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Non-contact atomizer of droplet by aerial ultrasonic source using two vibrating plates

２枚の短冊形たわみ振動板型空中超音波音源による液滴の非接触微粒化

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1. Introduction

Liquid atomizers are used in equipment such as humidifiers, liquid separators, and mass spectrometers. There are several methods of atomization, including evaporating liquid with heat and bringing liquid of into contact with an ultrasonic vibrating surface.[1] However, the properties of the liquid can be altered by heating and by contamination with impurities, and the device can be damaged by contact between the liquid and the vibrating surface.

We consider noncontact ultrasonic atomizers to be the most promising way to solve these problems. However, existing noncontact atomizers are too large. Therefore, we have developed a miniaturized 28 kHz ultrasonic source that uses two vibrating plates. We examined the noncontact atomization of a liquid by aerial ultrasonication. The results demonstrate that this method of atomization is feasible. In this paper, we report the area in which the atomization of water occurs in our atomizer and the particle size distribution of the droplets produced.[2],[3]

2. Ultrasonic Source

A schematic of the ultrasonic source is shown in **Fig. 1**. The ultrasonic source is a 28 kHz bolt-clamped Langevin-type ultrasonic transducer, connected to an exponential horn for increasing the amplitude, and two small rectangular transverse vibrating plates are inserted between two resonance rods. The two plates are inserted at an equal distance from the antinode of the longitudinal vibration. The spacer length was used to form the standing wave field in air between the vibrating plates. The vibrating plates were 46 mm long, 25 mm wide, and 3 mm thick. The length of the vibrating plates was taken as the X-axis, the width as the Y-axis, and the vertical direction as the Z-axis.

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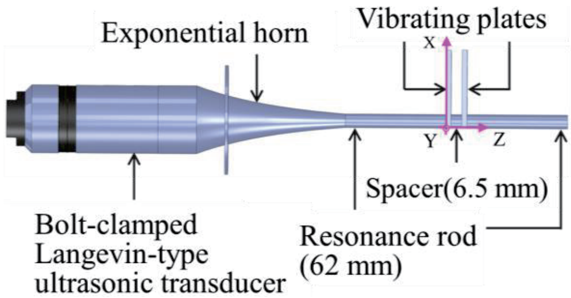

Fig. 1 Schematic of ultrasonic vibration source.

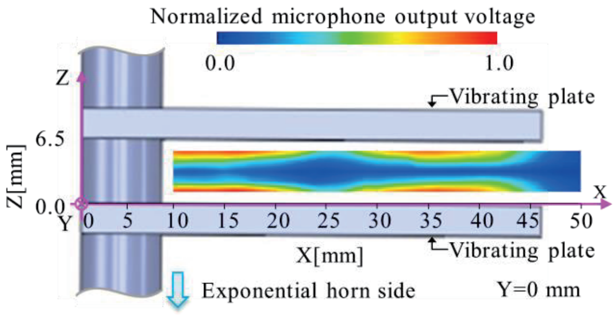

Fig. 2 XZ-plane sound pressure distribution.

3. Sound Pressure Distribution between Vibrating Plates

To know the standing wave field between the two vibrating plates, we measured the XZ-plane sound pressure distribution. We applied 40 mA constant incoming current to the sound source for the measurement and used condenser microphone with probe to measure sound pressure.

Result of XZ-plane sound pressure distribution is shown in **Fig. 2**. The horizontal axis is the X-axis direction and the vertical axis is the Z-axis in the figure. The sound pressure is shown by the normalized color bar. Blue and red represent lower and higher sound pressure, respectively. The figure shows that the sound pressure forms an antinode near the vibrating plates and a node at Z = 3.25 mm; the center of the Z-axis. This indicates that a standing wave field is formed between the vibrating plates.

4. Examination of Non-contact Atomization of Water

To identify areas that are capable of atomization when a drop of water is introduced into the standing wave sound field, we examined the area in which the drop becomes instantly atomized. The atomization in different areas was measured by introducing water (5.0 μL) into the wave sound field using a ring attached to the top of a needle and taking a photograph with a high-speed camera. The measurement point was in the range of X = 25 to 46 mm, Y = -12 to 12 mm, Z = 3.25 mm and the input electric power was changed between 2 and 5 W. The measurement was performed five times for each input power and position.

The results are shown in **Fig. 3**. In the figure, the horizontal axis is the X-axis and the vertical axis is the Y-axis. The points at which atomization occurs at each input electric power are shown by a color scale. The center of the area in which the drops are atomized is at X = 35 mm, Y = 0 mm, Z = 3.25 mm. In addition, the atomization took place at powers greater than 2.5 W. The atomization area increased as the input power increased, and it reached a maximum around 4.0 W.

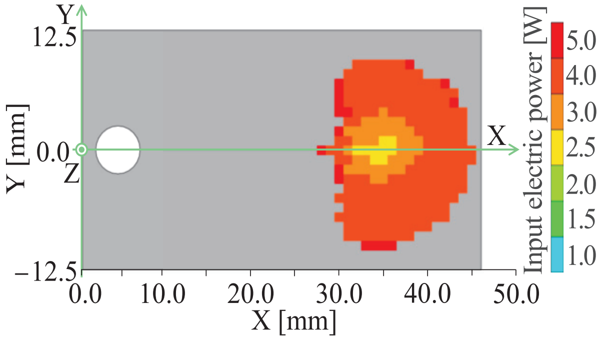

Fig. 3 Relationship between input electric power and range of water atomization. Z = 3.25 mm.

5. Particle Size Distribution of Droplets

We then measured the particle size distribution of the atomized water droplets The measurement conditions were a constant input power of 4 W and the water was introduced at X = 35.0 mm, Y = 0.0 mm, Z = 3.25 mm. Silicone oil was applied on a petri dish in order to catch the particles those were atomized. The experiment was conducted as follows. First, a petri dish containing silicone oil was placed under the atomization position. Then, the water was atomized by the sound wave, and the fine droplets were scattered on the silicone oil in the petri dish. The droplets were observed with an optical microscope, and the area, which was 6.8 × 61.3 mm, was imaged in 12 separate regions (6.8 × 5.1 mm, 1920 × 1440 pixels). Because the droplets evaporate over time, the measurement was carried out within 2.5 min of atomization. To ensure the results were reliable, the particle size distribution was measured 10 times under the same conditions, and the average was taken.

The results are shown in **Fig. 4**. The horizontal axis is the particle size and the vertical axis is the average number of particles in the figure. The particle size distribution is concentrated around a median particle size of 55 μm, the average number of particles was 1003. There were few particles 300–900 μm in size.

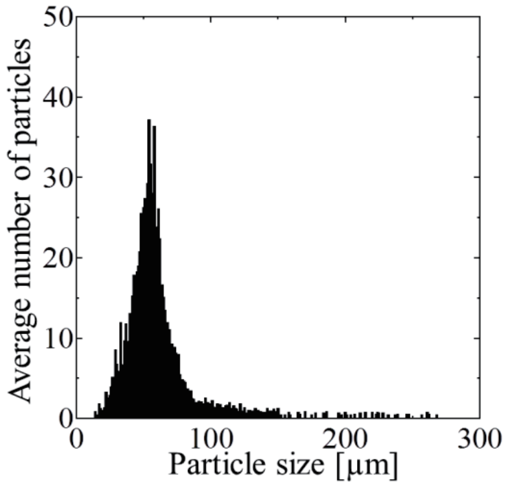

Fig. 4 Particle size distribution.

6. Conclusions

An atomization experiment inside the standing wave sound field suggests that the center of the area in which atomization occurs is at X = 35.0 mm, Y = 0.0 mm, Z = 3.25 mm. In addition, the particle size distribution for water atomized at an input power of 4 W indicates that the particle size is concentrated narrowly around a median value of 55 μm.

References

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