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A Study on Spatial Distribution of Cavitation Generation by Using Cavitation Sensor

キャビテーションセンサを用いたキャビテーション発生量の空間分布測定

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1. Introduction

Recently, acoustic cavitation generated by high-pressure ultrasound exposure has come to play a key role in the medical field. Cavitation has been studied for use in cancer treatment.[1)] However, cavitation can be hazardous in diagnostics. For both cases, it is important to control the amount of generated cavitation. Therefore, a technique for measuring the amount of generated cavitation is required for its control.

To this end, we have been studying a technique for measuring the amount of generated cavitation by broadband integrated voltage (BIV). BIV is the integrated value of broadband noise in the frequency spectrum. Broadband noise is changed by the production of cavitation bubbles. In previous studies, we experimentally showed that BIV is a parameter reflecting the level of cavitation.[2)]

In this paper, we compare BIV values with the distribution of sonochemical luminescence (SCL) emissions to measure the spatial distribution of cavitation generated in a water vessel.

2. Experimental Method

A hollow cylindrical cavitation sensor was used to measure BIV. The sensor was made in reference to the structure proposed by Zeqiri.[3)] The sensor had a three-layer structure consisting of an acrylic tube, a closed cell sponge, and poly(vinylidene fluoride) (PVDF) film. The sponge acted as an acoustic isolator. Therefore, the sensor received only signals generated inside of the cylinder. The thickness of PVDF film was approximately 110 μm.

Figure 1 shows the configuration of ultrasound exposure system. The system used a stainless steel vibrating disk with a Langevin transducer (Honda Electronics HEC45402). The output signal from a function generator (Agilent 33250A) was amplified with a power amplifier (AR 75A250) and then was applied to the transducer. The output signal of the cavitation sensor was sent to an oscilloscope (Sony Tektronix TDS2012B) which was used as spectrum analyzer. The operating frequency was 150 kHz. The transducer was attached to the bottom of a water vessel (190 mm long, 190 mm wide, and 120 mm high). Distilled water with a dissolved oxygen level of around 8 mg/L filled the vessel to a depth of about 100 mm. A standing wave acoustic field was then formed in the vessel. In the horizontal direction, the sensor scanned along the centerline of the vibrating disk at a height of 40 mm above the bottom of the vessel. In addition, a hydrophone (ONDA HNR-1000) measured sound pressure along the same horizontal line. In the vertical direction, the sensor scanned in a straight line from the center of the bottom of the vessel to the surface of water.

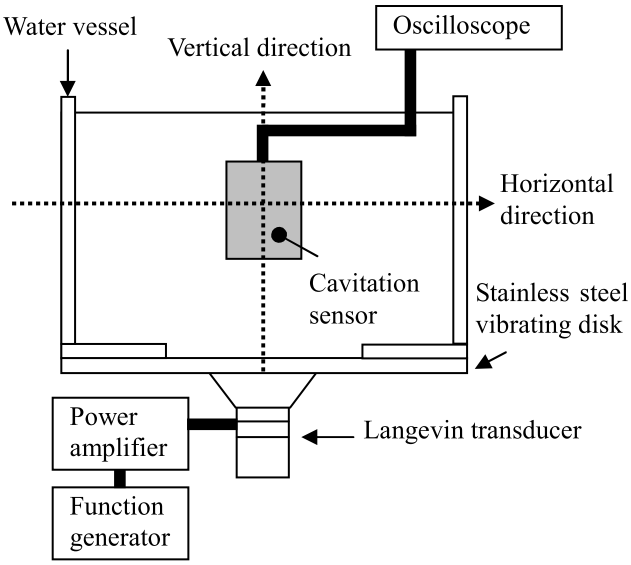

Fig. 1 Ultrasound exposure system for generation of acoustic cavitation.

3. Experimental Results

Figures 2 and 3 show scanning results in the horizontal and vertical directions.

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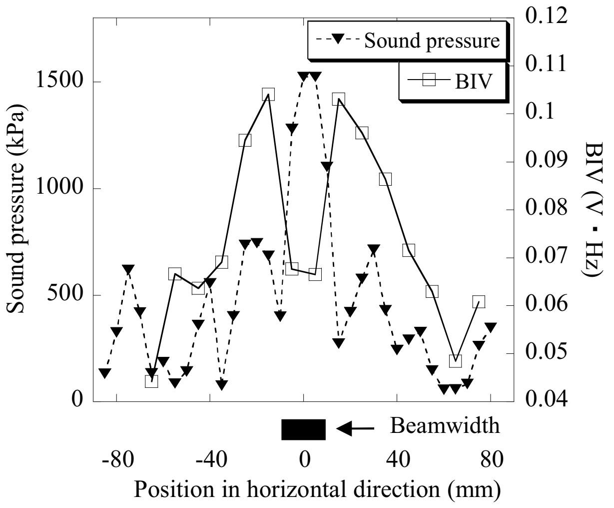

Fig. 2 Change in BIV and sound pressure with position along centerline of vibrating disk.

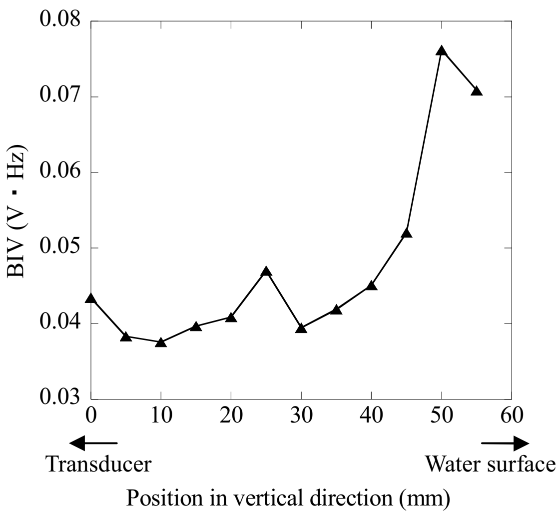

Fig. 3 Change in BIV in vertical direction.

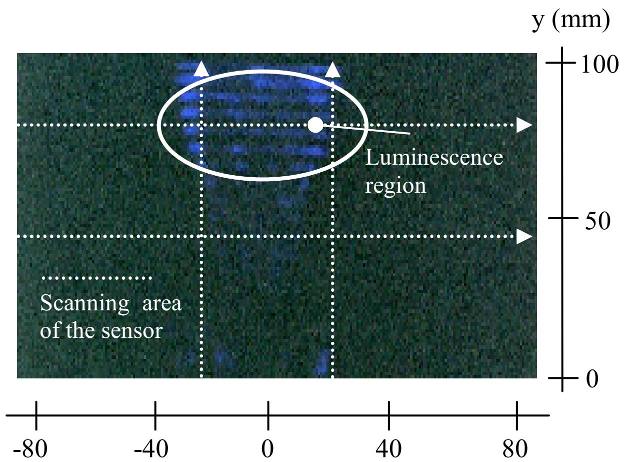

Fig. 4 Photograph of sonochemical luminescence in water vessel of our experimental system.

From the results in the horizontal direction, peaks of BIV and sound pressure were located at different positions, as shown in Fig, 2. The peaks of sound pressure were found at the center of water vessel. However, the BIV peaks were found at either side of the sound pressure peaks at ±15 mm from the midpoint of the vessel. Furthermore, in the vertical direction, BIV was high toward the water's surface higher than 40 mm from the vessel floor, as shown in Fig. 3.

To further study differences between peak positions of BIV and sound pressure in the vessel, SCL was observed. A photograph of SCL is shown in Fig. 4. SCL is chemical reaction between luminol anion and active oxygen species generated by cavitation bubbles. Therefore, SCL was observed to confirm the position of generated cavitation bubbles. As a result, SCL was not observed in the central region at heights less than about 60 mm from the vibrating disk. This result showed that cavitation bubbles were not trapped in the central region. Hence, although sound pressure was high at the midpoint of the vessel, BIV in accordance with the magnitude of the collapse and pulsation of bubbles was low in the region, as shown in Fig. 2. It is considered that cavitation bubbles were not trapped because acoustic streaming was generated toward water's surface. Additionally, as shown in Fig. 3, BIV was high near the water's surface, in agreement with SCL observation.

From these results, correlation was found between BIVs measured in the horizontal and vertical directions and distribution of SCL emissions.

4. Summary

We investigated measurement of the spatial distribution of acoustic cavitation generation in a water vessel by BIV. As a result, BIV has potential as an accurate tool for measuring the spatial distribution of cavitation generation.

In the future, detailed investigations by optimizing the size of the cavitation sensor will be performed.

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