3Pa4-7

Proceedings of Symposium on Ultrasonic Electronics, Vol. 33 (2012) pp. 367-368
13-15 November, 2012

Observation of spatial distribution of acoustic cavitation by ultrasound diagnostic equipment and consideration on application of cavitation sensor.

US 診断装置によるキャビテーション分布の観測と
キャビテーションセンサ適用範囲の検討

Yuuki Uemura [1‡], Michihisa Shiiba [1], Takeyoshi Uchida[2], Tsuneo Kikuchi[2], Minoru Kurosawa [3], Pak-Kon CHOI[4], and Shinichi Takeuchi[1]
([1] Toin Univ. of Yokohama; [2] NMIJ., AIST.; [3] Interdisciplinary Grad. School of Sci. and Eng., Tokyo Inst. of Tech.) ,[4]Meiji Univ.
植村 友樹 [1‡], 椎葉 倫久 [1], 内田 武吉 [2], 菊池 恒男 [2], 黒澤 実 [3], 崔 博坤 [4], 竹内 真一 [1]
([1] 桐蔭横浜大, [2] 産総研 NMIJ, [3] 東工大院 総合理工, [4] 明治大学)

1. Introduction

Recently, it becomes to use actively high intensity ultrasound acoustic field with generation of acoustic cavitation not only in ultrasound cleaner in industrial field but also in medical field like HIFU and sonoporation. Then, a cavitation sensor which has spatial resolution and can identify the incepting position of acoustic cavitation was developed by using piezo polymer film by Dr. B.Zequri et al in NPL（National Physical Laboratory）in England. [1),2)] We developed small and tough cavitation sensor with diameter of 4.8mm and height of 1mm by deposition of hydrothermally synthesized PZT poly-crystalline film on the outer surface of Ti hollow cylindrical pipe for long life, for suppression of disturbance to acoustic field and improvement of spatial resolution. Amount of incepted acoustic cavitation and spatial distribution of acoustic cavitation were measured by using broad band integrated voltage (*BIV*) calculated by integration of high frequency components included in the output waveform from the cavitation sensor. The spatial distribution of BIV in the water vessel of the sonoreactor was compared with the sonochemiluminescence (SCL) pattern in order to confirm the validity of BIV. As a result, SCL pattern showed ring shaped pattern with center at directly above of mounted position of Langevine type transducer on the bottom of water vessel. Spatial distribution of BIV showed similar ring shaped pattern as the SCL pattern. High acoustic intensity of ultrasound was measured at directly above of mounted position of the transducer. We think that the ring pattern without central area caused to absence of cavitation babble.

We think that SCL and *BIV* could not be observed in the center area of ring shaped pattern, because cavitation bubbles were moved away by affect of acoustic streaming.
However, some investigator pointed out that SCL could not be observed in the center area, because luminal was broken by high intensity ultrasound in this area. Then, we observed the spatial distribution of acoustic cavitation bubbles by using ultrasound diagnostic equipment without use of any sonochemical effect. Furthermore, we considered the applicable limit of our cavitation sensor.

2. Structure of our cavitation sensor

Extremely small cavitation sensor with same basic structure as conventional sensor was fabricated in this tome. Hydrothermally synthesized PZT poly-crystalline film was deposited on the outer surface of hollow cylindrical titanium pipe with inner diameter of 4.5 mm and height of 1mm and outer surface of the PZT film was covered with closed cell sponge acoustic isolator. The basic structure and photograph of fabricated sensor are shown in Fig. 1.

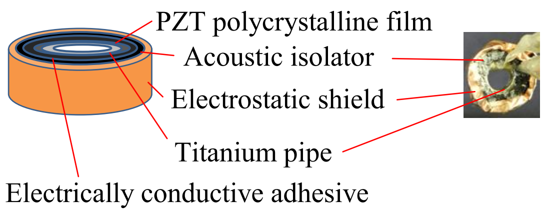


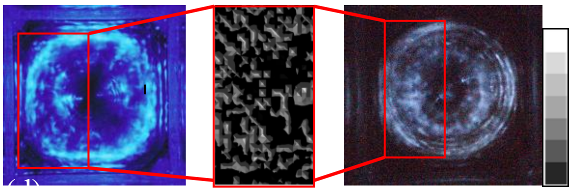
Fig. 1 Basic structure and photograph of our fabricated cavitation sensor

150 kHz continuous sinusoidal wave with voltage amplitude of 500 mV$_{0p}$ was amplified with a power amplifier with gain of 50 dB and applied to the Langevine type transducer to drive stainless steel disk diaphragm equipped on the bottom of water vessel of the sonoreactor. Acoustic cavitation was

b22c009u@ust.toin.ac.jp

generated in water. Spatial distribution of BIV (BIV pattern) was measured by scanning our fabricated cavitation sensor in the water vessel. BIV pattern, SCL pattern and SL pattern are shown in Fig. 2.

As results, spatial distribution of BIV and SCL pattern showed ring shaped pattern with center at directly above of mounted position of Langevine type transducer on the bottom of water vessel. High acoustic intensity of ultrasound was measured at directly above of mounted position of the transducer. We think that the ring pattern without central area caused to absence of cavitation babble. We think that SCL and *BIV* could not be observed in the center area of ring shaped pattern, because cavitation bubbles were moved away by affect of acoustic streaming. SL pattern without use of luminal showed similar pattern as SCL pattern. Therefore, we think that ring shaped SCL pattern did not caused to broken luminal by high intensity ultrasound.



(a)SCL (b) *BIV* (c)SL

Fig.2 SL,SCL pattern and spatial distribution of BIV measured in water vessel of sonoreactor

3. Observation of acoustic cavitation by ultrasound diagnostic equipment

B-mode image of acoustic cavitation generated in the same water vessel of sonoreactor as the water vessel used in previous experiments was recorded by using ultrasound diagnostic equipment (GE Logic-e) with 4 MHz convex type probe. Ring shaped image for acoustic cavitation was displayed continuously for long time in B-mode image of the ultrasound diagnostic equipment as shown in Fig. 3. Similar ring shaped pattern as SCL, SL and BIV patterns as shown in Fig. 2 was observed in the B-mode image shown in fig. 4.

Fig. 3 B-mode image of acoustic cavitation generated in the standing wave acoustic field in water vessel of 150 kHz sonoreactor (B-mode image was recorded with ultrasound diagnostic equipment)

Focused acoustic field was formed in water by using concave type ultrasound transducer with focal length of 100 mm, aperture diameter of 100 mm, resonance frequency of 1.78 MHz. B-mode images of acoustic cavitation bubbles generated near focal point of focused acoustic field were recorded with ultrasound diagnostic equipment at every 5 seconds. B-mode images are shown in Fig. 4. Ring shaped patterns of acoustic cavitation were observed near focal point after more than 30 seconds from start of ultrasound irradiation. Generating position of acoustic cavitation were changed unstably and dynamically immediately after ultrasound irradiation. Our present cavitation sensor should be scanned mechanically in the acoustic field. Therefore, we think it is difficult to use our present cavitation sensor for measurement in such focused type acoustic field.

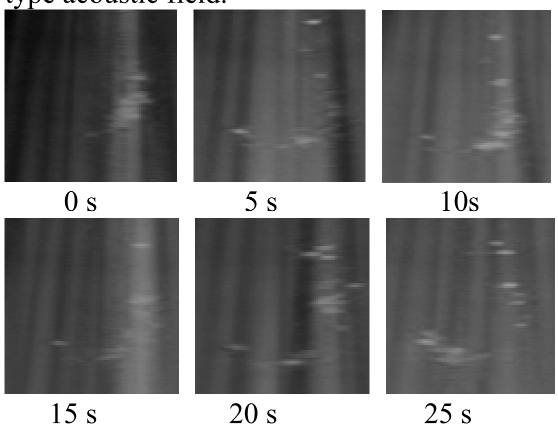


Fig.4 B-mode image of acoustic cavitation generated near focal point of focused acoustic field formed with concave type ultrasound transducer (B-mode image was recorded with ultrasound diagnostic equipment)

5. Conclusions

Cavitation bubbles generated in the standing wave acoustic field like water vessel of sonoreactor were trapped at loops of acoustic pressure standing wave. Such acoustic cavitation can be observed by using our cavitation sensor. However, it is difficult to estimate acoustic cavitation generated in focused ultrasound field by using our present cavitation sensor. We should develop real time cavitation sensor for estimation of focused ultrasound field.

Reference

[1] B. Zeqiri, et al., IEEE Trans.U.F.F.C, **50**, (2003) 1342.
[2] B. Zeqiri, et al., IEEE Trans.U.F.F.C, **50**, (2003) 1351.
[3] M.Shiiba, et al., Jpn J. Appl. Phys. **50** (2011) 07HE02
[4] M. Shiiba, et al.,AIP Conf. Proc.**1433**,