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Basic Study of Aerial Ultrasonic Source Using Cylinder Typed Vibrating Plate with Axial Nodal Mode
円周方向に節を持つモードである円筒形振動板を用いた空中超音波音源の基礎検討

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1. Introduction

High-power aerial ultrasonic sound waves are used in the agglomeration of aerosols and fine particles[1). Also, the plug conveying has been reported to reduce the power required for transportation by ultrasonic wave irradiation[2)]. In these applications, the aerial ultrasonic source using a vibrating plate should not allow the aerosol and fine particles to leak out during irradiation.

We have been developing an aerial ultrasonic source using a rectangular vibrating plate with two rigid walls for these applications[3)]. We developed a new aerial ultrasonic sound source using cylinder typed vibrating plate combined with two rigid walls with an axial nodal mode. The flexural vibration of the nodes and loops of the vibrating plate are alternately generated along the length direction of the cylinder. A so-called axial nodal mode is used, in which the flexural vibration of nodes or loops is generated in a circle shape on the circumference orthogonal to the length direction. In this paper, we clarify the characteristics of the aerial ultrasonic source using cylinder typed vibrating plate with a rigid wall in the axial nodal mode.

2. Aerial ultrasonic source

Figure 1 shows the aerial ultrasonic source using cylinder typed vibrating plate combined with two rigid walls with the axial nodal mode. The aerial ultrasonic source consists of a bolt-clamped Langevin-type longitudinal vibration transducer (NGK Spark Plug D4427PC), and an exponential horn, resonance rod, and cylinder typed vibrating plate combined with two rigid walls. An exponential horn, a resonance rod and a cylinder typed vibrating plate are made of A2017. The resonance rod and cylinder typed vibrating plate are connected by a hole 5 mm in diameter and a screw.

Figure 2 shows cylinder typed vibrating plate combined with two rigid walls. The rigid walls are connected to either end of the cylinder. The cylinder and two rigid walls have an integral structure. The cylinder has an inner diameter of 105.2 mm, a thickness of 4.3 mm, and a length of 109 mm. The rigid wall is a cylinder with an inner diameter of 105.2 mm, a wall thickness of 40 mm, and a length of 25 mm. The rigid wall is thicker than the cylinder. The rigid wall is designed not to vibrate. The aerial ultrasonic source has a resonance frequency of around 27.4 kHz, determined by measuring the admittance loop. The center of the cylinder was taken as the origin of the XYZ-axes.

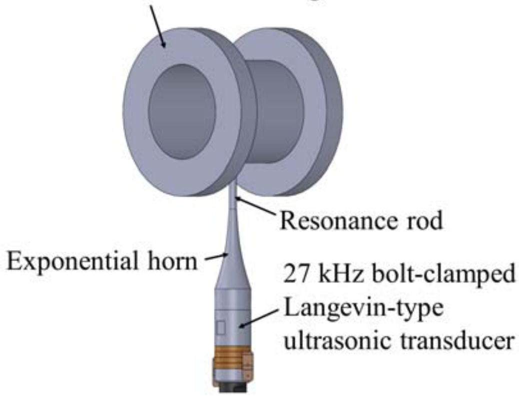

Fig. 1 Aerial ultrasonic source.

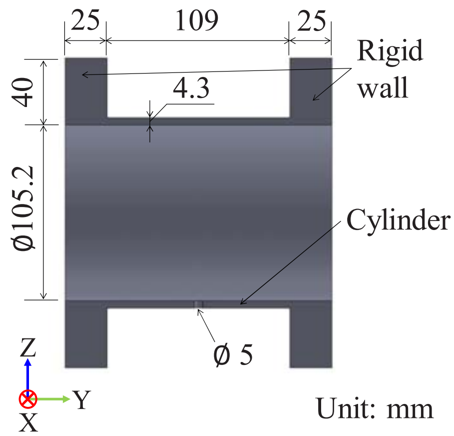

Fig. 2 Cylinder typed vibrating plate combined with two rigid walls.

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3. Measurement of flexural vibration distribution of cylinder typed vibrating plate

To clarify the vibration mode of the vibrating plate, the flexural vibration displacement distribution on the Y-axis (Y = -79.5 to 79.5 mm) of the outer diameter of the vibrating plate was measured. Measurement conditions were set to a constant input power of 1 W and a driving frequency of 27.4 kHz. The flexural displacement vibration of the vibrating plate was measured by a laser Doppler vibrometer (Ono Sokki LV-1610).

Figure 3 shows the vibration distribution. The horizontal axis represents the Y-axis, and the vertical axis represents the flexural displacement vibration. The schematic diagrams in the figure show the measurement lines and symbols on the Y-axis. The results showed that the flexural vibration displacement of the cylinder (Y = -54.5 to 54.5 mm) had a distribution with six node positions at either measurement line. The node position of the flexural vibration displacement was similar on the Y-axis for both measurement lines. Thus, the node position of the flexural vibration displacement was six nodal circles on the circumference orthogonal to the length direction of the cylinder.

In the rigid walls (Y = -79.5 to -54.5, 54.5 to 79.5 mm), the flexural vibration displacement was smaller than the vibration of the cylinder for both measurement lines. Consequently, the connecting cylinder with a wall thickness of 40 mm behaves as a rigid body.

4. Sound pressure distribution

To clarify the sound distribution inside the cylinder typed vibration plate, the sound pressure distribution in the Z-axis (X = 0 mm, Y = 79.5 mm) was measured. Measurement conditions were set to a constant input power of 0.5 W and a driving frequency of 27.4 kHz. The sound pressure was measured by a microphone with a probe (ACO TYPE-7017).

Figure 4 shows the result. The horizontal axis represents the Z-axis, and the vertical axis represents the normalized sound pressure by the maximum value of the microphone output voltage. From Fig. 4 , it was found that the sound pressure distribution had 16 nodal lines in the Z-axis direction. This is because there are eight sound pressure nodes concentrically in the cylinder typed vibrating plate. This result showed that the sound wave inside the cylinder typed vibrating plate formed a standing wave field. The maximum sound pressure occurred at the center of the Z-axis. Our findings show that high-power ultrasonic sound waves can be obtained at the center of the cylinder typed vibrating plate.

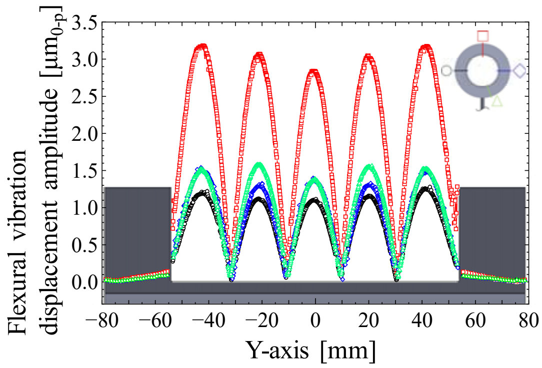

Fig. 3 Flexural vibration displacement distribution of the cylinder typed vibrating plate.

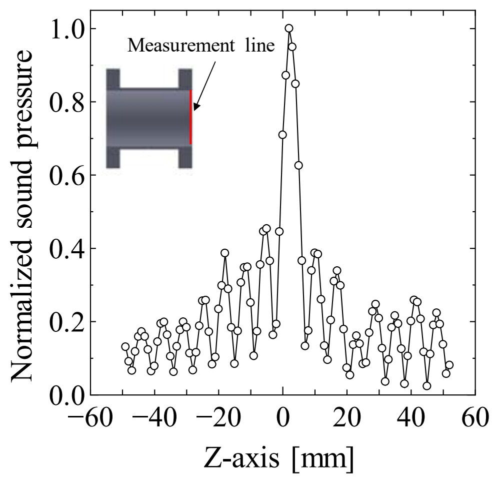

Fig. 4 Sound pressure distribution inside the cylinder typed vibrating plate.

5. Conclusions

In this paper, the fundamental characteristics of a source using a cylinder typed vibrating plate with rigid walls were clarified. The vibration plate vibrated in the axial nodal mode. The flexural vibration of the rigid walls was sufficiently smaller than the flexural vibration of the cylinder for the rigid walls to behave as a rigid body. We found that high-power sound pressure was obtained at the center of the cylinder.

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References

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