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Two-dimensional noncontact transportation using near-field acoustic levitation

近距離場音波浮揚を用いた 2 次元非接触搬送

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1. Introduction

The near-field acoustic levitation has been studied for the application to noncontact transportation of a flat object such as liquid crystalline glass substrate[1].

The authors have found that a levitated object which is slightly larger than a vibration board aligned in transportation direction is transported step by step toward the next vibration board which has larger vibration amplitude[2].

This paper reports some experimental results of two-dimensional(2D) noncontact transportation using stators arranged horizontally in two dimensions.

2. Operating principle

2.1 Near-field acoustic levitation

Figure 1 shows forces around a levitated object. An acoustic field is formed between a vibration board and the levitated object. An acoustic radiation pressure occurs on the levitated object according to the difference of energy density between the top and bottom of the levitated object. The acoustic radiation pressure results in a levitation force[3]. An acoustic streaming is formed between the vibration board and the levitated object, and it yields an acoustic viscous pressure which acts as a holding force. Hence, it is considerable that the levitated object is held on the vibration board[4].

2.2 Transportation principle

Figure 2 shows the operating principle of a noncontact stepping transportation. A levitated object is transported by making a difference between vibration amplitudes of adjacent vibration boards. In this situation, the vibration boards act as stators. The procedure of noncontact-stepping transportation is as follows[2]:

1) Hold the levitated object on a stator.
2) Increase the vibration amplitude of an adjacent stator. Then the levitated object on the stator is shifted and is held on the adjacent stator.
3) Decrease the vibration amplitude to the degree to which minimum levitation and holding of the object are maintained.

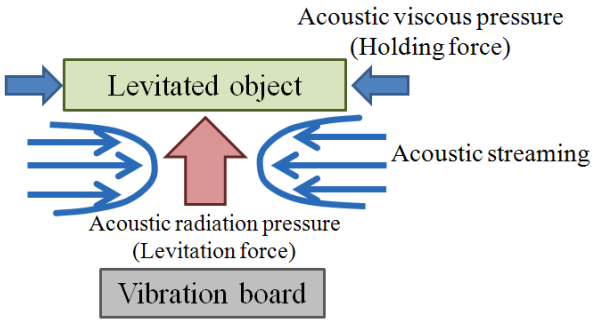

Fig.1 Forces around levitated object.

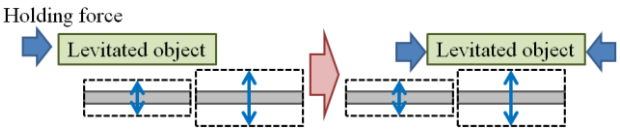

Fig.2 Operating principle of noncontact stepping transportation.

3. Structure of apparatus

3.1 Piezoceramic annular vibrator

A fundamental radial vibration mode and a nonaxisymetric ((1,1)) vibration mode of a piezoceramic annular vibrator are degenerated under the condition that the ratio of an inner and outer diameters is approximately 0.27[5]. In this case, vibration nodes are formed near outer circumference of the annular vibrator[6]. The annular vibrator used in experiments had the outer and inner diameters of 20mm and 5mm, respectively, the thickness of 3mm, and the inner-outer diameter ratio of 0.25. The resonance frequency was 89 kHz. This annular vibrator can be vertically supported at the node near the outer circumference of the vibrator without vibration suppression. Hence this type of a vibrator can be easily arranged into an array-form on a single substrate without the interference of the vibration among closely arranged vibrators.

3.2 Stator

Figure 3 shows the prototype of a stator. The stator is constituted with the vibration board in the upper part, the piezoceramic annular vibrator in the central one and the support part in the lower one. Those parts are piled up and glued together.

Therefore it is possible to horizontally arrange the stators in two dimensions on the base. The resonance frequency of the stator was 91 kHz. A cross stripes flexural vibration mode was caused at a square vibration board (A2017, 19×19×0.5mm^3), as shown in Fig. 4 which shows Chladni's sand figure of the stator. Vibration amplitudes at Point2 and Point3, which were loops of the vibration mode, were more fifth time larger than that at Point1 which was the driving point by the annular vibrator. The vibration amplitude of the base was about one-hundredth of that of the vibration board. Thus, the interference of vibration between adjacent stators was negligibly small.

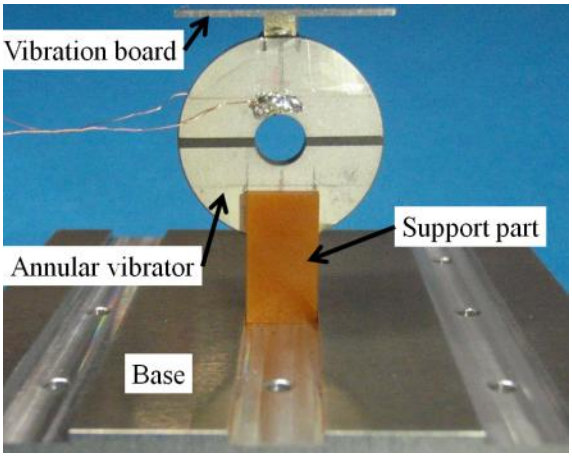

Fig.3 Structure of stator.

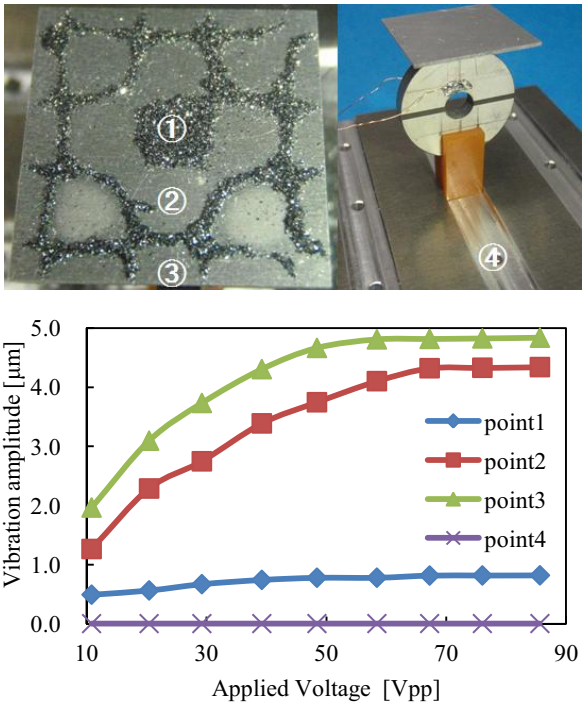

Fig.4 Vibration amplitude at some points,①point1, ②point2,③point3,④point4 on vibration board and base shown in upper pictures.

4. Experiment of 2D noncontact transportation

Figure 5 shows stators arranged in two lines and two rows. It was attempted to transport a flat object in 2D-direction by noncontact. A polyester sheet (21×21mm^2, 80mg) was used for a levitated object. The object on the stator at the upper right corner in this figure was able to be reversely transported in longitudinal and transverse directions.

To transport the object which was levitated and held on the stator with the vibration amplitude of 2.4μm toward the adjacent stator, the adjacent stator needed the vibration amplitude around 1.3 times larger than that of the holding stator. The rotation of the object was observed quite often while the object transferred to the adjacent stator. What both of the vibration board and the object were square is considered as one of causes of disturbing the holding and transportation of the object.

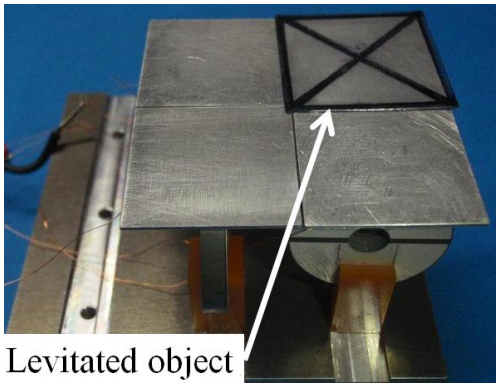

Fig.5 Apparatus of 2D noncontact transportation.

5. Conclusions

The 2D noncontact transportation of a flat object by the stators arranged in an array-form on a base was successfully realized. It is necessary to clarify the mechanism of this transportation in detail to transport a flat object quickly and stably. Moreover, the cause that a levitated object rotates while transporting must be considered and solved.

References

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