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Evaluation of the sound field in ultrasonic atomization using a horn

ホーンを用いた超音波霧化における音場の評価

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1. Introduction

Ultrasonic atomization technique is used to generate mist of small water droplets of several micrometers in diameter. When water is irradiated with ultrasound of MHz range, a water surface vibrates intensely and small droplets are separated from the water surface [1, 2]. The mist increases humidity by evaporation because a smaller droplet has a larger surface area relative to its volume.

The authors have studied on ultrasonic mechanistic application. In the previous paper the experimental results for ultrasonic atomization was shown using a horn attached to the transducer in order to study the effect of a horn on the generation rate of mist atomized at 2.55 MHz [3, 4]. The results showed that the amount of mists was larger with a horn compared to that without a horn. In the present paper, the effect of diameter of the upper end of a horn is studied experimentally on the mist formation rate. Moreover, the sound pressure distribution is studied by a finite element method (FEM).

2. Experimental method

Figure 1 shows a basic experimental system. **Figure 2** shows photograph and a schematic diagram of a transducer and a horn. The transducer is a disk of a circular plate of 20 mm in diameter and 2.5 MHz in resonance frequency. The horn is removable and a guide tube with a hole made by 3D printer. The inner diameter of the bottom end of the horn is 13 mm. The inner diameter of the upper end of the horn is 3 mm and 7 mm. The length of every horn is 28 mm.

The transducer was settled at the center of the bottom surface in the water tank with the size of 142 mm x 142 mm x 195 mm. When the transducer is driven by a function generator (NF, WF1946B) through an amplifier (ENI, 325LA), it radiates a sound wave into the water, and vibrates the water surface, which causes atomization. The voltage of the transducer was about 80 Vpp, and the electric power was 16 W. The weight of water in the water tank was measured every second with an electric balance (A&D, FX-5000i) and was recorded on PC. The water tank was filled with mists during the generation of mists. To remove mists, air blow was made using an electric fun.

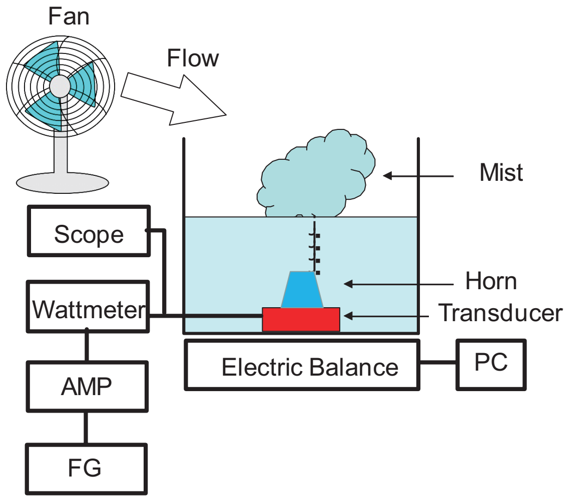
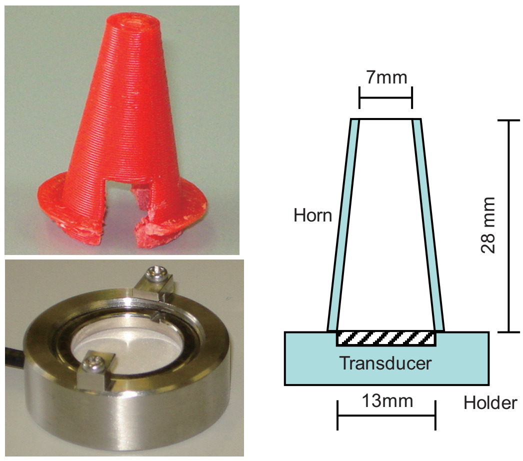


Fig. 1. Experimental apparatus.



(a) Photo (b) Schematic diagram
Fig. 2. External appearances of a transducer and a horn (a), and the dimension of the horn (b).

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3. Experimental result and discussion

Figure 3 shows the experimentally measured mist volume as a function of water level with a horn of ϕ3 mm, ϕ7 mm in the inner diameter as well as without a horn. The amount of mist was larger with a horn. However, when the water level is over 30 mm using the ϕ3 mm horn, the atomization is suppressed, where the top end of the horn is below the water surface.

The sound pressure distribution was numerically calculated with and without the horn by the FEM (COMSOL Multi physics) for sound generation. **Figure 4** shows the sound pressure distribution on the sound beam axis. When the horn is attached to the transducer, the higher amplitude of sound pressure is formed on the sound beam axis. The maximum sound pressure is 0.71 [-] at 35.1 mm from the transducer using the ϕ7 horn.

To study the influence of the diameter of the horn on the sound pressure amplitude, the sound pressure was calculated with changing the horn diameter from 1 to 20 mm. **Figure 5** shows the maximum sound pressure and its position relative to the transducer. When the horn diameter is relatively small around 4 mm, the amplitude of sound pressure becomes high inside the horn. However, the spatial distribution of sound pressure, which is not shown here, showed that the amplitude of sound pressure outside the horn suddenly decreased. This is probably the reason why the suppression of atomization occurs at 30 mm water level for 3 mm horn in Fig. 3. Therefore, there is an optimal size of the horn diameter in relation to the water level.

4. Conclusion

This paper shows the influence of liquid height on mist generation rates in ultrasonic atomization with / without a horn. Horns with various dimensions were made by a 3D printer. The inner diameter of the top end of the horn was 3 mm or 7 mm. The sound pressure distribution was numerically calculated by the FEM for sound generation.

The results showed that the amount of mist with a horn was larger than that without a horn. There is an optimal size of the horn diameter in relation to the water level.

References

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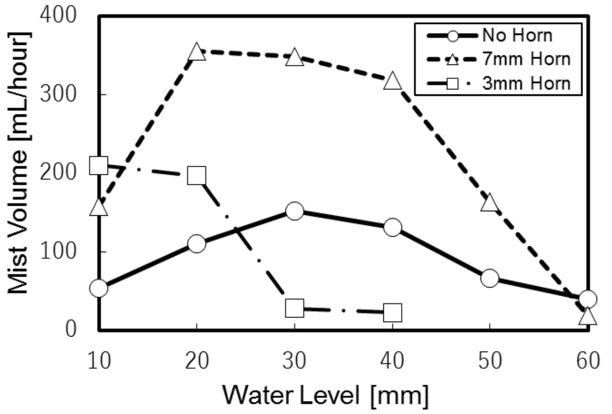

Fig. 3. Dependence of mist volume on water level in the absence and presence of a horn with 7 mm or 3mm in inner diameter of the upper-end hole.

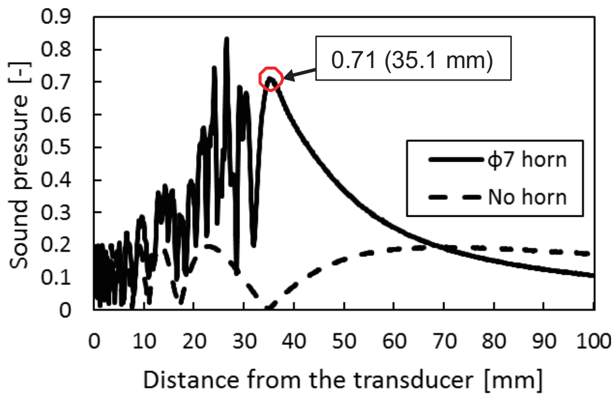

Fig. 4. Distribution of the calculated sound pressure amplitude on the sound beam axis.

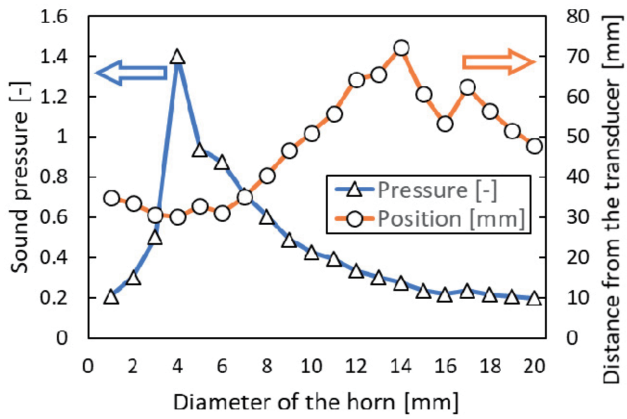

Fig. 5. The calculated maximum sound pressure with changing the diameter of the horn.