2P2-11

Proceedings of Symposium on Ultrasonic Electronics, Vol. 33 (2012) pp. 189-190
13-15 November, 2012

Detection of microcrack tips in a plate using laser induced pulse waves under the Lamb wave excitation

レーザ励起パルス超音波を用いた薄板試料中の微小き裂の検出

Kazuki Nakata[1†], Nobuaki Hirose[1], Takaharu Kitamura[1], and Mami Matsukawa[1] ([1]Doshisha Univ.)
中田和樹 [1†]，廣瀬暢亮 [1]，北村暁晴 [1]，松川真美 [1] （[1] 同志社大）

1. Introduction

Ultrasonic nondestructive evaluation of cracks is well known. However, some cracks remain difficult to be detected because they are often closed at the tips. One recent interesting solution to evaluate closed cracks in solid materials is the nonlinear techniques, which are based on the detection of nonlinear components, such as superharmonics or subharmonics of incident waves. They are generated by the interaction of a large-amplitude ultrasonic wave with crack tips[1].

We have proposed a simple system for detecting crack tips, especially, the distribution of crack tips in a thin plate. In our former studies, we combined two techniques. One is a pulsed laser, which enables us to generate ultrasonic pulse waves by the thermoelastic effect. This techniques enable good spatial resolution. The other technique is a PZT transducer attatched at the bottom of plates, viblating low frequency longitudinal waves or symmetric Lamb waves. As a result, crack tips could be detected[2][3].

In this study, we have used a handmade hollow cylindrical PVDF transducer which enables transmission and reception of waves at one surface. Low frequency excitation was also achieved by the oblique incidence of low frequency waves from the surface.

2. Experiment

2.1 Sample

To check crack positions by eye, we have used an acrylic sample. We have evaporated thin aluminum film on one surface of the acrylic plate sample to generate pulse ultrasonic wave by the thermoelastic effect. **Figure 1** shows a sample (35 $\times$100$\times$5 mm^3) with a plane crack.

2.2 Experimental system

Figure 2 shows a block diagram of the measurement system and propagation direction of S_0 mode Lamb wave. Nd-YLF pulse laser (wave-length 1047 nm, pulse energy 80 μJ, pulse width 5 ns, repetition time 1 ms) was irradiated to a sample surface through the center of a hollow cylindrical PVDF transducer. Ultrasonic pulse waves were generated by the thermoelastic effect. The induced pulse wave propagated in the sample, and reflected at the reverse side or the crack. The wave received at the transducer was amplified (46 dB) and observed at an oscilloscope (54852A, Agilent). We have scanned the pulse laser irradiation a distance of 0.3 mm as shown **Fig. 1**.

We have fluctuated the sample by low frequency ultrasonic waves. A PZT transducer has transmitted waves through water with an angle of 45 [deg.]. 2 cycles sinusoidal burst wave at 250 kHz and 140 Vpp was applied to the transducer. Propagation of the Lamb wave in the sample was confirmed by a laser Doppler vibrometer (LV-1610, Ono sokki). The surface displacement of S_0 mode Lamb wave was about 16 nm. **Figure 3** shows the

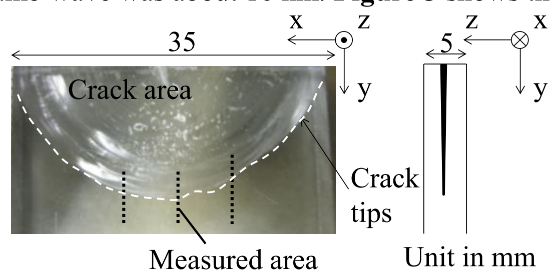

Fig. 1 Measured sample.

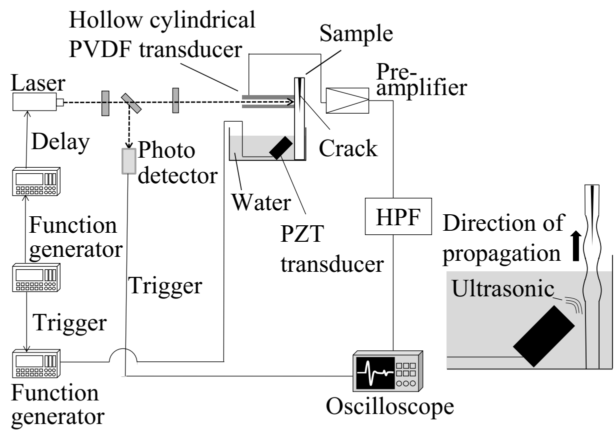

Fig. 2 The measurement system.

mmatsuka@mail.doshisha.ac.jp

displacement distribution of both surfaces at the same time. In this study, we irradiated the sample surface at the positive (E) or negative peaks (C) of the Lamb wave with the laser. **Figure 4** shows images of excitation.

3. Results and Discussion

Figure 5 shows examples of observed waveform without Lamb wave excitation. We can see a reflected wave from the crack (around 2.6 ~ 2.8 μs), and the reverse side (around 3.8 μs). The time of reflected wave from the crack has differed due to the measurement points. Therefore cracks are not distributed parallel to the surface of the sample. The amplitude of reflected wave from the crack clearly changed due to the area. Next, we focused on the frequency spectrum of the reflected wave from the crack under the Lamb wave excitation. **Figure 6** shows the change of amplitude spectrum ratio E(f)/C(f) near the crack tips. We focused on the data at 5 MHz, where the amplitude spectrum was the maximum. E(f)/C(f) becomes larger near the crack tips. S_0 mode Lamb wave excitation at low frequency makes crack tips fluctuating in several nm. When the laser induced ultrasonic passed through crack tips at different conditions, the attenuation seemed to change. Therefore, the effects of compression and extension states could be observed as small changes in apparent wave properties. Thus, this technique seems to be useful for the nondestructive evaluation of plane crack tips in a plate.

4. Conclusion

In this study, we proposed a new measurement system for detecting crack tips using two techniques: a laser induced pulse ultrasonic waves and low-frequency S_0 mode Lamb wave excitation. Using this technique, we have detected crack tips in a thin plate. Using hollow cylindrical PVDF transducer, we could transmit and receive pulse ultrasonic waves at the same side of the sample. This method is very simple and practical for the non-destructive evaluations. Future investigation of the precise physical mechanism of crack tips detection will be important for the development of this system.

Reference

[1] Y. Ohara, T. Mihara, and K. Yamanaka: Ultrasonics **44** (2006) 194.

[2] R. Nakase, K. Nakata, and M. Matsukawa: Jpn. J. Appl. Phys. **51** (2012) 07GB16.

[3] A. Miyamoto, M. Matsukawa: Proc. 2009 IEEE Int. Ultrason. Symp. (2009) 2793.

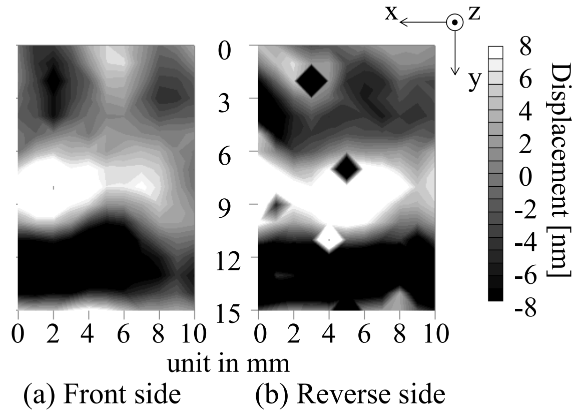

Fig. 3 Excitation of S_0 mode Lamb wave.

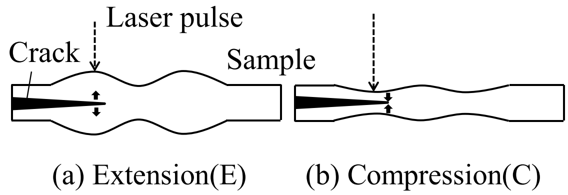

Fig. 4 Timing of irradiation pulsed laser.

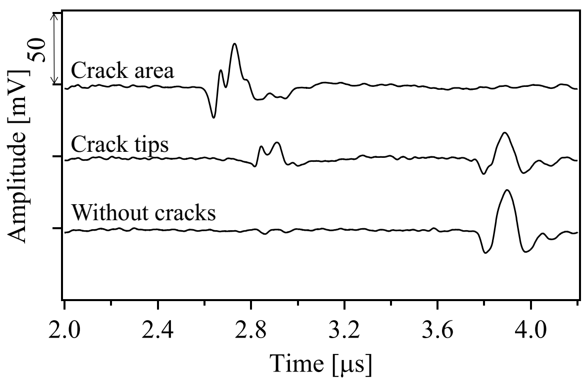

Fig. 5 Measured waveforms.

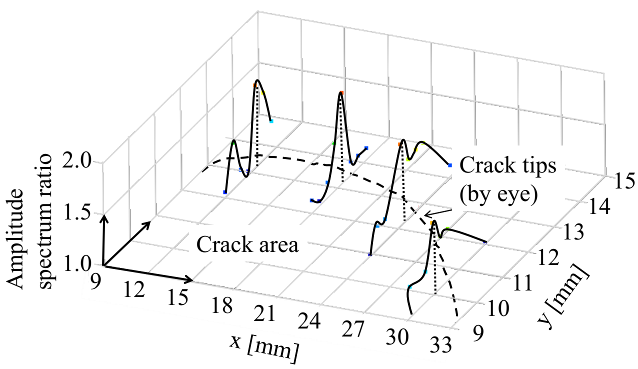

Fig. 6 Amplitude spectrum ratio as a function of measured positions.