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Convergence of intense acoustic field by rectangular reflective plates using a transverse vibrating plate
たわみ振動板を用いた短冊形反射板による集束音場の検討

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1. Introduction

Intense ultrasonic waves can be emitted into the air by an ultrasonic source using a transverse vibrating plate and an external jutting driving point. This transverse vibrating plate is characterized by a driving location that is offset from center of the plate. We have investigated an unconventional new method for making the sound waves converge in a direction perpendicular to the nodal line of the transverse vibrating plate. We previously reported that the sound waves can be made to converge on a line at an arbitrary position by placing several rectangular reflective plates near the vibrating plate. In this work, we investigate placing additional planar reflective plates ahead of the convergence point in order to increase the sound pressure there.

2. Ultrasonic Sound Source

Figure 1 shows a schematic diagram of the ultrasonic source with transverse vibrating plate. The sound source consists of a 20 kHz bolt-clamped Langevin transducer, to which an exponential horn is attached for amplifying the amplitude. A resonance rod made of duralumin is attached to the end of the horn, and a transverse vibrating plate is bolted to the tip of the rod. The vibrating plate consists of duralumin of thickness 3 mm, long side length 173.5 mm excluding protrusions, and short side length 122.6 mm. The stripe-mode resonant frequency of this sound source is 19.8 kHz. **Figure 2** shows a schematic diagram showing the convergence line and the ultrasonic source with transverse vibrating plate. The figure shows the case where the reflective plates are placed on only one side. To maximize the sound pressure on the convergence line, 10 rectangular planar reflective plates (A to J) are placed near the vibrating plate such that the sound waves emitted from the vibrating plate converge on the line. The distance to the convergence point from the edge of the vibrating plate is set to 50 mm. The X, Y, and Z coordinate axes are defined as shown in Fig. 2.

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3. Sound pressure distribution of the acoustic field

To determine the distribution of sound pressure at the convergence point of the intense acoustic field, we investigated the distribution of sound pressure emitted from the vibrating plate. The input power was set to a constant 1 W. Sound pressure was measured in the XZ-plane at a Y-axis position of 40 mm using a microphone on a probe (ACO, TYPE-7017). **Figure 3** shows the results. In the figure, the horizontal axis represents the X-axis and the vertical axis represents the Z-axis. Colors show the value of the sound pressure normalized to the maximum value from Fig. 5. The white areas in Figs. 3 and 5 indicate not measured. As the figure shows, the distribution of sound pressure converges in the vicinity of the convergence point (X=173 mm, Z=0 mm) from the reflections from the 20 reflective

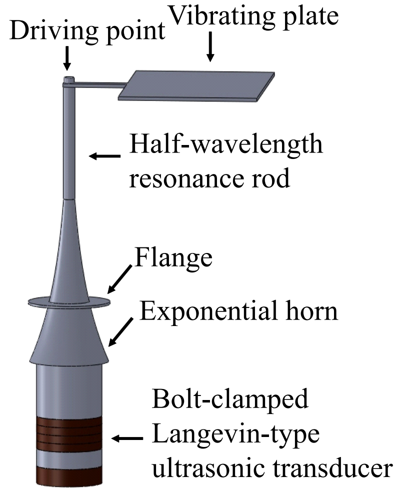

Fig. 1 Outline of an ultrasonic source.

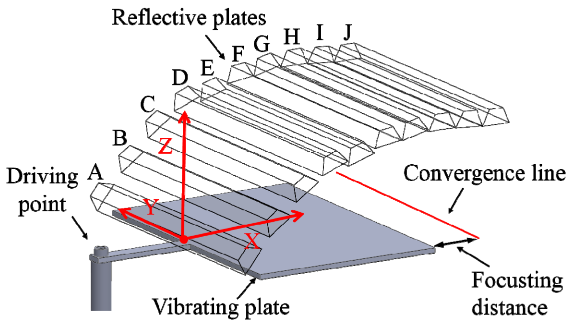

Fig. 2 Positon of reflective plates.

plates on both sides. Furthermore, the sound pressure is almost constant along the Y-axis direction.

4. Increasing the sound pressure by placing additional reflective plates

4.1 Placement position of additional reflective plates

To determine the positions for placing two additional reflective plates ahead of the convergence point, the sound pressure at the convergence point was investigated. The additional reflective plates were kept equidistant from the convergence point. Acrylic plates of thickness 10 mm, short side length 20 mm, and long side length 173.5 mm, which is longer than the vibrating plate, were used for the additional reflective plates. The angle between the vibrating plate and additional reflective plates was set to 55 degrees from preliminary experiments. **Figure 4** shows the results. The vertical axis represents normalized sound pressure taking the sound pressure of the convergence point in Fig. 3 as 1, and the horizontal axis represents the distance from the convergence point. From the figure, the sound pressure takes a maximum at a distance of 9 mm, with peaks at 9 mm intervals thereafter. The sound pressure at the convergence point at the distance of 9 mm was approximately 2.5 times that at the convergence point in Fig. 3.

4.2 Measuring the sound pressure distribution

To determine the distribution of sound pressure in the case where additional reflective plates were placed, the distribution of the sound pressure emitted from the plate was investigated. The measurement parameters were the same as for the results shown in Fig. 3. **Figure 5** shows the results for the case where plates were placed a distance of 9 mm from the convergence point. From the figure, the sound pressure distribution converges at the convergence point (X = 173 mm, Z = 0 mm) when the two additional reflective plates are placed due to reflections from the additional reflective plates. Furthermore, the sound pressure is virtually the same along the Y-axis direction.

5. Conclusions

We investigated the convergence sound field for the case where additional reflective plates were placed ahead of the convergence line of a convergent ultrasonic source. From the results, it is clear that the sound pressure at the convergence point increased approximately 2.5-fold.

References

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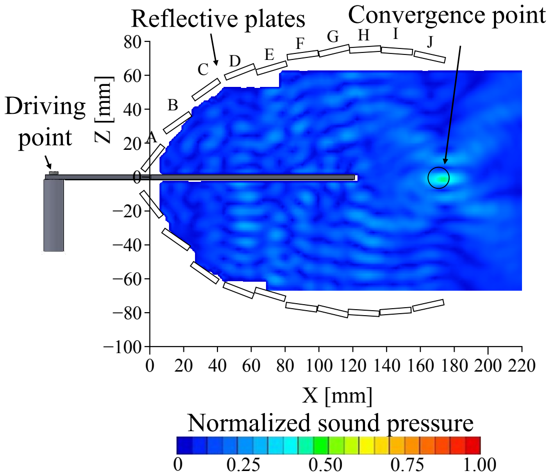

Fig. 3 Sound pressure distribution with 20 reflective plates (Y=−40 mm).

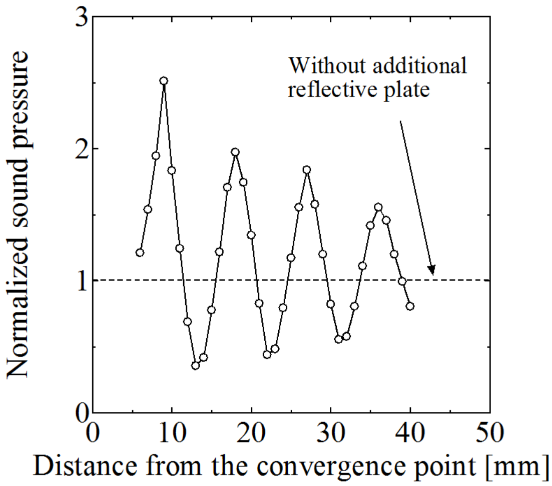

Fig. 4 Relationship between the distance and normarized sound pressure.

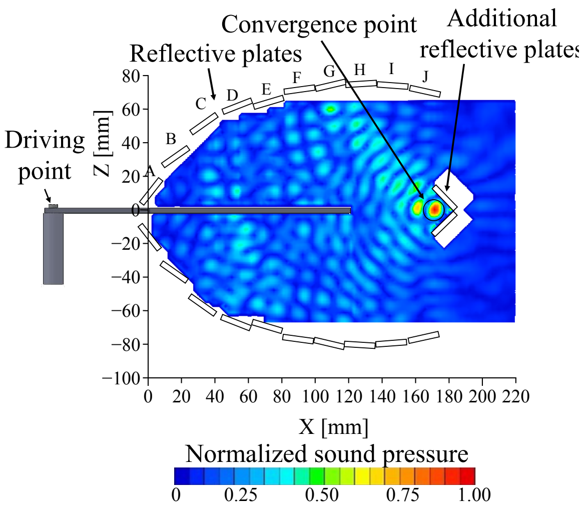

Fig. 5 Sound pressure distribution with additional reflective plates (Y=−40 mm).