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Delta *T* source location for acoustic emission

Matthew Geoffrey Baxter*, Rhys Pullin, Karen M. Holford, Sam L. Evans

School of Engineering, Cardiff University, 5 The Parade, Cardiff, CF24 3AA, UK

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Abstract

Acoustic emission (AE) source location provides a powerful tool for the engineer. Current methods, time of arrival (TOA) location and single sensor modal analysis location (SSMAL), are based on assumptions derived from a simplistic structure. In complex geometric structures these assumptions are incorrect. This paper describes a novel solution for AE source location in complicated geometric structures. "Delta *T*" source location utilises an artificial source; recording differences in times of arrival information from a number of locations, to improve source location. This method does not require knowledge of the sensor location or wavespeed. A 5-step description of the process is provided and practical results from an initial trial are presented. Results from the initial trial demonstrated a considerable improvement over the conventional TOA source location method, with a reduction in location error from 4.81% using the conventional TOA technique, to 1.77% using "Delta *T*" location.

Keywords: Acoustic emission; Source location

1. Introduction

Acoustic emission (AE) has gained increasing credibility in recent years [1]. This is largely due to the advances in acquisition speeds and processor speeds required to handle the high signal rates and events at relatively high frequencies (20 kHz–1 MHz). Current research and development involves implementing AE techniques into global [2] and local monitoring of structures providing 'health' monitoring systems for complex structures [3]. One of the most important and useful attributes of AE is its ability to locate sources of energy release from within a structure. These sources include such mechanisms as fatigue crack growth, corrosion and fretting. Identifying the source location of an AE event can allow other NDE techniques (e.g. dye penetrant and ultrasound) to be utilised to investigate the specific area. It can also provide as much information about the source mechanism as the AE feature data gained from the analysis of the received waveform. Certain source mechanisms are only associated with particular geometric features and/or conditions. If the source location is known, the number of source mechanisms that could be responsible for the event are reduced. For example, it is unlikely that fretting would occur on a structure where there is no moving

*Corresponding author. Tel.: +44 2920875707.
E-mail addresses: BaxterMG1@cf.ac.uk (M.G. Baxter), PullinR@cf.ac.uk (R. Pullin), Holford@cf.ac.uk (K.M. Holford), EvansSL6@cf.ac.uk (S.L. Evans).

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contact between two parts. Therefore combining feature data, source location and loading regime provides an invaluable tool for monitoring the integrity of the structure.

Development is underway at Cardiff University to produce a system to detect and monitor fatigue crack growth in complex structures during qualification testing. NDT methods such as dye penetrant and ultrasound, though very useful tools, can be costly in terms of time and labour if a test has to be paused for the assembly to be dismantled, examined and re-installed. AE has the ability to monitor the structure throughout test and enable an assessment of the structural integrity providing a passive health monitoring system.

Complex geometric structures make theoretical wavepath analysis difficult and time consuming. For example in aircraft landing gear components, each component consists of many wall thickness changes, lugs, small radii and other geometric features (Fig. 1), and AE source location on such items is very difficult. Current source location methods, such as time of arrival (TOA) [4,5] and single sensor modal analysis location (SSMAL) [6] require a large number of sensors and careful planning to accurately locate a source within this type of structure.

AE tomography as described by Schubert [7] was considered. Using AE tomography to determine a wavespeed map of the structure, rather than using one average wavespeed, would improve source location, however this method requires accurate sensor location, a large number of sensors and the wavepath duration (time for signal to travel from source to sensor) for the iterative arguments used to develop the wavespeed maps. These requirements were deemed unsuitable for this particular test environment and therefore an alternative method was sought.

Recently AE mapping using a spatially located time series, as discussed by Nivesrangsan et al. [8], considers the use of energy content of the received wave to estimate distance from the source. This requires the user to complete a series of Hsu-Nielson (H-N) sources [9,10] (a simple method for producing a reproducible broadband AE source using a retractable pencil) to interrogate the system to determine the expected energy attenuation from various locations. This method has some comparisons with the method described in this paper, although unfortunately as yet no practical location results have been published.

The method described in this paper utilises a H-N source and involves the recording of time of arrival information to improve source location, "Delta *T*" location. This method does not require information on sensor location, or the time of occurrence of the source.

2. Current source location methods

2.1. Time of arrival location (TOA)

The TOA method relies purely on the arrival times of the signal at each of the sensors. Considering an infinite plate with 2 AE sensors located a distance 'D' apart, calculating the time difference in signal arrival between sensors 1 and 2, Δt, and knowing the wavespeed in the component, C_{AE}, it is possible to identify a hyperbola on which the source location lies, as shown in Fig. 2 and described by Eq. (1).

$$R = \frac{1}{2}\frac{D^2 - \Delta t^2 C_{AE}^2}{\Delta t\, C_{AE} + D\cos\theta}. \tag{1}$$

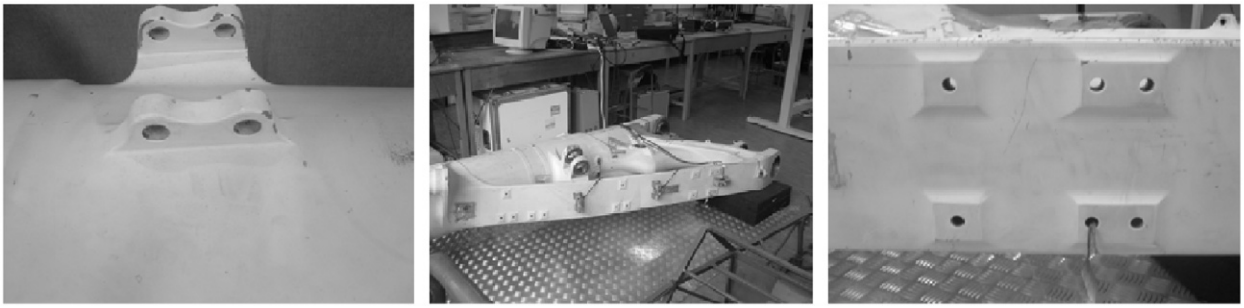

Fig. 1. Examples of geometric features in an Aircraft Landing Gear Component.