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Proceedings of Symposium on Ultrasonic Electronics, Vol. 33 (2012) pp. 251-252
13-15 November, 2012

Suggestion of HIFU Transducer with Controllable Curvature

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1. Introduction

Recently, the focal point control methods by phase weighting has been studied for High Intensity Focused Ultrasound (HIFU) transducer[1]. However, the different phases in the vibrating elements cause not only the reduction of the acoustic intensity but the acoustic aberration at the focal point. To distribute the different phases to each vibrating elements (piezoelectric transducers), the electric device for driving the array transducer has to be complicated and oversized. In this study, we suggest a focal length controllable concave-type ultrasonic transducer by changing curvature of the concave surface. This transducer can change the focal depth, and it allows to choose targets in wide range. To change the curvature, we make a pressure difference between both surfaces of the concave, in which the piezoelectric elements are arrayed. The acoustic fields are measured with the different curvature to investigate the driving performance of the array transducer.

2. Acoustic field calculation

To calculate acoustic field of concave-type array ultrasonic transducer, geometry is established as shown in Fig. 1. Piezoelectric elements with radius a are arrayed on the concave surface with curvature R. Acoustic field at point $p(x,y)$ is given by[2]

$$p(x,y) = \sum_i Q_i \frac{e^{-jkr_{pq}}}{r_{pq}} . \quad (1)$$

Here, Q_i is source strength of piezoelectric element, and k is wave number. The distance r_{pq} between field point $p(x,y)$ and source point $q(x_i,y_i)$ is given by

$$r_{pq} = \sqrt{(x-x_i)^2 + (y-y_i)^2} . \quad (2)$$

The coordinates of each source points are obtained as follows;

$$x_i = R - R\cos\theta_i , \quad (3)$$

$$y_i = R\sin\theta_i . \quad (4)$$

For the m-th piezoelectric element from the center, the angle θ_i has following range.

$$\frac{(2m-1)a + ml}{R} < \theta_i \le \frac{(2m+1)a + ml}{R} . \quad (5)$$

Here, l is the distance between two piezoelectric elements.

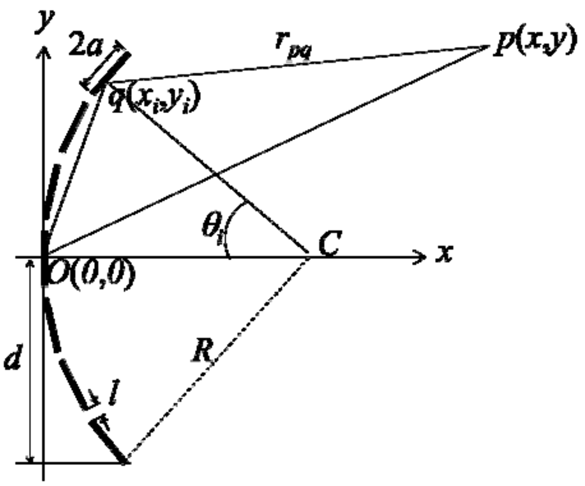

Fig. 1 Geometry of concave-type array ultrasonic transducer

3. Experiment and results

The construction of the array transducer with controllable curvature is shown in Fig. 2. The piezoelectric elements with resonant frequency of 2.0 MHz were arrayed on the silicon rubber layer with thickness of 4 mm. The radius of aperture of the array transducer is about 45 mm. The housing made of plastic was sealed to have different pressure to outside. To avoid electric short, the surface of the piezoelectric elements were coated by waterproof film. A silicon tube with diameter of 6 mm is connected to inside of the housing to control the air pressure level. The silicon rubber layer can be a concave surface when the pressure of the inside is less than that of outside. The curvature of the concave surface can be controlled by the

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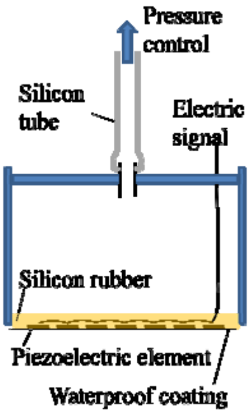
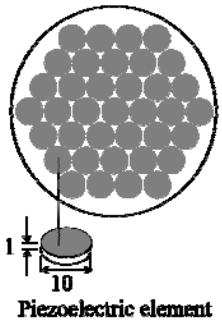
pressure level. As shown in Fig. 2(b), the piezoelectric elements, 37, were arrayed with hexagonal shape. The thickness and diameter of the element are 1 mm and 10 mm, respectively. The nearest distance between the elements is 2 mm.



(a)



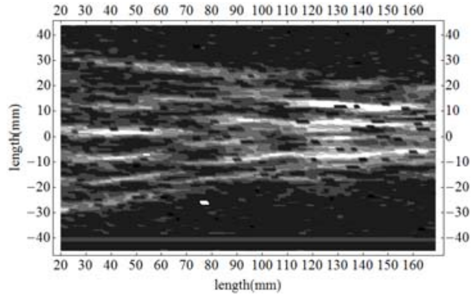
(b)

Fig. 2 Construction of the array transducer (a); Array pattern of vibrating elements of transducer (b)

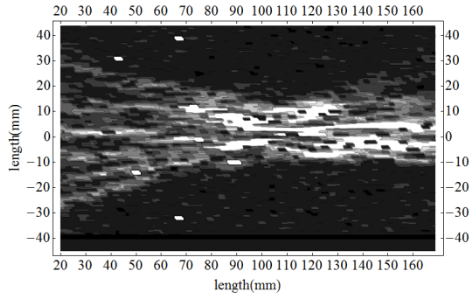
The array transducer was driven by burst wave with center frequency of 1.89 MHz. The acoustic pressure was measured with a needle point hydrophone (ϕ0.2 mm, Precision) by scanning with a pitch of 1 mm. The measurement area was 150 mm×90 mm in front of the transducer. The water tank for the measurement was 0.8 m×0.8 m×1.2 m. The acoustic fields of the concave-type transducer are measured as shown in Fig. 3. The acoustic field from the transducer was focused gradually when the curvature was 400 mm as shown in Fig. 3(a). However, changing the curvature to 105 mm, the acoustic field showed obvious converging in Fig. 3(b). From these results, we can confirm that the focal point of the transducer changed by the different curvature of the surface. The acoustic fields were also calculated by Eq. (1) as shown in Fig. 4. These results show similar tendency with those of measured ones even though there are many speckles due to the noise.

4. Summary

A focal length controllable concave-type ultrasonic transducer was suggested by changing curvature of the arrayed surface. The pressure difference between both surfaces of a silicon rubber layer, where piezoelectric elements were arrayed, could control the curvature of the transducer to change the focal point. The acoustic fields of the transdcer were measured when the curvature was changed. The focal point of the transducer could be easily changed.

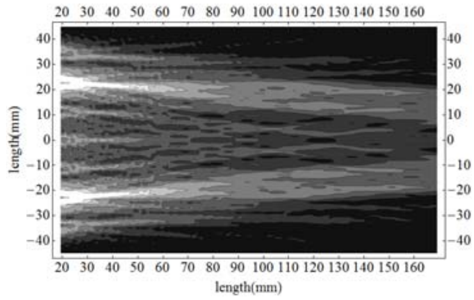


(a) R=400 mm

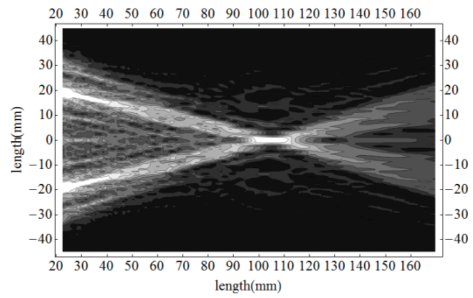


(b) R=105 mm

Fig. 3 Measured acoustic field of concave-type ultrasonic array transducer with different curvature



(a) R=400 mm



(b) R=105 mm

Fig. 4 Calculated acoustic field of concave-type ultrasonic array transducer with different curvature

Acknowledgment
This research was supported by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology (2012-032240).

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