

Fatigue Crack Monitoring Using an Additive Wave Analysis: a Hits Based Approach to Wavestreaming with Acoustic Emission

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Abstract

In Acoustic Emission (AE), wavestreaming approaches can be used to provide a clear indication of when changes occur in a process or structure. However, the conventional format of wavestream data collection can result in large amounts of noise being recorded, which can hinder analyses and drive up the power requirements of a structural health monitoring (SHM) system. In a bid to reduce the amount of noise recorded, a novel Additive Wave Analysis (AWA) is investigated. This technique uses AE hit data to mimic the wavestream approach, and as a result, does not suffer from the inclusion of vast periods of noise. To directly compare the results of an AWA to those from conventional wavestreaming, a pre-notched, 300M grade steel beam was restrained in a cantilever arrangement and subjected to a cyclic loading regime until substantial cracking had occurred. AE activity was monitored during this time in both hit format and wavestream format. The novel AWA conveyed results inline with those obtained using conventional wavestreaming, though incorporated just 18% of the data points, making it a more streamlined solution.

Introduction

Satisfying power requirements is one of the hurdles to developing of a fully realised Structural Health Monitoring (SHM) system. Incorporating large power reserves, such as batteries, will add mass. This is particularly undesirable when discussing SHM for aerospace applications, where an increase in mass is met with increases to both running costs and greenhouse gas emissions. Therefore, the power requirements of each component of an SHM should be kept to a minimum. Due to its high sensitivity, and passive nature, acoustic emission (AE) lends itself well to being incorporated as one of the damage detection elements of an SHM system. There are a number of ways in which AE data can be recorded; one such way is wavestreaming, in which small packets of AE are recorded periodically. This could be particularly useful for SHM as it would require less power than recording AE continuously. By comparing the parameters of wavestreams recorded at different times throughout a test it is possible to determine changes in the structure or process under investigation. For example, by comparing the RMS values of the wavestreams collected in a tensile fatigue test, Pullin et al [1] were able to identify the presence of impact damage in a carbon fibre composite panel. Mascaro et al [2], and Eaton et al [3] used wavestreaming to monitor the drilling process in a carbon fibre panel; the RMS of the wavestreams was used as an indication of the level of wear of the tool, and thus the quality of the hole being drilled. A windowed frequency analysis was then conducted on a wavestream-by-wavestream basis to determine the damage mechanisms which began to develop around the hole as the drill bit became more worn. Holford et al [4] experimented with a rolling cross-correlation approach to determine the presence of damage; wavestreams recorded after the onset of damage became increasingly irregular, due to the release of more AE, and thus correlated to a lower degree to the wavestreams recorded before damage occurred.

However, wavestreaming is not without its disadvantages. A typical wavestream contains several million data points. This makes their manipulation and analysis computationally intensive, and thus power demanding. Furthermore, wavestreams frequently contain only a small number of transient AE signals, meaning that the majority of the data is noise; this can act to skew frequency spectra and complicate attempts to extract useful information from the recording. To maintain the advantages that wavestreaming offers, whilst overcoming the issues involved with large data file sizes, a novel method of analysing hit data, called an Additive Wave Analysis (AWA), is presented. An AWA consists of consecutively adjoining the AE hits which are recorded within a specified time window to produce one, longer signal. The resulting additive wave signal closely resembles a wavestream recording, but excludes the vast periods of low amplitude noise which would have otherwise been included in a conventional wavestream. In this study, AE data recorded from a fatigue experiment is used to compare the results of an AWA to those from a conventional wavestream analysis, in order to determine their likeness and determine their effectiveness at monitoring the development of damage in the specimen.

Method

A 1000x70x20mm 300M grade steel bar was restrained in a cantilever arrangement. The specimen was notched prior to testing in order to accelerate crack development, and to provide a region in which damage could be expected to occur. Four MGL Nano 30 AE sensors (125-750kHz) were adhered to the specimen around the region of the notch, using Loctite 595 silicone sealant, in the positions shown in Fig 1. The sensors

were connected to PAC pre-amplifiers, each with built in frequency filters of 20-1200kHz, set to a gain of 40dB. The pre-amplifiers were connected to a PAL PCI-2 acquisition system which was used throughout the entirety of this testing to record AE data. The region of the specimen containing the notch was also monitored with Digital Imaging Correlation (DIC), an optical, full field displacement/strain measurement technique.

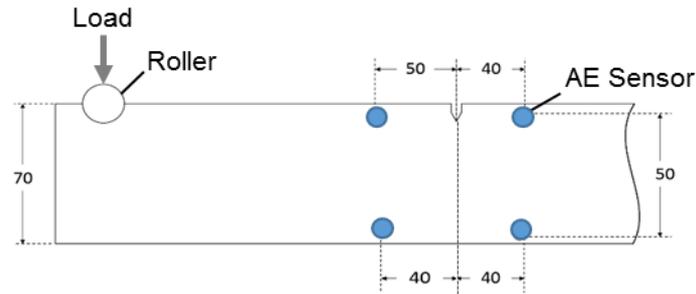


Fig 1: Position of AE sensors in region of notch

In order to develop a fatigue crack, the specimen was loaded cyclically from 0.5 to 11kN at a rate of 1Hz; the force was applied vertically downwards to a steel roller. Conventional AE hit activity was recorded for the entire duration of the experiment. As well as this, once every 500 cycles the AE acquisition system would trigger the collection of a 1.5 second long wavestream. The specimen was loaded for 67,099 cycles until significant cracking had occurred.

Results and Discussion

As shown in Fig 2, the trends in the RMS vales of the additive wave data and conventional wavestreaming data are very similar. The additive hits data typically has a higher amplitude RMS due to the fact that there is less noise in each data set to dilute the amplitude. Both sets of data display a marked rise in RMS around the 8000 second period, the same point in the test at which the DIC indicates that crack growth rate began to increase. Both techniques display larger RMS values as the experiment progresses, suggesting an increase in AE activity; a phenomenon indicative of higher rates of crack growth.

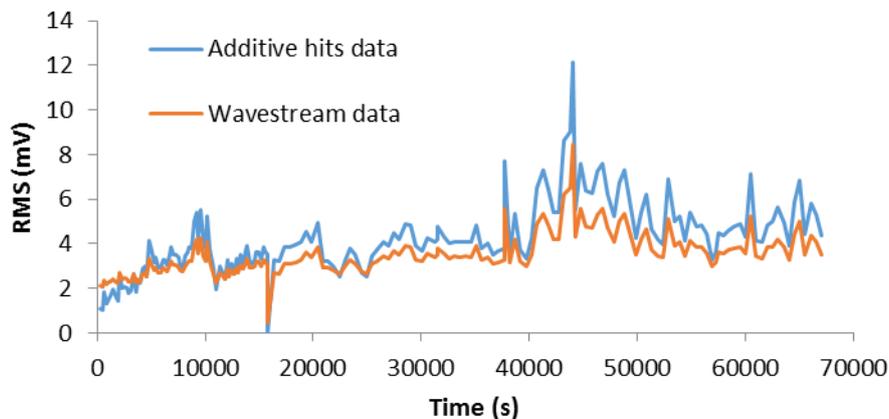


Fig 2: Comparison of RMS values of conventional wavestreams and additive waves data

Conclusion

Both the AWA and wavestream analyses were able to provide an indication of crack growth rate change in the specimen. The trends in the additive wave analysis closely matched those of the wavestream analysis. The additive wave data sets were, on average, just 17.5% of the size of the wavestream data sets. By incorporating less noise, the frequency spectra of the additive wave data set were also less skewed. Thus the novel additive wave approach offers a number of improvements over conventional wavestreaming without compromising the effectiveness of the analysis.

References

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