1P4-8
Proceedings of Symposium on Ultrasonic Electronics, Vol. 36 (2015)
5-7 November, 2015

Study on measurement technique for amount of generated cavitation -Relationship between concentration of microbubbles and output signal of sensor-
キャビテーション計測技術の開発 －マイクロバブル濃度とセンサ出力信号の関係－

Takeyoshi Uchida[1†], Masahiro Yoshioka[1], Youichi Matsuda[1], Shinichi Takeuchi[2], and Ryuzo Horiuchi[1] ([1]NMIJ・AIST; [2]Grad. School of Eng., Toin Univ. of Yokohama)
内田 武吉[1†], 吉岡 正裕[1], 松田 洋一[1], 竹内 真一[2], 堀内 竜三[1] ([1]産業技術総合研究所, [2]桐蔭横浜大 医用工)

1. Introduction

Acoustic cavitation is a phenomenon that the radiation of high-power ultrasound results in micro-sized bubbles.[1)] Acoustic cavitation has been used in many cases such as cancer threatment, ultrasonic cleaning and sonochemistry.[2)] However, the cavitation can have a drawback of destroying the object by the radiation of ultrasound. For the safe and efficient use of cavitaion, it is essential to measure and control the cavitation quantitatively.

In this respect, the NMIJ has been studying the technique on the quantitative measurement of cavitaion by using the parameter of broadband integrated volatge (BIV). The BIV is determined by integrating only the high frequency components of broadband noise in the frequency spectrum of a signal from a cavitation sensor. When the cavitation is observed, the frequency spectrum consists of many line spectra at the driving frquency, its harmonics, subharmonics, and broadband noise.[3)] The harmonics can be caused either by the influence of acoustic emission from cavitation bubbles or by the nonlinear propagation of ultrasound. However, it is difficult to find the reason by the evaluation of harmonics. On the other hand, the level of broadband noise and subharmonics changes only by cavitation bubbles. Therefore, in the previous study, we have been studying the cavitation by focusing on broadband noise. As a result, we concluded that the BIV depends on the dissolved oxygen (DO) level in distilled water and increases in conjunction with the intensity of sonochemiluminesence.[4)]

In this paper, we carried out experiments by focusing on the BIV and subharmonics. So far, it is thought that the BIV and subharmonics correspond to the different state of cavitation bubbles because they are observed at the differrent acoustic pressure threshold. Therefore, our intention is to evalute the BIV and subharmonics by changing the state of the bubbles.

2. Experimental method

We have developed the cylindrical cavitation sensor for measuring the BIV and subharmonics. The basic structure of the sensor is shown in Fig. 1. The sensor has three layers: an acrylic pipe, a closed cell sponge, and a thin PolyVinylidene DiFluoride (PVDF) film from the outside. The cylindrical acrylic pipe has an outside diameter of 50 mm and a height of 10 mm. The closed cell sponge with a thickness of 5 mm and a height of 10 mm is attached to the inside surface of the acrylic pipe, and then the PVDF film is attached to the inside surface of the sponge. This type of sensor can detect only the signal from cavitation bubbles at the PVDF surface because the signal from outside the acrylic pipe is reflected by the sponge due to the same effect as air layer.

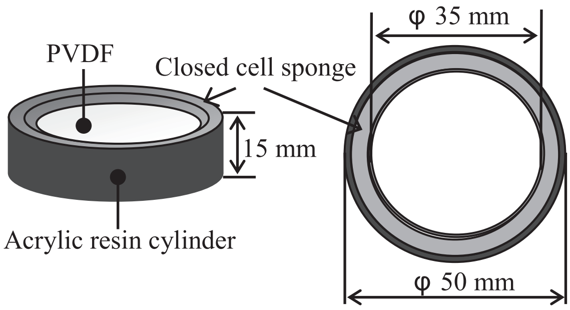

Fig. 1 Basic structure of cylindrical cavitation sensor.

Our experimental system is shown in Fig. 2. An ultrasound transducer with a center frequency of 1 MHz is attached in the bottom of a water vessel. The output voltage from a function generator (Agilent 33250A) is amplified by a power amplifier (AR 75A250) and fed to the transducer. The output voltage from the cavitation sensor is sent to an oscilloscope (Keysight DSO-X3024A) after the BIV and subharmonics are observed. The integral range of the BIV is between 5 MHz and 10 MHz.[4)] Acoustic pressure in the vessel is controlled to about 100 kPa. Dissolved oxygen level of water is 2 mg/L. Water temperature is about 21.5 ºC and room temperature is 23 ºC ± 0.5 ºC. In this measurement conditions, the acoustic field has standing waves.

Practically, it is very difficult to control the state of cavitation bubbles. Instead of cavitation bubbles, we used microbubbles (Daiichi-Sankyo Sonazoid) which are usually used as an ultrasound contrast agent. The drop amount of microbubbles is increased by 0.1 ml. The diameter of microbubbles is about 2 μm. MI (Mechanical index) value of the microbubbles is 0.3 and corresponds to the acoustic pressure of 300 kPa at 1MHz.

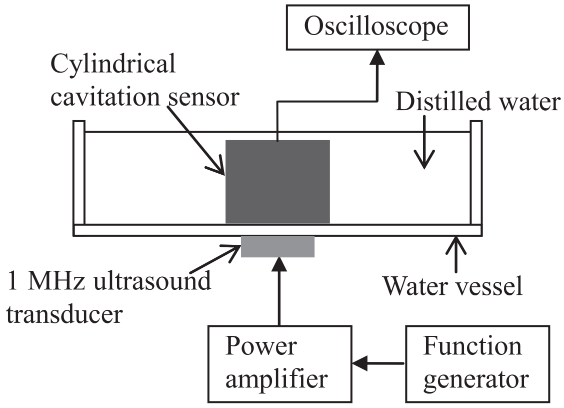

Fig. 2 Ultrasound exposure system and cavitation sensor.

3. Experimental results

The relationship between the drop amount of microbubbles and the BIV is shown in Fig. 3. The relationship between the drop amount of the microbubbles and subharmonic of 500 kHz is shown in Fig. 4.

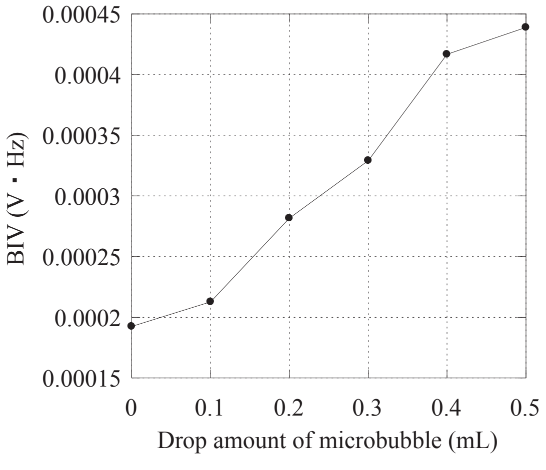

Fig. 3 Relationship between drop amount of microbubbles and BIV.

Fig. 3 clearly shows that the drop amount of the microbubbles is positively correlated with the BIV. On the other hand, Fig. 4 shows that the relationship between the drop amount of the microbubbles and subharmonic does not have a definite correlation.

It is generally thought that the BIV implies the number of stable cavitation bubbles with the repetition of expansion and compression. The acoustic pressure in the experiments is 100 kPa and below the MI value of 300 kPa. This indicates that the bubbles keep expanding and compressing at the node of standing waves in the acoustic field. Further study is required but there is a possibility that the BIV indicates the number of expanding and compressing bubbles.

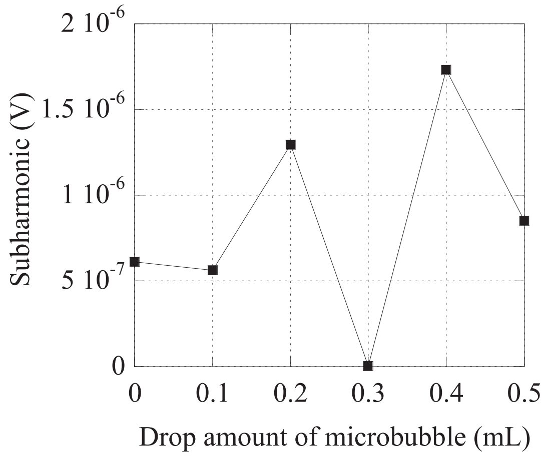

Fig. 4 Relationship between drop amount of microbubbles and subharmonic.

4. Conclusions

We experimentally showed the relationship between the BIV, subharmonic and the number of microbubbles at the acoustic pressure less than MI value. The BIV may be a parameter to reflect the number of the stable cavitation bubbles. Further study includes the similar experiments at the MI value over 0.3.

Acknowledgment

This work was supported by a Grant-in-Aid for Scientific Research C (No. 24560537)

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