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Piezoelectric probe for measurement of longitudinal and shear components of elastic wave.

弾性波の縦波および横波成分を計測する圧電プローブ

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1. Introduction

We focus on ultrasonic probes for non-destructive testing and evaluation. In ultrasonic array flaw detection with conventioal ultrasonc probe, artifacts may appear because the probe miss-detects unnecessary waves generated in the process of mode convirsion. As shown in **Fig. 1**, it is unable to distinguish whether the received signal is longitudinal or shear wave using conventional probes. Therefore, we have previously reported the principle to transmit and receive longitudinal and shear components of elastic wave independently using matrix-like probe with multiple electrodes[1). However, transient characteristics of previously proposed probe were not sufficiant[2). There are a number of studies to obtain broadband frequency characteristics by designing the shape of probe[3, 4).

The purpose of this study is to improve the transient characteristics by changing the shape of the probe. Transient characteristics of probes in longitudinal and shear driving were evaluated by applying inverse Fourier transformation of frequency response of longitudinal and shear components, using 2-D finite element method (FEM).

2. Objective specification of proposed probe

In order to distinguish longitudinal or shear waves, array probe must be able to measure both direction of arrival and vibration direction of incoming wave. Vibration direction of longitudinal wave is orthogonal to that of shear wave. Thus, received signal is determined whether it is longitudinal wave or shear wave by comparing the magnitude of parallel and orthogonal components to the arrival direction of sound. For measuring arrival sound, array signal processing is used. Also, for measuring vibration direction, proposed probe is used. **Figure 2** shows principle of transmission and reception of normal and tangential component of vibration on contact surface for measuring vibration direction. The shape of proposed probe is piezoelectric plate having plural grooves. In addition, proposed probe have multiple electrodes for the slope of the groove which correspond to two channels CH_L and CH_R. While using this probe as receiver, normal and tangential components of vibration on the contact surface are measured by taking the sum and difference output of CH_L and CH_R. On the other hand, while using this probe as a transmitter, thickness-longitudinal and thickness-shear vibration is generated by input in-phase and anti-phase voltage to CH_L and CH_R[2). Proposed probe should have flat frequency response to obtain good transient characteristics because non-destructive testing such as the pulse echo method is assumed. In general, frequency band for non-destructive testing is used from 100 kHz to 10 MHz. To achieve this specification, resonant frequency of probe is generally chosen from the vicinity or above of limit of the frequency band. However, it is difficult to process such a probe using piezoelectric ceramics since the thickness of the probe must be approximately 100 μm to obtain resonant frequency of 10 MHz. If thickness of proposed probe is in the order of approximately 1mm, sufficiently large attenuation is required.

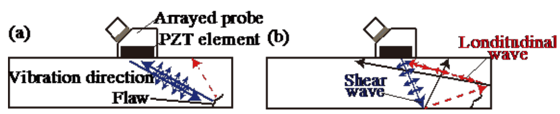

Fig. 1 Problem for ultrasonic array flaw detecting methods(a)correct detection of flaw, (b)artifact will occur by missdetection.

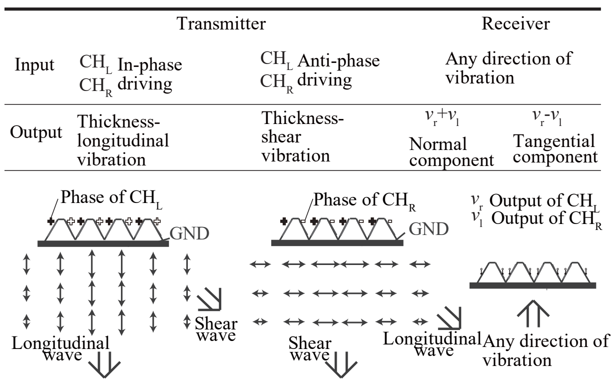

Fig. 2 Principle of transmitting and receiving normal and tangential components of vibration on the contact surface.

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3. Simulation condition and result

Figure 3 shows schematic view of simulation condition. PZT-4 was assumed as piezoelectric ceramics. Frequency response was simulated from 100 kHz to 10 MHz at 20 kHz intervals to verify effect in changing the area of the electrode, the depth of the groove and the number of grooves, in longitudinal and shear driving. As the result, in longitudinal driving, significant effects in comparison with conventional thickness-longitudinal probe were not obtained in any conditions, and. On the other hand, in shear driving, improvement of transient characteristics compared with conventional thickness-shear probe was found. The results contributing to transient characteristics were shown. **Figure 4** shows shape of ultrasonic probe by increasing the number of grooves. **Figure 5** shows time wave form of shear component of shear driving. In Fig. 5 an arrival time of first echo was indicated by an arrow. When compared Fig. 5(i) with 5(iv), results showed that width of echo of 5(iv) was smaller than that of Fig. 5(i). In other words, probe of Fig. 4(iv) had better transient characteristics than conventional probe. **Figure 6** shows frequency responses of admittance in shear driving. According to Fig. 5(i), components of half wave-length resonance appeared. On the other hand, according to Fig. 5(ii), 5(iii) and 5(iv), frequency components appeared except for harmonic components. In addition, admittance was increased while increasing the number of grooves.

4. Conclusion

The purpose of this study is to evaluate effect for transient characteristics by changing the shape of probes. As a result, improvement in admittance and transient characteristic of the proposed probe were verified when increasing the number of grooves in shear driving.In our future works, probe will be desined considering sound field was generated by probe.

References

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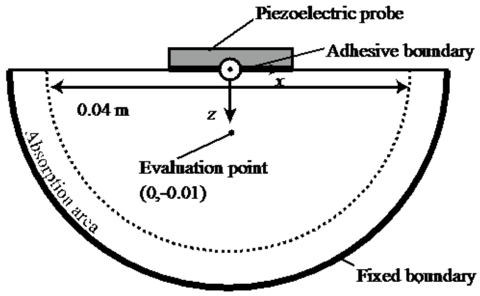

Fig. 3 Schematic view of simulation condition.

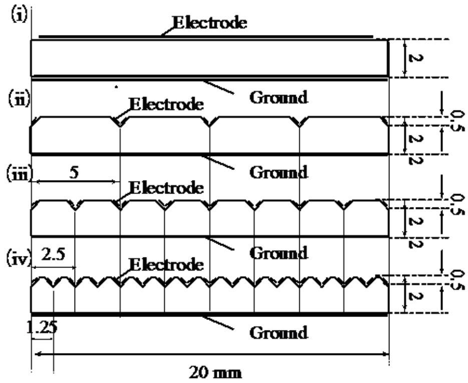

Fig. 4 Shape of ultrasonic probe

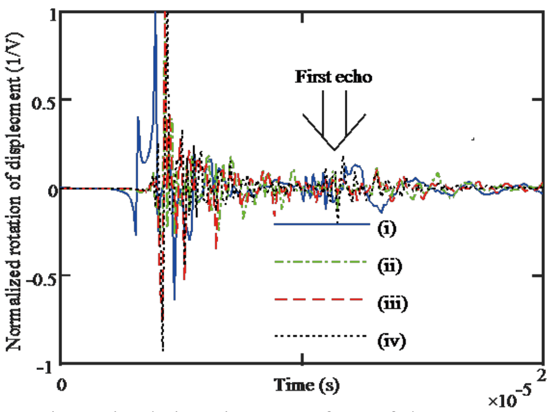

Fig. 5 Simulation Time wave form of shear component in increasing the number of grooves.

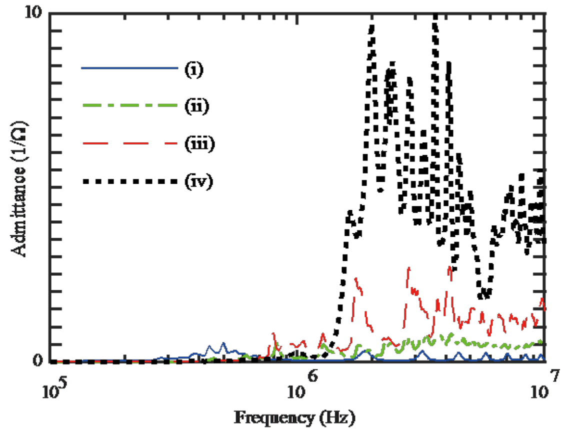

Fig. 6 Simulation result of frequency response of admittance in shear driving in increasing the number of grooves.