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Study on measurement technique of ultrasonic power for low frequency by radiation force balance method

天秤法による低周波数帯域の超音波パワー計測技術の検討

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1. Introduction

Ultrasonic cleaning device is used in several fields. For example, silicon wafer that is substrate of semiconductor is cleaned by ultrasonic cleaning device in order to obtain a clean surface whose degree affets the performance of the semiconductor[1]. Also, in medical filed, it is important to keep high cleanliness of medical equipment by ultrasonic cleaning[2]. Because high cleanliness of the equipment is required as the preprocessing of sterilization to prevent in-hospital infection by various pathogens such as Covid-19 that is novel coronavirus.

It is required to investigate the characteristics of ultrasonic cleaning device for efficient and effective use of the device. However, technology for investigqating the device is underdeveloped. The convential index of the device is applied voltage or supplied power to ultrasonic transducer. However, it is difficult to investigate accurately because of not evaluating sound field of ultrasound. Also, though there is evaluation method by aluminum foil, it is difficult to investigate accurately because of qualitative evaluation. In terms of the evalution by sound pressure, most of commercial hydropone is destroyed by acoustic cavitation generated in the device.

Therefore, we considered the measurement technique on ultrasonic power by radiation force balance (RFB) method for establishnig the index of ultrasonic cleaning device[3]. RFB is the most precise method for measuring ultrasonic power and is adopted as ultrasonic power primary standard between 1 MHz and 20 MHz in many countries. However, little is known about the measurement of ultrasonic power below about 1 MHz which is used in ultrasonic cleaning device by using RFB. The purpose of this study was to clarify the relationship between the applied voltage to the transdcuer and ultrasonic power in the low frequency range less than 1 MHz.

2. Experimental method

Figure 1 shows a schematic view of RFB device for low frequency range. The device consisted of electronic balance (R&A, MC-1000) with weighing capacity of 1000 g and resolution of 0.1 mg. We used two targets in the experiment. One is the target for low frequency (Precision Acoustic, F48) with a diameter of 80 mm. The target had the absorption characteristics between 50 kHz and 3 MHz. The other is the targets (Precision Acoustic, HAM A) with a diameter of 80 mm. The target had the absorption characteristics between 1 MHz and 20 MHz.

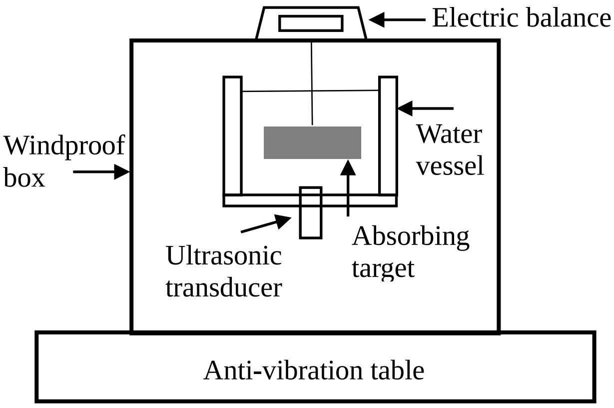

Fig. 1 Ultrasonic power measurement device for low frequency.

We conducted the experiments by using the operating frequencies of 150 kHz which was generated by bolt clamped Langevin type transducer with a diameter of 45 mm, and 1MHz which was generated by air backing PZT transducer with a diameter of 40 mm. These transducers were placed at the bottom of water vessel which had a long and a wide of 190 mm, and a height of 120 mm. The output signal from a function generator (Agilent, 33250A) was amplified by a power amplifier (R&K, CA010K010-5353R).

The water vessel was full of 1200 mL of degassed water. The dissolved oxygen level of degassed water was about below 2 mg/l. Room temperature was control within 23 °C±0.5 °C, and water temperature was controlled within 23°C± 1.0 °C. Ultrasound exposure time was 30 s. Pre-ultrasound exposure time was 30 s, and post-ultrasound exposure time was 120 s. Comparison range of ultrasonic power was below 15 W.

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3. Results and Discussion

We carried out the comparison between the novel ultrasonic power device for low frequency and NMIJ primary standard with the absorbing targets of HAMA and 1 MHz ultrasonic transducer. The result is shown in Fig. 2. As the results, the results by the novel ultrasonic power measurement device and NMIJ primary standard agreed within measurement uncertainty at 5 %. Measured values by the novel device for low frequency are systematically small compared to the primary standard in NMIJ. Systematic difference is caused by the difference in resolution ability of two devices. The primary standard in NMIJ has 1 μg of resolution ability, and the novel device for low frequency range has 0.1mg. It is considered that this difference has occurred as above. Also, ultrasonic power measured by two devices became a quadratic curve with respect to the applied voltage to the ultrasound transducer, and coefficient of determination was high value. This showed that the measurements could be carried out with high accurately. It was confirmed that the novel device was operating properly.

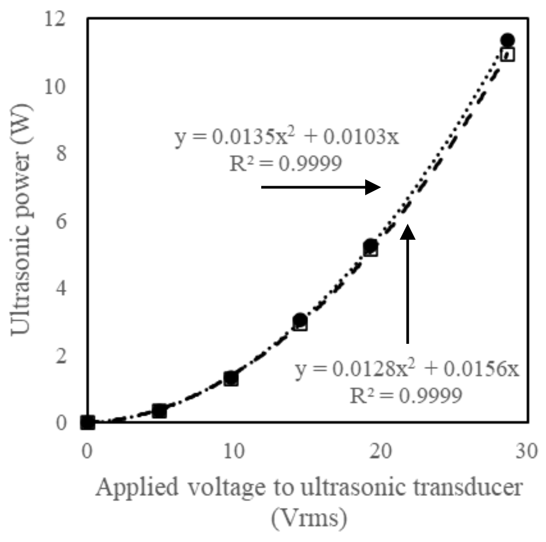

Fig. 2 Change in measured values by the novel RFB device for low frequency and primary standard in NMIJ at 1 MHz ultrasonic transducer

Next, we carried out the experiment by 150 kHz transducer which was the ultrasound frequency used in ultrasonic cleaning device. We used the absorbing target of F48. The change of ultrasonic power at frequency of 150 kHz is shown in Fig. 3. The relationship of quadratic curve between applied voltage to the transducer and ultrasonic power was shown at the frequency of 150 kHz. Also, coefficient of determination was high value. This showed that the measurement was carried out accurately. From these results, the validity of the novel device was assured from these results. The RFB device with the absorbing target of F48 has the potential ultrasonic power measurement on frequency range used in ultrasonic cleaning device.

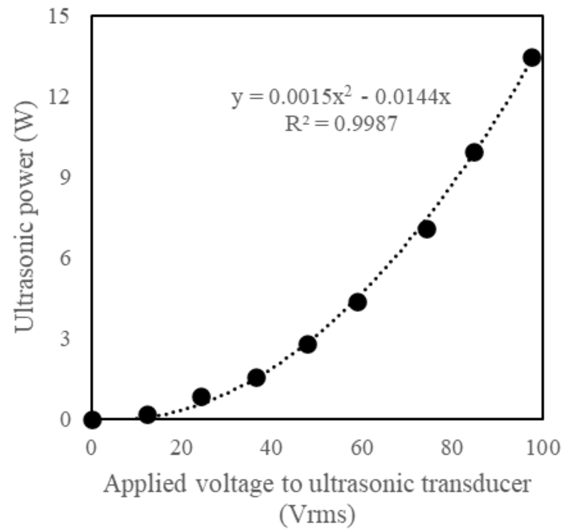

Fig. 3 Change in ultrasonic power by radiation force balance method for low frequency at 150 kHz ultrasound transducer.

4. Summary

We considered evaluation of RFB method for low frequency. As the results, compared with primary standard of ultrasonic power in NMIJ at 1 MHz ultrasonic transducer, the measured values by the novel device agreed within uncertainty of measurement at 5% of primary standard in NMIJ. In case of 150 kHz ultrasonic transducer, we got the results relationship of a quadratic curve between applied voltage to the transducer and ultrasonic power. The results show that the novel method by RFB has potential use in quantitative measurement for the performance of ultrasonic cleaning device.

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References

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