Localization of Damages in Plain And Riveted Aluminium Specimens using Lamb Waves

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The Lamb wave-based localization of damage is presented here separately for the plain and riveted aluminium (Al) specimens. The first part of this paper deals with the experimental damage localization of the plain Al specimen using Lamb waves and four piezoelectric wafer (PW) transducers. The PW transducers mounted onto the specimen in a collocated way are used to actuate and sense Lamb waves. The responses are obtained for both the pristine and damaged states of the Al specimen. The signal processing is carried out on the residual response using the continuous wavelet transform (CWT), and time of arrival (TOA) data is obtained for each collocated actuator-sensor pair. The TOA data of the wave reflected from the damage is used in the two arrival time difference and astroid algorithms to locate the damage in an enclosed area. The genetic optimization (GO) method is used to further refine the location of damage within the enclosed area obtained using astroid algorithm. The second part of the paper deals with the localization of a faulty rivet in a riveted specimen. The responses are obtained in the cases of both healthy and faulty riveted specimens. The presence of a faulty rivet is indicated by the inflation in amplitude of the second harmonic. A new algorithm is therefore proposed by the authors to localize the faulty rivet, using the spectral content information. The results obtained through both the studies manifest the ability of the proposed methods for locating different types of defects and faulty rivets using an array of PW transducers.

1. INTRODUCTION

Structural health monitoring (SHM) refers to a system having the ability to anticipate and interpret the changes in a structure in order to improve the reliability of the system and thereby reducing the overall life-cycle costs. SHM of aircraft structures is a flourishing field and of paramount importance, as their failure may lead to loss in the economy, and most importantly, the loss of life. An aircraft usually operates in very savage conditions and because of this, there is a need to implement different types of non-destructive tests and evaluations. There are several inspection methods currently being applied to appraise the health of structures in service namely visual inspections, penetrant liquids, magnetic particle-based inspections, Eddy currents, radiography, and ultrasonic testing.[1–3] Most of these techniques are time consuming, costly, and need the structures under inspection to be in downtime. Among these, ultrasonic testing using Lamb waves has been studied for several years by many researchers. The Lamb wave-based testing offers many advantages, such as large inspection areas because of long distance propagation with lesser attenuation, no need of dismantling and direct access to the structures, and adjustable frequency range for investigation of different sizes of damages.[2,3] A damage detection system based on ultrasonic Lamb waves requires transducers for the actuating and sensing of elastic waves to interrogate the structures. The vital issues of concern for this system are the multimodal and dispersive nature of Lamb waves and the behaviour of the transducers in action. Due to this, various types of transducers have been invented, out of which piezoelectric wafer (PW) transducers have mustered much attention as they are cost-effective, small, and can be easily bonded onto the structure.[4] Lemistre et al. successfully detected the structural damage using Lamb waves generated by piezoelectric transducers.[5]

A lot of research is going on around the world for damage detection in metallic and composite plates using Lamb waves for past few decades. Raghavan and Cesnik presented the experimental and analytical survey of candidate methods used for damage detection in thin plate structures.[1] Giurgiutiu et al. gave a brief review of the Lamb wave principles with emphasis on understanding of the particle motion and group velocity dispersion.[2] Su et al. gave a comprehensive review on the state of the art of Lamb wave-based damage identification approaches for composite structures, addressing the advances and achievements in these techniques in the past decades, the unique characteristics and mechanisms of Lamb waves in laminated composites, approaches in wave mode selection, generation and collection, modelling and numerical simulation techniques, signal processing and identification algorithms, and sensor network technology for practical utility.[3]

Masurkar et al. presented an experimental and numerical