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Experimental Study of Thickness Distribution Imaging Using Laser Source Scanning

Muhammad Nor Salim‡, Takahiro Hayashi, Morimasa Murase, Toshihiro Ito, and Shoji Kamiya (Faculty of Engineering, Nagoya Institute of Technology, Japan)

1. Introduction

Guided wave techniques are well known for a rapid inspection of large structures at a minimum cost. Pitch-catch method using piezoelectric type transducers, EMATs, and magnetostrictive sensors are generally adopted for guided wave inspections in plates and pipes. Although defects can easily be located in the guided wave inspection, remaining thickness of plates and pipes, which is the most important factor in maintenances of oil storage tanks and pipe networks, are not evaluated. This study proposed rapid thickness measurement technique by scanning laser source over the surface of plates. The Lamb waves were excited by heating the surface of the plates with laser beams and detected by an angle beam transducer[1], which offers a fast screening with a high spatial resolution. This technique also has an advantage to perform a remote measurement without the requirement of retaining the focal length and direction of the laser beam which is required in measurement of guided wave using a laser Doppler vibrometer.

Measurement of A0 mode that propagates from the scanning points in plates was performed using a fixed angle-beam transducer placed at the end of plate. The results successfully represented the distribution of thickness in plate with greater amplitudes in defect regions and smaller amplitudes in intact regions.

2. Principle of Imaging Technique

From the simulations in previous studies[2], high amplitudes of A0 mode were observed in defect region compared to the intact regions as shown in **Fig. 1**.

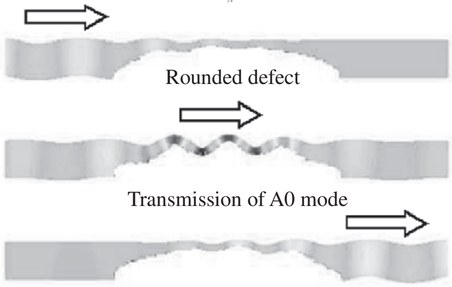

Fig. 1 Propagation of A0 mode through defect.

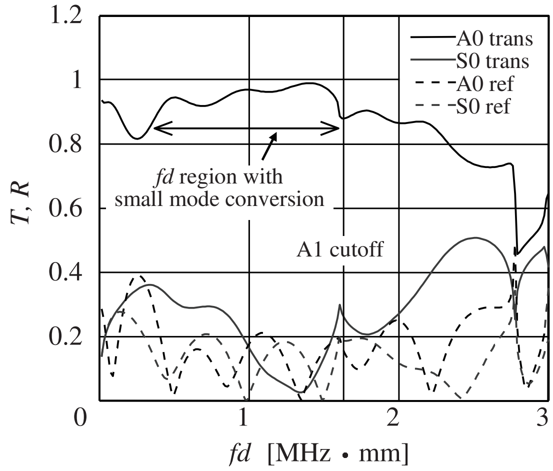

Fig. 2 Transmission and reflection ratios.

The antisymmetric A0 mode of the Lamb waves was also found to exhibits high transmission ratio through defect in a test plate as in **Fig 2**.

Using the reciprocal theorem, high amplitudes of A0 mode also can be obtained from the transducer placed at the end of the plate when the laser source was scanned over the defect region as shown in the next section.

3. Experiments

Two different depths of grooves at 1 mm and 2 mm in maximum depth were made on two aluminium plates using a ball end mill. The scanning laser source used consists of a Q-switched Nd:YAG pulse laser (Quantel Brilliant Ultra, 532 nm wavelength, 20 Hz rate, 7.2 ns pulse duration, and 32 mJ pulse energy) as shown in **Fig. 3**. The energy of the laser beam was reduced using an attenuator to avoid damages on the surfaces of galvo mirrors and the test plates. The 1 mm of slit was used to change the laser spot diameter of 3 mm into a line source of about 1 mm width and 3 mm length to improve the spatial resolution of the images. This line source was scanned in *x* and *y* directions using the 2-axis galvo mirrors at 160 x 120 points over scanning region of 80 x 60 mm2 for the test plates with 2 types of defects. The scanning process was automated using a LabVIEW that sent signals to the galvo mirrors to control the location of scanning locations on the plates and laser source to control the output of pulse laser. An angle-beam

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chd16510@stn.nitech.ac.jp

piezoelectric transducer with the central frequency of 400 kHz were placed at the end of the plates on the same surface of the laser excitation region to measure the A0 mode that propagated from the scanning locations.

The measured RF signals of A0 mode from the transducer were sent to a 1 MHz analog low-pass filter to remove the high frequency noise before being amplified by 60 dB. The signals were then sampled at 5 MHz sampling frequency and filtered using a 400 kHz of fourth-order Butterworth digital low-pass filter to extract the component of A0 mode below the cut-off frequency of A1 modes as in **Fig. 4**. The final maximum amplitude of A0 mode at each scanning location was used to indicate the thickness distribution.

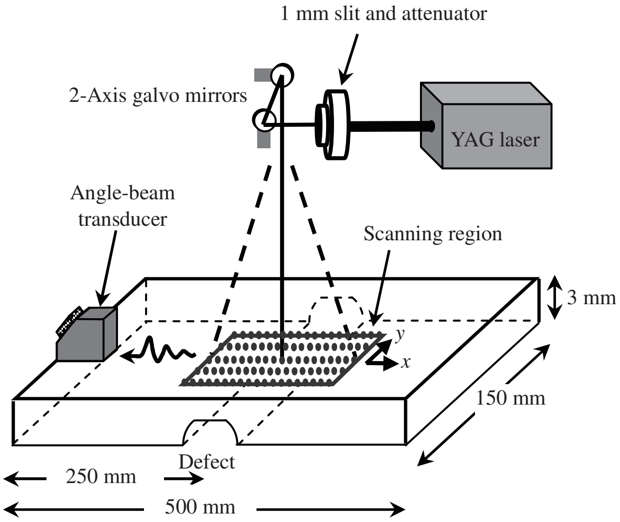

Fig. 3 Laser source scanning system.

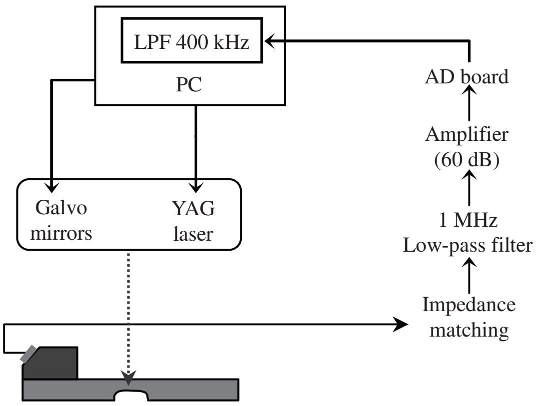

Fig. 4 Signal processing in measurement.

4. Results

The thickness distributions obtained from the laser scanning over plates with grooves of 1 mm and 2 mm of maximum depths are shown in **Figs. 5-6**. From the images, we observed that the difference in amplitudes become greater as the defect depth increases from 1 mm to 2 mm. This increase in defect depth is equivalent to the decrease in the remaining thickness of the plate and the thickness distribution can be evaluated in mm to show the actual decrease of thickness in plates.

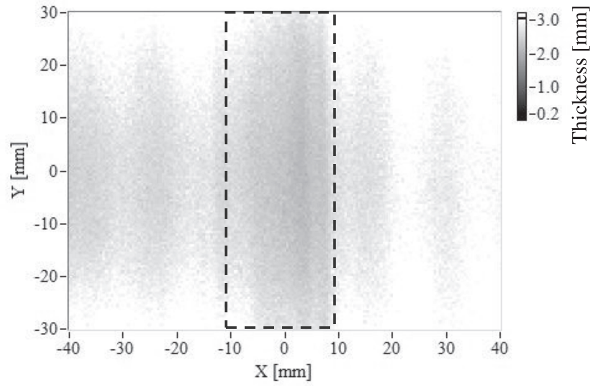

Fig. 5 Thickness distribution measured from the flat surface side of the plate with a grove of 1 mm of maximum depth.

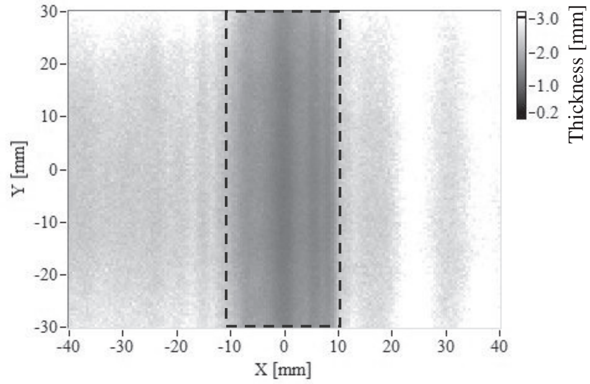

Fig. 6 Thickness distribution measured from the flat surface side of the plate with a grove of 2 mm of maximum depth.

5. Conclusion

Amplitudes of the excited A0 mode were used to indicate the thickness distribution in plates. This potential of nondestructive testing can be applied to locate defects and evaluate the remaining thickness of plates and pipes, which is usually the most important factor in maintenances of oil storage tanks and pipe networks that are not evaluated in typical guided wave inspection technique.

References

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2. T. Hayashi, M. Murase, and M. Nor Salim: to be published in J. Acoust. Soc. Am.