Original
Received October 26, 2012
Accepted for Publication November 25, 2012

Experimental Study on the Mode Conversion of Lamb Wave Using a Metal Plate Having a Notch Type Defect

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Propagation of Lamb wave in an aluminum plate having a notch type defect is observed. Lamb waves passing through the aluminum plate were analyzed by two-dimensional Fourier transform (2D-FFT) to discriminate the modes and their mode conversions. A0-mode Lamb waves which is transmitted into aluminum plate is discriminated using the 2D-FFT charts. The mode conversion from A0 to S0 and A1-mode waves by the notch type defect is clearly detected in the reflected and the transmitted waves. The suggestive result that the ratio of S0 or A1 to A0 indicates the degree of damage has been described. Possibility of a Lamb wave method for detecting defect such as ablation, wear and wall reduction is also referred.

Key Words : Lamb wave, Mode conversion, notch type defect, two -dimensional Fourier transform

1. Introduction

Ultrasonic waves are frequently used in the pulse-echo and pulse transmission methods for the detection of defects in the material. Recently, plate waves have been employed in the nondestructive evaluation (NDE) of materials[1,2]. Guided waves such as Lamb waves have the unique feature of propagation of great distance in the plate or cylindrical structures[3]. In the Lamb measurement, defects in the material can be quickly detected with one time measurement compared with the point-to-point measurement such as ordinal bulk wave inspection. In the NDE systems employing for a metal plate or pipe structures, Lamb waves or Rayleigh waves have only recently been constructed with a tilted angle polarization type piezoelectric transducer[4] or air-coupled ultrasonic waves in the megahertz range by the authors[5,6].

As is known widely in the Lamb wave studies, the propagation of Lamb waves in a plate is extensively affected by the thickness d of materials and the frequency f of the ultrasonic waves. Studies on the propagation behaviors in the plate having varying thicknesses might be useful for obtaining the information about defects.

However, the behaviors of Lamb waves propagation around the defect are very complex[7,8], so that few theoretical research has been conducted. Therefore, only experimental research about Lamb waves propagation in plate of varying thickness has been reported[9,10]. To understand the propagation behavior of Lamb waves in a plate of varying thicknesses is very important for the NDE or health monitoring to evaluate the properties such as wear, abrasion and corrosion-induced wall reduction etc..

In this paper, the propagation of Lamb waves in an aluminum plate having a notch type defect is experimentally observed using optical detection method to clarify the propagation characteristics of Lamb waves. The mode conversion of Lamb waves in an aluminum plate and its possibilities of use in NDE will be discussed.

2. Propagation characteristic of Lamb wave

2.1 Generation of Lamb wave

The propagation modes of Lamb wave in plate depends on both the thickness d of materials and the frequency f of the ultrasonic waves. The propagation characteristics of Lamb waves can be calculated by the Rayleigh-Lamb equations. Dispersion curves of phase velocity c_p and group velocity c_g in aluminum plate (longitudinal wave velocity $c_L = 6410$ m/s, shear wave velocity $c_T = 3040$ m/s) are shown in Figures. 1(a) and (b), respectively. Group velocity c_g was calculated as,

$$c_g = \frac{c_p{}^2}{c_p - fd \cdot \frac{dc_p}{d(fd)}} \tag{1}$$

Lamb wave can be efficiently excited when the incident angle θ_c satisfies phase matching condition[3,4]. This angle is calculated from the Snell's law as,

$$\theta_c = \sin^{-1} \frac{c_w}{c_p} . \tag{2}$$

Where c_w (=2500 m/s) is the ultrasonic wave velocity in a wedge which exists between a piezoelectric transducer and the plate to insure the oblique incidence of sound wave. Figure 1 shows the dispersion curves of the critical angle θ_c in aluminum plate. Thickness $d = 1.0$ mm and frequency $f = 2.0$ MHz are selected to excite the A0 mode Lamb waves because A0 mode Lamb wave has relatively constant group velocity c_g, small velocity dispersion in other word, as shown in Figure 1(b). When $fd = 2.0$ MHz mm, the incidence angle θ_c is 72° for the phase matching condition to excite the A0-mode Lamb wave in the aluminum plate.