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A new qualitative acoustic emission parameter based on Shannon's entropy for damage monitoring

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ABSTRACT

An important objective of acoustic emission (AE) non-destructive monitoring is to accurately identify approaching critical damage and to avoid premature failure by means of the evolutions of AE parameters. One major drawback of most parameters such as count and rise time is that they are strongly dependent on the threshold and other settings employed in AE data acquisition system. This may hinder the correct reflection of original waveform generated from AE sources and consequently bring difficulty for the accurate identification of the critical damage and early failure. In this investigation, a new qualitative AE parameter based on Shannon's entropy, i.e. AE entropy is proposed for damage monitoring. Since it derives from the uncertainty of amplitude distribution of each AE waveform, it is independent of the threshold and other time-driven parameters and can characterize the original micro-structural deformations. Fatigue crack growth test on CrMoV steel and three point bending test on a ductile material are conducted to validate the feasibility and effectiveness of the proposed parameter. The results show that the new parameter, compared to AE amplitude, is more effective in discriminating the different damage stages and identifying the critical damage.

1. Introduction

Acoustic emission (AE) is defined as the class of phenomena in which elastic waves are generated by the rapid release of energy from a localized source or sources within a material [1]. The primary sources of AE activities include micro-structural deformation processes such as plastic deformation, crack initiation and extension, corrosion and other kinds of material failures.

In recent years, AE technique has become a significant non-destructive testing (NDT) method in condition monitoring of various engineering structures [2,3]. In comparison with other NDT methods, the main advantages of using AE technique are that the position of discontinuities in material such as cracks can be located and the long-term monitoring in real time can be achieved without having to shutdown equipments. The AE monitoring involves the utilization of sensors and preamplifiers to detect elastic waves propagated inside a material, as shown in Fig. 1. The waves are directly transmitted to the AE instrument, where they would be recorded, stored, analyzed and transferred to digital signals [4]. An AE signal consists of several parameters, i.e. rise time, duration, energy, amplitude, counts and counts to peak, etc. The definitions of typical AE parameters are presented in Fig. 2.

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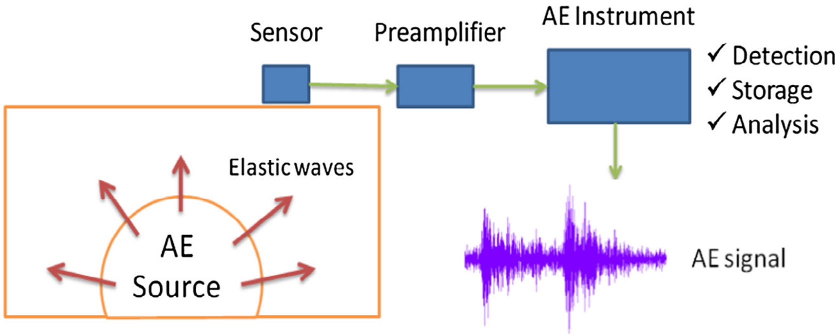

Fig. 1. Principles of AE detection.

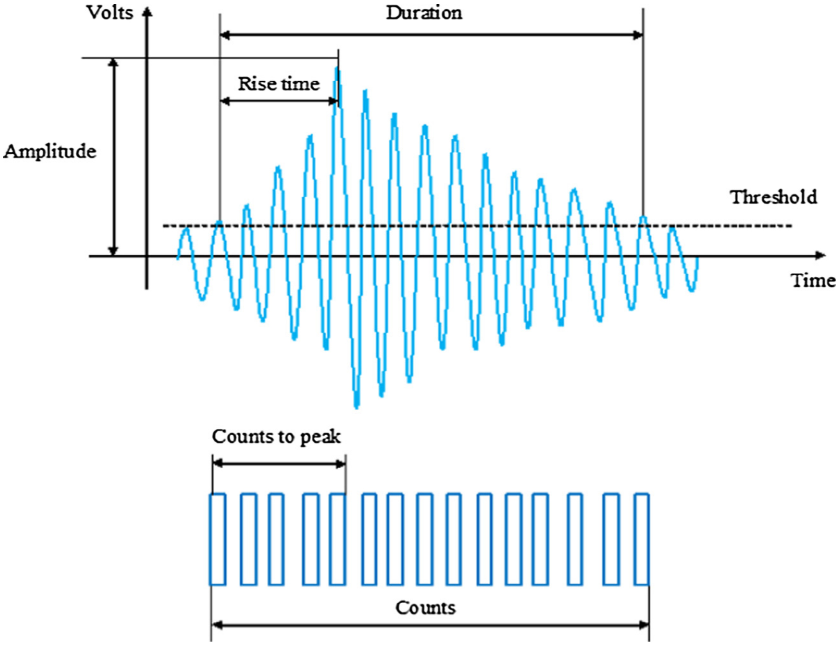

Fig. 2. Typical AE parameters.

In the application of AE technique for assessment of structural integrity, signal parameters are widely utilized to qualitatively evaluate the grade of damage. Early and accurate identification of the approaching critical damage stage is of paramount significance in order to avoid premature failure [3–5]. This is essential for civil engineers to make an efficient and optimal decision. However, damage identification is still met with great challenges due to the following three reasons. First, parameters except for AE amplitude depend strongly on the selected threshold. As shown in Fig. 2, the values of rise time, duration, counts and counts to peak are closely related to the magnitude of threshold. Moreover, setting of peak definite time (PDT), hit definite time (HDT) or hit lockout time (HLT), if set inappropriately, could affect the values of rise time and duration. Thus, these parameters may hinder the correct reflection of original AE waveform and limit real-time application of parameter analysis. Second, the high extraneous noises during some monitoring conditions such as fatigue tests on servo-hydraulic machine or operation of engineering structures generally cause high emissions. These emissions could mask the signals from the primary source such as crack growth and hence bring difficulties for the accurate identification of the early failures. Third, many AE sources generate elastic waves during the degradation of material and the mixture of different signals makes the determination of primary AE evolution become a tough task. For instance, it was reported that the occurrence of appreciable plasticity ahead of the crack tip in ductile materials could generate high amplitude signals and thereby cause difficulties in accurate determination of crack initiation and growth [6–8].

Therefore, the purpose of this investigation is to propose a new qualitative parameter based on Shannon's entropy to meet with the requirement for efficient and accurate identification of critical damage in materials. The new parameter derives from the idea that each waveform of AE signals is a unique probability distribution and thus the measure of distribution namely Shannon's entropy can be achieved. Moreover, a change in the entropy will be mainly resulted from the vari-