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Design of an Acoustic Bender Transducer for Low Frequency Active Sonobuoys

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1. Introduction

Sonobuoys are mainly classified into active and passive sonobuoys. Recent underwater vehicles can operate with a much lower level of noise, thus the need of an active sonobuoy with high detection performance is increasing. These active sonobuoys mainly use bender transducers as a projector that emits sound waves [1,2]. In this study, we designed a high performance bender transducer and verified the validity of the design. For the purpose, fist, we analyzed the variation of resonance frequency and transmitting voltage response (TVR) of the bender transducer in relation to its structural parameters. Based on the results, we derived the optimal structure of the bender transducer to achieve the highest transmitting performance. Furthermore, a prototype of the bender transducer was fabricated, and its acoustic properties were measured to verify the validity of the design.

2. Optimal Design of Bender transducer

Fig. 1 is the schematic structure of the bender transducer. A finite element analysis (FEA) model was constructed to analyze the effects of structural parameters on the performance of the transducer. The FEA was conducted using the commercial software package, PZFlex®. We used PZT-5A for the piezoelectric material to excite the transducer. A circular PZT-5A disc was attached to the top and bottom surfaces of the aluminum case, respectively. The PZT-5A disc on the top surface has a poling direction opposite to that of the PZT-5A disc on the bottom surface of the aluminum case. The volume inside the aluminum case is empty. Acoustic absorbing boundary conditions were imposed on the outer edges of the radiation medium to prevent wave reflection at the edges.

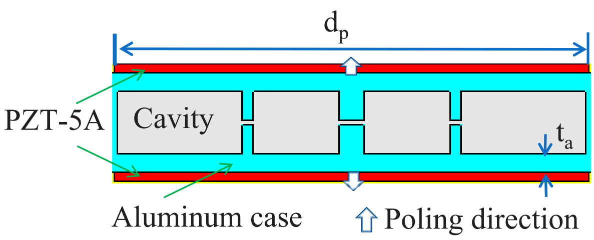

Fig. 1 Finite element model of the bender transducer.

TVR was the main acoustic characteristic of the bender transducer. The two PZT discs were connected in parallel. An impulse signal centered at 5 kHz was applied to the PZT discs and then the sound pressure at a far field from the transducer was calculated through transient analysis.

The optimal structure of the bender transducer was derived through the optimization process shown in **Fig. 2**. First, thickness of the aluminum plate (t_a) and diameter of the piezoceramic (d_p) were selected as the design parameters to be optimized. Next, the initial value and variation range of respective design parameter were established through preliminary analysis of the effect of the parameters on the performance of the transducer. The initial aluminum plate thickness was set as 4 mm, and its range of variation was set to be from 2 to 6 mm. The initial diameter of the PZT-5A disc was set as 99 mm, and its range of variation was set to be from 97 to 101 mm. The purpose of this optimization was to design the structure of the bender transducer to have the highest TVR while satisfying the constraint that the center frequency of the transducer should be between 1.78 kHz and 1.82 kHz.

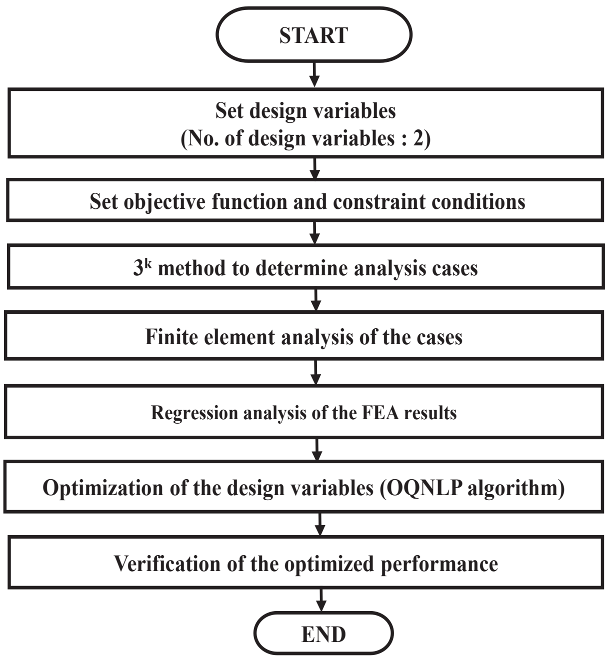

Fig. 2 Flow chart of the optimization process.

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The TVR characteristic of the bender transducer was analyzed based on the 3^k experimental design method. A total of 9 samples were generated and the interaction between the design parameters was analyzed. Regression analysis was carried out on the results of the FEA to derive the TVR as a function of the t_a and d_p. Then, the optimal combination of the two parameters was derived to maximize the TVR using the OptQuest NonLinear Program algorithm [3]. The optimal dimensions of the bender transducer were determined to be 4.3 mm for t_a and 99.1 mm for d_p, respectively. The bender transducer having the optimal dimensions was simulated to have the TVR spectrum as that in **Fig. 3**. The maximum TVR level of the optimized structure is 140.4 dB, which is higher than that of the initial model by 0.4 dB. The TVR level has the maximum value at 1.82 kHz, which satisfies the constraint.

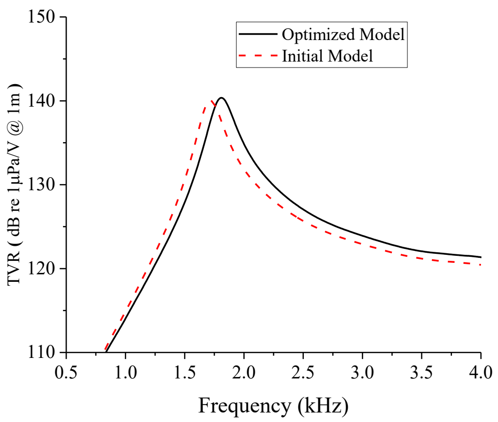

Fig. 3 Comparison of the optimized and initial TVR spectra.

3. Fabrication and characterization of a prototype of the bender transducer

A prototype of the bender transducer was fabricated as shown Fig. 4 and was characterized to verify the validity of design. The dimensions of the prototype bender transducer are identical to those of the optimized structure. The TVR was measured from 1.5 kHz to 2.0 kHz by an interval of 50 Hz. The measured TVR spectrum is compared with the optimized TVR spectrum in Fig. 3. The two TVR spectra in Fig. 5 show overall agreement with each other, which verifies the validity of the bender transducer design. However, there is some discrepancy in the maximum TVR level, which seems to be due to the limitation in experimental measurement condition such as the limitation of the water tank size to do the low frequency measurement and imperfect prevention of wave reflection at edges of the water tank.

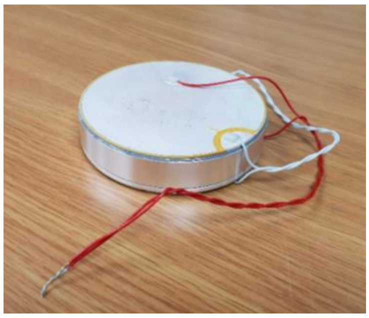

Fig. 4 Prototype bender transducer.

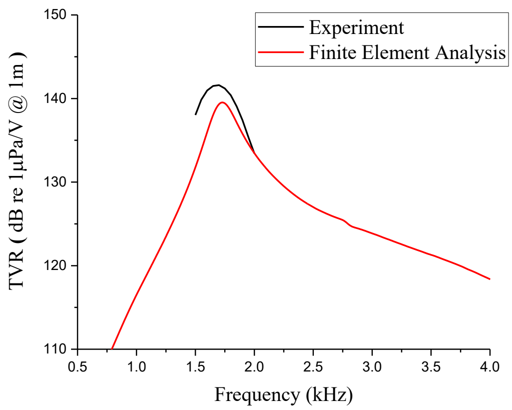

Fig. 5 Comparison of the experimental and simulated TVR spectra.

4. Conclusions

In this study, the structure of the bender transducer was optimized to increase the TVR level within a given frequency range. The maximum TVR level of the optimized transducer turned out to be higher than that of the initial transducer by 0.4 dB having its center frequency at 1.82 kHz. Based on the design, a prototype bender transducer was fabricated and its acoustic characteristics were measured. Comparison of the measured and simulated TVR spectra showed overall agreement, which verified the validity of the design. The bender transducer developed in this work can be employed by active sonobuoys to achieve more accurate underwater communication and detection capability in comparison with existing passive sonobuoys.

References

1. Z. Tianfang, L. Yu, and L. Wei: IEEE/OES China Ocean Acoustic Symp., (2016) p. 1.
2. J. L. Delany: J. Acoust. Soc. Am. **109**, (2001) 554.
3. A. D. Belegudu and T. R. Chandrupatla: *Optimization Concepts and Application in Engineering* (Cambridge Univ. Press, New York, 2014)