

单轴压缩下水饱和和煤样损伤演化及声发射特性研究

Study on damage evolution and acoustic emission characteristics of water-saturated coal samples under uniaxial compression

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摘要: 煤层的低孔低渗特征成为制约煤层气高效率抽采的主要瓶颈, 现多采用水力压裂技术来提高开采效率。本研究以山西某煤层气开发的主要矿井内的褐煤样品为研究对象, 对其在干燥状态下以及水饱和状态下开展实验室准静态单轴加载试验, 对其损伤演化过程进行分析, 并利用声发射 (AE) 技术监测煤样破裂过程中的声学信号。运用声发射三维定位技术来表征应力作用下煤样内部的微裂纹产生及扩展规律, 通过快速傅里叶变换 (FFT) 分析 AE 信号的振幅特性和频率分布。现有试验结果表明, 煤样经水饱和后, 抗压强度明显降低, 累计 AE 事件数也有所减少; 破裂过程可分为裂纹闭合、裂纹逐渐稳定扩展以及裂纹不稳定发展直至失稳三个不同阶段; 损伤过程中, 高频信号占比会增加, 低频信号占比会减少, 且低频带分布会变宽, 高频带分布会更集中; 另外, 声发射幅值也较干燥状态下有所减小。下一步将对水饱和和破裂过程微观破裂机制进行定量分析, 以更好地认识水饱和对煤样损伤的影响规律, 探究声学信号与损伤评价的内在关系。本研究希望通过对水饱和条件下对煤的变形和裂纹扩展过程的影响规律以及其声学信号的认识, 为煤层气水力压裂效果评价进一步提供基础理论数据支持, 能更好地服务于煤层的安全开采。

关键词: 煤样压裂; 水饱和; 单轴压缩; 声发射 (AE)

Abstract: The low porosity and permeability characteristics of the coal have become the main bottleneck restricting the efficient extraction of coalbed methane. At present, hydraulic fracturing technology is mostly used to improve the production efficiency of coalbed methane. In this study, the representative coal samples of a lignite mine in Shanxi Province were taken as the research object. The quasi-static loading uniaxial compression test was carried out in the laboratory under dry and water-saturated conditions, and the damage evolution was analyzed. At the same time, the acoustic emission (AE) technology was used to monitor the acoustic signal induced by micro deformation and fracture process of coal samples. The three-dimensional positioning technology based on acoustic emission signal is used to characterize the micro-crack generation and propagation of the water-saturated coal sample under loading, and the amplitude characteristics and frequency distribution of the AE signal are analyzed by fast Fourier transform (FFT). The existing test results show that the compressive strength of coal samples is obviously reduced after water saturation, and the cumulative number of acoustic emission events is also reduced. The fracture process can be divided into three different stages: crack closure, crack gradually stable expansion and crack unstable development until instability. In the process of damage, the proportion of high-frequency signal will increase, the proportion of low-frequency signal will decrease, and the distribution of low-frequency band will widen and the distribution of high-frequency band will narrow. In addition, the acoustic emission amplitude is also reduced compared with the dry state. The quantitative analysis

for focal mechanism of micro fracture will be conducted to illustrate the effect of water saturation on damage evolution in the future. We will probe the relation between acoustic signal and damage evaluation. This study will provide the theory for the evaluation of hydraulic fracturing, and better serve the safe mining of coal mines through the understanding of the influence of water saturation on the deformation and crack propagation process of coal and its acoustic signals.

Keywords: coal sample fracturing; water saturation; Uniaxial compression; Acoustic Emission