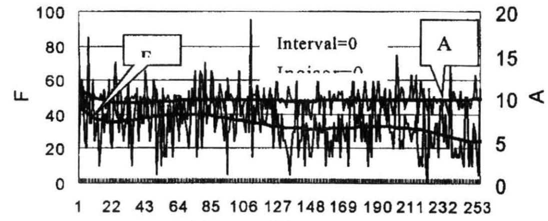
Figure 2. The general characteristics of AE and EMR during the fracture of original coal specimen (from Xuzhou Coal Mining Bureau, Jiangsu, China).

Finally, by statistical analysis, EMR signals during the deformation and fracture of coal or rock conforms quite well to the statistical rule, with Hurst index H between 0.5~1.0. The analysis results prove that prediction of coal or rock fracture is possible by monitoring the EMR since it is positively correlated with the stress and deformation, i.e., EMR enhances with the increase of deformation.

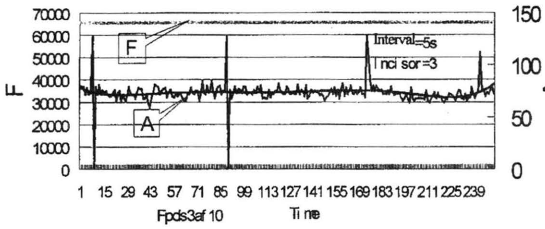
The Hurst index H of EMR of each frequency band is different. The leading frequency band of EMR during the fracture process is changing. So, it is not suitable to predict outburst by monitoring a spot frequency of EMR.

APPLICATION

Based on laboratory experiment and subsequent analysis, an EMR monitoring equipment with wide frequency band is developed. It has been used in the prediction of rock outburst or coal and methane outburst in 8th Coal Mine, Pindingsan Coal Mining Bureau, Henan Province, with some of the results shown in Figure 3.



a



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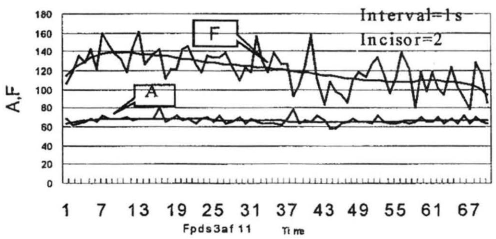

c

In Figure 3, A and F mean separately the amplitude and frequency of EMR measured on site.
a--- EMR monitoring results before the explosion in the coal head of a downhill roadway.
b--- EMR, 23 minutes after the explosion in the coal head of a downhill roadway.
c--- EMR 41 minutes after the explosion in the coal head of a downhill roadway.

Figure 3. Site EMR monitoring results before and after an explosion in the outburst prone coal head of a downhill roadway, 8th Coal Mine, Pingdingsan Coal Mining Bureau.

Site experiment results, show that both the amplitude and the pulse number of EMR before and after explosion change greatly. The number of EMR pulses oversteps the limit of the equipment just 23 minutes after the explosion, as shown in Figure 3b. And then they both decline with time. Some parallel experiments between outburst prone and non-outburst prone heads are carried out, and in the same time other outburst prediction methods are also used. Finally, it is proved that the higher the EMR pulse number and the EMR amplitude are, the larger chance for the outburst.

CONCLUSION

Both the laboratory and on site experiment it can be found and proved that the signal of EMR is more sensitive than that of AE during the damage or fracture of coal or rock. By EMR monitoring during coal or rock fracture, much fracture information can be gathered. And this technology can be used in the prediction of coal, methane, and rock outbursts.

Even so, there is much research work to be done in future, especially to produce an outburst prediction guide line through site experiment, to ascertain the orientation of EMR.

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