Positioning of an object in near-field acoustic levitation and its application

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1. Introduction

Near-Field Acoustic Levitation（NFAL） ・・・ A flat object is levitated above a radiation surface about several μm.

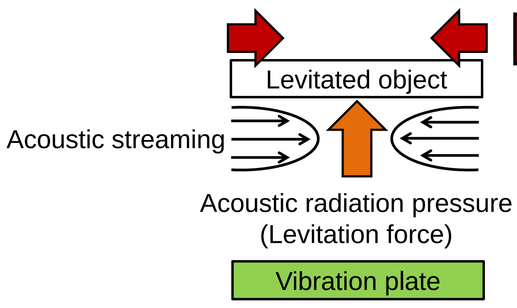
Applications: Non-contact transportation; Non-contact ultrasonic motor

Problem → It is difficult to position of a levitated object.

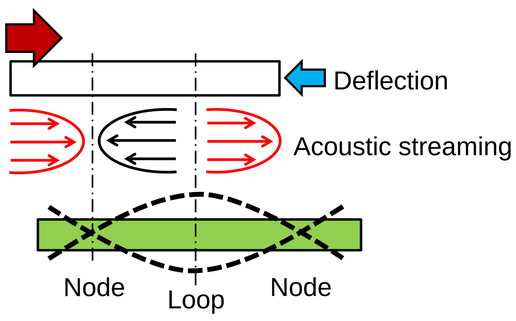
Objective

Positioning of a flat object levitating above stator vibrator.

Apply → **Holding force**



The holding force occurs at the edge of vibration plate.



The holding force occurs from loop toward node.

Apply → **Non-Contact-Stepping Ultrasonic Motor (NCS-USM)**

This motor has a possibility of high torque compared with ordinary non-contact USM using traveling wave.

2. Non-contact-stepping ultrasonic motor（NCS-USM）

The holding force is in proportion to vibration amplitude of the vibration plate.

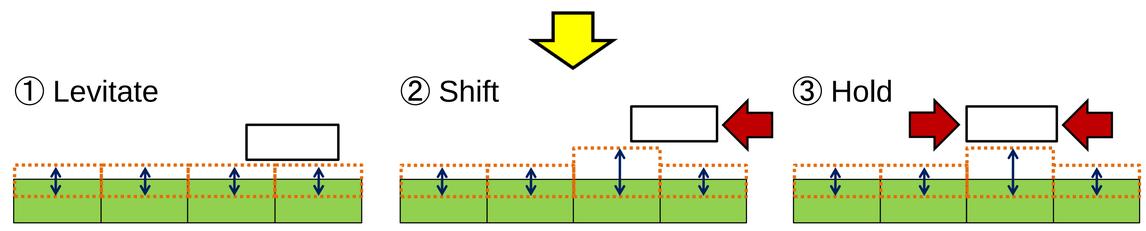


Fig. An operating principle of positioning and NCS-USM

A linear and rotary type NCS-USM can be proposed from this technology.

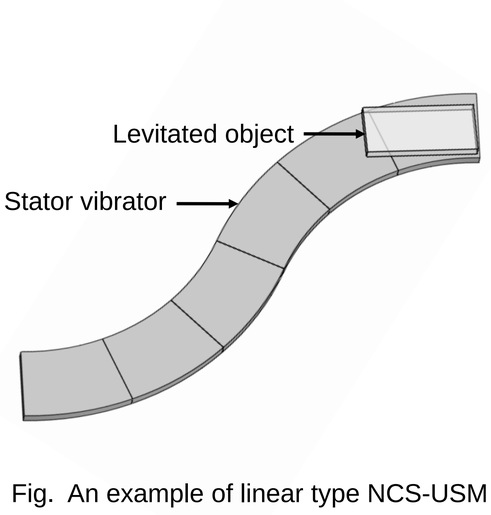


Fig. An example of linear type NCS-USM

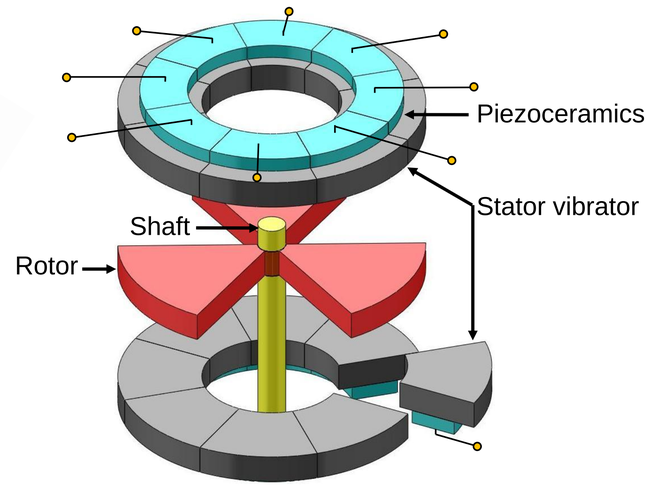
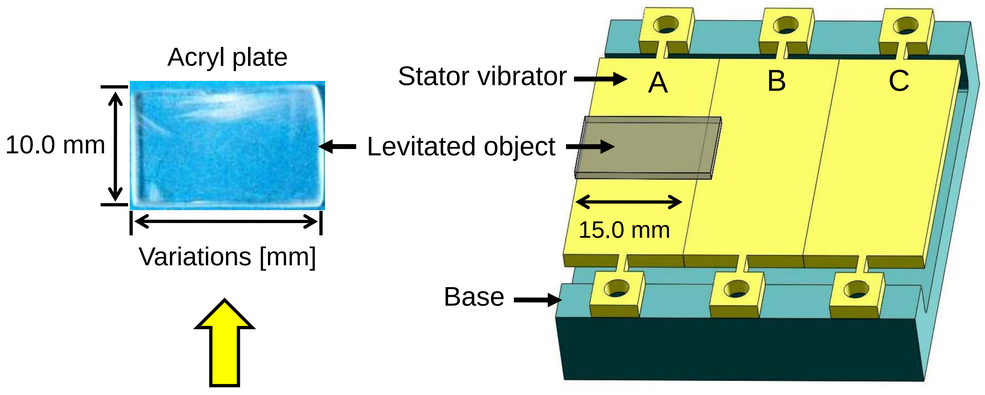


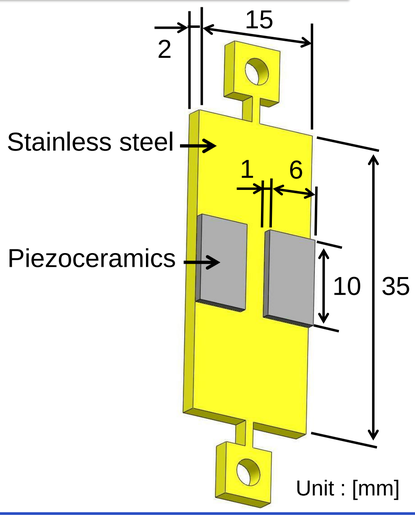
Fig. An example of rotary type NCS-USM

3. Experimental setup

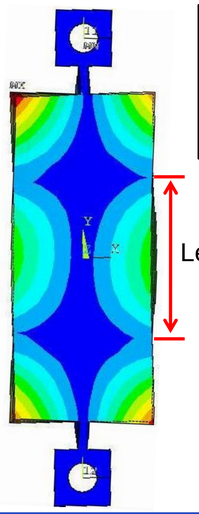


We changed the long of levitated object against the wide of stator vibrator, 15.0 mm.

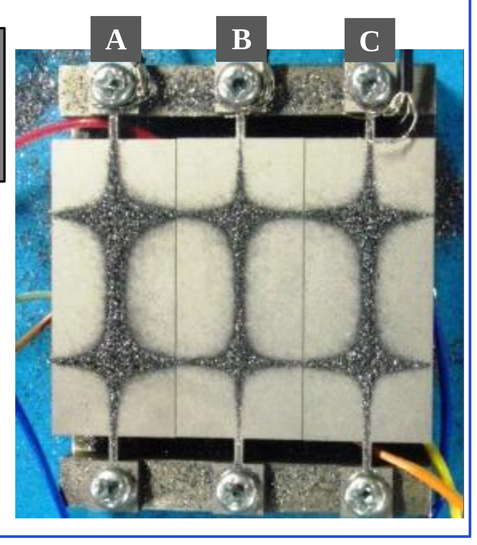
4. Stator vibrator



FEM analysis →



Resonance frequency
- Stator A : 22.52 KHz
- Stator B : 22.61 KHz
- Stator C : 22.64 KHz



5. Experimental results

The levitated object can be moved to the next stator vibrator and hold there.

- **The next stator vibrator has a high vibration amplitude.**
- **The long of levitated object is 16.0 mm to 18.0 mm.**

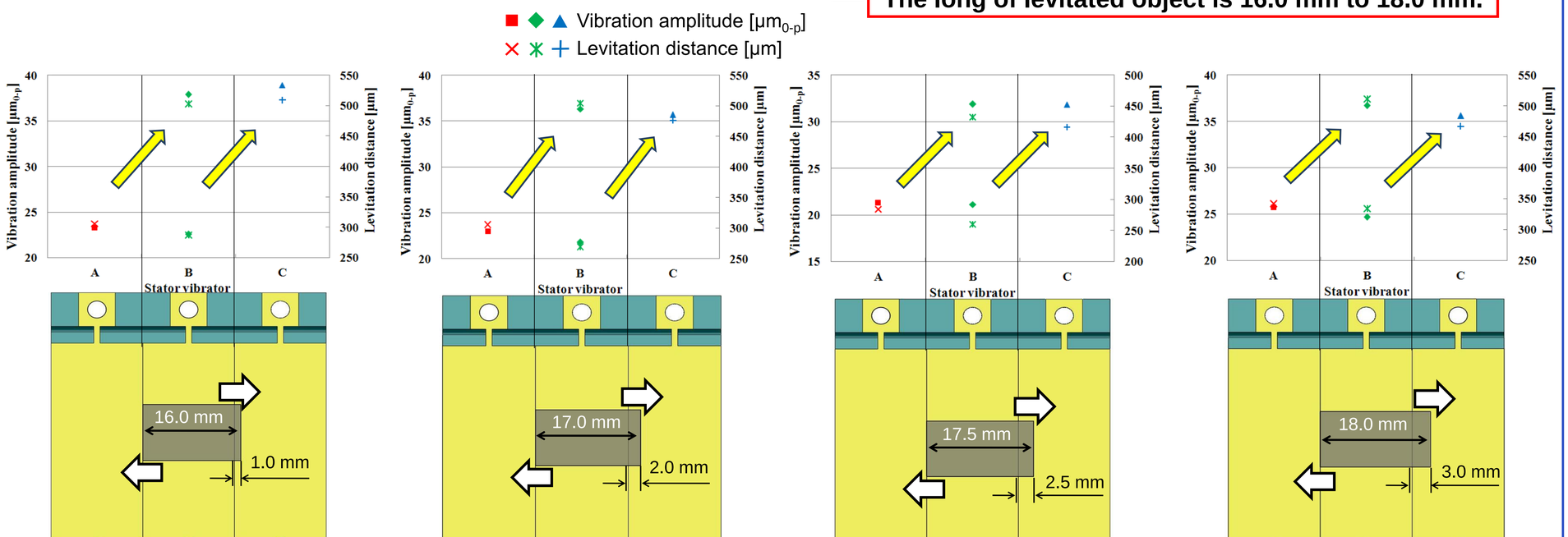
Table. Sizes of levitated object and differences of vibration amplitude as the levitated object enable to shift the adjacent stator vibrator.

Long [mm]	Wide [mm]	Thick [mm]	Weight [mg]	D_A / D_B
16.0	10.0	1.0	184	1.67
17.0			193	1.63
17.5			198	1.50
18.0			209	1.47

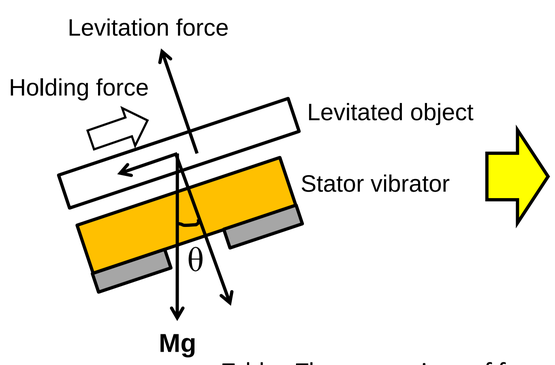
D_A [$\mu m_{0\text{-}p}$] : The vibration amplitude of stator vibrator when the levitated object can be shifted to the next stator.

D_B [$\mu m_{0\text{-}p}$] : The vibration amplitude of stator vibrator when the levitated object can be left the stator.

- To increase the vibration amplitude of next stator vibrator more than that of stator levitating the object.
- To make over about 1.57 times differences between vibration amplitude of adjacent stator vibrators.
- The long of levitated object is 1.07 to 1.20 times lager than the wide of stator vibrator.



6. Estimation of the holding force



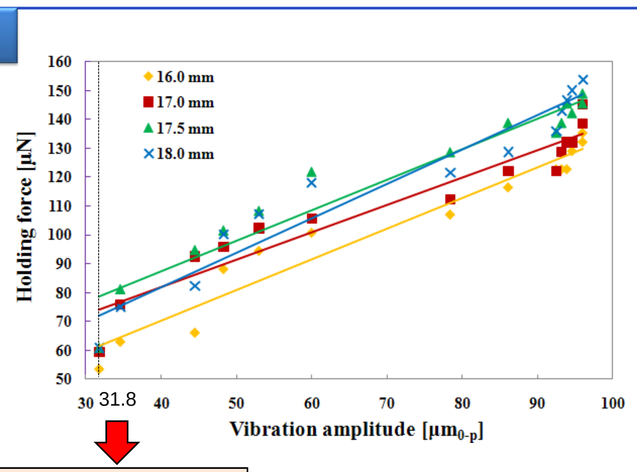


Table. The comparison of forces.

	Measurement result				Traveling wave type non-contact USM※	
	The long of levitated object [mm]				Radius of rotor [mm]	Starting torque [μNm]
	16.0	17.0	17.5	18.0	13.0	0.87
Dimensions [mm^2]	160.0	170.0	175.0	180.0	530.9	
Thrust [μN]	53.5	59.5	61.0	60.8	66.9	
Shearing stress [mN/mm^2]	334.4	350.0	348.6	337.8	126.0	

※ Y. Yamayoshi: Doctoral dissertation (2010) p. 139

7. Summary

The method of positioning of a levitated object many aligned stator vibrators

1. The vibration amplitude of adjacent stator vibrator is over about 1.57 times larger than that of stator levitating the object.
2. The long of levitated object is 1.07 to 1.20 times lager than the wide of stator vibrator.

Hereafter

- The control of an oscillation which the levitated object reached the adjacent stator vibrator with large displacement.
- Making and testing another shape of stator vibrator to apply into a linear and a rotary type of NCS-USM.

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