Proceedings of Symposium on Ultrasonic Electronics, Vol. 34 (2013) pp. 457-458
20-22 November, 2013

Miniatureized Structure of Ultrasonic Motor Using a Linked Twin Square Plate

双正方板リンク形超音波モータの小型化構造

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1. Introduction

The ultrasonic motor (USM) using a linked twin square plate vibrator was proposed.[1-2] **Figure 1** shows operation principle of the single-phase driving of the USM. Either-or square plate is driven with the breathing mode. Moving direction of the slider can be switched by changing the electric terminals.

The stacked plate structure has the advantage of low-profile. Therefore, the USM is required to develop the miniaturized structure with lower height .

In this report, we analyzed to design the stator vibrator with half dimensions of the first trial structure. Thickness of the ceramic and metal plates had to be modified because spurious modes affected.

2. Dimensions of the stator

Figure 2 shows dimensions and parameters of the stator vibrator. The dimensions of (a) previous and (b) miniature stators are described in Table I. The diameters of fixing-pins and ceramic-holes are same in the both stators, because the fixing rigidity has to be retained.

3. Finite element method analysis results

For suitable design of the USM, we analyzed by FEM using COMSOL Multiphysics 4.3 with following guidelines:

- Voltage step-up ratio $|V_{out}|/|V_{in}|$ must be small.
- Driving-side link must be vibrated along the diagonal direction; thus, it is desirable for u_{xc}/u_{yc} , defined as shown in **Fig.3(a)**, to be almost 1.
- The in-plane displacement of the friction-edge u_{xt} and u_{yt} as shown in **Fig.3(b)** have to be large.
- Conversely, the out-of-plane displacement ratio u_{zt}/u_{yt} must be small.

Analyzed results of 10×10 mm^2 square plates models are shown in **Figs.4** and **5** when the metal thickness t_m = 1.0 and 0.5 mm, respectively. The out-of-plane displacement ratio u_{zt}/u_{yt} deteriorate strongly in some thickness conditions. It is thought that the breathing mode is affected by spurious modes as shown in **Fig.6**. The both models of t_m = 1.0 and 0.5 mm showed similar characteristics. Therefore, we selected the thinner model. When t_m = 0.5 mm, Eigen frequency analyzed result is shown in **Fig.7**. The ceramic thicknesses with large u_{zt}/u_{yt} accord with the ones that the frequency of breathing mode crossed spurious modes S1 or S2.

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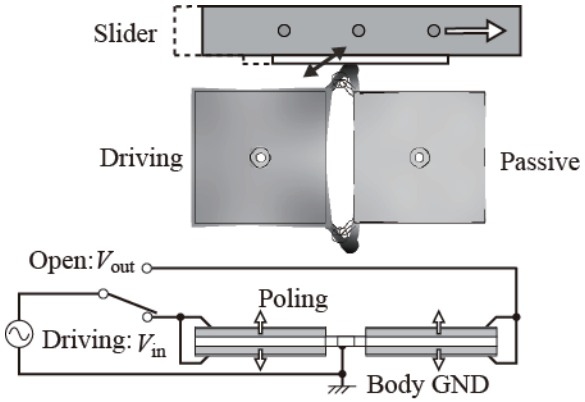

Fig. 1 Fundamental operation of single-phase USM using breathing vibration mode.

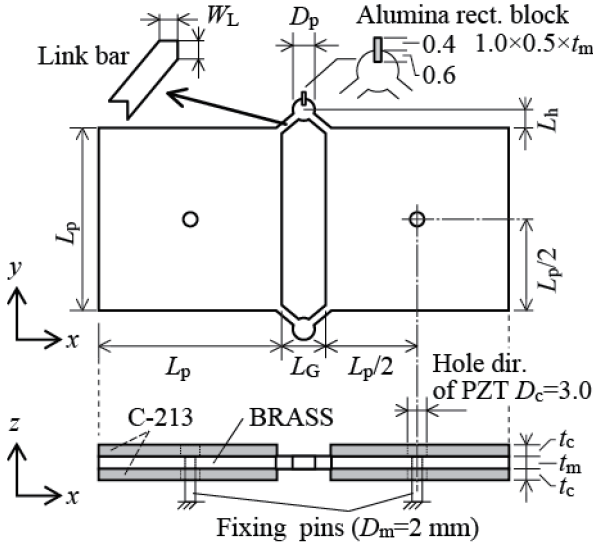

Fig. 2 Analyzed model of stator vibrator consists of a linked twin square metal plate and four piezoceramic square plates.

Table I Dimensions of the stator. (unit: mm)

	L_p	L_G	L_h	W_L	D_p	t_c	t_m
(a)	20	4.5	2.0	1.5	2.4	2.0	2.0
(b)	10	2.25	1.0	0.75	1.2	–	–

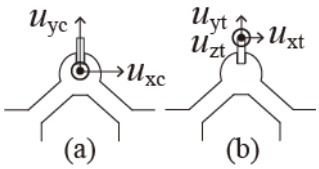

Fig.3 Definitions of the displacement at (a) center of a V-link and (b) the friction-edge.

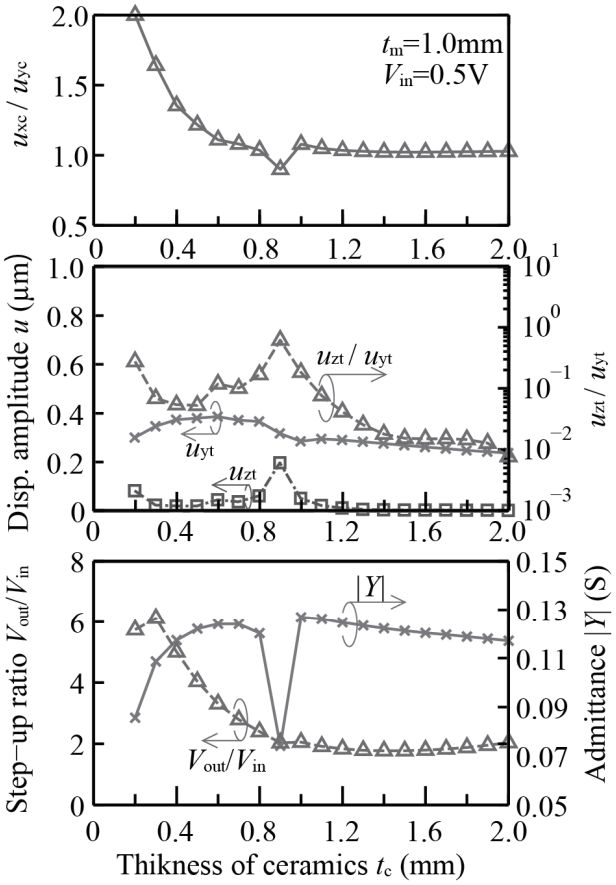

Fig. 4 Analyzed results of 10×10 mm^2 square plates models of t_m = 1.0 mm

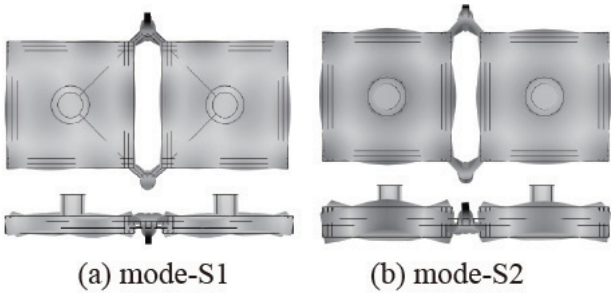

Fig. 6 Spurious modes.

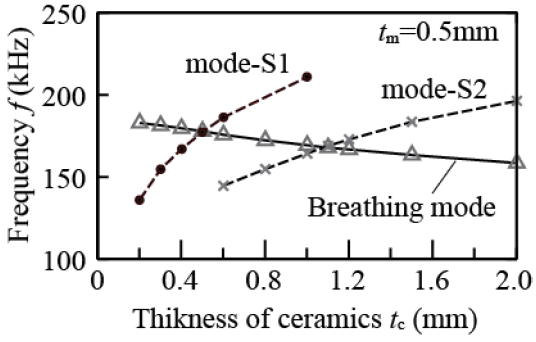

Fig. 7 Resonant frequency of the breathing mode and affected spurious modes depended on the ceramic thickness.

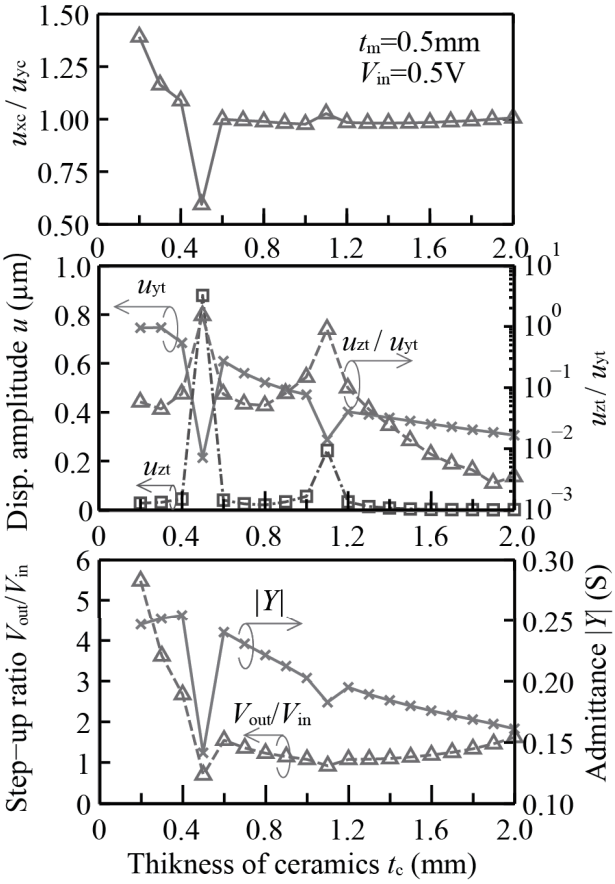

Fig. 5 Analyzed results of 10×10 mm^2 square plates models of t_m = 0.5 mm

Table II Analyzed result. (unit of len.:mm, V_{in}=0.5V)

	L_p	t_m	t_c	$\lvert V_{out}\rvert/\lvert V_{in}\rvert$	u_{yt} (μm)	u_{zt}/u_{yt}
(a)	20	2.0	2.0	0.56	0.44	0.06
(b1)	10	0.5	0.7	1.42	0.56	0.04
(b2)	10	0.5	1.5	1.18	0.36	0.01

From these circumstances, we chose two types of practical dimensions for the low-profile stator as shown in Table II (b1) and (b2). Type-(b2) has enough small u_{zt}/u_{yt}, though the total height is as thick as 3.5 mm. Another Type-(b1) has large u_{zt}/u_{yt} of 4% and the voltage step-up ratio of 1.42, nonetheless the total height is only 1.9 mm.

4. Conclusions

To obtain the suitable miniaturized stator structure for 10×10 mm^2 square plates, FEM analyzed results were shown. Although we did not reach the discovery of perfect conditions, two practical dimensions types were chosen. In a future work, the both types will be experimentally evaluated.

References

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2. K. Yokoyama, H. Tamura, K. Masuda, and T. Takano: Jpn. J. Appl. Phys. Vol.52, No.7, 07HE03 (2013)