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Measurement of Distribution of Sound Pressure of Fundamental, Subharmonic and White Noise in Sonochemical Reactor
超音波反応器内の音圧の基本波、サブハーモニクスとホワイトノイズの空間分布測定

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1. Introduction

Ultrasound is applied to several devices, such as an ultrasonic cleaner, a homogenizer, and a sonochemical reactor. The evaluation method of the ultrasonic field is carried out by calorimetry, the radiation force balance method, and the sound pressure measurement method, etc. The sound pressure measurement is effective to obtain distribution of the sound pressure in the sonochemical reactors. However, in a strong ultrasound field where cavitation is generated, a sound pressure spectrum measured by hydrophone has many frequency components as shown in **Fig.1**. In this figure, f_1, $f_{1.5,}$, f_2 are frequencies of fundamental, subharmonic and harmonic, respectively. The shadowed area is a white noise component. When ultrasonic cavitation is generated, white noise and subharmonics component apprear[1,2)]. Uchida et al. estimated the sonochemical reactor performance from the white noise component [3,4)].

In this study, the spatial distribution of sound pressure of fundamental, subharmonic, and white noise in the sonochemical reactor are measured, in order to develop a sonochemical reactor with a higher efficiency.

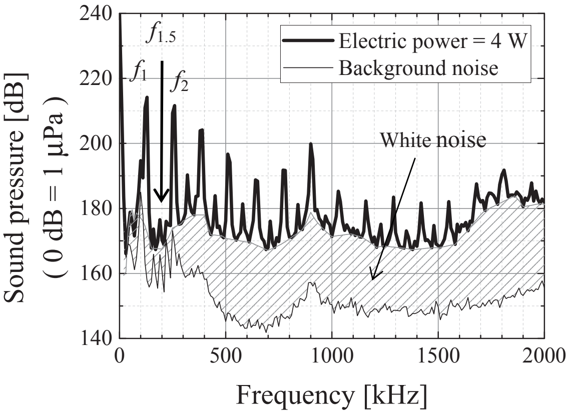

Fig. 1 The frequency components of sound pressure at 129 kHz in the sonochemical reactor.

2. Experiment

The experimental setup is shown in **Fig. 2**. The inside diameter of sonochemical reactor was 56 mm. The side of sonochemical reactor came with two tiers to circulate temperature controlled water at 298 ± 0.1 K. The sample was air-saturated water and volume was 100 mL. Sound pressure components of various frequencies were measured by a hydrophone (Honda Electronics HUS-200S) and a spectrum analyzer. A sensor of hydrophone was produced by hydrothermal synthesis method[5)]. The hydrophone was calibrated from 20 kHz to 20 MHz. A preamplifier (Honda Electronics HUS-200A) was used to transform output

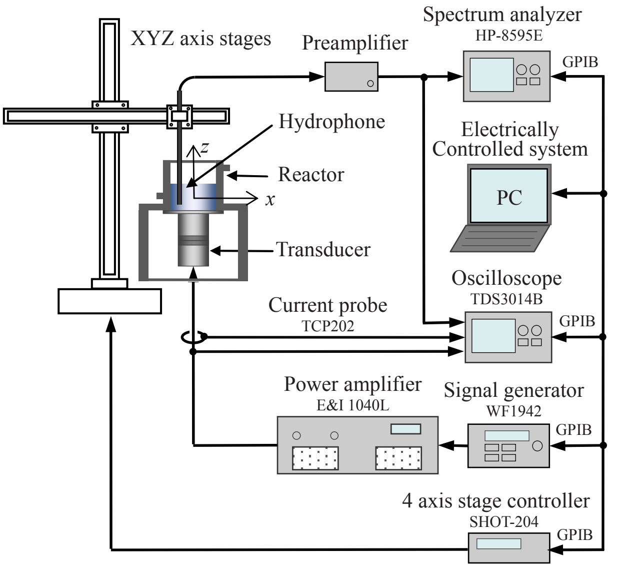

Fig. 2 Experimental setup.

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impedance of the hydrophone. The hydrophone was moved in two dimensions of *x*-*z* coordinates in Fig.2 by XYZ axis stages. A Langevin type transducer with a diameter of 45 mm was driven by a power amplifier which amplified a continuous sinusoidal wave with a frequency of 129 kHz produced by a signal generator. An effective electric power applied to the transducer was calculated from a voltage at both ends of the transducer and a current measured by an oscilloscope and a current probe. At this time, the effective electric power applied to the transducer was 4 W.

3. Results and discussion

Figure 3 shows the distribution of sound pressure at fundamental frequency in the sonochemical reactor. Standing waves are observed in the direction of *x* (reactor radius) in addition to the direction of *z* (transducer axis). The reason of which is considered to be due to coupled vibration of vibration between transducer and water surface, and vibration of reactor radius direction. The sound pressure at $x = 0$ mm and $z = 26$ mm has a maximum value.

Figure 4 shows the distribution of sound pressure at subharmonics frequency (1.5 times higher than fundamental). The maximum sound pressure of subharmonic appears at the same position as that of fundamental. However, the value of maximum sound pressure of subharmonics is two orders of magnitude less than that of fundamental.

Figure 5 shows the distribution of white noise component. The sound pressure of white noise component, Average of broadband sound pressure (ABP) was calculated from the next equation.

$$\mathrm{ABP} = \frac{\int_{f_1}^{f_2} P df}{f_2 - f_1} , \qquad (1)$$

where *P* is sound pressure removed those of fundamental, subharmonics and harmonics. In this figure, f_1 and f_2 are 20 kHz and 10 MHz, respectively. By using ABP, a comparison of sound pressure between white noise and subharmonic is possible. Compared with subharmonic, white noise is observed in wide area. Standing waves of ABP are observed in the same manner of sound pressure of fundamental. However, the position of maximum sound pressure for white noise is different from that for fundamental. This result means that the position at maximum sound pressure is different from that at many cavitation generations.

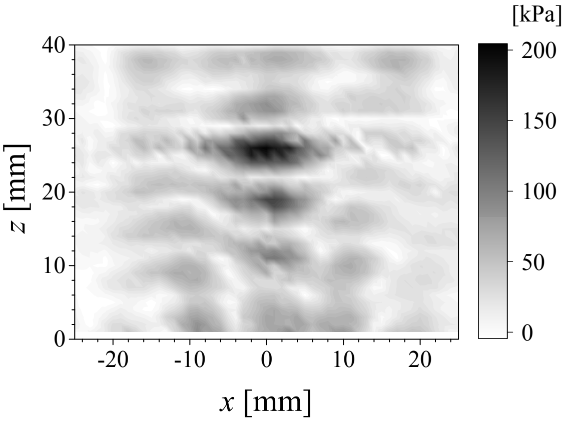

Fig. 3 Distribution of the sound pressure at fundamental frequency in the sonochemical reactor.

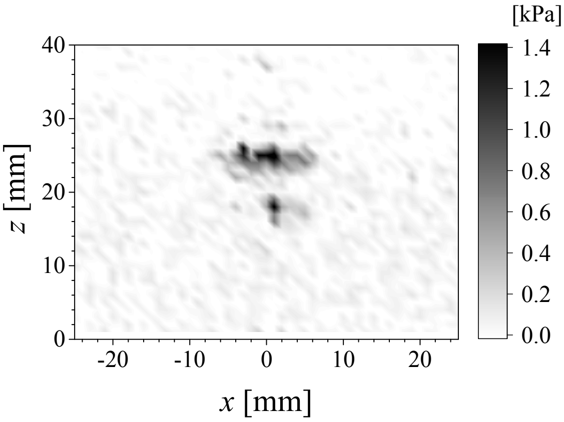

Fig. 4 Distribution of the sound pressure at subharmonic frequency.

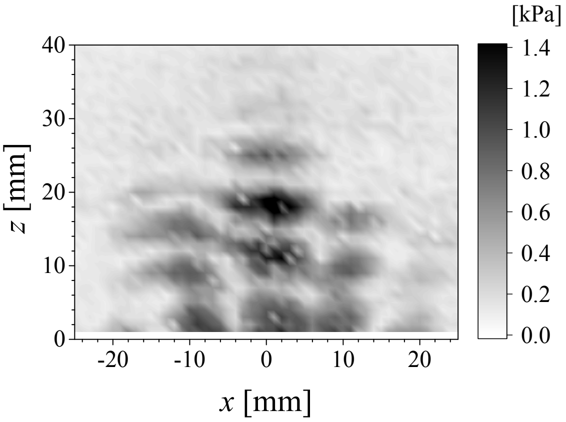

Fig. 5 Distribution of ABP.

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