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Breathing Mode Ceramic Element for Therapeutic Array Transducer

超音波治療用アレイトランスデューサのための呼吸振動モード圧電素子

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1. Introduction

In focused ultrsound treatment, to focus the ultrasound energy correctly onto the target tissue surrounded by non-uniform tissues in the body, the ultrasoud transmission should preferably be controlled precisely using an array transducer.

Piezocomposite is mainly used as such therapeutic array transducer material because of a few reasons. Each piezoceramic element in composite can deform in the desired direction without much stress in the other unwanted directions. Therefore, the shape of an electrically independent element can be chosen freely from coupled vibration modes, avoiding which is always a great concern in designing a piezoceramic array element. Moreover, unlike piezoceramic materials, piezocomposites are flexible enough to form a spherical shell for geometrical focusing.

To solve this problem, we are investigating a new concept of piezoceramic element using its breathing mode. A hemispherical breathing mode transducer has been developed as an audio tweeter[1). In audio applications, the resonance of a transdcuer is out of the audio frequency range. In therpeutic application, however, the resonance has to be used for the efficiency. For the resonance, a hemispherical shell with a diameter in the order of a wavelength in water may be used inward rather than outward. This size may be a little too large as an imaging array elelment, but small enough for a therapeutic array.

In this paper, we numerically analyze the behavior of such a transducer element using PZFlex, a finite element time domain piezoelectric simulator (Weidlinger Assc. Inc.).

2. Analysis Model

Fig. 1 shows a schematic view of the air-backed hemispherical array transducer element. Its breathing motion may couple with the compressive motion of water so as to achieve a good acoustic matching.

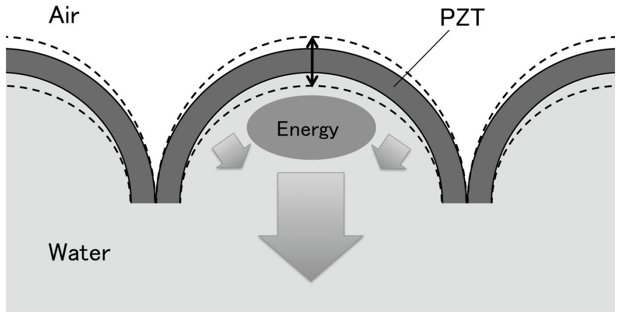

Fig. 1. Schematic view of breathing mode array transducer.

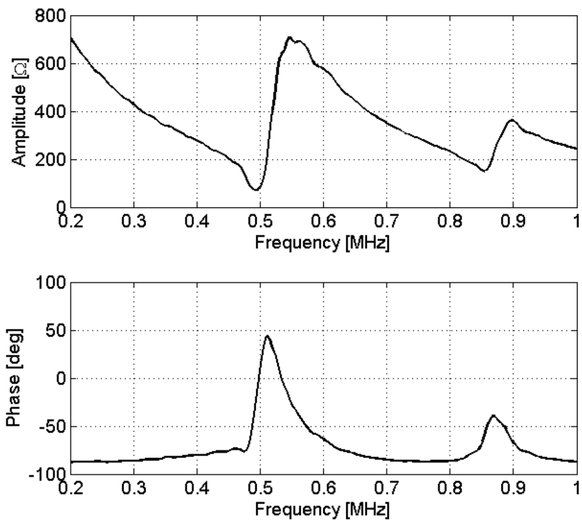

Fig. 2. Electrical impedance curve.

In a numerical simulation, the PZT shell was divided into radially poled small pieces. Electrodes were placed on the front and back surfaces, and either impulse voltage or continuous sinusoidal voltage at the resonance frequency was applied. The output acoustic power was calculated covering the aperture of the transducer element.

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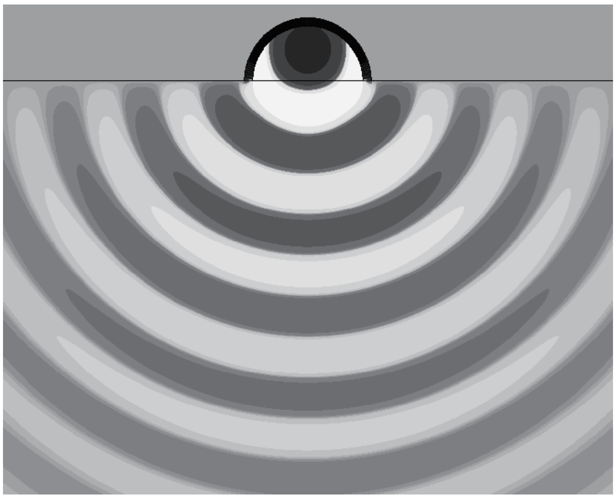

Fig. 3. Acoustic waves emitted from breathing mode ceramic element.

3. Results

Fig. 2 shows the electrical impedance curves obtained from the impulse response for a 0.3-mm thick hemispherical shell transducer with an inner diameter of 4 mm. The resonance frequency of 0.50 MHz corresponds to the breathing mode coupled with water. **Fig. 3** shows the acoustic pressure emitted into water when it was driven at the resonance.

Fig. 4 shows the dependence of the normalized output acoustic power on the shell thickness at the same drive voltage. The thickness from 0.25 to 0.35 mm may be chosen. **Fig. 5** also shows the dependence on the convergence angle of the spherical shell. Here, the inner diameter of the aperture was kept the same as 4 mm. Hemisphere may be chosen from this comparion.

4. Discussion

The resonance frequency of a sphere can be calculated using spherical Bessel functions. The resonant diameter of a water sphere at 0.50 MHz is estimated to be 3 mm. This resonance seems to have significant influence to the coupling with the breathing motion of the spherical shell as seen in Fig. 3, and may have resulted in the higher output for the larger convergence angle in Fig. 5.

Further investigation by fabricating an actual transducer element is needed to further discuss the efficacy of the proposed concept of transducer.

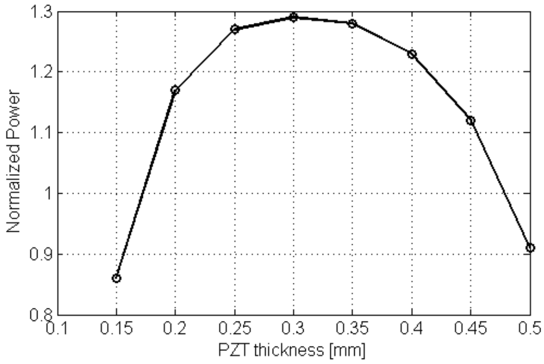

Fig. 4. Optimization of PZT thickness.

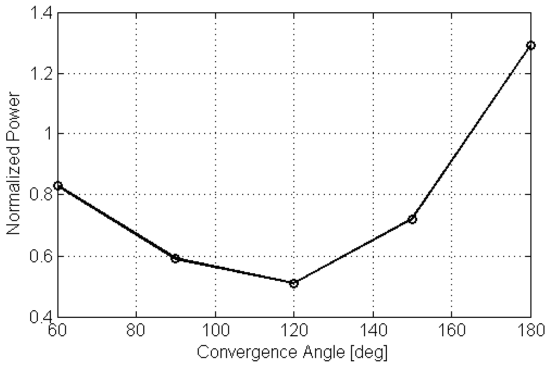

Fig. 5. Effect on convergence angle.

5. Conclusion

A breathing hemisphere piezoceramic transducer was proposed as a therapeutic array transducer element. From a numerical simulation, a good acoustic matching was predicted by coupling between the breathing of the piezoceramic shell and the compression of water.

Acknowledgment

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Reference

1) T. Nakamura et al: Ceramics Japan (1999) 647.