Lamb Wave Based Experimental and Finite Element Simulation Studies for Damage Detection in an Aluminium and a Composite Plate using Geodesic Algorithm

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The present research focuses on localizing structural damages in an aluminium and a woven fabric composite laminate. Finite Element (FE) and experimental simulation studies are carried out on specimens of these plates with and without damages, and the response data are collected at various sensor locations. Piezoelectric wafer (PW) transducers are used for actuation and reception of Lamb wave. The group velocity dispersion curves obtained through the experiment and simulation are compared with those obtained analytically to ensure effective actuation and sensing of Lamb wave. A Continuous Wavelet Transform (CWT) is used for receiving the arrival times of the wave reflected from the damages to the sensor locations. After acquiring arrival time data, the geodesic algorithm is employed to locate the damage in the specimens. The geodesic algorithm used is a two-step strategy initially using the Pythagorean Theorem to find the discrete geodesics in the structure, using mesh information and followed by locating the intersections of these geodesics to get the damage locations. Herein, the geodesic algorithm is shown to be effective in detecting several damages in a plate, both experimentally and through FE simulation.

1. INTRODUCTION

The process of implementing a damage detection method for civil, aerospace and mechanical engineering infrastructure is referred to as structural health monitoring (SHM). Damage is defined as a change in the material and/or geometric properties of these systems, which has an adverse effect on the system's performance. Several varieties of nondestructive tools are available for such monitoring.

Ultrasonic wave-based nondestructive evaluation (NDE) methods are widely used in investigating structures for the presence of damage, and, more recently, with a greater emphasis towards quantifying the damages; however, the conventional NDE methods, such as ultrasonic C-scan, thermography, or radiography, require the approximate location of damage to be known *a priori* and that the inspected region be directly accessible.

Further, if the structure is larger and of complex geometry, these NDE methods may not be suitable for monitoring such structures.[1] Among SHM techniques, more emphasis has been given to Lamb wave for years because of its efficiency in travelling long distances, and its propagation being affected by cracks and other structural defects.

Lamb wave-based NDE method has the potential to meet the capabilities, such as large coverage area of inspection, no need for direct access of the structure, and rapid inspection, without disassembly and adjustable frequency range for the investigation of various types of damage.[1]

A brief review about the Lamb wave-based damage detection literature is given here: Cesnik et al. gave an overview of damage prognosis, description of the basic methodology of guided wave SHM, and reviewed developments from the open literature of this multidisciplinary field.[2] Su et al. provided a comprehensive review on the Lamb wave-based damage identification approaches for composite structures.[3]

Beadle et al. studied the interaction of the first antisymmetric A_0 mode of Lamb wave in an aluminium plate with small surface notches.[4] Mofakhami et al. studied the Lamb wave propagation in an aluminium plate containing a circular hole with edge notches, both theoretically and experimentally.[5] Willberg et al. studied the use of Lamb wave for damage detection and nondestructive evaluation.[6]

Silva et al. studied a piezoelectric transducer network based system to be applied to aluminium and composite plates.[7] Kessler et al. presented the experimental and analytical survey of candidate methods for in situ damage detection of composite materials.[8] Yamada et al. studied the development of a new source location method using Lamb wave on anisotropic carbon fibre reinforced plastic plates.[9] Liu et al. studied a signal analysis method using a WT for nondestructive damage detection in the life cycle management of wind energy converters.[10]

Zabel et al. studied wavelet analysis for applying to the numerous problems within the general field of SMH.[11] Giurgiutui et al. presented the results of a systematic theoretical and experimental investigation of the fundamental aspects using PW active sensors to achieve embedded ultrasonics in thin gage beam and plate structures.[12] Finally, Gangadharan et al. proposed a geodesic-based approach using Lamb wave to locate a damage in an isotropic metallic plate.[1]

The studies presented in this literature[1] mainly focused on locating individual damage, and no FE simulation was carried out for locating them. The present work encompasses extensive experimental investigations to study the interaction of Lamb wave generated using PW transducers with damages in