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Behavior of liquid in a vessel irradiated by high-intensity aerial ultrasonic waves

強力空中超音波を照射した容器内の液体の挙動

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1. Introduction

Previous studies have investigated a noncontact method for stirring liquid in a small vessel in water by irradiating the liquid with ultrasonic waves [1, 2, 3]. However, given findings that a solid surface can be excited using high-intensity aerial ultrasonic waves [4, 5, 6], we expect that a liquid in a small vessel can be stirred using high-intensity aerial ultrasonic waves as well.

In this study, we examined the behavior of a liquid in a small vessel irradiated with high-intensity aerial ultrasonic waves.

2. Experimental device

The experimental devices that comprised of the acoustic source, experimental sample, and a high-speed camera, were arranged as shown in **Fig. 1**. The acoustic source used to generate high-intensity aerial ultrasonic waves was a point-converging source with a stripe-mode vibration plate (frequency: 20 kHz) [7]. Convergence point O is on the x-axis running through the center of the vibration plate, approximately 130 mm from its edge.

Fig. 2 shows the sound pressure distribution of ultrasonic waves and focused at the convergence point O in the y–z plane. The ultrasonic waves converged to an area of about 15 mm diameter and the intensity of the aerial ultrasonic waves was about 23.5 kPa at an input power of 150 W.

Fig. 3 shows the sample in a small acrylic vessel with external dimensions of 6.2×9×32 mm, and internal dimensions of 4×5×30 mm. The wall exposed to the ultrasonic waves irradiation (labeled B) has a thickness of 0.2 mm and the others are 2 mm. The vessel is fixed to sandwich between the upper and lower sides. After the liquid sample is injecting, the top of the vessel was covered with a rubber sheet to prevent ultrasonic waves from entering through the top.

The sample liquid was 150 μl ethanol, which filled about one-quarter of the vessel. The surface of the liquid sample was set to coincide with the convergence point O of the radiated ultrasonic waves.

Using a digital microscope with a high-speed camera located to the side of the sample, the behavior

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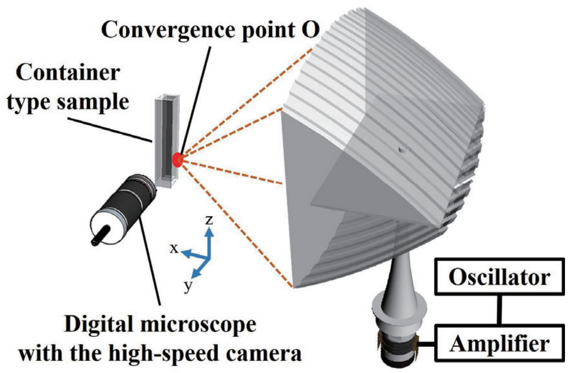


Fig. 1 Experimental devices

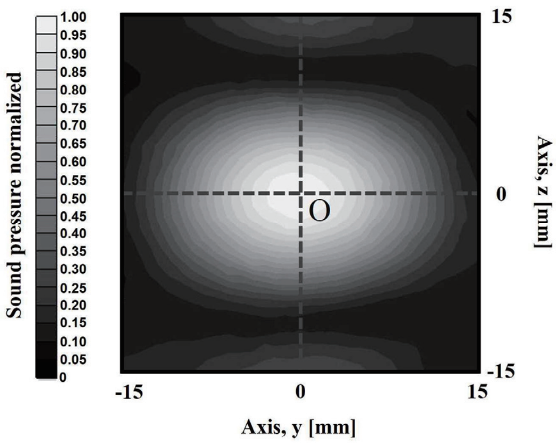
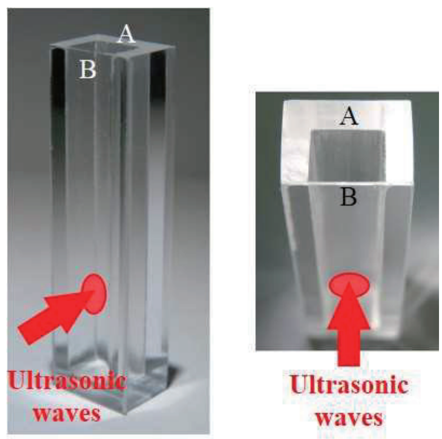


Fig. 2 Sound pressure distribution around the convergence point



(a) Front perspective view (b) Top view

Fig. 3 Container type sample

of the liquid in the small vessel under ultrasonic irradiation was observed. The shutter speed was 1 / 6000 s and the frame rate was 500 fps.

3. Experimental result

Fig. 4 shows the observation results over time from the beginning of ultrasonic waves irradiation. Before ultrasonic irradiation, the liquid surface is raised about 5 mm along the wall surface due to the wettability of the ethanol (4a). After 10 ms, atomized liquid have begun to be released from the liquid surface into the small vessel, immediately after the liquid surface had raised along the B-side wall (4b). After 20 ms, the B-side surface was greatly raised compared to before irradiation, and the A-side surface was lowered correspondingly (4c). After 30–50 ms, droplets of liquid were released obliquely upward, colliding with A-side wall surface (4d, e). After 100 ms, the liquid surface was more violently atomized and the liquid in the vessel had large flow as a result (4f).

We also investigated the same observations when the ultrasonic irradiation point on the wall of the vessel was changed. The behavior of the liquid was different when the irradiation position and intensity of the converged ultrasonic waves was changed.

4. Conclusion

We observed the behavior of a liquid (ethanol) in a small vessel where one wall was irradiated with high-intensity aerial ultrasonic waves, and found that large flow occurs in the liquid in the small vessel.

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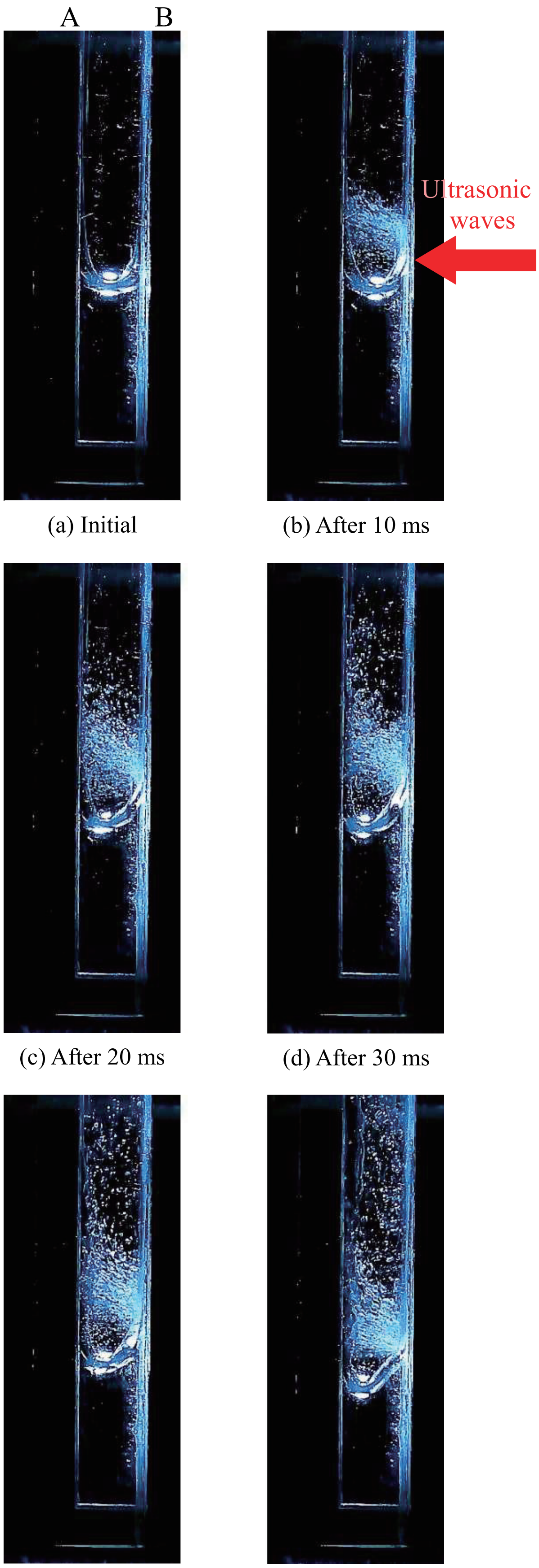

(a) Initial (b) After 10 ms

(c) After 20 ms (d) After 30 ms

(e) After 50 ms (f) After 100 ms

Fig. 4 Experimental results