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Detection of a Crack on a Plate by an IDT Type Lamb Wave Transducer

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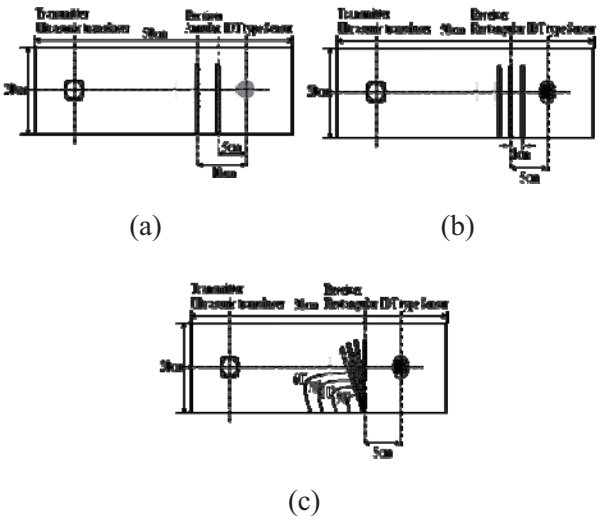
1. Introduction

Lamb waves are widely employed for the structure health monitoring system using elastic waves [1,2]. It has attracted many researcher's attention because Lamb waves propagate in the whole thickness of a plate over a wide range without energy dissipation. Accourding to many recent researches, the Lamb wave has been mostly generated by PZT patch sensors. The problems with the patch sensors are that beam pattern of the sensors is controllable, thus the sensor is vulnerable to noises including the effects of unexpected reflection from structural boundaries. Besides, once the PZT element is given, the operation frequeny of the sensor can not be modified due to its fixed resonant frequency. For that reason, in this paper, an inter-digital transducer (IDT) type sensors have been developed to overcome the problems of the patch sensor. For the IDT sensor, the operation frequency and the directionality can be very easily modified by changing the IDT finger pattern.

In this work, two different IDT type sensors are designed and applied to estimate the length, number and orientation of cracks in an aluminum plate by Lamb waves. The two sensor types are omni-directional annular IDT sensor and uni-directional rectangular IDT sensor [3]. The amplitude and time of flight (TOF) variation of Lamb waves are analyzed in accordance to the crack geometry, then the feasibility of the proposed IDT sensor is verified.

2. Scheme of crack imposition

The experimental scheme is presented in **Fig.1**. Artificial cracks were imposed on aluminum plates of the dimensions 50 cm long, 20 cm wide, and 1 mm thick. A bulk wave ultrasonic transducer with the center frequency of 1 MHz was used to launch the Lamb along the plate. The excited Lamb wave was received by the IDT sensor placed at the other end of the plate. The Lamb wave propagates along the plate experiencing the effects of any cracks imposed on its propagation path. Hence, analysis of the wave properties such as amplitude and TOF can reveal the configuration of the cracks. Annular IDT sensor can receive the Lamb wave coming from everywhere while the rectangular IDT sensor can receive the Lamb wave coming straight from the bulk wave transducer.



(a) (b)

(c)

Fig. 1 The scenario of crack imposition: (a) variation of crack length, (b) variation of crack number, and (c) variation of the crack orientation.

3. Length of cracks

The length of cracks could be estimated with the through transmission signal as shown in **Fig. 2**. TOF values of both annular and rectangular IDT sensors were constant until the crack becomes 9 cm long. When the crack intruded the beam width from 9cm to 11cm, TOF gradually increased. For the signal amplitude, the annular IDT sensor was sensitive in the range outside the beam width, while the rectangular IDT sensor reacted only to the crack having its length within the beam width. Thus we could confirm experimentally that annular IDT sensor was omni-directional whereas the rectangular IDT sensor was highly uni-directional.

4. Number of cracks

The number of cracks could also be identified with the through transmission signal as shown in **Fig. 3**. Although the TOF of both the annular and rectangular IDT sensors increased with the number of cracks, the TOF from the annular IDT sensor were influenced by edge of the plate. Amplitude of annular IDT sensor was constant while that of the

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rectangular IDT sensor gradually decreased with the number of cracks.

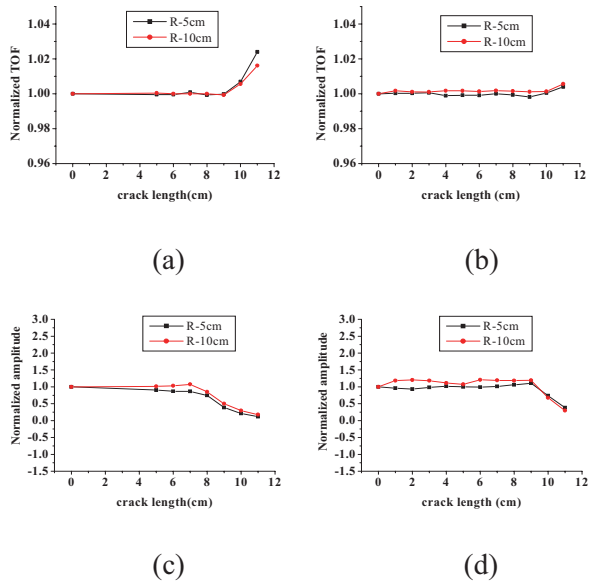

Fig. 2 The variation of TOF and amplitude in response to the length of cracks: (a) annular IDT sensor, (b) rectangular IDT sensor, (c) annular IDT sensor and (d) rectangular IDT sensor.

5. Angle of cracks

The angle of cracks was also estimated by means of the TOF and amplitude of the through transmission signal as shown **Fig. 4**. TOF of annular IDT sensor gradually increased as the angle of cracks grew up. However, TOF of the rectangular IDT sensor remained almost constant with respect to the variation of the crack's angle because the position of crack's tip altered, too, in proportion to the angle of crack. Amplitude of the annular IDT sensor gradually decreased while that of the rectangular IDT sensor increased with the angle of cracks. Scattering of the Lamb waves at the tip of the crack is responsible for the variation in Fig. 4. [4].

6. Conclusions

Two different IDT type sensors were proposed and applied to estimate the length, number and orientation of cracks in an aluminum plate by Lamb waves. The amplitude and TOF variation of the Lamb waves were analyzed in accordance with the crack geometry to verify the feasibility of the proposed IDT sensor.

Acknowledgment

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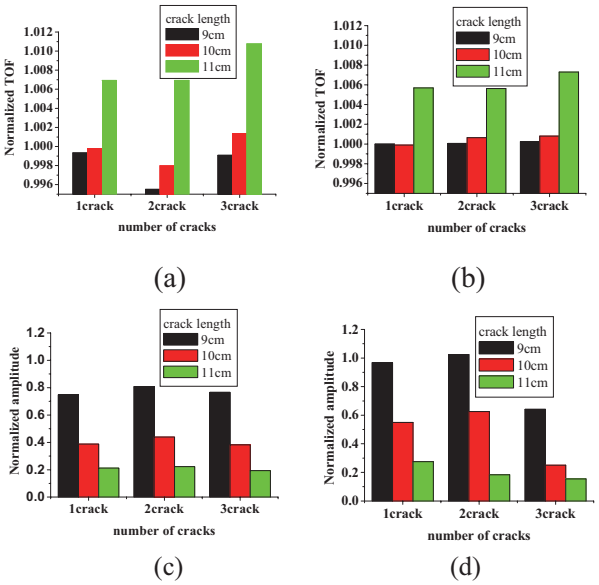

Fig. 3 The variation of TOF and amplitude in relation to the number of cracks: (a) annular IDT sensor, (b) rectangular IDT sensor, (c) annular IDT sensor and (d) rectangular IDT sensor.

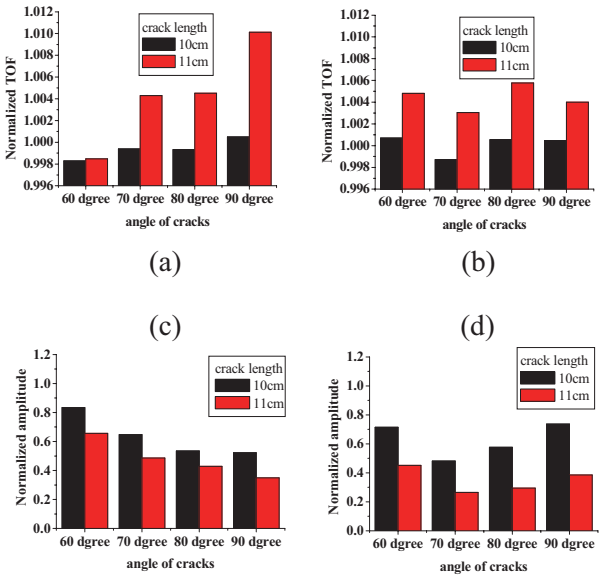

Fig. 4 The variation of TOF and amplitude in relation to the angle of cracks: (a) annular IDT sensor, (b) rectangular IDT sensor, (c) annular IDT sensor and (d) rectangular IDT sensor.