2Pa2-1

Experimental method to locate the nodal points of the high power ultrasonic transducer

Moojoon Kim[1†], and Jungsoon Kim[2]
([1]Dept. of Physics, Pukyong Nat'l Univ.; [2]Dept. of Electrical Eng., Tongmyong Univ.)

1. Introduction

In the bolt-clamped Langevin-type ultrasonic transducer widely used in power ultrasonic application fields[1-2], the flange position for fixing the transducer is an important factor that has an influence on electro-mechanical efficiency of the transducer[3-4]. Therefore it is significant problem to find the nodal point of the Langevin-type ultrasonic transducer. However, since the bolt-clamped Langevin-type ultrasonic transducer has a structure in which a metal bolt penetrates and fastens metal blocks and piezoelectric ceramic layers, it is difficult to accurately simulate the vibration distribution by theoretical analysis using an equivalent circuit. When using finite element analysis, as another method, there is a constraint condition that accurate physical properties for constituent materials must be provided.

In this study, we suggest a practical method that can locate the optimum position of the nodal point for different resonance modes of the bolt-clamped Langevin-type ultrasonic transducer, and the validity of the suggested method is verified.

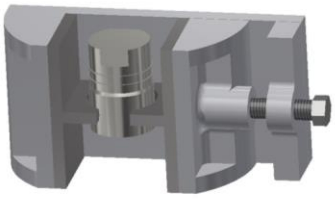
2. Experimental method

The bolt-clamped Langevin-type ultrasonic transducer is made up of fixing with stainless steel bolt inserting two disk-shaped piezoelectric vibrators with a thickness of about 5 mm between the aluminum rods having a thickness of 16.0 mm and 27.5 mm, respectively. The material constants of aluminum rods and piezoelectric ceramics were measured, and the results are shown in **Table I**.

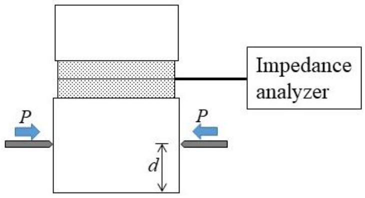
Table I. Material constants of PZT and aluminum.

	Piezoelectric vibrator	Aluminum
Density (kg/m^3)	7811.56	2740.9
Phase velocity (m/s)	4530.59-1.18 *i*	4146.2
Dielectric constant ()	922.76	-
Piezoelectric *e* constant (C/m^2)	11.71	-

To realize the flange effect for fixing the ultrasonic transducer, a semicircular wedge-shaped jig was manufactured and moved along the lateral surface of the transducer, as shown in **Fig. 1**. The vibration characteristics of the transducer was examined after a constant pressure was applied to the semicircular wedge-shaped jig. At this time, the constant pressure applied to the vise is uniformly provided with a torque wrench. The input impedance of the Langevin-type ultrasonic transducer is measured for different position using the impedance analyzer (Keysight, E4990A), as shown in **Fig. 1(b)**.



(a) Design of a semicircular wedge-shaped jig



(b) Schematic of the experimental setup

Fig. 1 Design and schematic of the experimental setup.

3. Results and discussion

Figure 2 shows the results of the input admittance without the jig. In the figure, the solid line and the dotted line refer to the conductance and the susceptance of the input admittance,

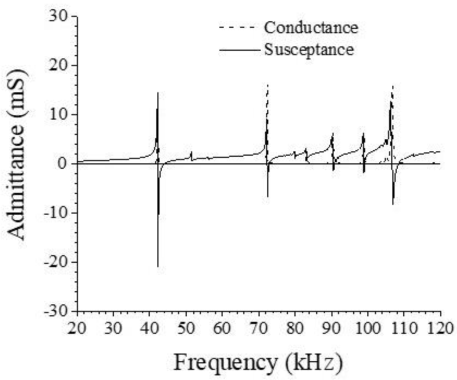
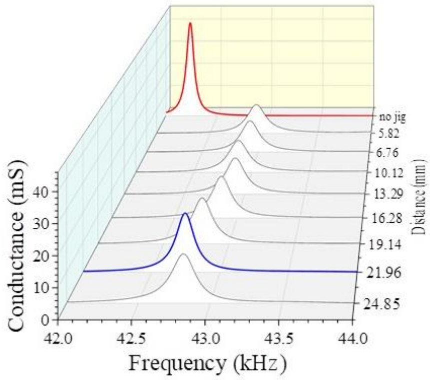


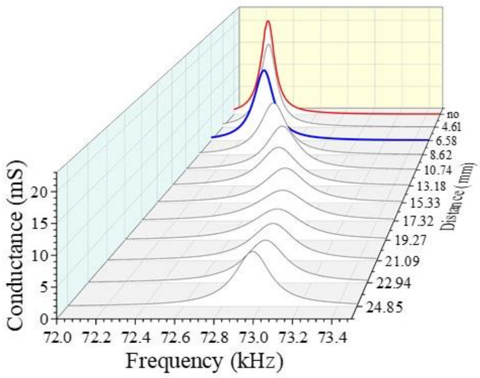
Fig. 2 Input admittance characteristic of the bolt-clamped Langevin-type ultrasonic transducer.

kimmj@pknu.ac.kr; kimjs@tu.ac.kr

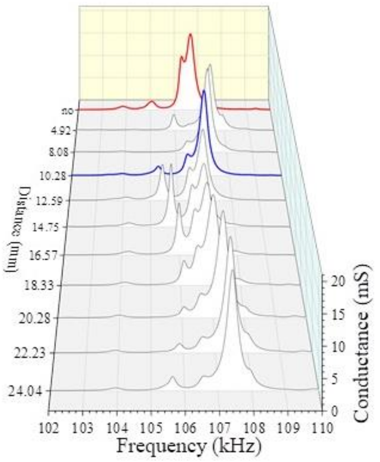
respectively. It can be seen that fundamental resonance and harmonic modes appear around 40 kHz, 75 kHz, and 110 kHz, respectively.



(a) Fundamental mode



(b) Second harmonic mode



(c) Third harmonic mode

Fig. 3 Variation of the conductance depending on the fixing point on the lateral surface of the transducer.

Figure 3 shows the variation of the conductance depending on the fixing point on the lateral surface of the transducer. In the figure, the red line refers to the conductance for each mode of the transducer without the jig, and the gray lines refer to the conductance when the jig holds the transducer at each position of *d*. In the fundamental mode, the thick blue line shows the conductance when the position of the jig is about $d = 22$ mm, and it shows the closest resonant frequency to that of in the case of no jig. In the 2nd harmonic mode, the closest resonant frequency appears when the position of jig is about $d = 7$ mm, and in the 3rd harmonic mode, the closest resonant frequency appears when the position of jig is about $d = 10$ mm.

4. Summary

We suggested a practical method that can locate the positions of nodal point for different resonance modes of the bolt-clamped Langevin - type ultrasonic transducer. A semicircular wedge-shaped jig was manufactured and moved along the lateral surface of the transducer. The vibration characteristics were examined after a constant pressure was applied to the semicircular wedge-shaped jig. By observing the change of the input admittance of the transducer depending on the position of the pressure application, the optimum position for the flange installation could be determined.

Acknowledgment

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korea government (MSIT) (No. 2019R1F1A1062399).

References

1. K. Adachi and M. Saito: Jpn. J. Appl. Phys. **34** (1995) 2735.
2. C. Yun, T. Ishi, K. Nakamura, S. Ueha, and K. Akashi: Jpn. J. Appl. Phys. **40** (2001) 3773.
3. D. Yamaguchi, T. Kanda, and K. Suzumori: Sens. Actuators A Phys. **184** (2012) 134.
4. J. Kim and J. Lee: Sensors, **20** (2020) 1952.