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SIMULATION OF DAMAGE INDUCED ACOUSTIC EMISSION IN LAMINATES

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ABSTRACT

A main challenge in acoustic emission (AE) monitoring of damage in composite materials consists in determining a link between the AE sources (*i.e.*, the damage mechanisms) and the acquired signals. This is essential in order to set-up robust damage mechanism classification approaches [1-3]. Establishing such a correspondence is not straightforward since the AE signals acquired by the sensors are actually the result of the initial source signal that propagated within a medium and that was transformed by a sensor. The AE signals depend not only on the damage source but also on the specimen geometry, the material properties and the type of sensor and acquisition chain [4].

Transverse cracking induced acoustic emission in carbon fiber/epoxy matrix composite laminates is studied both experimentally and numerically. Monotonic tensile tests are performed on AS4 carbon fiber (60 vol.%) embedded in epoxy resin [0_n/90_n/0_n] or [90_n/0_n/90_n] laminates (n=1 or 3, one ply thickness being 0.3 mm). Four AE sensors (two sensors of two different types) are fixed on the specimens to detect signals originating from damage mechanisms occurring within the composites. Each couple of sensors are placed on both sides of the specimen. For each acquired signal, both temporal and frequency descriptors are extracted from the signal and its fast Fourier transform (FFT). Floating amplitude thresholds (0.1% for the beginning and 5% for the end of the signal) are used for the signal time windowing. In addition to the experiments, finite element (FE) simulations of matrix transverse cracking in 90 deg. plies are set-up. Boundary conditions consist of prescribed displacements at the end of the specimen. The symmetry of the studied configuration enables modelling only 1/8 ([0_n/90_n/0_n]) or 1/4 ([90_n/0_n/90_n]) of the specimen (Figure 1a) and compare the AE signal characteristic to the ones measured experimentally (Figure 1b).

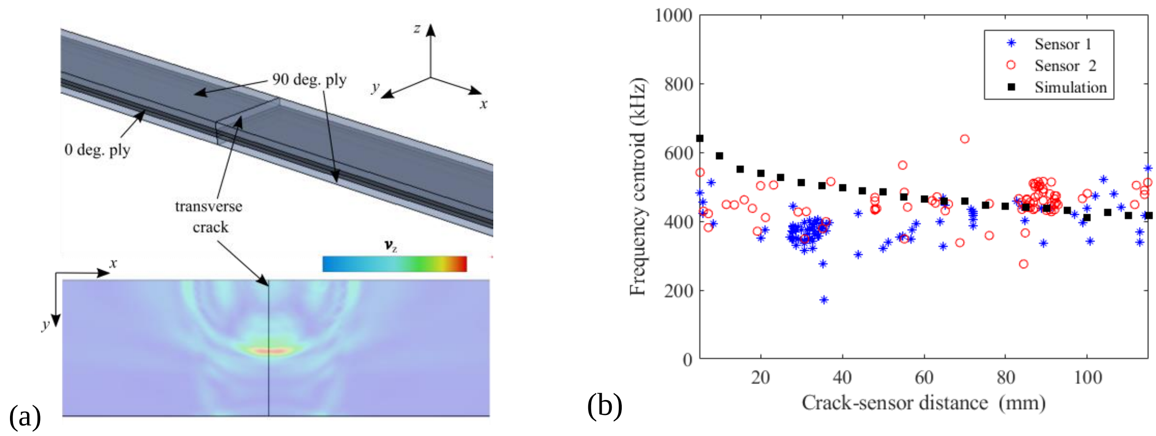

Figure 1: a) FE model of [90_n/0_n/90_n] laminates. Example of velocity field on the specimen surface. b) Frequency centroid variation as a function of the distance obtained numerically and experimentally.

A dynamic implicit solution is adopted in order to simulate first, transverse cracking nucleation dynamics and then acoustic wave propagation in the composite due to transverse cracking (Figure 1a). The mesh is refined in the vicinity of the transverse cracking location with at least 10 elements in one ply thickness, resulting in models containing approximately 500,000 degrees of freedom. Transverse cracking is modeled by progressively unbuttoning all the nodes along the crack surface during a given time at a loading level equal to the critical strain at first transverse cracking determined using finite fracture mechanics [5]. The maximum time step during the subsequent wave propagation is set to 10^{-7} s in order to consider a frequency range up to 1 MHz. AE signals are collected on a perfect punctual sensor at several distances from the transverse crack, from which temporal and frequency descriptors are calculated, such as e.g. the frequency centroid (Figure 2).

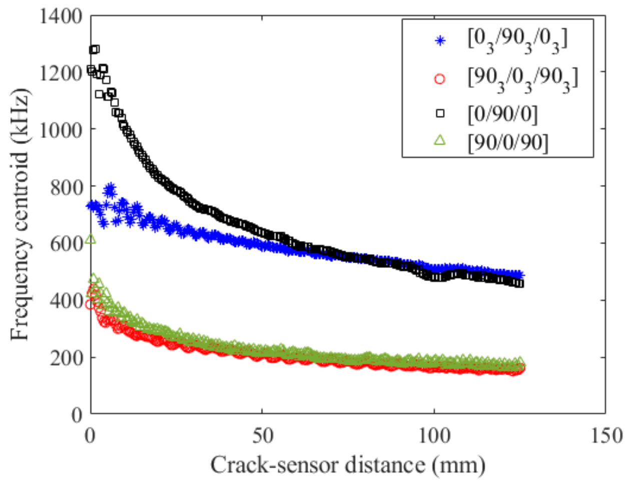

Figure 2: Frequency centroid variation as a function of the crack to sensor distance.

Results show that the influence of the ply thickness on AE signals acquired at the crack epicenter is significant only for inner ply transverse cracking. As a consequence, if classification approaches are set up, inner and outer ply transverse cracking should be considered as two different damage mechanisms since they lead to different signal descriptors depending on the ply thickness and location.

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