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Harmonic Generation in Lamb Wave in a Plate with Contacting Interfaces

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1. Introduction

Recently, nonlinear ultrasonic methods are actively investigated in the field of nondestructive characterization of imperfect interfaces. In these methods, one utilizes the frequency components in the acquired ultrasonic signal which differ from the frequency bandwidth of the incident wave, such as higher harmonics, sum/difference frequencies and sub-harmonics. These methods have so far been applied successfully to the characterization as well as imaging of some imperfect bond interfaces.[1,2)]

Although numerous investigations have been reported on such techniques, they mainly rely on the nonlinear ultrasonic effects in bulk waves. In contrast, there have not been many reports concerning analogous approaches using guided waves along imperfect interfaces. The subject of guided wave nonlinearity due to imperfect interfaces appears to be a new topic, although there have already been some works[3,4)] on guided waves in materials exhibiting stress-strain nonlinearity.

Recently, Shima et al.[5)] demonstrated second harmonic generation in Lamb wave in a plate in contact with a substrate. Kishiwada et al. [6)] studied harmonic generation in Lamb wave propagating in a plate compressed between two solid blocks. In the present work, the harmonic generation behavior in the A_0-mode Lamb wave was further studied experimentally for an aluminum plate compressed between two contacting blocks. The influences of the amplitude of the incident Lamb wave as well as the applied contact pressure on the harmonic generation behavior were investigated.

2. Experimental Procedure

The experimental setup is similar to the one employed by Kishiwada et al.[6)] and shown schematically in **Fig. 1**. Namely, for a 1-mm aluminum plate compressed between two aluminum blocks, a Gaussian wave packet with center frequency 1 MHz was excited by a Panametrics angle-beam piezoelectric transducer (with nominal center frequency 1 MHz) driven by a RITEC high-amplitude pulser RPR-4000, which amplified the source signal supplied from a signal generator. The incident angle was variable in this transducer

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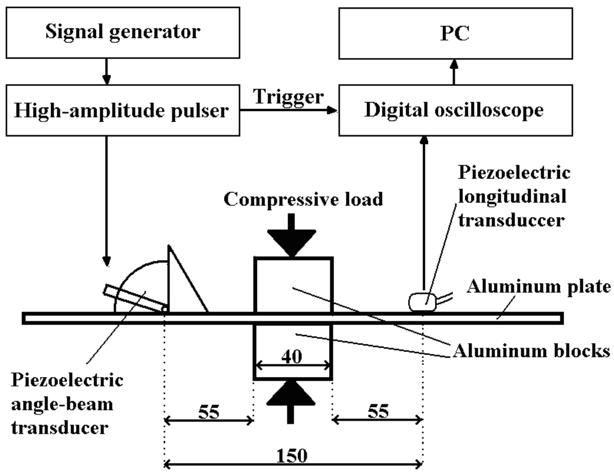

Fig. 1 Experimental setup.

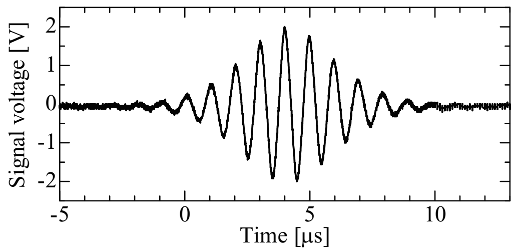

Fig. 2 A typical driving signal (monitor signal 40 dB smaller than the actual voltage).

and set as 75˚. A typical signal applied to the emitting transducer by the pulser is shown in **Fig. 2** (this is a monitor signal proportional to but smaller than the actual driving voltage by 40 dB). The magnitude of the driving voltage was changed at different levels to investigate the effect of the incident wave amplitude on the wave propagation behavior.

A wide-band longituidinal piezoelectric transducer (with nominal center frequency 5 MHz) was used as a receiver instead of the laser-Doppler vibrometer used previously[6)], mainly due to the better signal-to-noise ratio in the frequency range of the higher harmonics with the piezoelectric transducer. The acquired waveforms were stored into a personal computer via a digital oscilloscope, and their frequency components were analyzed using the short-time Fourier transform (STFT)

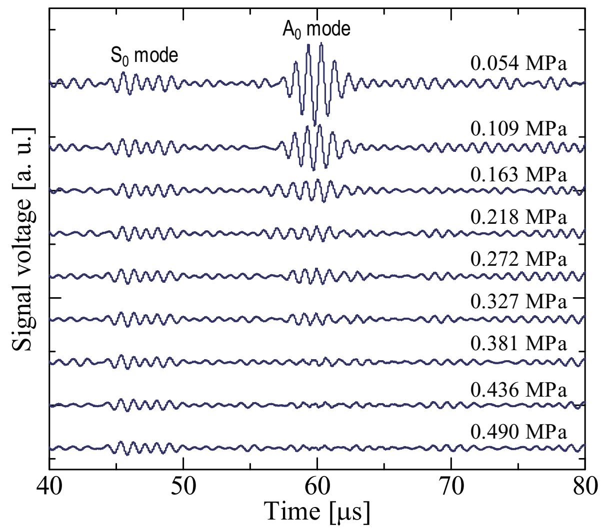

Fig. 3 Acquired waveforms for different nominal contact pressures.

technique. The magnitudes of higher harmonics were identified from the peaks of the absolute value of the STFTs.

3. Results and Discussion

The representative waveforms are shown in **Fig. 3** for different contact conditions. Two wave packets can be identified, namely, the S_0-mode and A_0-mode Lamb waves, as shown in Fig. 3. It is seen in Fig. 3 that the increase of the contact pressure with the contacting blocks decreases the magnitude of the A_0-mode Lamb wave packet significantly, but less so for the S_0-mode. This is considered to be due to the fact that A_0-mode is dominated by the vertical motion out of the plate plane, which is increasingly resisted by the contacting blocks with increasing pressure.

The relative amplitudes of the STFTs of the waveforms are shown in **Fig. 4** for different contact conditions, which reveals that the detected A_0-mode wave packet signal contains a component around 3 MHz, i.e., third harmonics of the incident signal. Furthermore, the amplitude spectrum at about 60 microseconds of the elapse time (corresponding to the A_0-mode arrival) was taken from the STFT results and shown in **Fig. 5**, for different levels of driving voltage. As examined from these results, the third-power dependence on the incident wave amplitude, as predicted in the harmonic generation due to the classical cubic nonlinearity, was not confirmed in the present experiment. The present results would indicate other mechanisms of contact acoustic nonlinearity, or a significant role played by the nonlinear damping.

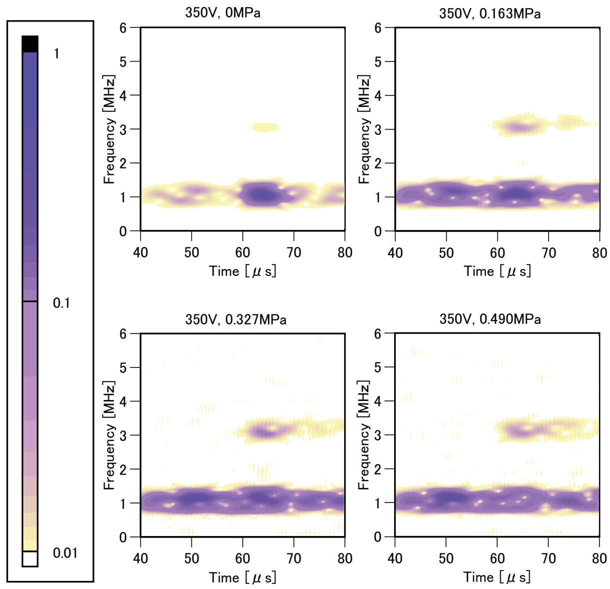

Fig. 4 STFTs of the acquired waveforms at different applied pressures (driving voltage amplitude 350 V).

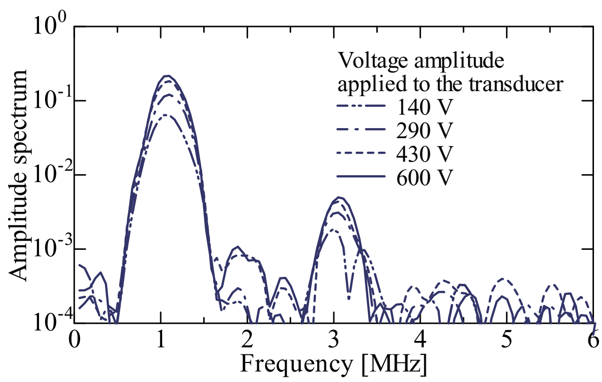

Fig. 5 Amplitude spectra for different voltage amplitudes (at 0.054 MPa).

4. Conclusion

The harmonic generation behavior of Lamb wave was studied experimentally for an aluminum plate in contact with solid blocks. Further investigations are needed to clarify the harmonic generation mechanism.

References

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