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Transient Characteristics of Acoustic Cavitation Noise after Starting Ultrasound Irradiation

超音波入射開始時における音響キャビテーションノイズの過渡特性

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1. Introduction

Oscillating fine bubbles are generated by strong ultrasound in liquid. This phenomenon is known as acoustic cavitation. The oscillation of the acoustic cavitation bubbles causes acoustic emission called acoustic cavitation noise. The spectrum of the acoustic cavitation noise consists of the fundamental component, the harmonic components, the subharmonic component, the ultra-harmonic components, and the broad band noise. The subharmonic component and the broad band noise are known as a good indicator of the physical and chemical effects caused by the acoustic cavitation bubbles[1)]. Neppiras suggests that the subharmonic component associate with the bubbles with large oscillating amplitude[2)]. Yasui *et al*. indicate that the broad band noise, which means the noise floor of the acoustic cavitation noise, is caused by the fluctuation of the number of bubbles by the numerical simulation[3)]. However, the report of the experimental observation of relationship between the acoustic cavitation noise and its physical origin is few. In this paper, to investigate the origin of the acoustic cavitation noise, the transient characteristics of the acoustic cavitation noise is observed. The rectified diffusion and the coalescence change the bubble size, and the bubble growth changes the noise spectrum. The temporal waveform of the acoustic cavitation noise and the transient characteristics of the subharmonic component amplitude are discussed.

2. Experimental system

Acoustic cavitation is generated by ultrasound irradiated by a Bolt-clamped Langevin-type transducer (BLT). The horn of the BLT is immerged into water in a glass cell with cross-section of 50 × 50 (mm^2). The diameter of the output surface of the horn is 30 mm and the height of the water is 44 mm. The BLT is driven by sinusoidal voltage with the frequency, f_0, of 19.2 kHz. The driving voltage is generated by a function generator and amplified by a power amplifier.

The acoustic cavitation noise is captured with the Poly Vinylidene Difluoride (PVDF) film glued to the outer wall of the glass cell. The output signal from the PVDF film is recorded by an oscilloscope with a sampling frequency of 50 MHz. The driving voltage and the current of the BLT is simultaneously recorded, and the driving power is determined. The power spectrum of the recorded acoustic cavitation noise is estimated employing Welch's method. The time evolution of the amplitude of the frequency component is calculated with synchronous detection. The upper cutoff frequency for the synchronous detection is f_0 / 4.

3. Results and discussion

Figure 1 shows the time evolution of the amplitude of the subharmonic (f_0/2), the fundamental (f_0), and the second harmonic ($2f_0$) components determined by the synchronous detection, respectively. Figures 1(a) – 1(c) correspond to the driving power of 2.7, 5.3, and 21.8 (W), respectively. **Figure 2** shows the raw

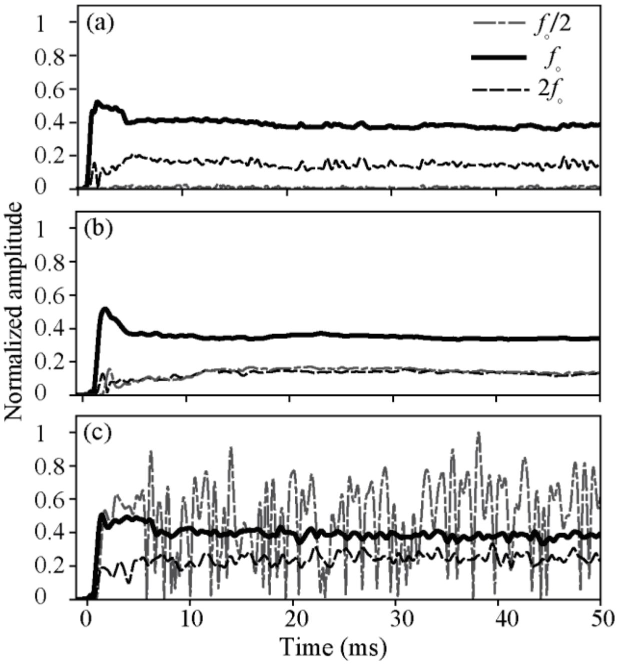

Fig. 1 Transition of subharmonics (f_0/2) , Fundamental (f_0) and 2nd harmonics ($2f_0$). Driving power of BLT are (a) 2.7 W, (b) 5.3 W, and (c) 21.8 W, respectively.

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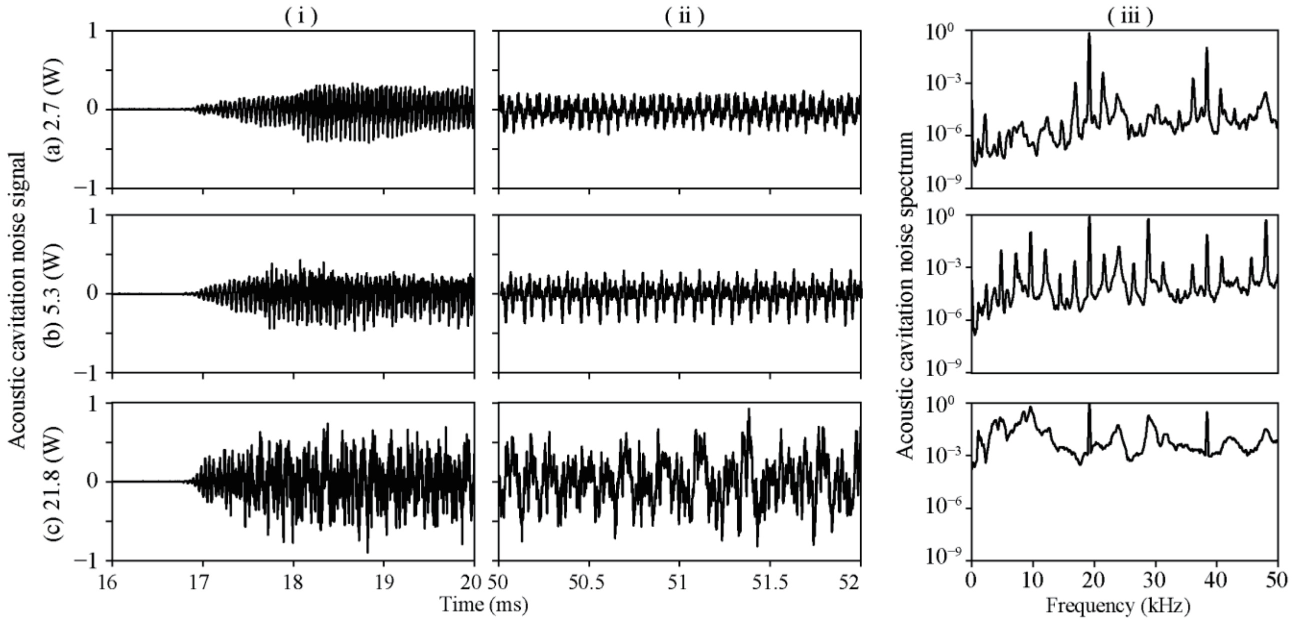

Fig. 2 Acoustic cavitation noises for driving powers of 2.7, 5.3, and 21.8 (W). (i) and (ii) show closeup waveform for 16 - 20 (ms) and 50 - 52 (ms), respectively. (iii) shows power spectrum of acoustic cavitation noise when bubbles are established sufficiently.

waveforms and the steady state power spectrum of the acoustic cavitation. Figures 2(i) and 2(ii) corresponds to the waveform immediately after starting the ultrasonic irradiation and that at the bubble is generated sufficiently (steady state). In all the input power conditions, the fundamental component amplitude reaches steady state within 1 ms as shown in Fig. 1. It indicates that the fundamental component is mainly caused by the incident ultrasound and not affected by the generation of the cavitation.

In Fig. 1(a), $2f_0$ component is clearly observed, but $f_0/2$ component is indistinguishable. The second harmonic component is derived from the wave distortion caused by the nonlinear acoustic propagation characteristics of the water and the nonlinear oscillation of large degassing bubbles. In the condition of Fig. 1(b), the subharmonic component evolves after stating the ultrasonic irradiation and reaches steady state at 15 ms. The subharmonic component evolving is accompanied with the growth of the bubble by the rectified diffusion and the coalescence of the bubbles. After the evolving, the periodic pulse with twice fundamental period ($2 / f_0$) is observed as shown in Fig. 2(ii-b). In this time window, the clear subharmonic peak is confirmed in Fig. 2(iii-c). In Fig. 1(c), the subharmonic component rises quickly within 1 ms. It means the bubble reaches the enough size for subharmonic generation in a few acoustic cycles. In addition, after 5 ms, the subharmonic component amplitude starts oscillation. The clear periodic pulse with $2 / f_0$ is no longer observed as shown in Fig. 2(ii-c). The peak of the subharmonic component is broadened, and the broad band noise level rises as shown in Fig. 2(iii-c). Thus, the moderate bubble growth with the low input power causes the clear subharmonic component peak but the excessive bubble growth causes the broad band noise.

4. Conclusion

The bubble transient behavior immediately after starting the ultrasound irradiation is experimentally observed to consider the origin of the subharmonic component and the broad band noise in the acoustic cavitation noise spectrum. The subharmonic components amplitude gradually increases immediately after starting the ultrasound irradiation and reaches steady state in the relatively low driving power condition. On the other hand, in the high driving power, the subharmonic component amplitude quickly rises and oscillates. Thus, we conclude that the subharmonic component is caused by the bubbles periodically oscillating with the half fundamental frequency and the aperiodicity of the bubble oscillation causes the broad band noise.

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References

1. G. A. Husseini *et al.*: J. Controlled Release **107** (2005) 253.
2. E. A. Neppiras: J. Sound. Vib. **10** (1968) 176.
3. K. Yasui *et al.*: Ultrason. Sonochem. **17** (2009) 460.