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Design and Fabrication of a Wideband Tonpilz Transducer with a Cavity-type Head Mass

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1. Introduction

A Tonpilz transducer is one of the most popular choices to transmit sound waves as a projector or to receive the waves as a hydrophone in underwater applications. A typical Tonpilz transducer is composed of a light head mass to radiate acoustic waves, a piezoelectric material stack as a drive section, a heavy tail mass to amplify the displacement of the head mass, and a bolt to fasten all the components together. Because of the tightened structure, the Tonpilz transducer is very suitable for generating high power acoustic waves [1]. However, when a wide frequency bandwidth is also required, the typical structure frequently fails to meet the requirement. In this work, a new structure of the Tonpilz transducer has been developed to broaden the bandwidth by facilitating the coupling between the longitudinal mode of the transducer and the flapping mode of the head mass. The authors of the present paper presented the concept of a new wideband Tonpilz transducer with a void head mass [2]. **Fig. 1** shows the schematic structure of the new transducer. With a cavity inside the head mass, the thickness of the head mass was allowed to extend over an evidently wider range without much increasing the weight of the head mass. However, validity of the concept was checked only through numerical simulations which required further experimental validation. Hence, in this work, we have carried out the optimal design of the new Tonpilz transducer structure. Based on the design, a prototype of the transducer has been fabricated and characterized experimentally. Measured performance of the transducer has been compared with the design and discussed to confirm the effectiveness of the new wideband Tonpilz transducer.

2. Finite element modeling of the tonpilz transducer

A 3D finite element (FE) model of the transducer was constructed with the commercial software package ANSYS®. The structural variables to control the performance were the head mass thickness, upper plate thickness of the head mass, and the tail mass thickness.

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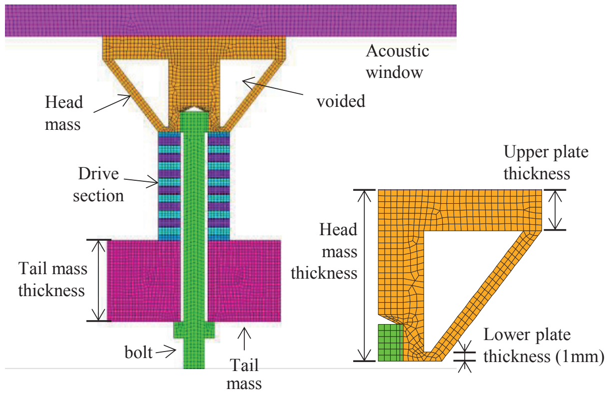

Fig. 1 Schematic structure of the Tonpilz transducer with the void head mass.

The three variables were verified to be most influential on the bandwidth from the previous work of the authors [2]. However, the effects of the structural variables were not independent but were cross-coupled with each other. Hence, the optimal combination of the structural variables needed to be searched to achieve the widest bandwidth within the variation ranges of the structural variables. The FE models were analyzed to find the trend of the transducer performance variation in relation to the structural parameter changes. Then, the functional forms of the bandwidth and center frequency were derived through multiple regression analysis of the FE analysis data. The functional forms of the bandwidth and center frequency were utilized to determine the optimal combination of the structural variables by means of the OQ-NLP algorithm. The –6dB fractional bandwidth of the optimized model turned out to be 130.6%.

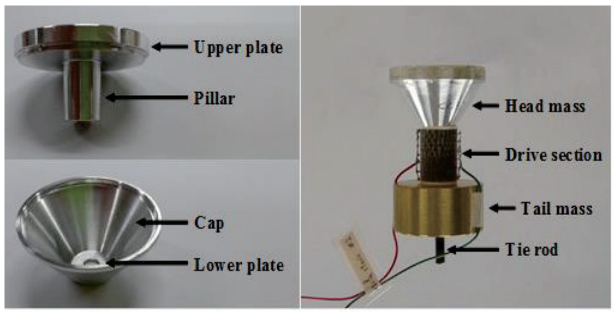

Fig. 2 Photograph of the Tonpilz transducer prototype with the void head mass.

3. Structural optimization of the transducer

To verify the validity of the design, a prototype of the Tonpilz transducer with the void head mass was manufactured. The transducer was made to have exactly the same geometry and material properties as that designed in §2. **Fig. 2** is a photograph of the components of the void head mass and an assembled Tonpilz transducer. The head mass is composed of an upper part (upper plate and pillar) and a lower part (lower plate and cap). The two parts are combined together to make the void head mass. Impedance spectrum of the transducer was measured and compared with the calculated spectrum, as shown in **Fig. 3**. The comparison shows good agreement between the modeled and measured spectra, with the differences between the resonant and anti-resonant frequencies of the longitudinal mode less than 2%. Further, the underwater performance of the transducer was measured with the experimental setup shown in **Fig. 4**. The Tonpilz transducer was driven by a function generator (Tektronix AFG3102) and a power amplifier (Instruments Inc. L20, San Diego, CA) to transmit a sound signal. The signal was received by a hydrophone (B&K 8104), was amplified with a charge amplifier (B&K 2651), and was processed with an oscilloscope (LeCroy WaveRunner 44Xi) and PC. **Fig. 5** shows the transmitting voltage response (TVR) spectrum measured with the experimental setup where it is compared with the modeled spectrum. Overall, there is good agreement between the modeled and measured TVR spectra. The –6dB fractional bandwidth (FBW) of the measured spectrum was 129.5% while that of the modeled spectrum was 130.6%. This result verified the validity of the FE model which in turn confirmed the efficacy of the void head mass in improving the bandwidth of the Tonpilz transducer.

4. Conclusions

A new Tonpilz transducer structure has been developed to have a void head mass that allows a wider frequency bandwidth than that of a conventional transducer. The void head mass meant a much lighter head mass, which produced a lower mechanical quality factor, thus a wider bandwidth. Validity of the design was verified by manufacturing and characterizing a prototype transducer of the optimized structure where the measured TVR spectrum had good agreement with the modeled spectrum. The optimized transducer had a FBW of 130.6% in the TVR spectrum which confirmed the efficacy of the void head mass in widening the frequency bandwidth.

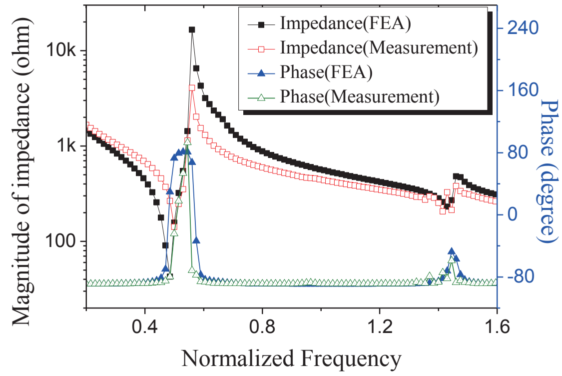

Fig. 3 Comparison of the modeled and measured impedance spectra of the Tonpilz transducer in air.

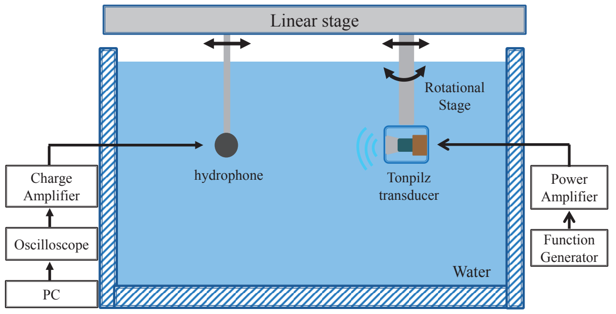

Fig. 4 Schematic diagram to measure the TVR of the Tonpilz transducer prototype.

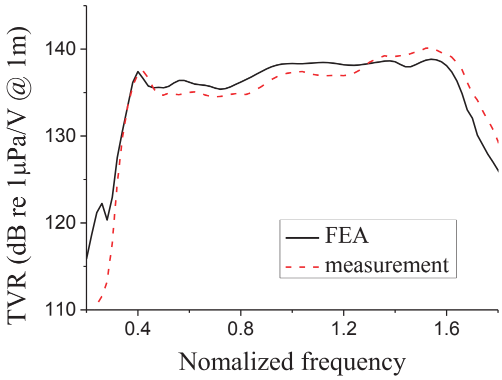

Fig. 5 . Comparison of measured and modeled TVR spectra in water.

Acknowledgment

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References

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