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Proceedings of Symposium on Ultrasonic Electronics, Vol. 32 (2011) pp. 203-204
8-10 November, 2011

Observation of Lamb Wave in Metal Plate Having a Notch Type Defect

ノッチ型欠陥を有する金属板中を伝搬する Lamb 波の観測

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1. Introduction

Ultrasonic waves are frequently used in the pulse-echo and pulse transmission methods for the detection of defects. Recentry, plate waves have been employed in the nondestructive evaluation (NDE) of material[1]. Guided waves such as Lamb waves have the unique feature of propagating a great distance in plates and cylindrical structures[2]. The propagation of Lamb waves in a plate is affected by the thickness d of the material and the frequency f of the ultrasonic waves. Propagation behavior in a plate having varying thickness might be useful to obtain information about defects. However, the behavior of Lamb waves at the defect are very complex. So the experimental research about Lamb waves propagation in plate of varying thickness has only been reported[3]. The propagation of Lamb waves in a plate of varying thickness is important for the NDE.

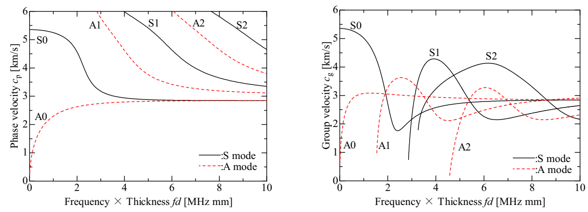
In this paper, as a gradual approach to clarify the propagation of Lamb waves in a plate of varying thickness, the propagation of Lamb waves in an aluminum plate having a notch type defect is experimentally observed using optical method.

2. Generation of Lamb waves

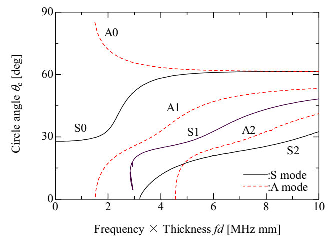
The propagation mode of Lamb wave in a plate depends on both the thickness d of material and the frequency f of the ultrasonic. The propagation of Lamb waves can be calculated by the Rayleigh-Lamb equation. Dispersion curves of the phase velocity c_p and group velocity c_g in an aluminum plate (longitudinal wave velocity c_L = 6410 m/s, shear wave velocity c_T = 3040 m/s) are shown in Fig.1 (a) and (b), respectively. Lamb waves can be effectively exited when the incident angle θ_c satisfies phase matching condition. This angle is calculated from Snell's law as

$$\theta_c = \sin^{-1}\frac{c_w}{c_p}, \qquad (1)$$

Where c_w (=2500 m/s) is ultrasonic wave velocity in the wedges seen in Fig.2. Dispersion curves of the critical angle in aluminum plate are calculated and shown in Fig.1(c). The thickness d = 1 mm and frequency f = 2.0 MHz are selected to excite the Lamb waves. When fd = 2.0 MHz mm, the incident angle θ_c is 72° for the effective generation of A0-mode Lamb wave.



(a) Phase velocity c_p (b) Group velocity c_g



(c) Critical angle θ_c

Fig.1 Dispersion curves of Lamb wave in aluminum plate

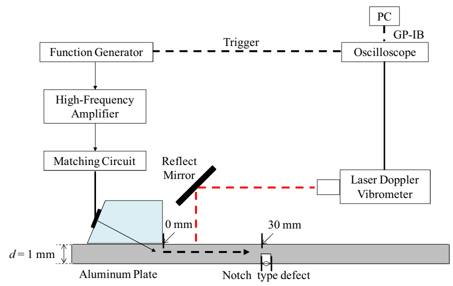


Fig.2 Experiment setup for measuring the surface vibrations of Lamb waves by optical observation

3. Experimental Method and Result

The measurement system for the Lamb wave is shown in Fig.2. A transmission signal comprising 10 bursts of 2 MHz, 130 V_{p-p} sinusoidal voltage was applied to the transducer. A Lamb waves from transducer propagates in the aluminum plate and is optically detected by a laser vibrometer. The beam

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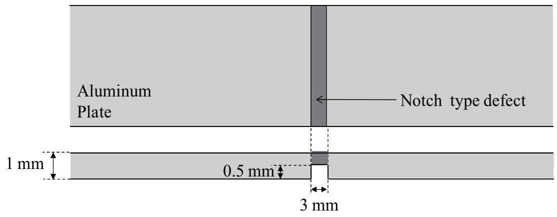


Fig.3 Geometry of the aluminum plate used in the experiment

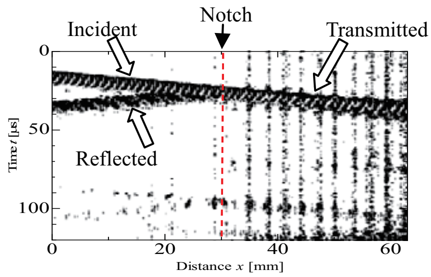
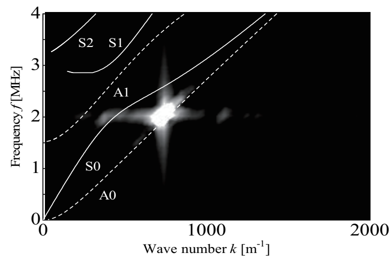


Fig.4 $x-t$ distribution of received waveforms

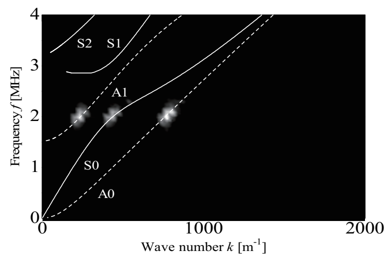
of the laser vibrometer scanned along the direction of Lamb wave propagation from x = 0 mm to 63 mm at intervals of 0.5 mm. Surface vibrations of Lamb waves at each point were measured. Vibrating waveforms from the laser vibrometer were digitized by oscilloscope and fed into a personal computer via a general purpose interface bus (GP-IG). The aluminum plate decrease in thickness by notch type defect is illustrated in Fig.3.

The two-dimensional distribution of the propagation distance x and time t of the waveforms determined by the measurement system is shown in Fig.4.

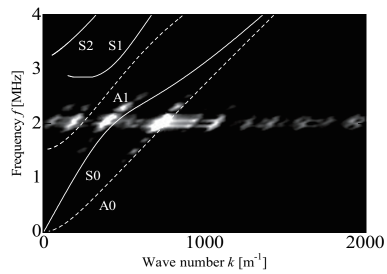
A two-dimensional Fourier transform method was introduced to discriminate the propagation mode of a Lamb wave. The $k-f$ distribution determined from the two-dimensional Fourier transform of the $x-t$ distribution is shown in Fig.5 (a), (b), and (c). The k-f distribution peak at incident wave region corresponds to the dispersion curve of the A0 mode Lamb wave. Peaks at reflected wave region correspond to dispersion curve of both the A0-mode, S0-mode, and A1-mode waves. Peaks at transmitted wave region correspond to dispersion curve of both the A0-mode, S0-mode, and A1-mode waves. These results imply that A0-mode Lamb waves were converted to S0-mode, and A1-mode Lamb waves at the defect border region.



(a) incident wave region



(b) reflected wave region



(c) transmitted wave region

Fig.5 k - f images obtained by two-dimensional Fourier Transform with the theoretical dispersion curves for d = 1 mm

4. Conclusions

Lamb wave propagation in an aluminum plate with notch type defect was measured optically to exploit the effect of thickness of plate. Conversion from an A0-mode Lamb wave to a S0 and A1-mode wave at the defect border in aluminum plate was observed. This mode conversion from the A0-mode Lamb waves to S0-mode, A1-mode Lamb waves were occurred by the thickness change in notch type defect. Therefore, observation of the mode properties of Lamb waves would be useful in identify the varying thickness in plates and pipes.

References

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