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Visualization of Leaky Wave Propagation from Thin Metal Plate with Defects by Nonlinear Airborne Ultrasound Excitation

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1. Introduction

We propose a method that combines nonlinear airborne ultrasounds[1-2] with a receiver array[3]. Our proposed method is a full non-contact and non-destructive testing method[4] for thin metal plates in power plants and chemical plants. In this report, as a basic study, we investigate the full non-contact[5] testing method of a defect in a thin metal plate by nonlinear airborne ultrasounds excitation.

2. Visualization of defects in thin metal plates using leaky waves

Figure 1 gives an overview of the full non-contact and non-destructive testing using a proposed method. The measurement procedure is as follows. First, nonlinear airborne ultrasounds are irradiated from a fixed high-intensity focused ultrasound source to generate Lamb waves with harmonic components in the thin metal plate to be measured. Next, as the Lamb waves propagate through the thin plate, faintly leaky waves propagate from the thin plate into the air. And then, by receiving the leaky waves while scanning with a microphone that simulates a receiver array, a Lamb wave propagation image is acquired, which enables visualization of the defect image.

3. Experimental equipment and method

Figure 2 shows a schematic of the experimental equipments, which comprised a source of high-intensity focused airborne ultrasound (input voltage: 40 Vp-p, driving frequency: 40.8 kHz), an acoustic guide, an amplifier (HAS 4051, NF), a synthesizer (WF1974, NF), a microphone (40DP, GRAS), a preamplifier (Type 12AA, GRAS), a data logger (USB-6363, NI), and a personal computer (PC). The sound source comprised 335 ultrasound emitters arranged on part of a spherical surface with a diameter of 150 mm. In addition, sound waves were radiated through an acoustic guide comprising an acoustic window (acrylic; thickness: 2 mm) and a pipe (acrylic; length: 50 mm; inner diameter: 6 mm) to prevent the effects of

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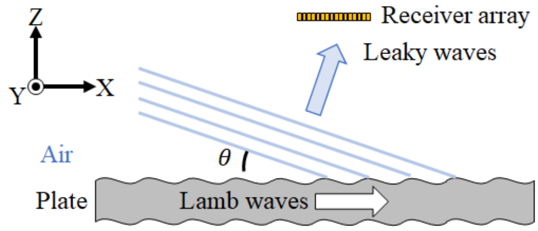


Fig. 1. Overview of a full non-contact and non-destructive testing using the proposed method.

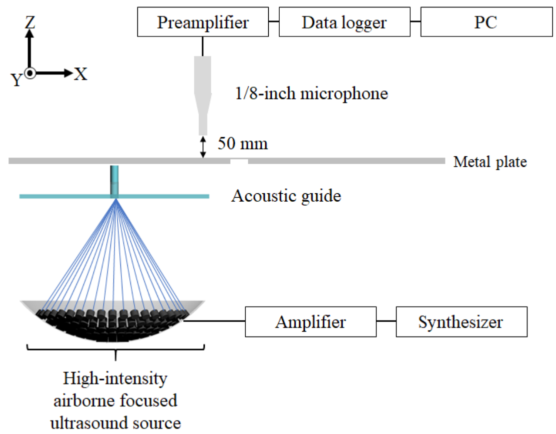


Fig. 2. Schematic of experimental equipments.

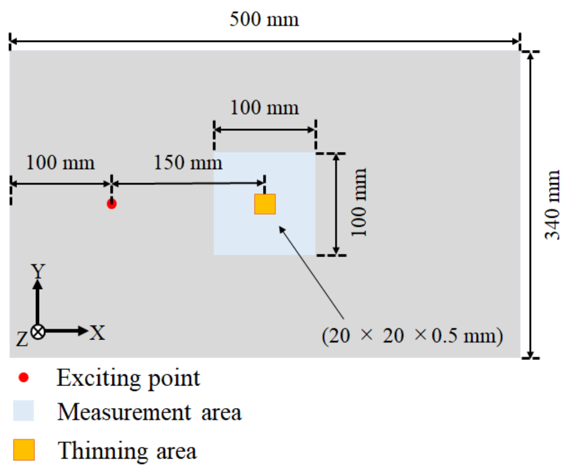


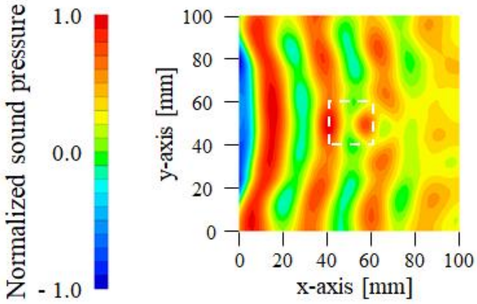
Fig. 3. Schematic of sample and measurement area.

side lobes that occur with sound wave focusing.

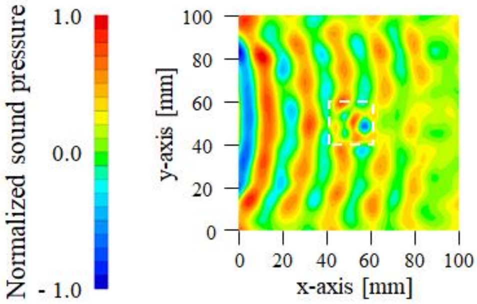
Figure 3 shows a schematic of the experimental sample. The dimensions of the sample (made of duralumin) is 500 mm × 340 mm × 3 mm, and a simulated defect of 20 mm × 20 mm is provided at a depth of 0.5 mm from the sample surface. The measurement area was 100 mm × 100 mm, and the microphone was positioned 50 mm from the sample surface.

The experiment was performed as follows. First, nonlinear airborne ultrasounds were irradiated to a position 150 mm from the center of the simulated defect shown in Fig. 3 to excite Lamb waves with harmonic components in the metal plate. Second, leaky waves from the metal plate were received by a microphone, amplified by 40 dB using a preamplifier, and recorded on a PC using a data logger. These operations were repeated while scanning a microphone at 2-mm intervals in the measurement range. A leaky wave propagation image was obtained by recording the received signals corresponding to the measurement point coordinates. After that, bandpass filtering corresponding to the driving frequency (40.8 kHz), second harmonic (81.6 kHz), and third harmonic (122.4 kHz) was performed on the received waveform, and delay-and-sum (DAS) beamforming[6] was performed for each component.

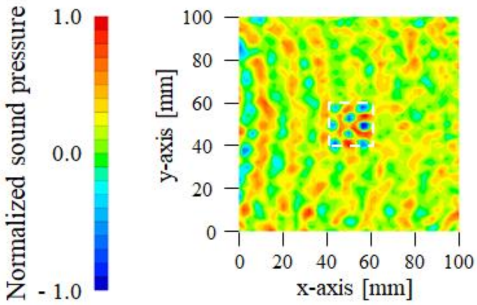
The measurement conditions were a sampling frequency of 1 MHz, a sampling time of 5 ms, and an averaging process of 20 times.



(a) 1st (t = 1057 μs).



(b) 2nd (t = 1066 μs).



(c) 3rd (t = 1084 μs).

Fig. 4. Experimental results.

4. Experimental results

The experimental results in **Fig. 4** show the propagation of the leaky waves at a given time, from the fundamental to the third harmonic. The results are in color maps and normalized by the maximum value in each case.

In the result for fundamental frequency [Fig. 4(a)], it was difficult to visualize the defect area because Lamb waves passed through the defect area, and almost no reflections were observed. On the other hand, in the results for second and third harmonic frequency [Fig. 4(b)-(c)], reflected waves at the defect were observed. In addition, a mode was visualized at the defect in the higher harmonics. By the above propagation behavior, the defect was accurately visualized by using the harmonics.

5. Conclusion

We reported a basic study of a full non-contact and non-destructive testing method for thin metal plates using nonlinear airborne ultrasounds. The results show that a defect could be visualized accurately by full non-contact testing method using the harmonic components of nonlinear airborne ultrasounds and DAS beamforming.

Acknowledgment

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