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Study on Electromagnetic Radiation in Crack Propagation Produced by Fracture of Rocks

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Abstract. The physics of electromagnetic radiation due to rock facture is complex, and understanding of this phenomena and its relationship with the extent of rock damage is imperative and remains challenging. In this paper, the relationship between the electric dipole moment and the stress change rate at the crack tip and the crack propagation characteristics are established. The stress change process is divided into three stages, the characteristics of electric dipole moment of each stage are analyzed. Simulation studies showed that the dipole frequencies, the angles between the electric dipole and detectors have a significant influence on the detection of those radiations. Self-expanding destructive experiments were designed and carried out for different types of rocks to observe more details of this phenomenon. In the rupture process of the sample, a number of electromagnetic radiation signals were detected. The duration of the signal is about 2 to 3 milliseconds, and the interval between signals varies from 23 to 210 milliseconds. The spectrum of the signal is between 4 kHz to 50 kHz. The complex variation of the signal spectrum and amplitude are due to the different electric dipoles produced by the different stages of crack propagation, and the change in the distance and angle of the radiation source from the detector during the crack propagation.

Keywords: electromagnetic radiation, rock fracture, electric dipole

Introduction

The phenomenon of electromagnetic radiation caused by material rupture has aroused the interest of many scholars with different mechanisms proposed for different materials [1] ~ [10]. Many kinds of materials can produce electromagnetic radiation in the rupture process. This phenomenon was first discovered by Stepanow in the process of the rupture of KCl crystals in 1933[11]. After that Caffin and Goodfellow observed alternating magnetic fields in ionic crystals [12]. Misra recorded this phenomenon from the iron, aluminium, copper, and zinc in the tensile stress [13]. Brady investigated this phenomenon in rock fracture, and recorded light emission from rock failure [14]. In addition, the phenomenon of electromagnetic radiation is also detected in the cracking process of ice [15], glass [16], and concrete [17]. Since the discovery of this phenomenon, it has been studied for many years, and many theories have been put forward to explain it. However, so far, there is no consensus on the mechanism of this phenomenon. Goldbaum et al. presented the relationship between the crack width and the frequency of electromagnetic radiation by observing and studying the fracture processes of ceramics and chalk [18]. The electromagnetic radiation signal model was established with fractographic methods by Frid et al., which can describe the characteristics of the electromagnetic radiation pulses [19][20]. Chmel et al. compared three physical phenomena, i.e., acoustic, electromagnetic and photon emission, during the process of granite fracture, and pointed out that the electromagnetic radiation phenomenon did not reveal scaling/non-extensive features in the energy release distribution [21]. Carpinteri et al. observed that the electromagnetic radiation phenomenon generally takes place only in correspondence to sharp stress drops in the load vs. time diagrams, and they put forward that the electromagnetic radiation phenomenon generated by the formation of new micro-cracks[22]. Misra et al. presented a theoretical model for the electromagnetic radiation during plastic deformation and crack propagation in metallic materials [23]. Vallianatos et al. studied this phenomenon in uniaxial compressed rocks, and discussed it in the frame of a superstatistical approach [24]. Singh et al. researched the energy release rate of the electromagnetic radiation signal in the fracture process of

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