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Estimation of Characteristics Change on Transverse Mode PZT Vibrator under Space Environment

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1. Introduction

Recently, many studies have been reported that communication and mechanical elements using the piezoelectric materials with excellent properties are tried to apply to the aerospace industries[1]. One of things that have to be considered for commercialization is the temperature dependence of the piezoelectric materials. The property change of the piezoelectric vibrator due to the temperature change under the space environment could cause the disorder of devices and the incorrect data. Therefore the piezoelectric elements using in the spaceship and air plane are used at limited space with a thermostat. To extend the utilization area to the external surface of the spaceship or the surface of other planets, the temperature dependence of piezoelectric material should be investigated. The extensive studies have been carried out on characteristics change of piezoelectric materials due to the ambient temperature[2]. Most of them have focused on the change of material constants such as elastic constants and piezoelectric constants. In this study, the electrical and mechanical characteristics of the piezoelectric vibrator are investigated experimentally according to the temperature change. To apply the piezoelectric vibrator practically under space environment, we use PZT-5 series piezoelectric ceramics. From the experimental results, the characteristics of the piezoelectric vibrator in the space environment are estimated by using linear and square regression functions.

2. Experiment conditions

As the transverse mode piezoelectric vibrator, commercialized PZT-5 series piezoelectric ceramic plates were used, and the size and density were listed in Table 1.

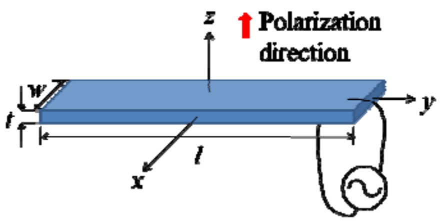

Fig. 1 Coordinate of piezoelectric plate

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Table 1. Size and density of piezoelectric plate

l(mm)	w(mm)	t(mm)	(kg/m^3)
30.0	5.0	1.0	7333

For one-dimensional analysis, the length along the vibration direction was 10 times longer than its thickness. To investigate the characteristics change of piezoelectric vibrator according to temperature in vacuum, a thermal vacuum chamber in Korea Aerospace Research Institute was used.

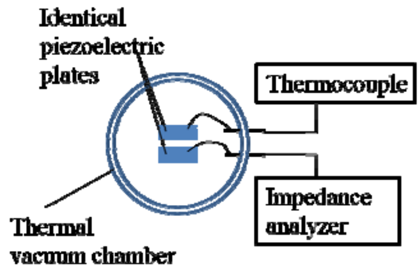

Fig. 2 Experimental setup of resonance method

The thermal vacuum chamber has inner diameter of 1 m and length of 1.5 m, and can control the temperature from 100℃ to -150℃ with high vacuum state of 10^{-4} Pa. It can make the similar state to the space environment. As shown in Fig. 2, identical two piezoelectric ceramic plates were fixed in the thermal vacuum chamber with absorber, and one of them was connected to impedance analyzer to measure the input admittance change. To avoid the mess loading effect, a thermocouple was put in the other piezoelectric plate to measure the temperature change. The input admittance was measured when the temperature of the chamber changes from 90℃ to -100℃ with several steps. At each temperature step, temperature was measured after 1 hr thermal equilibrium time.

3. Regression analysis

From the input admittance results, the resonant and anti-resonant frequencies were obtained as shown in Fig. 3. The change of frequencies according to temperature was analyzed by the regression analysis as following equation.

$$f(\theta)=a\theta^2+b\theta+c \tag{1}$$

Here, the constants *a*, *b*, and *c* are as follows;

	a	*b*	*c*
$f(\theta)=f_r$	2.77×10^{-4}	-1.56×10^{-2}	43.11
$f(\theta)=f_a$	2.91×10^{-4}	-2.37×10^{-2}	46.98

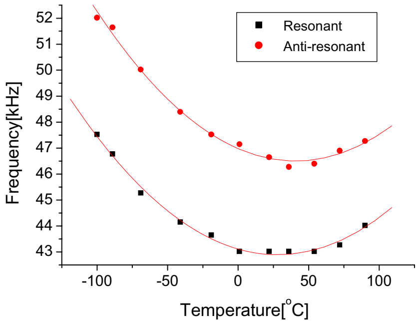

Fig. 3 Resonance characteristics change with temperature of the vacuum chamber

In the results of Fig. 3, the resonant frequency, which started from 47.5 kHz at -100℃, decreased gradually as the temperature increased, and it became 43.0 kHz, the minimum value, at the room temperature of 22 ℃ and then the frequency increased again to 44.0 kHz at 90℃. The anti-resonant frequency showed similar tendency. In this figure, the solid lines are the results of regression analysis calculated by Eq. (1). These results show that the resonant frequency of the transverse mode has variation range of 10.3% from the frequency at room temperature in given temperature range. In the case of the anti-resonant frequency, the variation range was 12.6%. Temperature dependence of electro-mechanical coupling factor shows in Fig. 4. The solid line shows the estimation value calculated by the results of Fig. 3. This result shows good agreement with measured one.

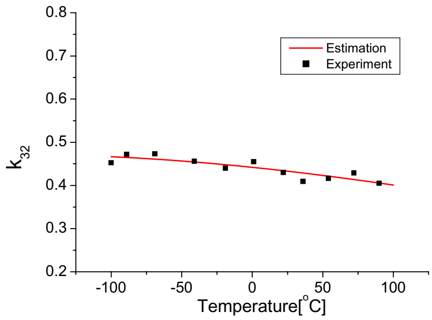

Fig. 4 Temperature dependence of the electro-mechanical coupling factor

The temperature dependence of the dielectric constant and the mechanical loss were also analyzed and compared with measured ones. From these results, the input admittance characteristics were estimated as shown in Fig. 5. In this figure, the estimated results are in good agreement with those obtained by experiment.

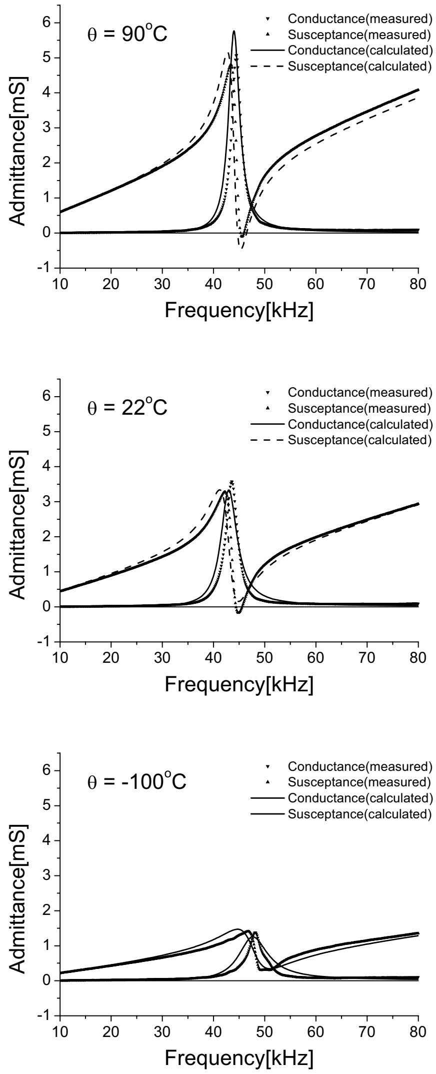

Fig. 5 Temperature dependence of the input admittance characteristics

4. Summary

The temperature dependence of the characteristics in a PZT-5 piezoelectric ceramic vibrator with the transverse mode was investigated in the range of -100℃ to 90℃ using by thermal vacuum chamber to utilize the vibrator to the aerospace industries. The temperature dependence functions of the characteristics were derived to linear and square regression functions. Applying the functions, the input admittance characteristics of the piezoelectric vibrator were calculated, and the results showed good agreement with measured ones.

References

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