Aspects of Lamb-Wave Generation and Transmission

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This paper presents numerical and experimental results concerning Lamb-wave actuation and reception in metallic or layered composite panels and pipes. The numerical simulations were carried out with LS-Dyna, run under ANSYS platform. The main goals of this approach were to find better models for actuating Lamb waves and tracking the wave transmission in order to get efficient in situ structural health monitoring. Prior adequate choice of the signal frequency using the dispersion curves proved to be beneficial for better transmission, in terms of signal detection, and it extended inspection range. The effects of the transducer-inspected item interface and transducer shape on the wave transmission were also evaluated. Signal generation with rectangular transducers, batteries of round piezoceramic transducer (PZT) patches or the use of prisms, which value Snell's law, were alternatively considered for getting guided waves in the inspected item. The experiments showed the performance of various transducers and devices used on the experimental chain. The Lamb waves were generated by PZT, in various shapes and configurations, aiming to lower the inspection cost. Experiments always aligned with theoretical results so that robust models could be selected for further investigations.

1. INTRODUCTION

Composite materials are a widespread class of advanced materials, with applications in various fields, from everyday–use products to high–tech structures. The special demands concerning reliability of the latter items require sound non–destructive evaluation (NDE) methods for monitoring their structural health. The Lamb-wave method has been applied in recent years for inspecting composite panels and shells, and researchers hope to extend a rather short list of available, trusted global inspection methods. The promising advantages of the method, mainly the possibility of combining long-range inspections with local inspections and the versatility that encourages in situ structural health assessment, are balanced for the moment by a number of difficulties yet to be overcome.

Various aspects concerning the generation, transmission, and reception of Lamb waves have already been investigated in a number of works by reputable scientists. The optical methods–high–power, ultrasonic contactless loudspeakers and classical–contact ultrasonic transducers–have been used in various applications in past decades.[1–3] Piezoceramic transducers of different types have become dominant in the applications mentioned in literature in the last 15 years.[4–7] The generally low cost and versatility in mounting on the inspected item, including within a network or measurement chain, still support their widespread use. The shape of the inspected structures created extra difficulties, composite pipes proving much more difficult for any transducer to inspect than composite plates or shells, due to a much higher diversity of wave modes.[8] Other difficult case studies, like the inspection of sandwich–type structures, repaired structures, or rib–stiffened composite structures, have been carried out adequately.[9, 10]

The necessary use of adequate actuation for obtaining certain modes, such as long-range transmission and sensitive interaction with flaws or damages, was another highly valued aspect many researchers followed. This issue was generally followed with adequate numerical modeling of Lamb–wave generation, transmission, and receiving.[9–13] In recent years, several authors performed a more complex analysis, using a multiphysics approach.[12–17] A way to simplify such complex and time–consuming simulation–shifting to structural–only models is presented in Ref.[17]

This work attempts to contribute ideas concerning the possibilities of better simulating generation and transmission of Lamb waves, considering the shape of the transducer, the interface with the inspected item, and consequent modeling techniques. It also outlines the necessity of having a prior selection of frequencies in the least–dispersive ranges revealed by the dispersion curves in order to get higher–quality signal generation and transmission. Our experiments further supported the attempt to build robust numerical models by evaluating the Lamb–wave generation and transmission, produced by various transducers and devices.

2. MODELING OF LAMB-WAVE PROPAGATION

2.1. Introductory Theoretical Aspects

Guided waves can usually be actuated using traditional or modified ultrasonic transducers and a large class of piezoelectric transducers. Such transducers can range from rather expensive patches or wafers to cheap circular or rectangular buzzers. Mounting these transducers on the surface of the inspected shell by stiff bonding leads to complex actuation and phenomena reception, which have to be simulated by a multiphysics approach.[12–17] Such additional difficulties are skipped in the case of a removable transducer, having a weak interface with the inspected item.

Lamb–wave generation and propagation can be modeled using a piezoelectric–structural coupling finite-element analysis. Piezoelectric modeling consists of the coupling of structural and electric fields, exploiting the natural material properties of quartz and ceramics. A voltage difference applied to a piezo-