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Quantitative evaluation of orientation-specific damage using elastic waves and probability-based diagnostic imaging

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A B S T R A C T

Different from the damage with relatively smooth boundaries or edges such as a through-thickness hole or delamination which scatters elastic waves omnidirectionally, orientation-specific damage of sizable length in a particular dimension (e.g., a crack or a notch) often exerts strong directivity to elastic wave propagation. As a consequence the damage-scattered waves may not be captured efficiently by sensors at certain locations, posing a challenging issue to elastic-wave-based damage identification. In this study, the influence of damage orientation on Lamb wave propagation was quantitatively scrutinised. Based on the established correlation between damage parameters (location, orientation, shape and size) and extracted signal features, a probability-based diagnostic imaging approach was developed, in conjunction with use of an active sensor network in conformity to a pulse–echo configuration. Relying on enhancive signal features including both the temporal information and signal intensity, this imaging approach is capable of indicating the orientation of individual damage edges clearly and further shape/size of the damage. The effectiveness of the approach was demonstrated by predicting orientation-specific damage cases including a triangular through-thickness hole (through finite element simulation), a through-thickness crack and an L-shape crack (through experiment) in aluminium plates. With the assistance of a two-level synthetic image fusion scheme, all damage cases were visually and quantitatively highlighted in the probability images.

1. Introduction

Structural health monitoring (SHM) involves a paradigm of sensor selection and allocation, signal activation and sensing, data feature extraction and fusion, as a means of appropriately assessing the health conditions of a structure under the monitoring. In the past two decades there has been increasing awareness of introducing SHM to various industrial sectors. Successful implementation of such a technique can substantially enhance operational efficiency of an engineering system, drive down exorbitant maintenance costs and prolongate its lifespan. Amongst different SHM techniques, those based on the mechanism of the interaction between elastic waves and structural damage present many advantages over the others in terms of resolution, practicality and detectability. Of particular interests are Lamb waves, the modality of elastic waves confined in thin sheet-like structures (with planar dimensions being far greater than that of the thickness and with the wavelength being of the order of the sheet thickness). With features including strong penetration,

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