1P4-3

Proceedings of Symposium on Ultrasonic Electronics, Vol. 37 (2016)

16-18 November, 2016

Effect of hydrophone on High-intensity Acoustic Fields with Generation of Acoustic Cavitation Bubbles

キャビテーションの発生を伴う強力超音波音場におけるハイドロホンの影響

Nagaya Okada[1†], Michihisa Shiiba [2], and Shinichi Takeuchi [3] ([1] R & D Div., HONDA ELECTRONICS CO., LTD.; [2] Department of Clinical Eng., Nihon Institute of Medical Science; [3] Department of Clinical Eng., Toin Univ. of Yokohama)

岡田長也 [1†]，椎葉倫久 [2]，竹内真一 [3] ([1] 本多電子(株)，研究部，[2] 日本医療科学大，保健医療学部，[3] 桐蔭横浜大，医用工学部)

1. Introduction

Recently, ultrasound treatment methods, such as high intensity Focused ultrasound (HIFU) are increasingly used in medical applications such as tumor therapy. Acoustic characterization of HIFU field is important for the accurate prediction of ultrasound induced bioeffects in tissue. For the reason, we have developed a tough hydrophone consisting of a titanium front plate that can withstand cavitation and a hydrothermally synthesized lead zirconate titanate (PZT) thick-film vibrator deposited on the back-side of the titanium-plate acoustic surface[1,2]. Our developed tough hydrophone resisted damage in a high-pressure field (15 MPa) when placed at the focal point of a concave HIFU transducer, which was driven in sinusoidal continuous-wave mode with up to 50 W of power input to the sound source[3]. The hydrophone was found to be suitable for HIFU fields, even though it has a flat-shape tip of 3.5 mm diameter. This diameter is slightly large relative to the wavelength of a few megahertz in water. The result of experimentally testing the effect of placing the tough hydrophone in the focal region was that acoustic bubbles were observed around the focal point of the HIFU transducer during sonication[4]. Because the generation of acoustic bubbles in a high-intensity ultrasound field cannot be avoided, the influence of having the tough hydrophone in the field, particularly changes in shape, were investigated using visualization of the spatial distribution of acoustic bubbles around the focal point of the HIFU transducer by using partical image velocitymatry (PIV) system, with the aim of achieving accurate and precise evaluation of acoustic fields.

2. Experiment

A diagram of the experimental arrangement used to measure acoustic bubbles in a high-intensity

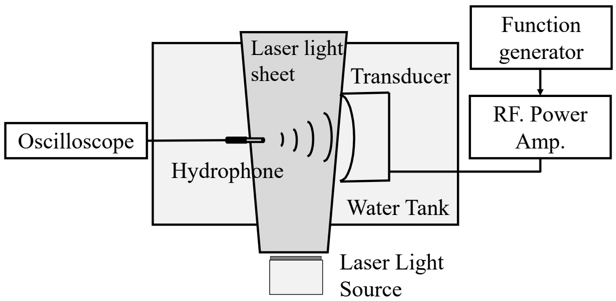

Fig. 1 Block diagram for the PIV measurement of the behavior of acoustic bubbles around tough hydrophone generated by the focus transducer.

acoustic field by using PIV system (Kato Koken, Kanagawa, Japan) is shown in **Fig. 1**. The ultrasound source was single-element concave focused transducer, with resonant frequency of 1 MHz, diameter of 80 mm, and geometoric focal length of 50 mm, and mounted in a custom-designed stainless steel housing, instead of a HIFU transducer. The tough hydrophone tip of 3.5 mm diameter having a flat shape (flat-shape tip) installed at the focal point of the transducer. Ultrasound waveforms received from the transducer was recorded by 12 bits resolution oscilloscope (5443B, Pico Technology Limited, Cambridgeshire, United Kingdom) during sonication. The transducer was driven by a function generator (WF1944A, NF Corporation, Kanagawa, Japan) and a linear radiofrequency amplifier (E&I2100L, Electronics & Innovation, Rochester, NY). The 1 MHz HIFU transducer was operated in sinusoidal continuous wave mode with a driving power of up to 93 W.

The behaviour of acoustic bubbles around the tough hydrophone set at the focal point of the transducer were observed by using the PIV system. In general, suspended filler particles in water as tracers were used, while no tracers were used during acoustic bubbles measurements. The water was irradiated with a laser light sheet located across the focal point from the bottom wall of the water tank (600 × 300 × 360 mm). The movement of the

nagaya@honda-el.co.jp

acoustic bubbles in the measurement plane was recorded by using a high-speed digital CMOS camera (K-III, Kato Koken, Kanagawa, Japan). Since the framerate was set up to 10000 FPS, the flow velocity vector was calculated by using flouid analysis software (Flow Expert 2D, Kato Koken, Kanagawa, Japan).

The behavior of the acoustic bubbles around the hydrophone tip was investigated with a high-intensity ultrasound field, using tap water to ease the generation of acoustic bubbles. Changes to the acoustic bubbles was observed depending on the shape of hydrophone tip. A needle shape stainless steel mock-up tapered at the extreme end (needle-shape tip) was compared with the tough hydrophone with flat-shape tip installed at the focal point.

3. Results and discussion

The acoustic bubbles around the tough hydrophone with flat shape tip using the PIV system shows trapping acoustic bubbles derived from the standing wave in **Fig. 2**(a). This standing wave was caused by the flat shape of the tough hydrophone. In contrast, the acoustic bubbles around the needle-shape tip were generated less frequently than with the flat-shape tip shows in Fig. 2(b). By the side of the hydrophone observation, a collision of acoustic bubble with the hydrophone tip and the explosion of acoustic bubble were shown in **Fig. 3**(a). Figure 3(b) is calculated velocity vector of acoustc bubble at the same time of Fig. 3(a). The bubble is considered to be exproded as evidence by expanding vector from the center of the bubble. **Figure 4** shows observed receiving voltage of the hydrophone during sonication. Distorted waveform from the hydrophone by nonlinear propagation in water were observed in stable condition shown in Fig. 4 (small). Meanwhile, the output was increased instantly and occasionally shown in Fig. 4 (large). This instantaneous increasing raises the possibility that the acoustic bubble may be exproded at the hydrophone tip, while the oscilloscop recording is not synchronized with the CCD frame.

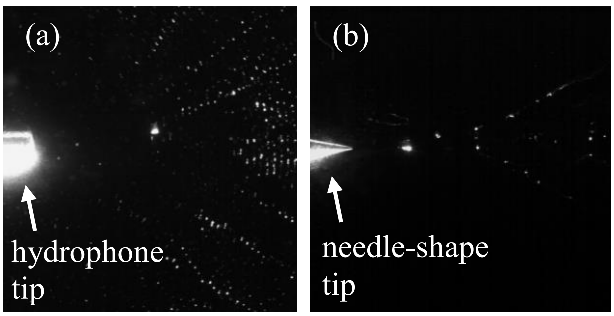

Fig. 2 Observation of the acoustic bubbles around (a) the tough hydrophone with flat-shape tip and (b) the needle-shape tip by using PIV system.

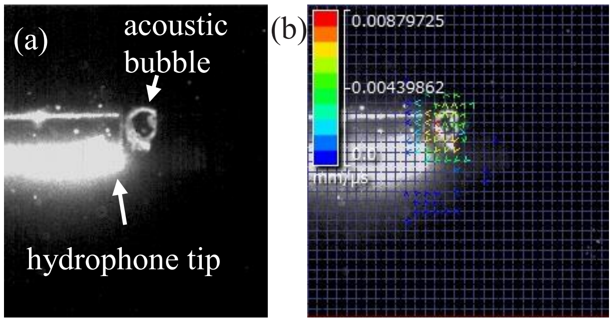

Fig. 3 (a) Collision of acoustic bubble with the hydrophone tip and (b) calculated velocity vector of exploded acoustic bubble.

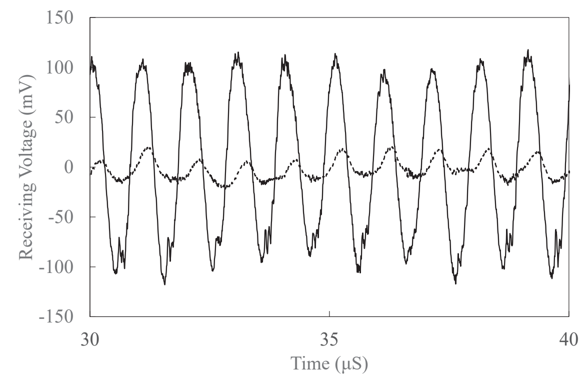

Fig. 4 Output waveform of the hydrophone in stable condition (small) and increased condition caused by the acoustic bubble explosion instantly (large).

4. Conclusion

The influence of the tough hydrophone's shape on the spatial distribution of acoustic bubbles around focal point of HIFU transducer was investigated by using PIV system. In the case of needle-shape tip, the trapping acoustic bubbles derived from the standing wave were reduced as compare to the flat shaped tip. The collision of acoustic bubble with the hydrophone tip and the explosion of acoustic bubble were observed. This event may be responded to the instantaneous increasing of the output of the hydrophone.

References

1. Shinichi Takeuchi *et al.*, Proc. IEEE Ultrason. Symp., (2010) 2239.
2. Michihisa Shiiba *et al.*, Jap. J. Appl. Phys., **53** (2014) 07KE06-1.
3. Nagaya Okada *et al.*, Proc. 2013 Joint UFFC, EFTF and PFM Symp., (2013) 1121.
4. Nagaya Okada *et al.*, Proc. 2015 IEEE Ultrason. Symp., (2015) .