Ultrasonic Levitation for Liquid Droplet

Tetsuro OTSUKA and Tomoo NAKANE
Department of Electrical and Electronic Engineering, College of Industrial Technology,
Nihon University, Narashino 275-8575, Japan

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Ultrasonic levitation in a gravity field was tested using a viscous liquid at a frequency range from 20 kHz to 28 kHz. Red ink and glycerin droplets having diameters in the range of 3 mm to 5 mm were placed at a node of a standing wave.
As a result, the droplets were not only flattened like a disk, but also found to contain fine air bubbles. Additionally, the droplets continuously changed their location moving from node to node while maintaining a constant volume.

KEYWORDS: ultrasonic levitation, flattening rate, standing wave field, time domain

It is well known that fine particles can float or be suspended in a high intensity ultrasound field1)-7). In this experiment, viscous fine particles were placed in a high-intensity standing wave field in the gravity field during ground experiments. Results show that these particles were not only flattened, but also fine air bubbles were found wrapped inside the droplets in the higher viscous liquid used. It was also found that these particles continuously moved from node to node in the high-intensity ultrasound field in the gravity field.

Figure 1 shows a schematic of the experimental set-up. A stepped circular vibrating plate was used to produce a high-intensity ultrasound field. Two plates were designed for frequencies of 20 kHz and 27 kHz.

The plates were connected to the tip of an exponential horn having the transformation rate of 5.6, and the Bolted-Langevin-type transducer (BLT) was connected to the tail of the horn. The reflecting plate was located 5 wavelengths from the sound source to produce the standing wave field. Particle shapes were monitored using a digital camera and a high-speed video camera, obtaining a top view and side view stored at the same time. For the high-speed camera, the shutter speed was changed up to 1/20,000 s and the frame rate was set at 500 fps.

Figure 2 shows a sample of sound pressure distribution at the frequency of 20 kHz. The sound pressure level was calculated to be in the range from 151 dB to 161 dB.

A liquid up to 100 μl was placed using a micro pipette at points A, B and C, as illustrated in Fig. 2. The liquid used in this experiment was a red ink manufactured by PILOT Co., Ltd. The viscosity was measured to be 1.5 mPa·s using a visco meter. The particles were depressed into an oval shape, similar to a football, and the length and width were measured using a calibrated scale. Figure 3 shows the levitated particles in the sound pressure distribution. Figure 4 depicts the flattening rate for the red ink particles at the frequencies of 20 kHz and 27 kHz. The particles were placed at points A, B and C, as indicated in Fig. 2.

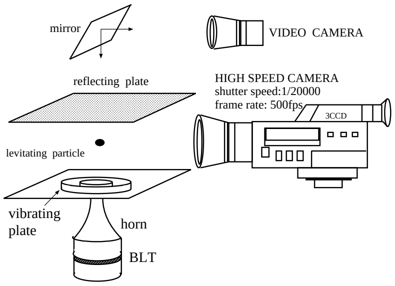

Fig. 1. Experimental set-up.

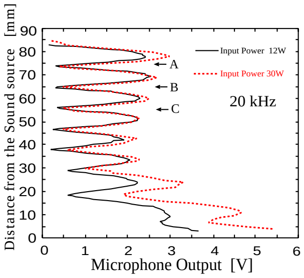

Fig. 2. Example of sound pressure distribution.

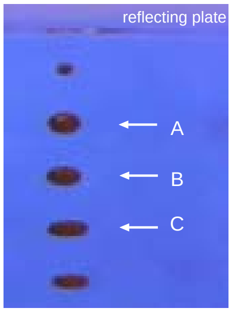

Fig. 3. Droplets levitating at nodes in standing wave field.

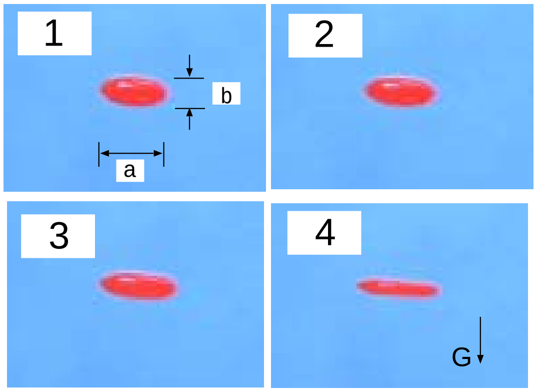

Fig. 4. Droplets whose shape was depressed with increasing input power from 1 to 4.

It was found that the particles were flattened at every three nodes when the input power was increased. At the frequency of 20 kHz, the particles were atomized in the range of over 14 W of electric input.

Figure 5 shows a cross section, as measured using the side view of the flattened droplet. Note that when the input power is increased, the cross section decreases. Moreover the pitch of the curve's slope becomes steeper when the frequency of 27 kHz is used.

sound pressure, it was flattened like a disk. This is because the weight of the droplet itself and the radiation force produced by sound energy were balanced. If the equilibrium of these two forces was not kept constant, the droplet changed its location to the next node. Figure 6 provides the sequence of the change in droplet shape in the time domain when changing its location in the standing wave field from node to node.

In the Fig. 6(a), the droplet was flattened at the node, and the head of the droplet slightly swelled after 10 ms. In Fig. 6(b), the tail was pressed flat.

Both the head and tail were pushed after 20 ms shown in Fig. 6(c), then the droplet started moving to the lower position while continuously changing its shape to a sphere. After 40 ms, it was located around the loop of the standing wave field and the shape was almost a sphere. The droplet was continuously changing its location and was trapped at the next node, as shown in Fig. 6(f). While changing its shape from Figs. 6(a)-6(f), there were no scattered fine particles observed.

In the case of higher viscous particles in the nodes, glycerin was placed and monitored using a high-speed digital camera. The viscosity of the glycerin was measured at 1500 mPa·s.

It was found that the droplet ballooned and the bubbles inside the droplet continuously grew or disappeared. This can be viewed in Fig. 7(a) where the droplet contained many bubbles. Figures from 7(b)-7(e) were taken at 500 ms. It should also be noted that the droplet was rotated akin to the arrows in the figure.

Ultrasonic levitation was tested in the ground operation at frequencies of 20 kHz and 27 kHz. Red ink liquid was used for lower viscous liquid and glycerin for higher viscous liquid. The following results were obtained.

When droplets having an average width of 4 mm were placed at the nodes of sound pressure distribution, they were not only levitated, but also rotated.

As the droplets changed their location to the next node of the sound pressure distribution, their shape was found to continuously change in the time domain. Moreover, no scattered fine particles were found.

When the glycerin droplet was placed at the node, it ballooned and fine air bubbles were wrapped inside it.

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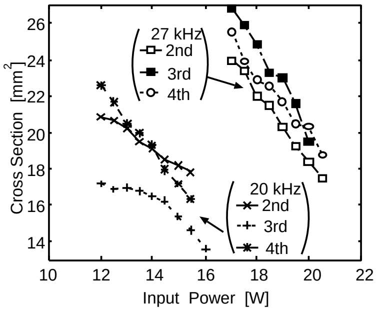

Fig. 5. Droplet flattened when input power increased.

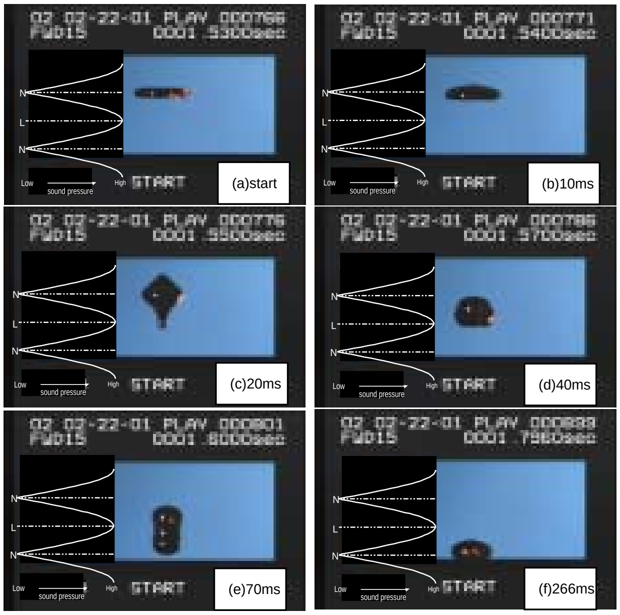

Fig. 6. Droplet continuously changing its shape in time domain.

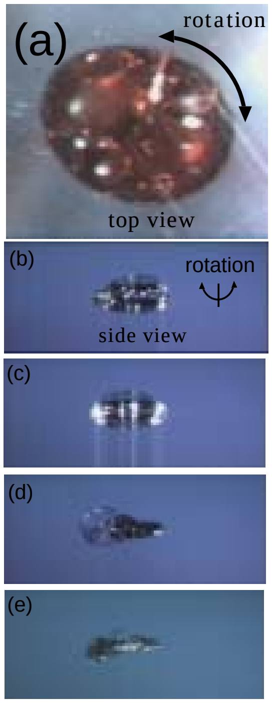

Fig. 7. Droplet containing fine air bubbles.