1P4-12

Characteristics of an intense aerial ultrasonic source using a small circular vibrating plate

小型円形振動板を用いた強力空中超音波音源の特性

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1. Introduction

Aerial ultrasonic sensors[1] need to be miniaturized, but the problem is that strong sound waves are difficult to generate. We have developed a compact sound source that can emit powerful sound waves in one direction by vibrating a small circular plate. We have shown that, although the radiation surface is small, it can radiate acoustic waves with large sound pressure to distant locations [2].

In this study, the vibration amplitude distribution of the circular plate and the sound pressure of the radiated sound wave were measured in the vibration mode in which the entire surface flexes in the same direction. The results were compared with those of a sound source with a uniform rod attached to the radiation surface instead of the plate.

2. Aerial ultrasonic sound source

Figure 1 is a schematic diagram of the aerial ultrasonic sound source. Its supporting structure is, a bolted 60 kHz Langevin-type transducer coupled by screws to a uniform rod (diameter, 15 mm; length, half the wavelength of the longitudinal vibration) with a flange (diameter, 25 mm; thickness, 1.0 mm). Figure 1 (a) shows a resonance rod attached to the end of the uniform rod, with a circular plate attached to the tip of the resonance rod via a small support column. Herein, this is referred to as the circular vibrating plate type sound source. The diameter of the circular vibrating plate is the same as the diameter of the transducer (15 mm). Figure 1 (b) shows a uniform rod with the diameter of 15 mm attached to the tip for comparison. Herein, this is referred to as the uniform rod type sound source.

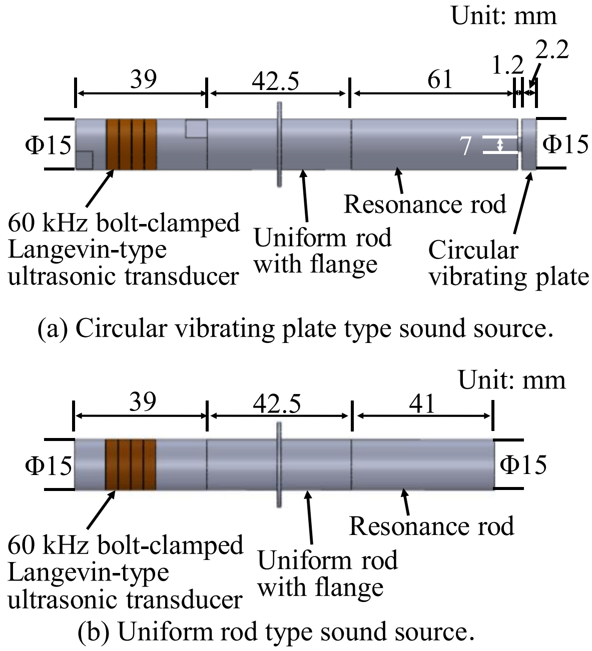

Fig. 1. Outline of the ultrasonic source.

3. Analysis of size of vibrating section

In order to obtain strong aerial ultrasonic waves in the direction perpendicular to the vibrating plate, the effect of changing the thickness of the vibrating plate which bends and vibrates with large amplitude in the same direction over its entire surface was investigated using the finite element method with the simulation software ‘COMSOL Multiphysics’. The simulation model is as shown in Fig. 1, the material is A2017 (duralumin) including the transducer part. Modal analysis of a two-dimensional axisymmetric model was performed. From this analysis, it was found that, in the case where the node of the flexural vibration does not occur in the circular vibrating plate, the optimal thickness of the vibrating plate tends to decrease as the diameter of the support is increased. A vibrating plate thickness of 2.2 mm and a diameter of 7 mm, achieved a relatively large amplitude, so this was manufactured. The flexural vibration amplitude distribution on this vibrating plate and the directivity characteristics of the radiated sound wave were investigated. The length of the resonance rod was also determined by the modal analysis to be 61 mm, which is half the wavelength of the vibration at a frequency of around 58 kHz.

4. Measurement of vibration amplitude distribution on vibration plate

The deflection vibration amplitude distribution on the circular vibrating plate was measured

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using a laser doppler vibrometer. In addition, the vibration of a uniform rod type sound source (Fig. 1 (b)) was also measured for comparison. The measurement range was the diameter (± 7.5 mm) along a line passing through the center, at intervals of 0.5 mm. The driving frequency of the sound source was set to the resonance frequency (about 58 kHz), and the current was set to a constant 50 mA. At this time, the amplitude of the transducer was about 0.12 µm.

Figure 2 shows the results. In the figure, the horizontal axis represents the radius from the center of the plate and the vertical axis represents effective value of the transverse vibration amplitude. From the figure it can be seen that the entire surface vibrates in the same direction; the vibration amplitude is relatively small near the center and increases towards the edge of the circular plate. On the other hand, the uniform rod type sound source has a constant vibration amplitude over the whole diameter. It can also be seen that the maximum vibration amplitude of the circular plate is about 9.5 times larger than the maximum vibration amplitude of the uniform rod type sound source.

5. Measurement of the directivity of radiated sound waves

In order to investigate the sound pressure distribution of the sound waves radiated from the circular vibrating plate, sound pressure was measured using a 1/8 in. condenser microphone on a probe (ACO, TYPE 7118) and a rotary stage on which the sound source was mounted. For comparison, the distribution for the uniform rod type sound source was also measured. For the measurements, the distance between the sound source and the measurement point was 300 mm, the angle of 0° was defined to be when the radiation surface was pointing directly at the microphone, and were taken in the range of ±90°. The driving frequency of the sound source was set to the resonance frequency (about 58 kHz), and the current was set to a constant 50 mA. At this time, the input power was 0.1 W for the circular plate sound source and 0.05 W for the uniform rod type sound source. **Figure 3** shows the results. In the figure, the horizontal axis represents the angle between the front of the radiation surface and the microphone, and the vertical axis represents the sound pressure. From the figure, both types of sound source have their maximum at 0°. The maximum sound pressure for the circular plate is about 38 Pa, which is about 5 times higher than the maximum sound pressure of about 7 Pa for the uniform rod.

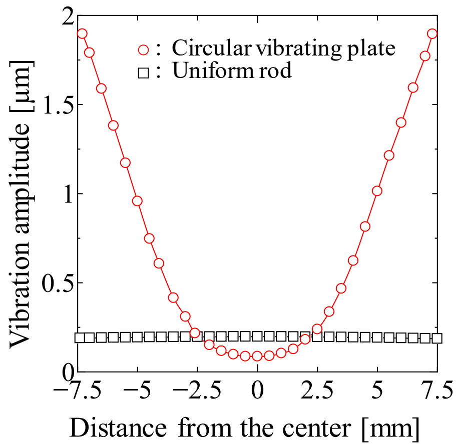

Fig. 2. Measured vibration distribution.

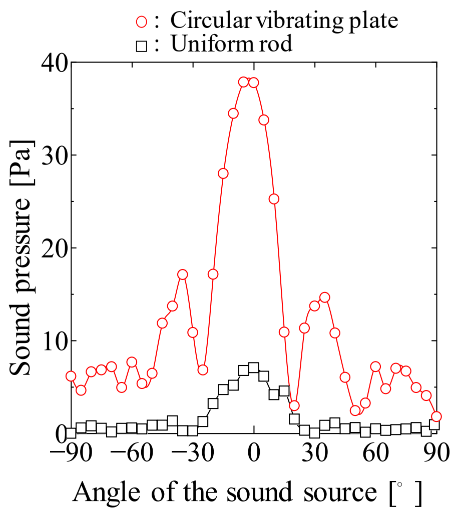

Fig. 3 Measured sound pressure distribution

6. Conclusions

To create a small aerial ultrasonic sound source, we determined the optimum size of a circular vibrating plate using a computer simulation analysis and manufactured it. Then, the vibration amplitude distribution and the sound pressure distribution of the circular plate were compared with those of a uniform rod type sound source. It was found that the circular vibrating plate type sound source performed much better than the uniform rod type sound source.

Acknowledgment
This work was supported by JSPS KAKENHI Grant Number 18K11700.

References

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