Proceedings of Symposium on Ultrasonic Electronics, Vol. 32 (2011) pp. 109-110
8-10 November, 2011

Motion control of an object in near-field acoustic levitation
近距離場音波浮揚を用いた浮揚物体の運動制御

Akihiro Okudera[1‡], Manabu Aoyagi [1], Hideki Tamura[2], Takehiro Takano[2]
([1]Muraon Institute of Technology, [2]Tohoku Institute of Technology)
奥寺 暁大 [1‡], 青柳 学 [1], 田村 英樹 [2], 高野 剛浩 [2] ([1]室蘭工大・院, [2]東北工大・工)

1. Introduction

A flat object can be levitated with small gap from an ultrasonic vibration plate. This phenomenon is called near-field acoustic levitation (NFAL). It has been reported that NFAL can be applied into non-contact transportation and non-contact ultrasonic motor.[1, 2] **Figure 1** shows forces around levitated object. An acoustic streaming occurs between a vibration plate and a levitated object, as shown in Fig. 1. The object is levitated by acoustic radiation pressure above the vibration plate. Acoustic viscous force is generated by the acoustic streaming in the horizontal direction. This force acts as a holding force for the levitated object. We focus on a holding force generated horizontally at the edge of a vibration plate and vibration nodes. The holding force is in proportion to vibration amplitude of the vibration plate. [3, 4]

The purpose of this study is to control positioning and motion of a flat object levitating above stator vibrators by adjusting the holding force. This technology can be applied into the development of a non-contact ultrasonic linear stepping motor.

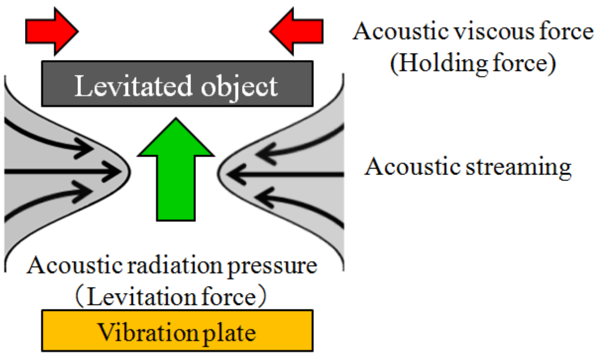

Fig. 1 Forces around levitated object.

2. Operating principle

Figure 2 shows an example of the operating principle for the transfer of a levitated object. Vibration plates (stator vibrator) which can be driven individually are arranged in a line. It is possible to control the motion of the levitated object by varying the vibration amplitude of each stator vibrators. An operating principle is described below.

(1) A flat object is levitated above the stator vibrators, as shown in Fig. 2(a).

(2) When increasing the vibration amplitude of the next stator vibrator, the holding force is generated as shown Fig. 2(b). Therefore, the object is shifted to the next stator.

(3) The object is held at the position where the holding forces balance, as shown in Fig. 2(c).

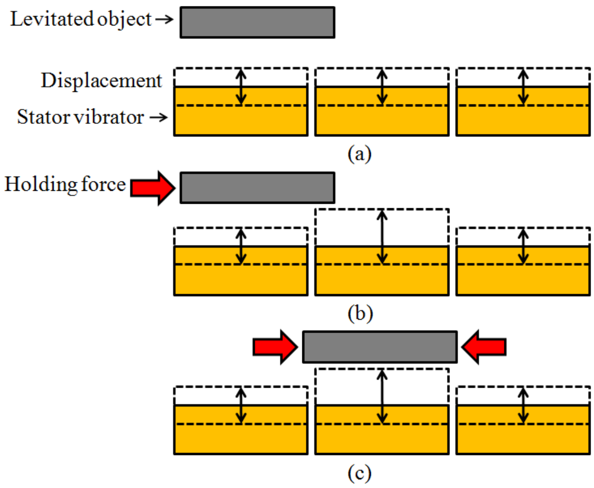

Fig. 2 An operating principle.

3. Experimental method

Figure 3 shows the configuration of the experimental setup. Three stator vibrators (A, B, C) which have the fundamental bending mode are aligned on the base. **Figure 4** shows the dimension of the stator vibrator and the levitated object. The stator vibrator is made of stainless steel and piezoceramics. An acrylic plate which weights 120 mg and is 2mm longer than the stator vibrator was used as a levitated object. **Figure 5** shows Chladni's sand figure which clears vibration modes of the three stator vibrators in the resonance frequency. There are two nodal lines at each support part of the stator vibrator.

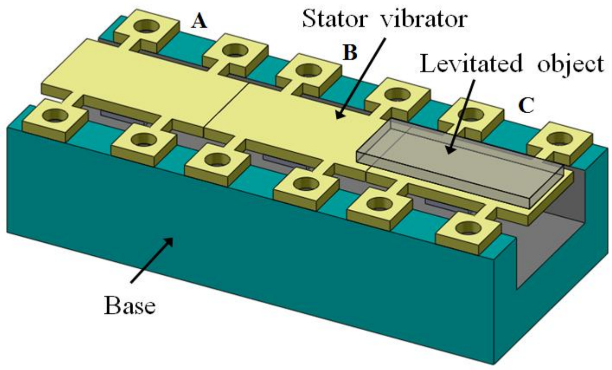

Fig. 3 Experimental setup.

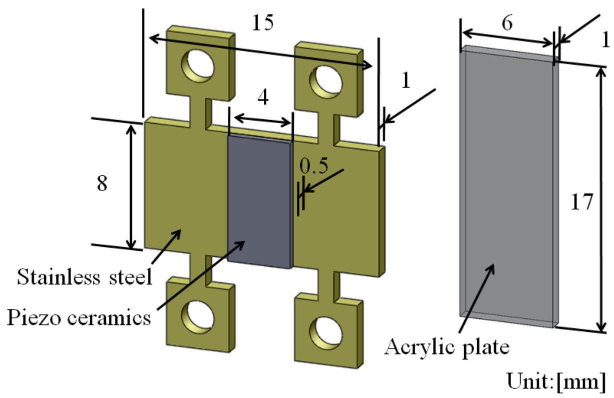

Fig. 4 Dimension of the stator vibrator and levitated object.

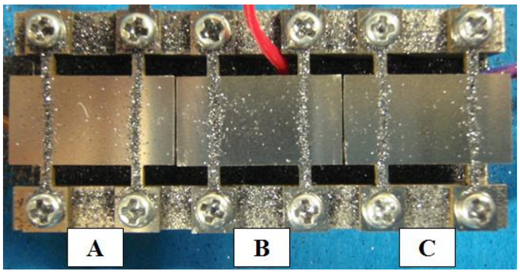

Fig. 5 Chladni's sand figure of three stator vibrators.

4. Experimental results

Figure 6 shows experiment results of vibration amplitude when the levitated object can be moved toward the next stator vibrator. The measurement point of vibration amplitude is the center of stator, as shown in Fig. 6. From experimental results, it was found that the conditions required to move the object to the next stator vibrator were to make over 1.5 times differences between the displacements of the two adjacent stator vibrators. The object was held at the center or vibration nodes of stator vibrators, as shown in **Figs. 7(a) or 7(b)**. In addition, when there was no difference in vibration amplitude of the adjacent stator vibrators, the levitated object was held between two stator vibrators, as shown in **Figure 7(c)**. Therefore, there were three patterns that holding forces generated by adjacent stators balanced. When the levitated object shifted to the next stator vibrator with larger vibration amplitude, the levitated object oscillated above the stator vibrator. It took a few seconds to stop the oscillation. The oscillation has to be reduced for an accurate positioning of a levitated object.

5. Summary

The position of levitated object can be roughly controlled by the holding force. An object moved to the next stator vibrator under the condition that the displacement of the next stator was over 1.5 times larger than that of the stator levitating the object. The holding position of the levitated object has three patterns. Hereafter, it is necessary to analyze the mechanism that the levitated object moves toward the next stator vibrator which has large displacement. Moreover, we have to consider ways to increase dumping an oscillation of the levitated object for motion control.

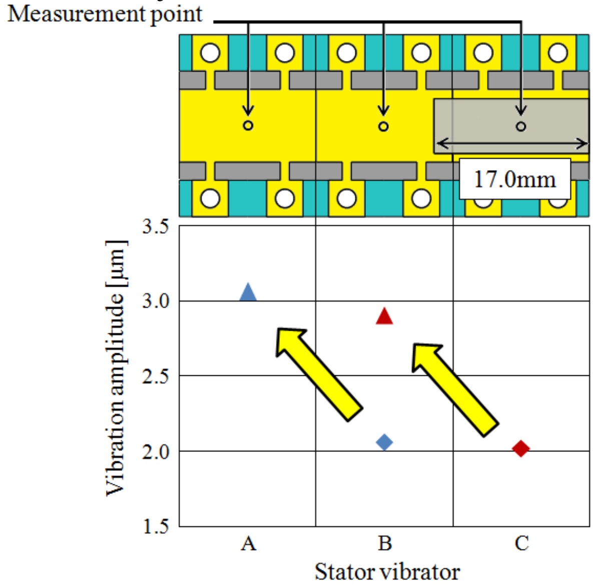

Fig. 6 Vibration amplitude at the center of stator in the case of a levitated object of 17.0 mm long.

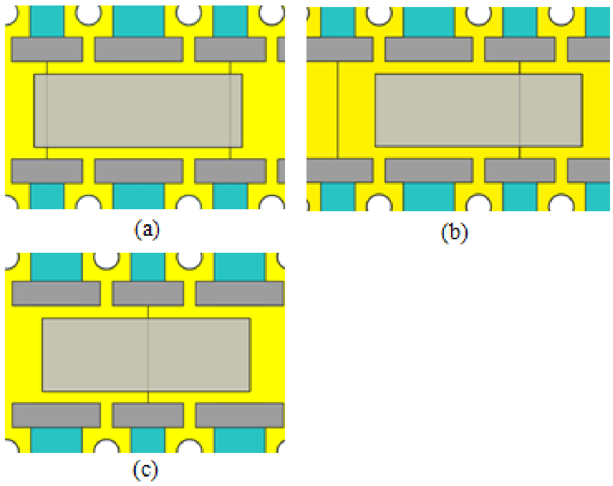

Fig. 7 The holding positions of levitated object.

Reference

1. Y. Hashimoto, Y. Koike and S. Ueha: Jpn. J. Appl. Phys. 36 (1997) 3140.
2. J. Saito, J. R. Friend, K. Nakamura and S. Ueha: Jpn. J. Appl. Phys. 44 (2005) 4666.
3. T. Ooyagi, Y. Morokuma, Y. Koike, S. Ueha and M. Takasan: Proc. of Spring Meet. of ASJ. 2-9-10 (2003) 1133. [in Japanese]
4. H. Isobe, A. Kyusojin, M. Okada, M. Otsuka and S. Miyajima: Proc. of Autumn Meet of JSPE. J64 (2007) 767. [in Japanese]
5. R. Yano, M. Aoyagi, H. Tamura and T. Takano: Jpn. J. Appl. Phys. 50 (2011) 07HE29.