Geometry-induced effects in acoustic emission testing of composite structures

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Acoustic Emission (AE) is a promising non-destructive technique for structural health monitoring (SHM), capable of capturing transient elastic waves from microscale damage events. However, interpreting AE in composites is complicated by anisotropy, heterogeneity, and geometry-dependent wave behaviour.[1] As structures deviate from idealized lab conditions, effects such as dispersion, mode conversion, and signal distortion increase, reducing localization accuracy and limiting damage characterization.[2] Despite broad recognition of these challenges, geometry-induced distortion remains insufficiently quantified.

This investigation explores the impact of specimen geometry on AE signal behaviour in CFRP structures using a combined experimental-numerical approach. Finite Element Modelling (FEM) provides a controlled environment to isolate wave phenomena, enabling full-field measurements, and generating large data volumes for future pattern recognition and machine learning applications.[3] Experimental validation ensures simulation accuracy under real-world conditions. By integrating both approaches, this study achieves a more comprehensive and reliable analysis of geometry-induced effects on AE signal propagation.[4]

AE wave propagation was simulated using explicit dynamic finite element analysis and anisotropic material models, as depicted in figure 1. Pencil lead break (PLB) sources were used to generate broadband waveforms, extracting arrival times, waveform shapes, frequency spectra, and mode content. PLBs were chosen for their repeatability, broadband frequency content, and sensitivity to geometry.[5] Experiments were conducted on CFRP specimens matching the simulated geometries. PLB events were performed at multiple specimen locations, recording waveform, arrival time, and frequency data using a MATLAB-based AE acquisition system.

Simulation and experimental results were compared to assess AE signal behaviour, focusing on arrival times, waveform distortion, directional attenuation, and spectral characteristics. It identified geometry-induced effects on wave propagation and isolated distortion patterns linked to structural features. Post-processing will quantify localization error across different geometries, visualizing geometry distortion patterns as distortion maps.

This study presents experimentally validated simulation models for AE wave propagation in anisotropic composites, improving the accuracy and reliability of AE source localization in complex components. The findings also inform the development of geometry-aware features for machine learning-based damage classification, highlighting the potential of high-fidelity simulation as a scalable tool for AE analysis.

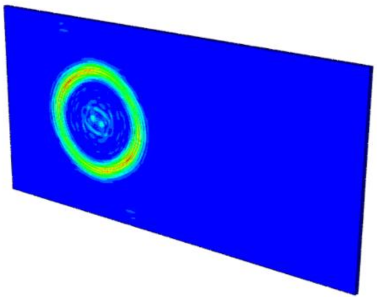

Figure 1: FEM simulation of the AE wavefront initiation and propagation from a PLB source in a CFRP plate

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