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Influence of Ultrasonic Cavitation on Measurement of Sound Pressure
音圧測定に及ぼす超音波キャビテーションの影響

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1. Introduction

Ultrasound is applied to several devices, such as an ultrasonic cleaner and a homogenizer. The evaluation method of the ultrasonic field of these devices is carried out by calorimetry, the radiation force method, the sound pressure measurement method, the physical action, the chemical action, etc[1]. The sound pressure measurement is effective to obtain distribution of the sound pressure in the sonochemical reactors. Sound pressure is proportional to the square root of the electric power applied to a transducer theoretically. However, it was reported that sound pressure became unstable in the case of high sound pressure[2]. The purpose of this study is to investigate influence of cavitation on sound pressure at various frequencies near the cavitation threshold.

2. Experiment

The photograph of sonochemical reactors and experimental setup is shown in **Fig. 1**. The sample was air-saturated water. The sound pressure at fundamental frequency and white noise were measured by a hydrophone and a spectrum analyzer while gradually increasing the electric power applied to the transducer. The generated cavitation was obtained by BIV (Broad Integrated Voltage) calculated from white noise[3-5]. The frequency, the diameter of transducers, and type of sonochemical reactor which were used in the experiment are shown in **Table I**.

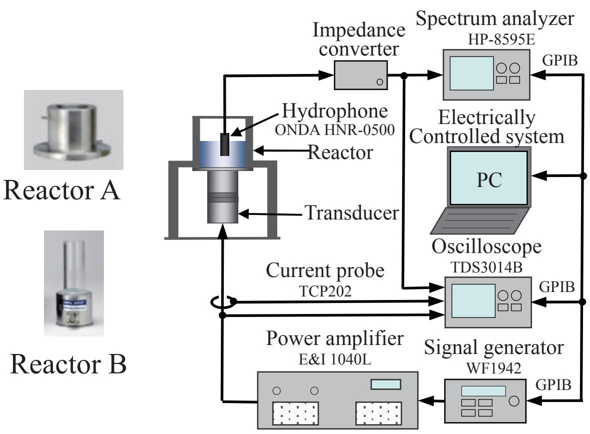

Fig. 1　Reactors and experimental setup.

Table I　Frequency and experimental condition.

Frequency (kHz)	Diameter of transducer (mm)	Type of reactor	Volume of sample (mL)
18	45	A	50
24	45	A	50
43	45	A	50
129	45	A	50
493	50	A	50
1000	20	B	25
2400	20	B	25
5000	20	B	25

3. Results and discussion

Experimental results at the frequency of 24 and 129 kHz are shown in **Fig. 2**. The sound pressure at the fundamental frequency and the BIV are plotted against the square root of the electric power applied to the transducer. When generated cavitation is non-existent, the sound pressure increases linearly while increasing the square root of the electric power. At all ranges of frequencies used in the experiment, the sound pressure at fundamental frequency is unstable when cavitation is generated by ultrasound. In the case of low frequency, such as 18, 24 and 43 kHz, when cavitation is produced, sound pressure may increase or decrease. In the case of high frequency, such as 129, 493, 1000, 2400 and 5000 kHz, when cavitation is produced, sound pressure reduces significantly. In order to investigate these reasons, the hydrophone output wave and bubbles of the sound field were observed by oscilloscope and ultrasonic diagnostic, respectively. The hydrophone output waves are shown in **Fig. 3**. The hydrophone output is the only wave propagated from the transducer below the cavitation threshold. However, above the cavitation threshold at low frequency, since the emitted ultrasound from cavitation

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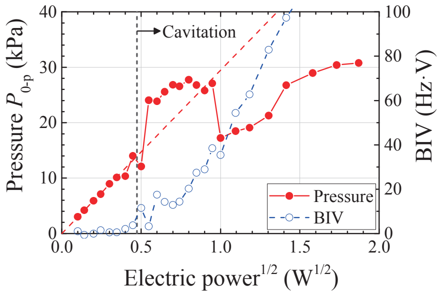
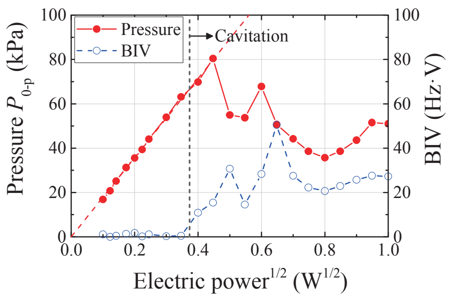
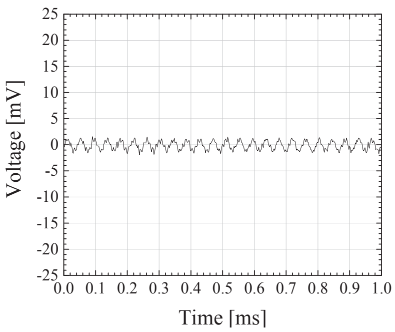


(a) 24 kHz

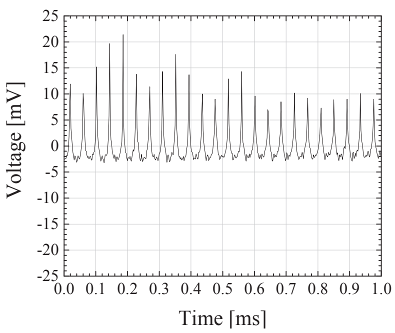


(b) 129 kHz

Fig. 2 Relations of pressure and the BIV to the square root of the electric power.



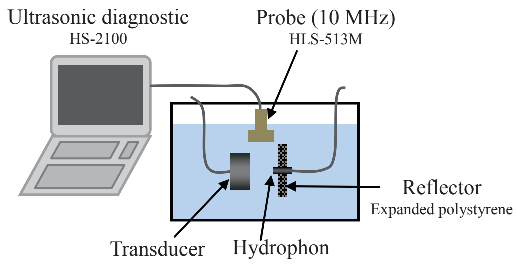
(a) Below the cavitation threshold



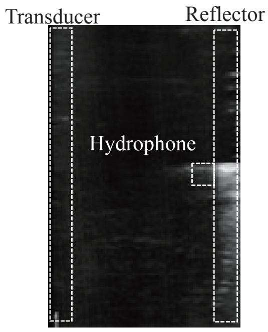
(b) Above the cavitation threshold

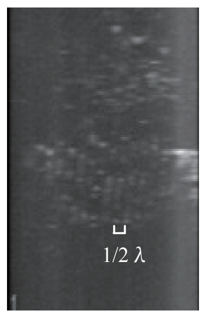
Fig. 3 Hydrophone output wave by oscilloscope at 24 kHz.

bubbles is added to the ultrasound wave to propagate, sound pressure may increase. Moreover, the sound pressure may decrease by attenuation and scattering caused by bubbles. As shown in **Fig. 4**, many bubbles are observed between the transducer and the hydrophone at 493 kHz. At high frequency above the cavitation threshold, as cavitation bubbles are trapped in standing waves and appear on the hydrophone, the sound pressure may decrease by attenuation and scattering caused by bubbles. Since attenuation and scattering of the ultrasound caused by bubbles increases with the increment in frequency, sound pressure reduces significantly at high frequency.



(a) Experimental setup





(b) Ultrasonic: OFF (c) Ultrasonic: ON

Fig. 4 Observation of bubbles by ultrasonic diagnostic in the reactor of 493 kHz.

4. Conclusions

When cavitation is produced, sound pressure at fundamental frequency becomes unstable caused by bubbles. The measurement of distribution of sound pressure in the solution by hydrophone must be carried out below the cavitation threshold.

References

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