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Proceedings of Symposium on Ultrasonic Electronics, Vol. 35 (2014) pp. 381-382
3-5 December, 2014

Observation of cavitation bubbles and acoustic streaming in high intensity ultrasound field
強力超音波音場におけるキャビテーションバブルと音響流の観測

Yuki Uemura[1†], Kazuma Sasaki[1], Kyohei Minami[1], Pak kon Choi[2], Toshio Sato[1], Shinichi Takeuchi[1] ([1]Toin Univ. of Yokohama; [2]Meiji Univ.;)
植村友樹 [1†], 佐々木一真 [1], 三並京平 [1], 崔博坤 [2], 佐藤敏夫 [1], 竹内真一 [1] ([1] 桐蔭横浜大, [2] 明治大学)

1. Introduction

In recent years, there are various devices using ultrasonic waves in industrial fields and medical fields. It tends to irradiate high intensity ultrasound frequently in the medical fields like HIFU (High Intensity Focused Ultrasound)[1,2) for cancer treatment. Therefore, measurement of the position and the amount of generation of acoustic cavitation bubbles become very important from the viewpoint of ensuring the biological safety of ultrasound irradiation on the above mentioned medical techniques, the research on acoustic cavitation has been attracting attention. [3~5)] On the other hand, the ultrasound cleaners using high intensity ultrasound are used in the industrial fields. It is important to control the generating positions of acoustic cavitation for improvement of cleaning efficiency. So far we were measured cavitation by using a hydrophone or a cavitation sensor. However, there are several problems with these sensors. Hydrophone was damaged by shockwave due to acoustic cavitation. Hydrophone cannot identify the generated positions of acoustic cavitation since hydrophone has no spatial resolution due to its wide directivity. On the contrary, since it is possible to identify the generated position of the acoustic cavitation in the cyllindrical hollow space of the cavitation sensor, our cylindrical cavitation sensor with hollow space has spatial resolution. However, the long measurement time is reqired. Therefore we observed the behavior and spatial distribution of acoustic cavitation and acoustic streaming by using sono-chemi luminescence (SCL), particle image velocimetry (PIV) in order to solve these problems.

2. Experimental methods

2.1 Standing wave type and focused type ultrasound irradiation system

A stainless steel vibrating disk is equipped on the bottom of water tank of the 150 kHz standing wave type ultrasound irradiation system. This stainless steel vibrating disk is driven with Langevin type transducer. 150 kHz continuous sinusoidal wave from a function generator was amplified with a power amplified with gain of 50 dB and applied to a Langevin type transducer.

1.75 MHz spherical concave type lead zirconate titanate piezoelectric transducer with aperture diameter of 100 mm, focal distance of 100 mm and thickness of 1.5 mm is used for the focused type ultrasound irradiation system. 1.75 MHz continuous sinusoidal wave from a function generator was amplified with a power amplified with gain of 55 dB and applied to a spherical concave type transducer.

2.2 Observation of acoustic streaming and SCL

The SCL is emitted near generating positions of acoustic cavitation. Therefore, the SCL pattern shows the spatial distribution of the generated acoustic cavitation in the 150 kHz standing wave ultrasound acoustic field and 1.75 MHz focused ultrasound field. The SCL pattern was recorded by using high sensitivity single reflex digital camera. However, long exposure time is required for taking pictures of SCL patterns. Therefore, they are not real time data.

The behaviors of acoustic streaming in the 150 kHz standing wave ultrasound acoustic field and 1.75 MHz focused ultrasound field were observed by using PIV. Fillite particles were used as tracer for our PIV measurement. By illuminating the laser sheet from the outside of the water tank, the movements of the tracer on the laser sheet in the ultrasound acoustic field were recorded by using a high speed video camera system in the PIV system as shown in Figs. 1 and 2. PIV analysis items like vector analysis, trajectory and vorticity in the ultrasound fields were analyzed in this study.

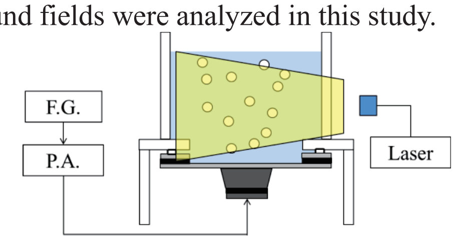

Fig. 1 Block diagram for measurement of acoustic streaming in the 150 kHz standing wave ultrasound field by using PIV

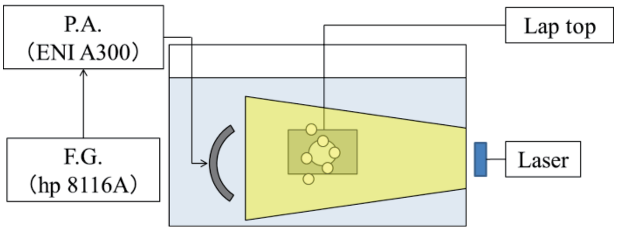

Fig. 2 Block diagram for measurement of acoustic streaming in 1.75 MHz focused ultrasound field by using PIV

3. Experimental results

Figures 3 and 4 show the results of SCL pattern, and acoustic streaming analysis by using PIV of standing wave acoustic field. SCL could not be observed luminescence in the central area. However, it could be observed in the circumference of stainless steel vibrating disk. Strong acoustic streaming could not be confirmed, but occurrence of local vortexes could be confirmed near the center axis of stainless steel vibrating disk.

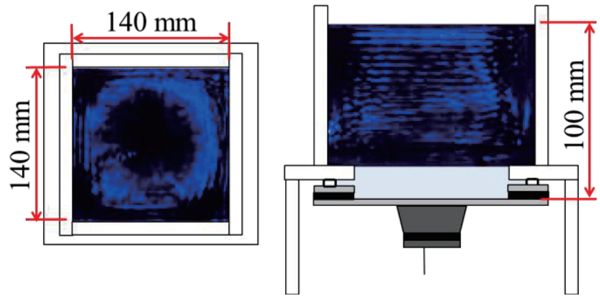

Fig. 3 Top view and side view images of SCL pattern observed in water tank of 150 kHz standing wave type ultrasound exposure system.

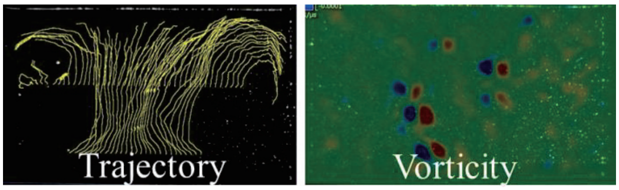

Fig. 4 Analyzed results of water flow and acoustic streaming in water tank of 150 kHz standing wave type ultrasound exposure system by using PIV system.

Figures 5 and 6 show the result of SCL pattern and acoustic streaming analysis by using PIV system of the 1.75 MHz focused acoustic field. SCL could not be confirmed in focal point. However, SCL could be confirmed luminescence in front area and behind area of focal point. Then, generation of the strong acoustic streaming toward focal point could be confirmed by using PIV system.

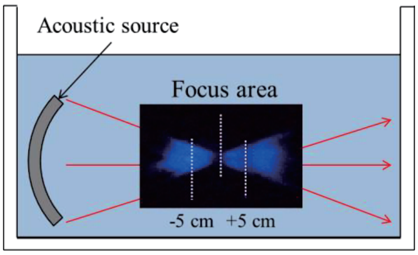

Fig. 5 SCL pattern observed at and near focal point (focal point ±5 mm) of focused ultrasound field.

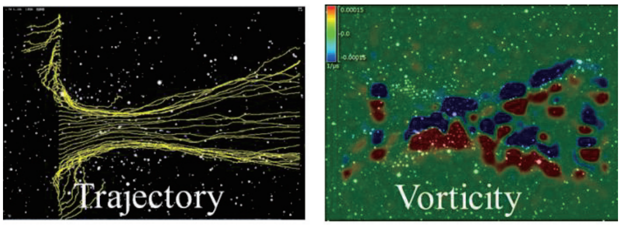

Fig. 6 Analyzed result of water flow and acoustic streaming in water tank of focus type 1.75 MHz ultrasound exposure system.

4. Conclusion

We could not confirm sono chemi luminescence pattern in the center area of the 150 kHz standing wave ultrasound field. Furthermore, we could observe the acoustic streaming of outward from center and the generated local vortex near the center axis of stainless steel vibrating disk. We considered that acoustic cavitation bubbles are stirred by convection acoustic streaming and occurring vortex in water in the water tank of the 150 kHz standing wave ultrasound irradiation system.

SCL could not be observed in the focal area of 1.75 MHz focused ultrasound acoustic field. Therefore, we considered that the acoustic cavitation is flowed by strong acoustic streaming due to the high sound pressure.

5. References

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