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Sound field between an object and a thin ultrasound touchless sensor using flexural vibration

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1. Introduction

Touch panel displays are now widely used following the development of electronic devices such as cellular phones and tablet devices. Noncontact operation techniques are required in next generation devices, and noncontact touch displays using camera systems, infrared light, and capacitive sensors have been reported[1.2]. Ultrasound is the promising tool where an object in front of the display can be detected through an ultrasound time-of-flight technique using array sensors. However, conventional noncontact touch displays consist of a lot of sensors and components, and the signal processing for detection of objects tends to be complicated.

We have been developing a technique to detect the position of an object in front of a sensor using change in the electrical impedance of an ultrasonic vibrating plate. In our previous study[3], a prototype with two bolt-clamped Langevin-type transducers was fabricated, but the sensing range was small (~12 mm from the sensor surface) and the sensitivity was low (~0.7%). In this paper, we proposed a thinnner touchless sensor with a PZT transducer and investigated the effects of the acoustic field between an object and the sensor on the sensing characteristics.

2. Method

Fig. 1 shows the structure of the ultrasonic vibrating plate used as a touchless sensor, consisting of a rectangular aluminum plate (20 mm wide, 100 mm long, and 1 mm thick) and a PZT transducer (20 mm wide, 20 mm long, and 2 mm thick). The shape of the plate and the mounting position of the PZT were determined by numerical simulation using the commercial finite element analysis software ANSYS 11 (ANSYS Inc.). A continuous sinusoidal electric signal at the resonance frequency of 29.7 kHz was input to the PZT to excite the flexural vibration mode of the plate in the length direction. Rectangular aluminum blocks (90 mm wide in *x*-direction, 30, 40, and 50 mm long in *y*-direction, and 40 mm thick in *z*-direction) were used as objects to be detected.

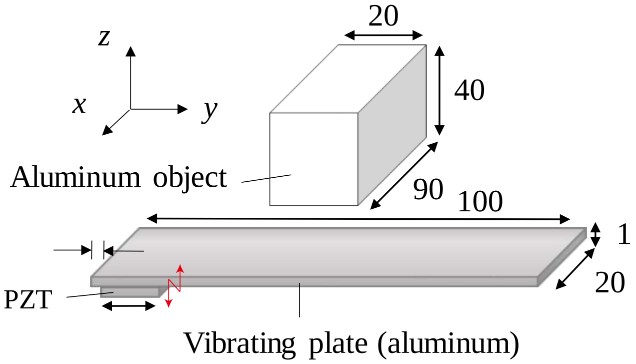

Fig. 1 Thin ultrasound touchless sensor using a PZT plate.

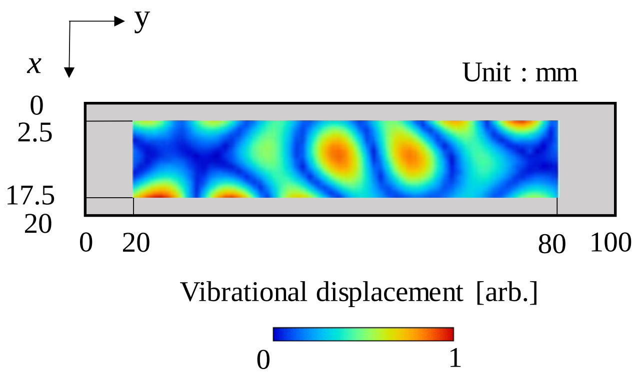

Fig. 2 Distribution of the vibrational displacement amplitude of the plate at 29.7 kHz.

3. Results and Discussion

A continuous sinusoidal signal at 29.7 kHz with 45 V_{pp} was input to the PZT to excite the flexural vibration on the plate. The out-of-plane vibrational distribution of the plate measured by a

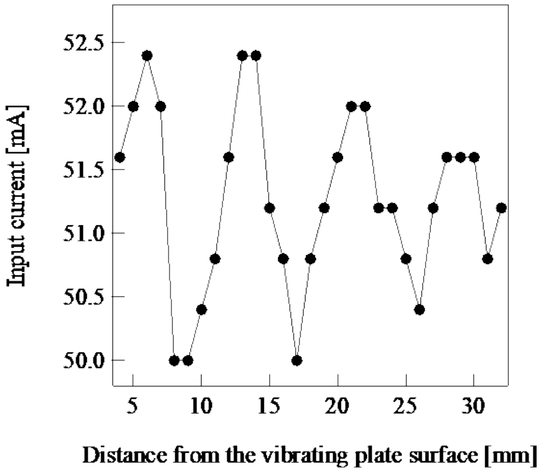

Fig. 3 Changes in the input current to the transducer with respect to the position of the planar object in z direction

laser Doppler vibrometer (NLV-2500-2, Polytec) is shown in **Fig. 2**. The maximum vibrational displacement amplitude was 13 μm and a flexural vibration mode with a wavelength of 22 mm was generated along the length direction of the plate.

When the sound wave is emitted into the air by the flexural vibration of the plate, the input current to the PZT changes due to the detected object because the sound field between the plate and the object affects the radiation impedance of the plate. **Fig. 3** shows the change in the input current to the PZT when changing the position of the object in *z* direction with 45 V_{pp}. The current decreased (or increased) every 9 mm, indicating that the radiation impedance of the plate increased (or decreased) since an acoustic standing wave was generated between the plate and the object; the current was reduced by up to 4.6% from the maximum value. The current did not change significantly when the position of the object was over z = 32 mm, implying the acoustic standing wave was not generated due to the attenuation of wave propagation in the air. **Fig. 4** shows the change in the phase difference between the input current and voltage to the transducer when moving the object in *y* direction. The horizontal axis indicates the center position of the object in *y* direction. The phase difference changed linearly with the position of the object, and the gradient, the sensitivity in the length direction, was 0.13 °/mm.

The sound pressure distributions were measured by a probe microphone (4182, Brüel & Kjær, Nærum) in *y*-*z* plane in the cases with the 30, 40, and 50-mm-long objects (**Fig. 5**). The maximum sound pressure amplitude was 1.0 kPa at the surface of the plate in the case of the input voltage of 45 V_{pp} and a 20-mm-long object. The 20-, 30-, and 40-mm-long objects generated a half- (Fig. 5(a)), one- (Fig. 5(b)), and 3/2-wavelength-resonance modes (Fig. 5(c)) in *y* direction in the air between the object and plate, respectively, indicating that the sound pressure distribution and the sensing characteristics was dependent on the shape of the object.

4. Conclusion

We proposed a thin touchless sensor for object detection using the change of ultrasonic radiation impedance. The sensing characteristics depended on the shape of the object and the acoustic field between the object and plate. The sensitivity was improved six-fold compared to our previous sensor[3] and the object position could be determined uniquely within a two-dimensional area.

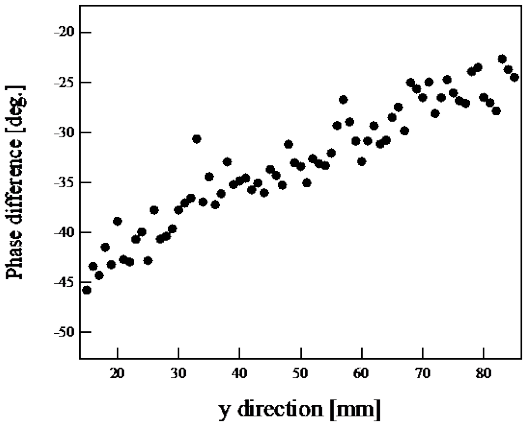

Fig. 4 Relationship between the object position in the *y* axis and the phase difference between the input current and voltage to the sensor.

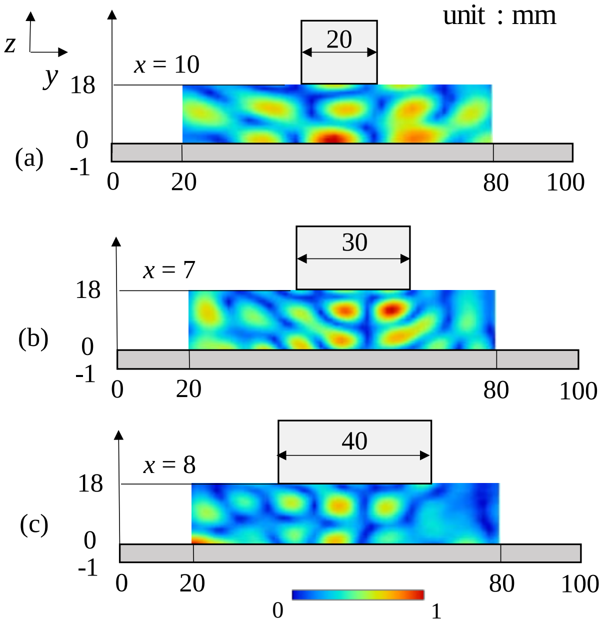

Fig. 5 Sound pressure distributions in *y*-*z* plane in the cases with the object length of (a) 30 mm, (b) 40 mm, and (c) 50 mm.

References

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