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COMPARISON OF CONTACT ACOUSTIC NONLINEARITIES OF LONGITUDINAL AND SHEAR WAVES

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ABSTRACT

The contact acoustic nonlinearity based on the nonlinear interaction between elastic waves and contact interface is known to be effective for the detection of micro-cracks. In this study, the contact acoustic nonlinearities of longitudinal and shear waves have been investigated and compared. In experiments, two aluminum blocks were contacted to simulate a solid-solid contact interface, and the contact pressure was adjusted to simulate closed crack conditions. The experimental results showed that the contact acoustic nonlinearity of shear waves is dominant in the generation of the third-order harmonic, whereas the generation of the second-order harmonic is dominant for longitudinal waves. The dominant harmonics had a maximum at a specific contact pressure, and the maximum of the third-order harmonic appeared at a higher contact pressure, than that of the second-order harmonic. This comparison result suggests that the use of the contact acoustic nonlinearity of shear waves may be effective for the detection of more closed cracks because the higher contact pressure simulates more closed cracks.

Keywords: contact acoustic nonlinearity, longitudinal wave, shear wave

1. INTRODUCTION

Early detection of micro-cracks in structures is desired to ensure their structural safety. For this purpose, nonlinear ultrasonic techniques using nonlinear resonance, mixed frequency response, or harmonic generation have been actively studied [1-3]. In this study, the harmonic generation based on the contact acoustic nonlinearity is investigated for longitudinal and shear waves. The harmonic generation characteristics in the bulk waves are also compared.

2. EXPERIMENTAL SETUP

Two aluminum 6061-T6 specimens with a diameter of 40 mm and a thickness of 30 mm were prepared. Both top and bottom surfaces were mirror-polished. These specimens were contacted to simulate a solid-solid contact interface, and the contact pressure was adjusted from 0 kgf to 10000 kgf to simulate closed crack conditions.

Figure 1 shows a schematic diagram of the experimental setup. A high-power gated amplifier (RAM-5000-SNAP) was used to provide a tone-burst electric signal with a 2 MHz central frequency. A 2.25 MHz PZT transducer was used as a transmitter, and a 5 MHz PZT transducer was used as a receiver for sensitively detecting both the second-order harmonic and third-order harmonic components in the transmitted wave.

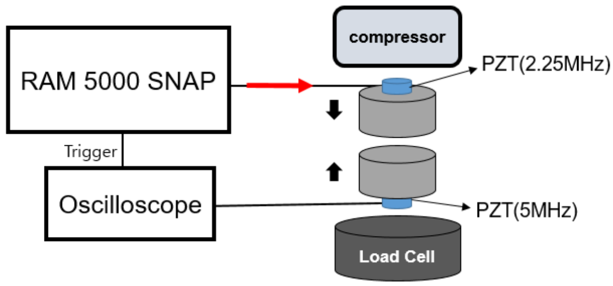

FIGURE 1: SCHEMATIC DIAGRAM OF THE EXPERIMENTAL SETUP

3. EXPERIMENTAL RESULTS AND DISCUSSION

Figure 2 shows the typical time-domain signal and its frequency spectrum when the longitudinal wave was used. The second-order harmonic is clearly observed at 4 MHz. Meanwhile, when the shear wave was used, the generation of the third-order harmonic at 6 MHz was dominant, as shown in Fig. 3. These results are in good agreement with the theorical results.

The magnitudes of the second-order harmonic in longitudinal waves and the third-order harmonic in shear waves as a function of the contact pressure are shown in Fig. 4, respectively. The second-order harmonic has a maximum at 470 kPa and the third-order harmonic has a maximum at 700 kPa.

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This comparison result suggests that the use of the contact acoustic nonlinearity of shear waves may be more effective for the detection of more closed cracks because the higher contact pressure simulates more closed cracks.

4. CONCLUSION

In this paper, the contact acoustic nonlinearities of longitudinal and shear waves have been investigated and compared. Experimental results showed that the harmonics had a maximum at a specific contact pressure, and the maximum of the third-order harmonic appeared at a higher contact pressure, than that of the second-order harmonic. These results suggest that the use of the contact acoustic nonlinearity of shear waves may be more effective for the detection of more closed cracks because the higher contact pressure simulates more closed cracks.

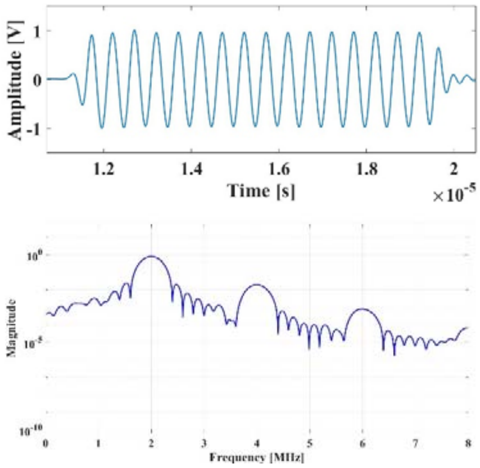

FIGURE 2: TYPICAL TIME-DOMAIN SIGNAL AND ITS FREQUENCY SPECTRUM FOR LONGITUDINAL WAVE

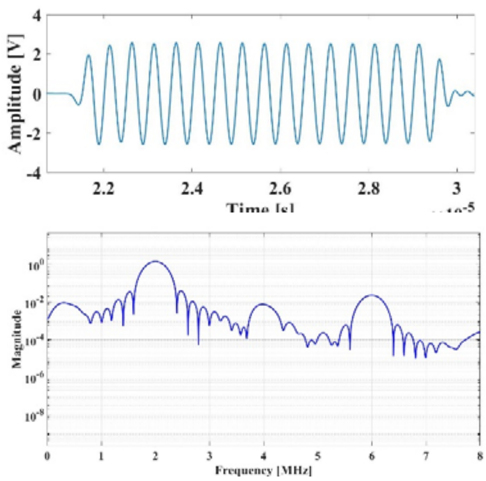

FIGURE 3: TYPICAL TIME-DOMAIN SIGNAL AND ITS FREQUENCY SPECTRUM FOR SHEAR WAVE

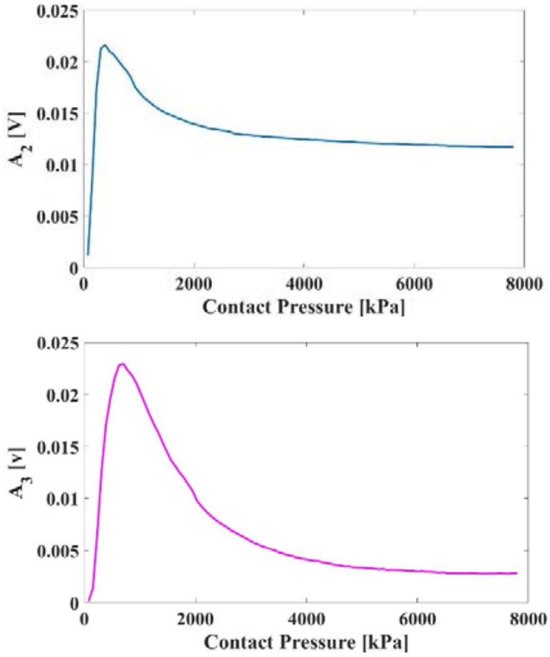

FIGURE 4: THE MAGNITUDES OF THE SECOND-ORDER HARMONIC IN LONGITUDINAL WAVES AND THE THIRD-ORDER HARMONIC IN SHEAR WAVES AS A FUNCTION OF THE CONTACT PRESSURE

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