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PIV analysis of Acoustic Streaming Generated by a Polyurea Ultrasonic Transducer

ポリ尿素トランスデューサから放射された超音波を駆動源とする音響流の PIV 解析

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1. Introduction

Polyurea is an oraganic piezoelectric material which can be made on to arbitrary shaped base structure. Our research group has studied about ultrasonic transducer made with aromatic polyurea piezoelectric material[1)2)3)], which can be used for non-destructive testing or medical imaging. The radiation and trasmission characteristics in under water have been evaluated for high-frequency transducers at 30 MHz, 60 MHz, and 100 MHz[4)5)]. In the ref. 4, the authors have evaluated the radiation characteristics of a polyurea ultrasonic transducer for 30 MHz in underwater by using PIV (particle image velocimetry) method[6)]. The radiated sound pressure of ultrasonic wave has averaged at an area in the water, however, distribution of the of velocities was not analyzed. Distribution of sound pressure radiated from a transducer is usually measured by a hydrophone, which is expensive and fragile device. By employing PIV, we expect measuring sound pressure without hydrophone in short measurement time. In this reoprt, we have performed PIV analysis of the 30 MHz polyurea transducer in the ref. 4 for entire region of the water tank to show a possibility to measure radiation characteristics without using hydrophone.

2. Measurement configuration of PIV

In our PIV measurements, nylon particles are mixed into water, a laser illuminates these, and movements of the particles are captured by a video camera to analyze flow of streaming. **Table I** summarizes the parameters of the PIV measurement in the ref. 4. Particle velocities of acoustic streaming were calculated from the captured images of each video frame by the block-based method, which is implemented in the OpenCV library. **Fig. 1** shows the distribution of measured particle velocities, which indicates the distribution of the acoustic streaming. A small green circle shows the position of the PU transducer. White arrows show the particle velocities calculated by PIV. As shown in the figure, downward stream into the water is observed directly under the transducer. The maximum downward particle velocity was observed 3.0 m/s at the depth of 0.025 m, which indicated as small yellow circle. The upward streams were observed near the left and right side of the wall of

Table I Summary of the PIV parameters.

Parameter	Value
Ultrasonic frequency	30.4 MHz
Input voltage	21V zero-to-peak
Wave length of the laser	632.8 nm
Power of the laser	10 mW
Diameter of nylon particles	80 μm
Size of the water tank	10*10*10cm
Pixel area	640*480 pix
Video frame rate	30 Hz
PIV block size	5(x)*15(y)
PIV range size	3(x)*7(y)

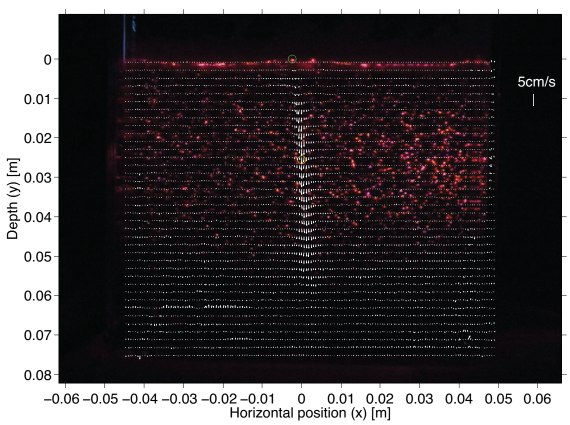

Fig. 1 PIV measured distributions of the particle velocities of acoustic streaming generated by 30 MHz polyurea ultrasonic transducer.

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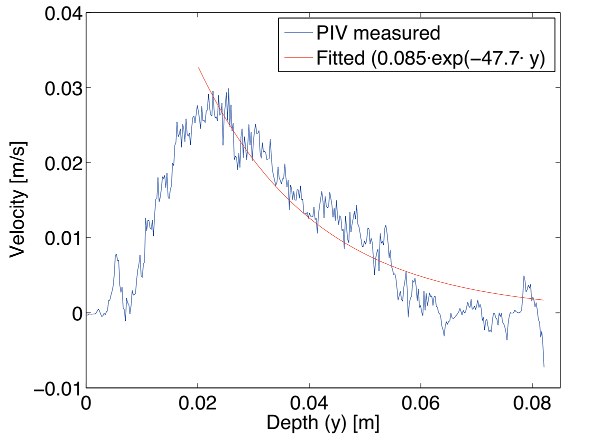

Fig. 2 Vertical distribution of PIV measured particle velocities (observed in the line directly downward the transducer).

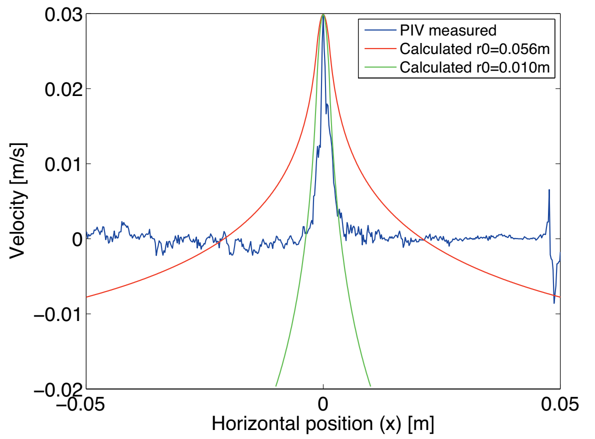

Fig. 3 Horizontal distribution of PIV measured particle velocities (observed in the line which includes the maximum velocity).

the water tank. As shown in the figure, only particles in the laser-illuminated plane were measured ($0.01\ \mathrm{m} \leq y \leq 0.05\ \mathrm{m}$). It is supposed that some of particles were in out-of-plane motion that cannot be observed by the experiment conditions.

3. Distribution of velocities in the plane

Fig. 2 shows the vertical distribution of the particle velocities of downward direction measured by PIV. The blue solid line shows the measured velocity, and the red line shows the fitted curve with exponential attenuation. The fitting is performed where depth is greater than 0.02 m. The velocities close to the transducer showed smaller value, which are supposed to out-of-plane motions in the measurement.

Fig. 3 shows the horizontal distribution of the particle velocities in the line which includes the maximum downward velocity. The blue line shows measured velocity, the red and the green lines show calculated distribution of velocity, respectively. Eckart flow is assumed for the calculated distributions[7]. There are two parameters to describe velocity distribution of a Eckart flow; r_0 :radius of the cylinder, and r_1 :radius of the transducer. Though the water tank used in the experiments is cubic shape and the transducer is rectangular shape, r_0 is assumed to 0.056 m, and r_1 is assumed to 0.0014 m, which are equivalent radius to the rectangular shape in the meaning of the area. However, good agreement between measurement and calculation is obtained when r_0 is assumed 0.010 m. As shown in the figure, measured velocity has a sharp peak and decreases gradually. Theoretically, negative flow is observed near the wall of the water tank. However, no negative flow is observed in the results of our experiment. It is supposed that the amount of the laser illumination is not sufficient the experiments.

4. Conclusion

In this report, distribution of acoustic streaming generated by the polyurea ultrasonic transducer was analyzed. The result shows that the distribution of acoustic streaming partially agrees with that of theoretical one. For further study, measurements are improved to capture detailed motion and to estimate the sound pressure emitted by the transducer by using distributions of velocity.

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