ACOUSTIC EMISSION; A TOOL FOR DAMAGE ASSESSMENT

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Abstract - Acoustic Emission (AE) is a well-established technique for damage monitoring and flaw location that has been used in a wide variety of fields, such as thenuclear industryand aerospace. Acoustic emission (AE) is known as a unique technique to identify damage in real time, i.e. when damage initiates or as it propagates. In order to ensure the safety of the structure, it is often necessary to carry out inspections. Conventional non-destructive evaluation (NDE) by acoustic emission (AE) techniques can be utilized for the evaluation of the damage in the materials. This paper presents the application of the acoustic emission that can be used as a monitoring system for damage assessment in different materials.

Keywords - Acoustic Emission, AE, Damage Assessment, Structural Health Monitoring, NDE, NDT

I. INTRODUCTION

Acoustic emission (AE) can be defined as the energy emitted as a result of the changes in the microstructure of a material, which is used for generating stress waves with transient elasticity[1][2]. The energy source usually originates from within the material's elastic stress field mostly generated due to the stress the material is subjected to such as mechanical, chemical, pressure and thermal stress. The resultant effect of these stresses on the material often leads to fatigue failure and is a common phenomenon in any operation or service. Several factors affect the propagation of these stress waves from their source (AE).Acoustic emission (AE) can be defined as the energy emitted as a result of the changes in the microstructure of a material, which is used for generating stress waves with transient elasticity[1]2]. The energy source usually originates from within the material's elastic stress field mostly generated due to the stress the material is subjected to such as mechanical, chemical, pressure and thermal stress. The resultant effect of these stresses on the material often leads to fatigue failure and is a common phenomenon in any operation or service. Several factors affect the propagation of these stress waves from their source (AE). Some of these include the material's geometry, velocity of propagation, discontinuities, refraction, attenuation and reflection. Also, some factors such as the property of the material, frequency and type of wave influence the velocity of propagation of the stress wave elasticity. The strength of this waves or the AE can be measured using sensitive transducers to determine the amount of surface displacement recorded as a result of the vibration caused by the stress waves as they reach the material's surface [3-5].

II. ACOUSTIC EMISSION WAVEFORM PARAMETERS

Acoustic emission (AE) waves are elastic stress waves that arise from the rapid release of energy from localized sources within a material [6]. Some common sources of AE in engineering materials are initiation and growth of cracks, yielding, failure of bonds, fibre failure and pullout in composites. AE technique involves recording the waves produced in a structure by means of sensors placed on the surface and analysing these signals to extract the information about the nature of the source [7]. In parameter based approach, signal parameters are used to assess the extent of damage. A typical AE signal along with commonly used parameters is seen in Fig.1. Commonly used parameters are defined next.

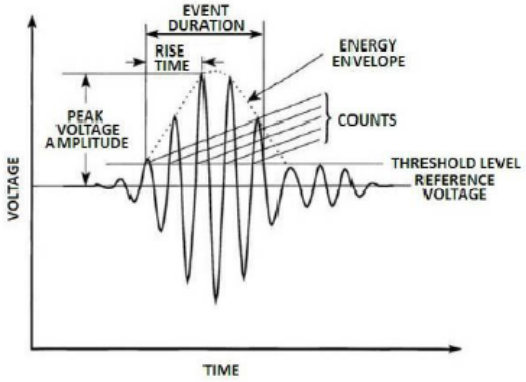


Fig.1. Acoustic emission events recorded by using definition [6, 8]

Amplitude: It is represented with A and shows the highest peak of the voltage signal. This is identical significant characteristic since it openly controls how much the AE event is detectable.

Counts: Counts commonly are presented by N. When the amplitude of the signal is larger than thethreshold, the number of pulses emitted by measurement circuitry is defined as N.

Hits: When a signal exceeds the threshold consequently a system channel accumulates data, this signal is known as the hit and describes an AE event.
Duration, D: The time interval between a signal trigger and the time it reduces below the threshold value is known as the duration of the signal.

MARSE Energy: Measured Area of the Rectified Signal Envelope is known as MARSE and sometimes represented by E and referred to as energy counts.
Rise time: Rise time is presented by R and defines the time interval between the maximum amplitude of the burst signal and the first threshold crossing. This parameter is frequently used when time dependent processes such as vibration or dynamic loading are involved.

Threshold: Threshold is a kind of set up parameter which is used for the elimination of electronic background noises. Its main objective is to eliminate as much background noise as it can. However, a balance should be struck so that the threshold does not also eliminate signals that are weak but useful given that background noises are characterized by low amplitude.

A brief outline of acoustic emission parameters and the information they convey about the source event has been summarised in Table.1.

Table .1. Acoustic emission parameters and their information about the source event [9]

Domain	Parameter	Information about the source event
Time domain variables	Rate	Rate of damage occurring
	Peak amplitude	Intensity of source event, orientation
	Relative arrival times	Source location
	Duration or count	Energy of source event
	Waveform	Structure of source event
	Energy	Energy of source event- damage type
Frequency domain variables	Frequency spectrum	Nature of source event
Time-frequency domain variables	Spectrogram	Energy distribution of source event through time
	The time variation of each frequency component	The intensities of source frequency components

III. APPLICATION OF ACOUSTIC EMISSION IN DAMAGE ASSESSMENT

Several industries such as power generation, refineries, structures (cranes, bridges, etc.), pipelines, aircraft, etc., make use of AE for non-destructive testing in their operations. Since its advent in Germany in the 1950s, AE has been very widely applied especially in the areas of quality control in manufacturing operations and process monitoring.
The NDT and NDE methods are important tools of characterization for several materials. The technique of AE, however reasonably problematic in application and clarification of results, has a great potential for characterization of fatigue, bearing properties, characterization of stress, and fracture of material[5]. AE differs from most other NDT methods in two primary ways. First, the signals originate in the material itself, not from an external source. This contrasts AE with other non-destructive method such as ultrasonic where response to a signal introduced in a specimen is studied by Vallen[10]. Second, AE detects movement while most methods detect existing geometrical discontinuities. The major differences between acoustic emission technique compared with other inspection methods can be summarized in Table.2[7].

Table.2. Characteristics of acoustic emission technique compared with other inspection methods

Acoustic Emission	Other methods
Detects movement of defects	Detect geometric form of defects
Requires stress	Do not require stress
Each loading is unique	Inspection is directly repeatable
More material sensitive	Less material sensitive
Less geometry sensitive	More geometry sensitive
Less intrusive on plant/process	More intrusive on plant/process
Requires access only at sensors	Requires access to whole area of inspection
Main problems: noise related	Main problems: geometry related

Chen.X and B.Li[11] investigated the AE signals of wavelet analysis for tool condition monitoring, while, Sun, Q. and Y. Tang[12] used wavelet transform modulus maxima to monitor operating bearings in order to identify any abrupt changes that may occur in the signals of the vibration. Teti, R., et al[13] conducted a very detailed review on sensor technology and the techniques employed for processing data in automated machine by using several sensors of varying levels of applicability based on the phenomenon type, precision level or control parameter requiring measurement so as to capture the necessary information on the manufacturing process. The wide applicability of AE technique is evident in several metal piping system evaluations and fibreglass reinforced plastics (FRP) [14, 15], concrete bridges [16], premature crack detection, fatigue crack development monitoring and the correlation of crack development with AE activity in steel parts [17-19]. A detailed discussion on AE fracture in metals is presented byOno.k[20], while cracking in concrete is well discussed byKishi., et al[21].

The two basic types of AE monitoring strategies which can be applied are local and global monitoring strategies. Global monitoring strategy aids in the assessment of the whole integrity of the structure, whereas the local monitoring strategy is concerned with a particular damage area [22].

The use and significance of composite structural components is on the increase particularly in commercial aircrafts such as (B787, Airbus A380, F35, Typhoon) due to the superior strength features

they have over metallic properties. Eglītis, E., et al[23] conducted a study on the laminate composites mechanical behavior loaded through a buckling test and displayed the presence of the different mechanisms of damage throughout the experiments. Failure in these composites results from the start and combination of damages of different types such as fiber matrix debonding, matrix cracks, delamination and fiber breaks. Pullin, R., et al [24] determined the distinct correlation between AE and crack growth and also used TRL5 (technology readiness level of five) to detect landing gears fractures in AE. Takeda, N [25] did a study on monitoring damages with small-diameter optical fiber sensors and structural health monitoring of composite structures. Romhány, G., et al [26] used AE to monitor and identify the sequence of failure mode that occurred in flax fiber reinforced composites during a tensile test. Their study revealed the possibility of identifying, during the failure of a composite, the AE amplitudes released by the flax fibers, despite the fact the previous values are lowered due to the damping effects of the matrix.Marec, A., et al[27] investigated the local damage of composite materials based on the acoustic emission signal analysis.

CONCLUSION

Several challenges have been experienced in recent times regarding the application of AE techniques for large scale structures with material or geometrical complexities as a result of the difficulties encountered in the interpretation of AE signals.An advantage of AE technique is the ability to determine the location of the source of emission. To accurately locate the source, it is important to know the velocity of the AE waves.

AE technique is one of the many techniques currently used and further explored for bridge health monitoring. No one technique can be expected to be sufficient and give fault proof results all the time. Use of different techniques to supplement each other is the best way to properly monitor a bridge. Integration of AE with other tools such as vibration based technique can be an efficient tool.

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