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Vibration and acoustic characteristics of piezoelectric ultrasonic transducers

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ABSTRACT

The paper deals with vibration and acoustic characteristics of piezoelectric ultrasonic transducers for distance measurement. The purpose of this research is to determine the vibration displacement distribution improving the acoustic directivity of an ultrasonic transducer because the measurable distance is longer with better directivity, which depends on the vibration of the transducer's housing plate. The response of the elastic circular plate excited by a small piezoelectric disc has been obtained by finite element analysis. Ultrasound radiating from the transducer plate has been considered in the acoustic finite element analysis. The acoustic results have been expressed in the form of sound pressure distributions, and then they have been transformed into beam pattern and acoustic directivity. The size of the piezoelectric disc relative to that of the elastic plate affects the vibration distribution and thus the acoustic directivity and beam pattern. We have achieved the basis of improving the acoustic directivity for design of ultrasonic transducers for long-distance ranging.

Keywords: Vibration, Ultrasound, Transducer, Directivity
I-INCE Classification of Subject Number: 42

1. INTRODUCTION

Ultrasonic sensors for distance measurement have been used to detect obstacles for vehicles and drones [1] or liquid level metering for industry and agriculture [2]. The ultrasonic sensors for automobiles consist of a piezoelectric element, a circular plate and a cylindrical wall as shown in Fig. 1. The piezoelectric element excites the circular plate, and the vibration of the circular plate radiates ultrasound into air.

It is needed to improve the acoustic directivity of the ultrasonic transducer because the measurable distance is longer with better directivity. The acoustic directivity of ultrasound depends on the vibration of the transducer's circular plate [3]. The purpose of this research is to obtain the vibration displacement distribution in the circular plate and calculate acoustic characteristics of ultrasound radiating from the sensor.

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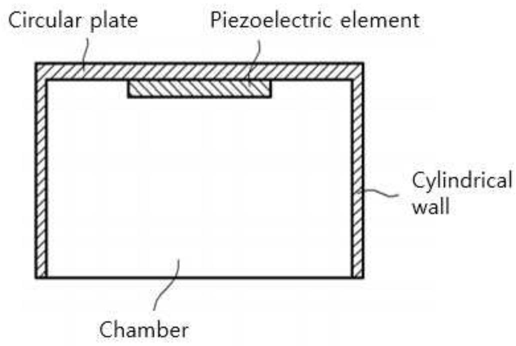


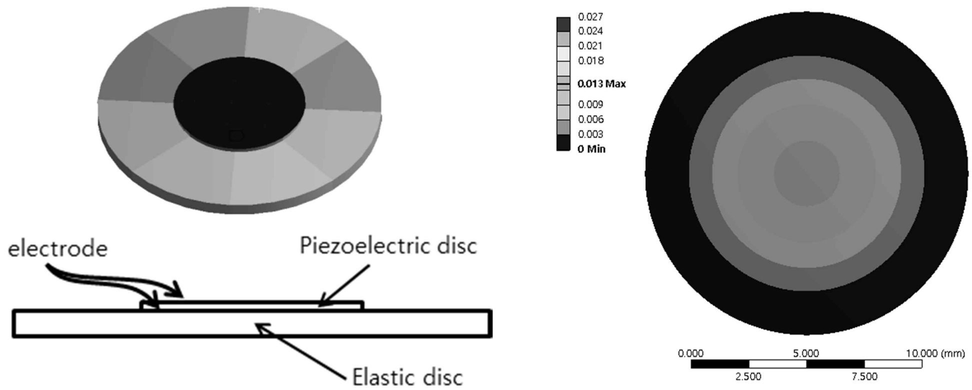
Fig. 1 Cross-sectional view of an ultrasonic sensor

2. VIBRATION CHARACTERISTICS

2.1 Piezoelectric Excitation

The diameter of the piezoelectric element is smaller than that of the elastic circular plate, and the excitation of the piezoelectric element must be considered carefully. If the diameter of the piezoelectric element is same as that of the elastic circular plate, the excitation may be simply assumed as bell-type distribution in the thickness direction [3]. However, the excitation of the small piezoelectric element includes radial component of stress as well as axial one [4]. Instead of analytical approach, this paper used finite element analysis with ANSYS.

The analysis model is shown in Fig. 2(a). The piezoelectric element is made of PZT4 and the elastic plate is aluminium 6061 T1. The diameter and thickness of the elastic plate is 14 mm and 0.65 mm, respectively. The diameter and thickness of the piezoelectric element is 6.5 mm and 0.2 mm, respectively. The element type is SOLID 185 and the element size is less than 0.2 mm. The natural frequencies of the elastic plate are 27 kHz, 123 kHz, etc. The excitation frequencies in the analysis are 15, 30, 60, 90, 120 kHz.



(a) analysis model (b) vibration distribution

Fig. 2 Analysis model and result

2.2 Response of an Elastic Disc

One example of the analysis results is shown in Fig. 2(b). It shows the displacement distribution of the vibration response at 30 kHz. The result is displayed in the form of a graph in Fig. 3. This figure includes other results theoretically obtained earlier in the assumption of uniform and non-uniform excitation. The results show that the vibration responses at the excitation frequency close to the natural frequency are similar to each other.

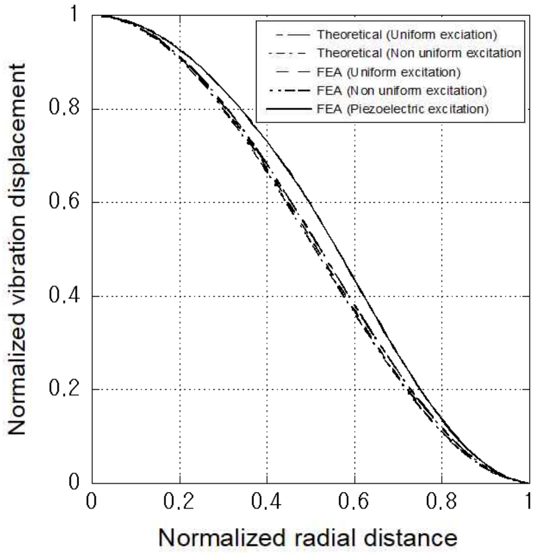


Fig. 3 Comparison of the response results at 30 kHz

3. ACOUSTIC CHARACTERISTICS

3.1 Radiation of Ultrasound

Ultrasound radiating from the vibrating plate has been considered in the acoustic finite element analysis. An acoustic analysis model was constructed as a hemispheric region of 0.1 m radius. Radiation condition was established on the spherical boundary. The vibration distribution obtained in the previous section was used as an excitation of acoustic field.

Analysis was conducted at several frequencies, and examples of the results were displayed in Fig. 4 in the form of sound pressure level(SPL) distribution. Fig. 4(a) is SPL distribution at 30 kHz, which is close to the first natural frequency of the vibrating plate. Fig. 4(b) is SPL distribution at 60 kHz, which is between the first and second natural frequencies. The magnitude of the sound pressure at 0.1 m along the axial direction is maximum at 30 kHz result

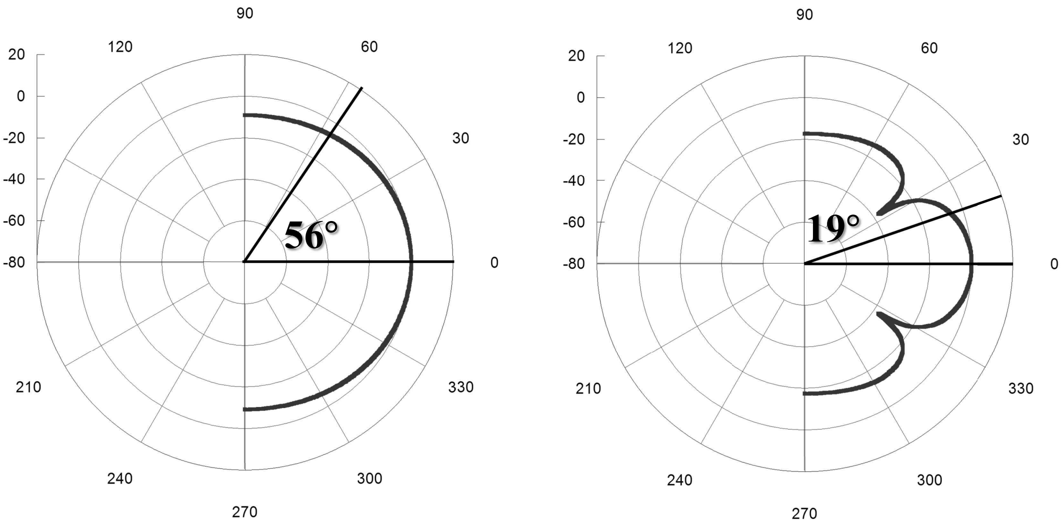
(a) at 30 kHz

(b) at 60 kHz

Fig. 4 Sound pressure level distribution

3.2 Beam Patterns and Acoustic Directivity

Relative SPL at 0.1 m boundary was displayed in a polar graph in Fig. 5. It is called as beam pattern [5]. Beam width is defined as the angle of direction showing half power of sound relative to the axial direction. The beam width is smaller at higher frequency. Acoustic directivity [5] was also calculated from the results of Fig. 5. Acoustic directivity is larger at higher frequency.



(a) at 30 kHz (b) at 60 kHz

Fig. 5 Beam patterns

4. CONCLUSIONS

The response of the elastic circular plate excited by a small piezoelectric disc was obtained by finite element analysis. Ultrasound radiating from the transducer plate was considered in the acoustic finite element analysis. The acoustic results were expressed in the form of sound pressure level distribution, and then they were transformed into beam pattern and acoustic directivity. The size of the piezoelectric disc relative to that of the elastic plate affects the vibration distribution and thus the acoustic directivity and beam pattern. We achieved the basis of improving the acoustic directivity and detection distance for design of ultrasonic transducers for long-distance ranging.

5. REFERENCES

1. L. Alonso, V. Milanes, C. Torre-Ferrero, J. Godoy, J. P. Oria, T. Pedro, *"Ultrasonic Sensors in Urban Traffic Driving-Aid Systems",* Sensors, Vol. 11, pp. 661-673 (2011).

2. R. R. Gross, *"Methods and Device for Ultrasonic Range Sensing"*, Unite States Patent 7,679,996 B2 (2010).

3. S. O. Seon, J. O. Kim, M. K. Chae, G. S. Yoo, *"Acoustic Characteristics Depending on the Vibration Distribution of Ultrasonic Sensors"*, Transactions of the Korean Society for Noise and Vibration Engineering, Vol. 28, No. 4, pp. 490-500 (2018).

4. C. Mo, R. Wright, W. S. Slaughter, W. W. Clark, *"Behaviour of a Unimorph Circular Piezoelectric Actuator"*, Smart Materials and Structures, Vol. 15, pp. 1094-1102 (2006).

5. L. E. Kinsler, *"Fundamentals of Acoustics"*, 4th edition, Wiley, New York, pp. 184-193 (1999).