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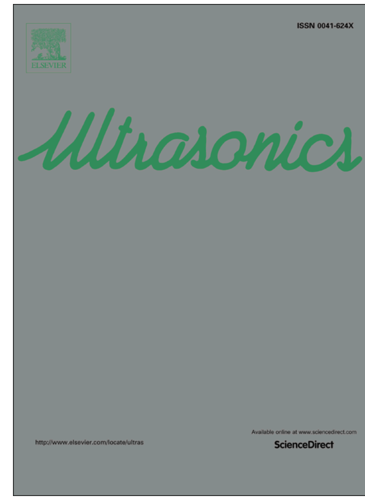

Characterisation of hidden defects using the near-field ultrasonic enhancement of Lamb waves

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Characterisation of hidden defects using the near-field ultrasonic enhancement of Lamb waves

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Abstract

Defects that propagate from the inside of a structure can be difficult to detect by traditional non-destructive inspection methods. A non-contact inspection method is presented here that uses the near-field interactions of ultrasonic Lamb waves to detect defects propagating into a 1.5 mm thick aluminium sheet from the opposite side to that which is inspected. Near-field interactions of the S0 Lamb waves with the defects are shown to give rise to a characteristic increase in the wave magnitude, which is used to position and characterise these hidden defects. It is shown that such defects are difficult to detect from a study of their influence on ultrasonic transmission alone. Single defects of different depths, and systems of multiple defects with varying separations and relative depths, are successfully detected in both experimental trials and FEM simulations. Reliable single defect detection is achieved for defects with a minimum depth of 30% of the plate thickness, and resolution of multiple defects is achieved for defect separations of 5 mm.

Keywords: Lamb Waves, Scanning Laser Detection, Stress Corrosion Cracking, Enhancement

1. Introduction

Early detection of cracking in industrial applications allows replacement of the faulty part, preventing component failures which are costly both in economic and environmental terms [1]. Surface-breaking cracks, such as defects caused by stress-corrosion cracking (SCC), in which defect growth occurs when a material is placed under stress in a corrosive environment, are of concern in industrial pipework and chemical storage systems [1–4]. SCC defects typically have a size scale of several millimetres with a complicated branched structure, and can occur singly or in groups of defects located close together [1].

Such defects are traditionally detected using dye penetrant inspection, however, the application of this technique requires extended downtime of the system under test as the inspection cannot be done during operation [5,6]. Dye penetrant inspection also requires direct access to the damaged surface and so success is limited when access to the object under test is restricted. Radiographic inspection can also be employed to detect these types of defects, however, safety concerns arising from the use of ionising radiation can limit the application in industrial settings [7].

Ultrasonic inspection is an attractive alternative to dye penetrant inspection, however, conventional piezoelectric ultrasonic transducers require the use of couplant, and as such have a limited capacity for scanning large samples or at elevated temperatures [4,8–10]. The use of non-contact ultrasonic generation and detection methods, such as laser ultrasonics [11] and electromagnetic acoustic transducers (EMATs) [12] removes the need for couplant, and thereby provides the potential to perform simple scanning inspections on components [13].

The use of ultrasonic waves with displacements throughout the thickness of a material, such as Lamb waves in sheets and guided waves in pipes [14,15], enables inspection of areas of the system that cannot be accessed directly, such as the internal surface of a pipe [8,16]. Several long-distance ultrasonic inspection methods exist that monitor in the defect far-field (defined as the region starting at a distance of several wavelengths away from the defect [17]) through changes in the reflection or transmission of guided waves as they interact with surface-breaking defects, and these methods are capable of estimating the position and depth of defects over a distance of several metres [8,9]. However, the reflectivity of small, shallow defects is low, which restricts the size of defects that can be detected by this far-field approach. The am-

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