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Focal point controllable ultrasonic array transducer with adjustable curvature

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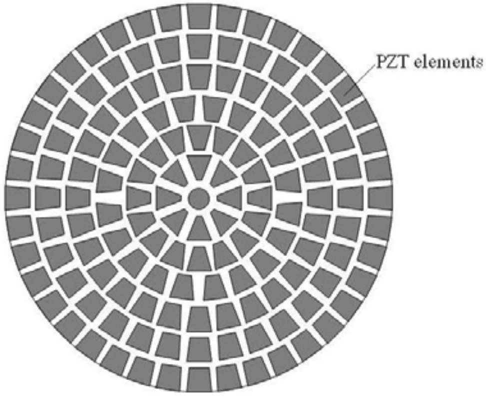
1. Introduction

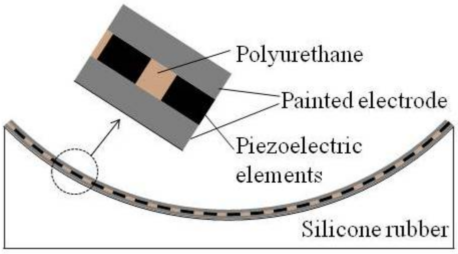
The conventional ultrasonic noninvasive medical treatment such as a High Intensity Focused Ultrasound (HIFU) has limited target area because the focal depth of the HIFU transducer is decided by its driving frequency and geometry, and the ultrasonic wave must be irradiated from the skin of human body[1]. Recently, the focal point control methods by phase weighting has been studied for the HIFU transducer[2]. However, the different phases in the vbrating 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 transducer has to be complecated and oversized. As a previous study, we suggested a focal length controllable PVDF transducer using bimorph-type bending actuator for the ultrasonic diagnosis[3]. However, to generate high acoustic intensity for the ultrasonic treatment, PVDF sheet is not appropreate. In this study, we suggested the focal length controllable ultrasonic transducer for noninvasive medical treatment using an electromagnetic actuator. To control the focal depth along the acoustic axis, the curvature of transducer is changed by the actuator because the bimorph -type bending actuator has not enough force to change the curvature. In order to develop the required piezoelectric actuator, the focal depth to be controlled is determined, and then the maximum displacement and applying voltage of the actuator is decided according to the focal depth.

2. Fabrication procedure

The construction of the focal point controllable ultrasonic transducer is shown in Fig. 1. The piezoelectric vibrating elements are arrayed on the concave surface as shown in Fig. 1(a). The number and the thickness of the elements are 153 and 1.0 mm, respectively. The radius of curvature of the concave surface is 71.62 mm. The concave surface is made of silicon rubber because of enough ductility and restoring. The aparture radius of the transducer is 38.0 mm. To form a lower electrode layer on the surface, a silver paint (CPI 05001-AB) is painted as shown in Fig. 1(b). The piezoelectric vibrating elements made of PZT ceramic are arrayed on the electrode surface, and the space between the vibrating elements are filled with polyurethane rasin to fix the vibrating elements. The surfaces of PZT ceramics and polyurethane are pinted with the silver paint to mold upper electrode layer. Figuer 2 shows the construction of electromagnetic actuator with the transducer. The moving coil bends the silicon rubber by the Lorentz force to change the radius of curvature of the transducer. The acoustic acoustic focal point of the transducer can be changed with the curvature variation as shown in Fig. 3.



(a)



(b)

Fig. 1 Array pattern of vibrating elements of transducer (a); Construction of electrode layers and filler of transducer (b)

3. Results and discussion

The resonant frequency of the transducer was measured 516.2 kHz. To confirm the variable range of the curvature, a variable DC power was applied to the electromagnetic actuator. The change of the radius of curvature was ±10% of the original one

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when the applied DC power was changed from -30 W to +30 W. The acoustic fields in water from the transducer were calculated by using Eq. (1)[4] as shown in Fig. 4. In this result, the focal point is shifted as the radius of curvature is changed. We will measure the acoustic field change with Schlieren method to confirm the theoretical results.

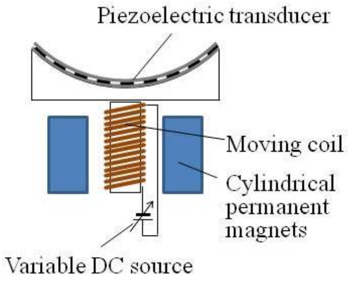


Fig. 2 Schematic of electromagnetic actuator and concave type transducer

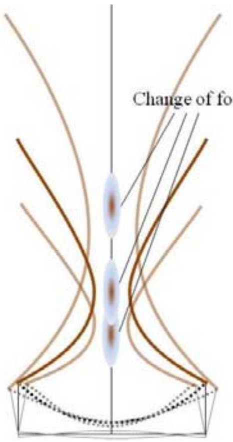


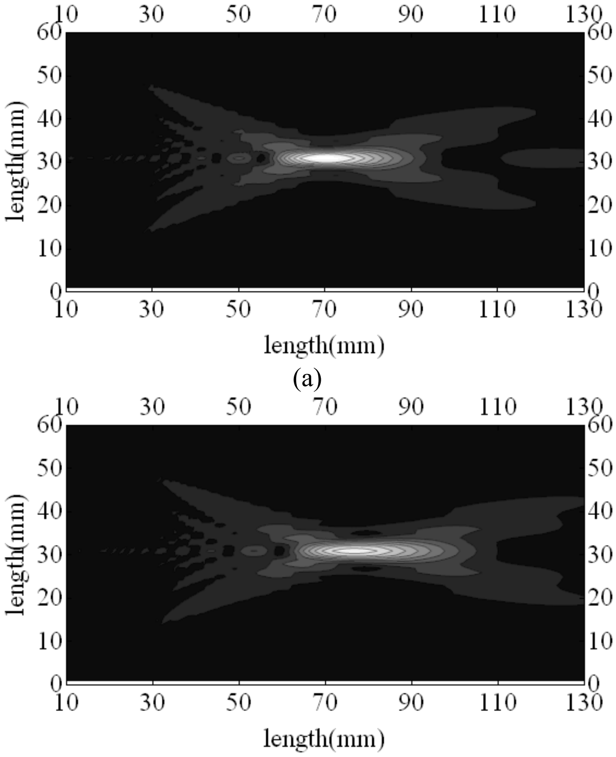
Fig. 3 Focal point change with curvature of transducer

$$p_1(r,z) = -j\frac{kp_{01}}{z}\exp\left(j\frac{kr^2}{2z}\right) \times \int_0^{r_1} \exp\left[j\frac{k}{2}\left(\frac{1}{z}-\frac{1}{D}\right)r'^2\right] J_0\left(\frac{krr'}{z}\right) r'dr' \qquad (1)$$

Here, k is wave number, D is radius of curvature of the transducer, r_1 is aparture radius of the transducer.

4. Conclusion

Using the electromagnetic actuator, the focal length of concave surface transducers made of PZT ceramic elements was controlled. The focal length of the transducer could be changed continuously about 20% of original one with applied DC power to the actuator. Using the HIFU transducer suggested in this study, the targets to treat can be chosen in wide range of depth from the skin.



(a)

(b)

Fig. 4 Calculated acoustic field change of the focusing ultrasonic transducer when the radius of curvature was 71.62 mm (a); 78.72 mm (b)

Acknowledgment

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