Virtual delta-t mapping technique using a local interaction simulation approach for location of Acoustic Emission damage events for aerospace applications

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Abstract. Acoustic Emission (AE) is a promising technique for Structural Health Monitoring applications (SHM) and involves detecting the ultrasonic stress waves generated by damage initiation growth in a structure. One advantage of AE for SHM is the ability to locate AE sources. Delta-t mapping was developed to overcome the limitations of the conventional AE location technique. The disadvantage of the delta-t mapping is that it requires the manual collection of experimental training data. This paper explores the possibility of using local interaction simulation approach (LISA) to generate simulated training data for the algorithm. The results for locating a fatigue crack are presented for both the experimental and simulated training data and showed average errors in source location of 3mm and 8mm respectively. This demonstrates the potential of using simulated training data for the mapping technique which would ultimately reduce implementation of delta-t mapping on large scale structures.

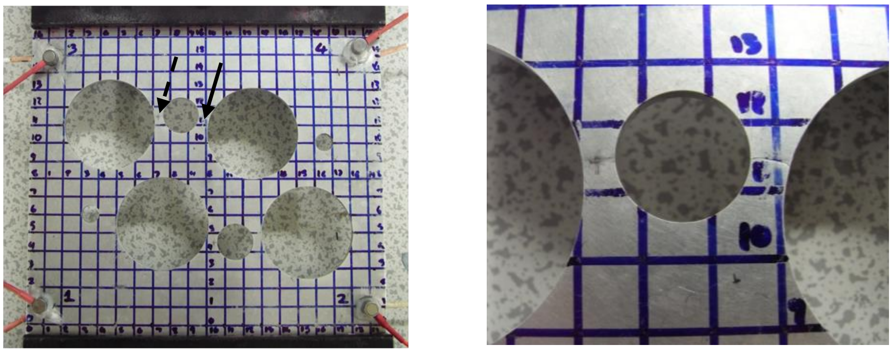
Introduction

Due to pressures to reduce greenhouse emissions of aircraft operations there is an industry-wide objective to save weight in aero structures. This has led to the application of complex structural solutions and materials. Because of this, combined with size and hard to access areas of modern aircraft, inspection during maintenance operations has become increasingly more costly, time-consuming and difficult in order to ensure structural integrity. By installing a structural health monitoring (SHM) sensor network onto an aircraft to continually monitor the structure for damage and its location, maintenance operations can be optimised, aircraft down-time can be reduced and substantial cost savings can be made. By incorporating SHM at the design stage of an aircraft, it has been suggested that weight savings of up to 15% could be achieved at component level [1].

One SHM method is sensing acoustic emission (AE) emitted during a damage event [2]. There has been a reluctance to apply AE to aircraft structures due to past experiences [3, 4] however great advancements have been made since particularly in the locations of AE events on complex structures. A method of AE location known as ‘delta-T’ was devised by Baxter et al. [5] which uses the difference in the times of arrival of an AE event between a sensor pair. An AE representative ‘Hsu-Neilson’ source is used to train an AE sensor network which can be then interrogated for improved AE location. This method has yielded great results in lab-based testing however, due to the time required to manually train the system there is reluctance to apply it on large scale structures.

Experimental Procedure

A 370mm x 200mm x 3mm 2026-T6 Aluminium plate with eight machined holes of numerous sizes was delta-t mapped using the traditional technique with a 4 sensor array shown in Figure 1. AE events were then recorded as the plate was subjected to a fatigue loading cycle until failure. A second set of training data was then created virtually by modelling the plate using the local interaction simulation approach (LISA). This virtual training data was then interrogated to locate the growth of the fatigue crack from the experimental data. This virtual technique shows great potential for automated training of sensor networks while also providing a useful tool for AE sensor network designers for the placement of AE sensors for aerospace applications.



(a) (b)

Figure 1. Damage locations for the complex geometry specimen.

Experimental Results

Figure 1(b) shows the specimen failure regions after the specimen had been subjected 96,000 fatigue cycles. From visual observation of the failure regions it was evident a small fatigue crack initiated at the right hand side thin section (Figure 1 (a) – solid arrow). This propagated a small distance before leading to a rapid failure, this then caused rapid failure of the left hand side thin section (Figure 1 (a) – dashed arrow). No evidence was found of a fatigue crack through visible observation at the last inspection prior to failure (76,000 cycles); suggesting that the damage initiated, propagated and caused failure within 20,000 cycles. Figure 2 shows the AE source locations from the entire fatigue test represented in terms of the total energy of the recorded locations within a specified spatial bin. The experimental data recorded throughout the fatigue test was located using the delta-t mapping algorithm using experimental and simulated training data. Both the experimental and simulated training data inputs to the delta-t algorithm have successfully located the fatigue crack. For the experimental training data input a region of higher energy is located in the precise position of the fatigue crack with an average Euclidean distance error of 3mm. The simulation (LISA) training data input also shows promising results with an area of higher AE energy located just above the fatigue crack region. The average Euclidean distance error for the simulated training data was 8mm. This shows great potential for reducing the amount of time an operator is required to collect training data for the delta-t mapping with very little difference in accuracy.

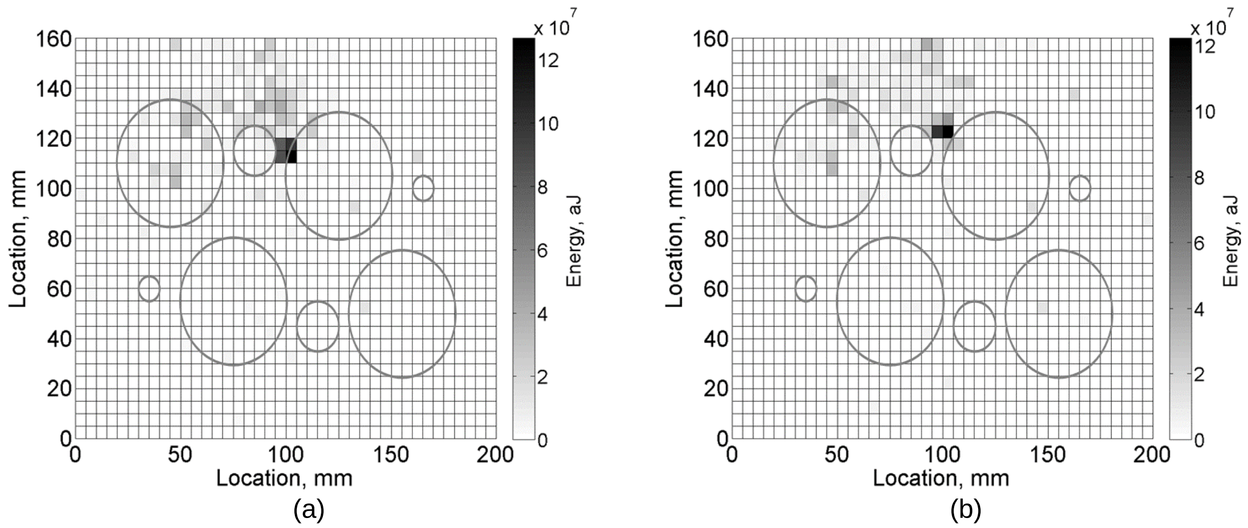


Figure 2 – AE source locations from the fatigue test with a) experimental and b) simulated training data

Conclusions

The use of LISA training data for input to the delta-t algorithm has shown very promising results and showed that the fatigue crack could be located using simulated training data. Also the accuracy of AE locations was similar to that of the experimental training data. The average Euclidean distance error for the experimental training data was 3mm whilst for the simulated training data the error was 8mm. This demonstrates great potential for the use of simulated training data to locate experimentally recorded AE events. This would dramatically reduce the implementation time in terms of operator hours in obtaining the training data, which would make the delta-t mapping technique more suitable for monitoring large scale structures.

References

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