2P4-3

Study of circular vibrating plate size of ultrasonic source with rigid wall
剛壁付き空中超音波音源における円形たわみ振動板の大きさの検討

Ryo Kuratomi‡, Takuya Asami, Hikaru Miura (Coll. of Sci. & Tech., Nihon Univ.)
倉富　涼‡，淺見拓哉，三浦　光（日大・理工）

1. Introduction

Sound sources that radiate strong ultrasonic waves into the air, such as stripe-mode rectangular vibrating plate or circular vibrating plate sources, are used for various purposes, including aggregation of aerosols and deodorization. For these applications, the vibrating plate and several reflective plates are often used to form a standing wave field. However, the reflective plate cannot be fixed to the vibrating plate, leaving a gap[1,2]. Therefore, to construct a closed area, we proposed a sound source with a rigid wall integrated at the circumference of a circular vibrating plate. Because this sound source can have a wall, such as a reflection plate, installed on the rigid wall, a strong standing wave field can be formed in the closed area on the vibrating plate[3].

2. Aerial ultrasonic sound source

Figure 1 shows a schematic of the ultrasonic source, which consists of a 28 kHz bolt-clamped Langevin-type transducer, an exponential horn, a resonance rod (length, 70 mm; diameter, 8 mm) and a circular vibrating plate combined with rigid wall.

Figure 2 shows a cross-sectional view of the circular vibrating plate with the rigid wall integrated at the circumference. The circular vibrating plate (thickness, 1 mm) is clamped with a duralumin ring on the circumference and fixed with bolts and nuts.

3. Study of circular vibrating plate size

To determine the size of the circular vibrating plate for driving the sound source with a rigid wall efficiently at resonance frequency, we investigate the relationship between the diameter of the vibrating plate and sound pressure in the vertical direction of the center of the plate with simulation software 'COMSOL Multiphysics' using the finite element method. The resonance frequency is 28.0 kHz, and a vibration amplitude of 1.0 µm is applied to the center of the plate. The diameter of the vibrating plate is changed from 50 to 150 mm at intervals of 0.1 mm (**Fig. 3**). The figure shows the diameter of the vibrating plate on the horizontal axis and the normalized sound pressure in the vertical direction of center of the plate on the vertical axis. The diameter of the circular vibrating plate required to drive the sound source efficiently at resonance frequency is the point at which the sound pressure reaches a maximum. The interval between the maximum points is 19 mm, and the positions are 53, 72, 91, 109, 128, and 147 mm.

Based on this result, vibrating plates with diameters of 72, 91, and 109 mm were made and their vibration modes were observed by the Chladni figures to determine whether the sound source drives efficiently at the resonance frequency. **Fig. 4** shows the results for the plate with a diameter of 91 mm as an example. The circular mode is formed on the vibrating plate, and there are five nodal lines. There

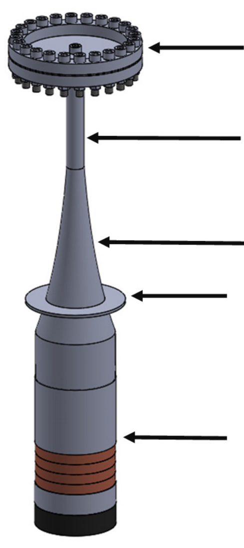

Fig. 1　Schematic of the ultrasonic source.

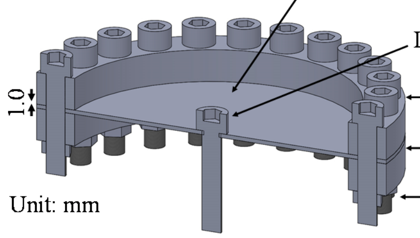

Fig. 2　Cross-sectional view of the vibrating plate.

E-mail : csry16017@g.nihon-u.ac.jp‡
asami.takuya@nihon-u.ac.jp
miura.hikaru@nihon-u.ac.jp

are four nodal lines for the 72 mm vibrating plate, and six nodal lines for the 109 mm plate. These results show that the diameter of the circular vibrating plate required to drive the sound source efficiently at resonance frequency can be determined from the analysis results in Fig. 3.

4. Sound pressure distribution of the aerial standing wave field

The standing wave field formed in a closed area was examined by installing a cylindrical wall and a parallel reflective plate on the 91 mm vibrating plate created in Section 3. The inner diameter of the cylindrical wall for forming a standing wave field is 79.6 mm, and the distance from the vibrating plate to the parallel reflective plate is 80 mm. The sound pressure is measured using a 1/8 in. microphone (TYPE-7017, ACO) on the vertical plane around the diameter of the circular vibrating plate.

Figure 5 shows the results. The input power is set to 0.5 W and the resonance frequency is set to 20.0 kHz. Colors show the value of the sound pressure normalized to the maximum value of microphone output voltage. The vibration plate is indicated in the figure. The aerial standing wave field is formed perpendicular and parallel to the vibrating plate. The intervals between the points at which the sound pressure is high are about 8 mm perpendicular to the vibrating plate and about 10 mm parallel to the vibrating plate. In addition, the sound pressure on the central axis is higher than the sound pressure around it.

5. Conclusions

We investigated the size of the circular vibrating plate required to drive a sound source with a rigid wall efficiently at resonance frequency. We created vibrating plates with different numbers of nodal lines at a resonance frequency 28 kHz. We used the sound source with a rigid wall to create a standing wave field in the closed area formed by the vibrating plate, the cylindrical wall, and the parallel reflective plate.

Acknowledgment
Part of this work was supported by JSPS KAKENHI Grant Number 15K05875.

References

1. R. Sato, T. Asami and H. Miura : Proc. National Spring Meet Acoust. Soc. Jpn (2016) pp. 1139-1140.
2. R. Sato T. Asami and H. Miura, Symp. Ultrason. Electron. **37** (2016) 3P4-11.
3. R. Kuratomi, T. Asami and H. Miura : Proc. National Autumn Meet Acoust. Soc. Jpn. (2016) pp. 1033-1034.

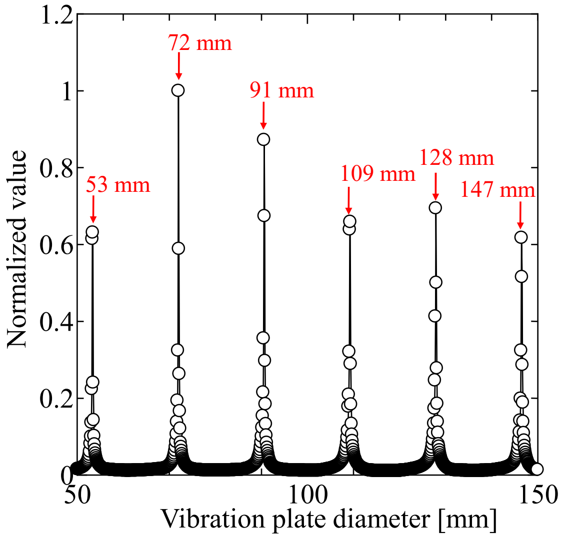

Fig. 3 Relationship between normalized value and vibration plate diameter.

Fig. 4 Chladni figure of a vibrating plate with a rigid wall (diameter: 91mm).

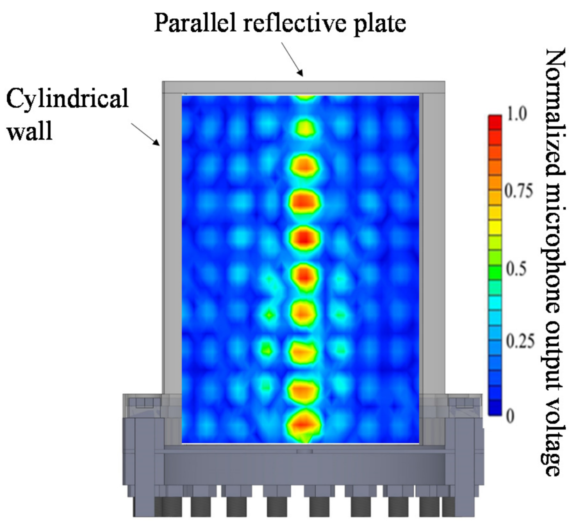

Fig. 5 Sound pressure distribution.