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Multi-frequency ultrasonic atomization of circular plate by single parabolic reflector transducer

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1. Introduction

Ultrasonic atomization has generally been utilized in several processes, such as nebulization therapy, spray pyrolysis and sewage treatment.[1-3] Compared with other commonly used techniques, ultrasonic atomization can control the droplet size and the fog amount independently.[4]

In previous work[5,6] the relationship between ultrasonic intensity, operating frequency mist amount, and droplet size has been studied thoroughly. However, the ultrasonic transducers used for atomization are usually based on Langevin transducer with a single operating frequency, which are not capable of changing the droplet size. To solve this problem, we introduce a new transducer consisting of a parabolic reflector and a bending plate, which can be excited to produce atomization at multi-frequencies.

2. Principle

A double-parabolic-reflectors ultrasonic transducer (DPLUS) was proposed and developed, which archives high energy intensity and multi-frequency excitation.[7,8] The principle of the DPLUS and a prototype are shown in **Fig. 1**(a) and (b). Plane waves can be generated by driving the piezoelectric ceramic ring with AC voltage. Through two reflections from the two parabolic reflectors sharing the same focal point, the plane waves can be focused and propagated along the waveguide with a high energy density. However, the conventional DPLUS was originally designed for the *in vivo* treatment, utilizing a slender waveguide, which is not suitable for atomization application.

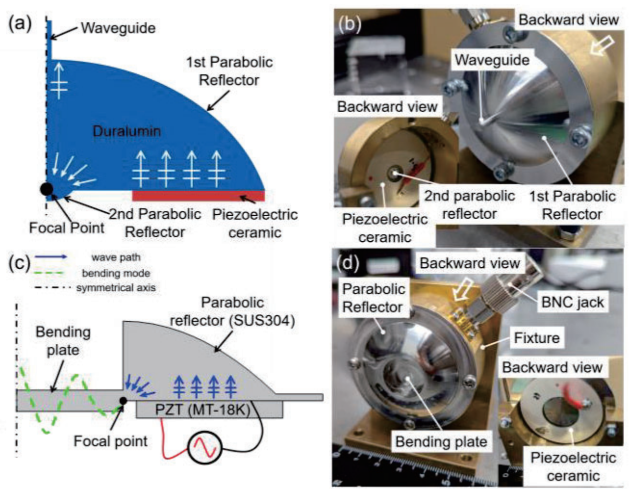

Fig. 1 (a) Principle of the DPLUS.[7] (b) Prototype of the DPLUS. (c) Focusing principle and the mode shape. (d) Prototype of the designed transducer.

In this study we propose a single parabolic reflector and a bending plate, as shown in Fig. 1(c). The waves reflected by the parabolic reflector can be focused to excite the bending mode of the plate. By introducing the plate structure, the water can be placed above, increasing the contact area and energy transfer efficiency. The prototype of the transducer is shown in Fig. 1(d), which consists of a hard-type PZT ring with the outer diameter of 40 mm, inner diameter of 18 mm and thickness of 1.3 mm (MT-18K, Nittera Co. Ltd.). A metal reflector (SUS304) is glued with the PZT by thermoplastic resin (EX-0293M, Epifine).

3. Methods

To evaluate the behavior of the designed transducer, electrical and mechanical properties were measured and compared with FEM simulation and experiments.

3.1 FEM simulation

The simulation model was built and calculated with COMSOL Multiphysics (COMSOL Inc.). In the range of 700 kHz to 2.5 MHz, the admittance and the axial vibration velocities at the center of the plate were simulated under continuous excitation with a voltage of 10 Vpp. The results are shown in **Fig. 2**(a) and (b). Several admittance peaks with high vibration velocities were archived in a wide frequency range, which showed the possibility of the transducer driving at multi-frequencies.

3.2 Experiments

To characterize the actual performance of the prototype and compare it with simulation results, experiments were conducted. Using the setup shown in **Fig. 3**, the admittance and axial vibration velocities at the center of the plate were measured.

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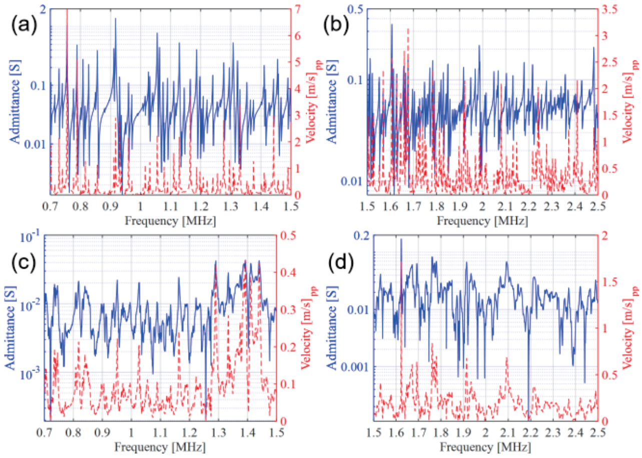

Fig. 2 Admittance and velocities results in simulation and experiments.

The input voltage to the frequency response analyzer (FRA5097, NF Corp.) was 0.5 Vpp, which was amplified 20 times by the power amplifier (HSA4101, NF Corp.) for driving the transducer. The measured results are shown in Fig. 2(c) and (d). It should be noted that a large velocity peak of 1.8 m/s was obtained in experiments at 1.62 MHz. This phenomenon arose from the fact that this frequency concurrently excited both the thickness mode of the PZT and the bending mode of the plate, which resulted in the plate receiving a stronger excitation during resonance, consequently yielding the large vibration velocity.

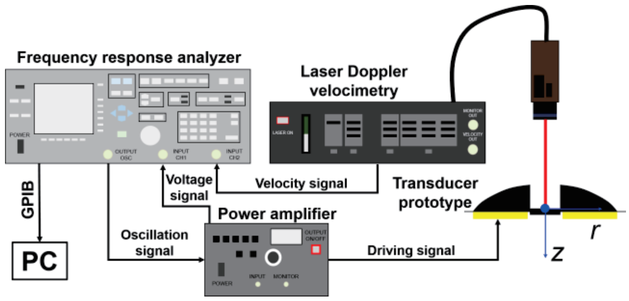

Fig. 3 Experimental setup for the admittance and velocities measurement.

4. Results and Discuss

In both simulation and experiments, several resonant peaks with large vibration velocities are observed. The value of the admittance and velocities differ considerably between simulation and experiments, which is caused by the existence of the resin layer. In the simulation, the thickness and damping of the resin were ignored. In the manufacture of the prototype, the thickness and uniformity of the resin layer affect the performance of the transducer, thus leading to these differences. Ultimately, we chose four frequencies: 0.73, 0.95, 1.16, and 1.65 MHz, to evaluate the atomization performance of the transducer. A volume of 1 mL of tap water was placed within the transducer, as shown

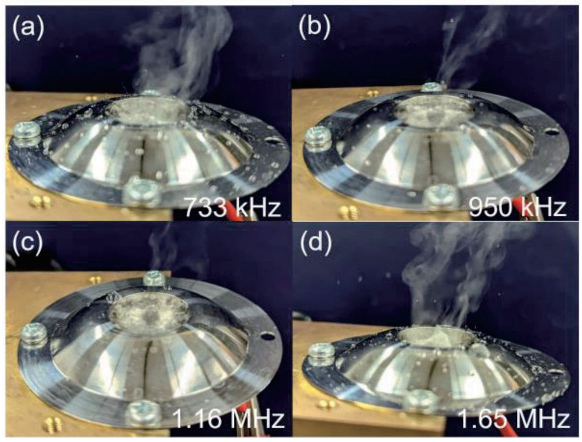

Fig. 5 Ultrasonic atomization at (a) 733 kHz, (b) 950 kHz, (c) 1.16 MHz, and (d) 1.65 MHz.

in **Fig. 5**. At all four frequencies, significant atomization phenomena occurred, thereby proving the successful design of multi-frequency excitation.

In the future study, we will measure the acoustic pressure distribution and evaluate the cavitation in the water to analyze the causes of atomization theoretically. Furthermore, we will also conduct measurements of the droplet size and the atomization amount at different operating frequencies, and compared the performance with the conventional transducers.

Acknowledgment

This work was supported by JSPS KAKENHI Grant No. 21KK0065 and 20H02097.

References

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