Lamb Waves Topological Imaging of Multiple Blind Defects in an Isotropic Plate

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The study investigates the feasibility of the Lamb wave topological imaging method for detecting multiple blind-holes in an isotropic plate. The topological imaging method is performed based on the computations of two wave fields, a forward and an adjoint, in the defect-free reference medium using different emitting sources. The image is computed by multiplying the forward and adjoint wave fields together and integrating them over time or frequency. The interferences of multimode aliasing and the scattering effect can thus be eliminated at the defect-free positions with an improved image resolution. To investigate the physical mechanism, the refocusing process of the multimode Lamb waves at the defect positions is presented by a face-to-face comparison between the snapshots of the forward and adjoint wave fields using the finite element simulation. The Lamb wave topological imaging method is numerically and experimentally verified to identify multiple blind-holes in an isotropic aluminium plate. The results demonstrate that the topological imaging method enables the suppression of the artefacts resulting from the mode conversion and achieve high-resolution imaging of the blind defects.

1. INTRODUCTION

The inverse scattering imaging has attracted considerable attentions in the biomedical engineering, industrial nondestructive testing and geophysics. Diffraction tomography, developed from inverse scattering algorithm, is capable of rapidly fulfilling the tomography imaging by using the Fast Fourier Transform (FFT) under the Born approximation assumption. However, the application of diffraction tomography is limited since Born approximation assumption is only applicable to the weak scattering case.

The topological optimization method has been applied to ultrasonic bulk wave imaging. The topological asymptote is applied and the defect imaging can be obtained without the prior assumptions of locations and shapes of defects. This method is derived from the shape optimization in mathematics. Early in 1994, Eschenauer et al. proposed the concept of topological gradient for topological optimization of mechanical structures. In 2001, Garreau et al. developed an asymptotic expansion in the context of linear elasticity for general functional and arbitrary shaped holes by using an adaptation of the adjoint method and a domain truncation technique. The proposed method was general and can be readily adapted to other linear partial differential equation and other types of boundary conditions. In 2004, Bonnet and Guzina extended the topological derivative to solve elastic wave inverse scattering problem. They illustrated the methodology enables to characterize the topological differentia towards the gradient-based imaging. In the field of ultrasonic nondestructive inspection, Gallego et al. conducted the inspection of crack and chamber defects using topological sensitivity boundary integral method. Topological gradient method has been used to achieve a high resolution imaging. However, the method requires many iterations. Subsequently, the researchers began to explore the use of other fast imaging methods, for instance the time domain topological energy method proposed by Dominguez and Gibiat and frequency domain topological imaging by Rodriguez et al. Owing to the refocusing properties of the time-reversal for the scatterers, an accurate image could be readily obtained by solving two wave propagation problems in an homogeneous medium. Despite the iterative nature of the topological method, a single iteration leaded to an accurate image. Basing on the improvement of the topological imaging theory and algorithm, the experimental works are carried out successively. Tokmashev et al. has conducted the experimental investigation of elastic wave topological sensitivity for the aluminum plate with dual defects of a circular hole and a rectangular slit using a single longitudinal piezoelectric trans-