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Non-contact Handling Equipment Utilising Ultrasonic Vibration

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1. Introduction

Recently, non-contact chucks have been strongly required to handle various precision parts such as IC chips, optical lenses and silicon wafers to avoid adhering contaminations on the surface of these parts. Therefore, we have proposed a non-contact chuck utilizing ultrasonic vibration (called 'the squeeze chuck' in this paper)[1]. It is known that when a flat surface vibrates vertically at ultrasonic frequencies, both vertical and horizontal forces act on an object placed on the vibrating surface, enabling the vibrating surface to support an object vertically and horizontally without any contact[2]. The proposed non-contact chuck utilising this phenomena to handle various precision parts. In this study, we have experimentally investigated holding characteristics of the squeeze chuck.

2. Squeeze effect and experiment

Figure 1 shows the schematic principle of the squeeze effect. When one of two opposing planes vibrates in ultrasonic frequency, an air film which has larger time-averaged pressure than atmospheric pressure is generated between two opposing planes. As a result, one of them is held vertically without any contact. When the shapes of two planes are the same, it is experimentally known that when a flat surface vibrates vertically at ultrasonic frequencies, both vertical and horizontal forces act on an object placed on the vibrating surface. In this study, we propose a small squeeze chuck by using these characteristics to hold an RFID chip without any contact.

2.1. Measurement of resonance frequency and vibration amplitude at the tip of the chuck

Figure 2 shows the schematic view of the experimental apparatus. In the present study, because the pressure rise due to the squeeze effect is larger as the vibration amplitude becomes larger, the amplitude of the Langevin oscillator was amplified by using horn and resonance of the horn. The oscillating voltage (it has offset voltage v_{off}, oscillating voltage v_{amp} and frequency f) of the Langevin oscillator was generated by function generator and amplified to desired volume by actuator driver. Then, the oscillating voltage was converted into physical vibration by Langevin transducer. This vibration was amplified by the conical portion of the horn. In the experiments, effects of the oscillating voltage (v_{off}, v_{amp} and f) on the vibration amplitude of the tip of the chuck were measured by using capacitance type displacement gauge.

2.2. Measurement of floating height of the object

The floating height of an object supported by the proposed non-contact chuck was measured by using the experimental apparatus. In the experiments, the RFID (Radio Frequency Identifier) chip was used as the floating object. The outer shape of the RFID chip was a square with a 3.2mm wide, and the tip of the chuck has the same shape. In this experiments, we have prepared 2 types of chucks. The one has a flat surface on the tip of the chuck and the other has a suction hole at the center of the tip. It was thought that the suction pressure would enhance the holding force of the chuck.

2.3. Measurement of horizontal holding force

Figure 3 shows schematic views of the experimental set up to measure the horizontal holding force action on the floating object. The squeeze chuck was mounted to the jig and the cantilever beam load cell was mounted to the X stage. In the experiments, the horizontal displacement was given to the RFID chip by moving the cantilever beam load cell on the X stage and the horizontal holding force was measured with the load cell. The horizontal displacement of the RFID chip Δx was measured with a microscope. And holding stiffness k is evaluated by following equation.

$$k = \frac{F}{\Delta x} \tag{1}$$

3. Experimental results

3.1. Resonance frequency of the chuck

Figure 6 shows relationship between oscillating frequency, f and vibration amplitude of the tip of the chuck a when V_{off} and V_{amp} were changed. As shown in this figure, a increases with V_{amp} increases, and it becomes resonance frequency at f = 54.6 kHz. Figure 5 shows the relationship between a and V_{off}. As shown in this figure, the value of a increases quadratically with respect to V_{amp}, however the value does not change when V_{off} is changed.

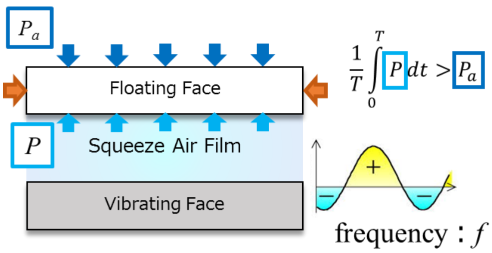

Fig.1 schematic principle of the squeeze effect

3.2. Vertical Floating height of a holding object

Figure 8 shows the relationship between V_{amp} and average floating height h of the RDIF chip. The average floating height h increases linearly with V_{amp} increases. Figure 9 shows the relationship between the suction pressure p_v and the average floating height h. As shown in this figure, the average floating height, h decreases with p_v increases, and gradually approaches a constant value.

3.3. Horizontal floating force

Figure 10 shows the relationship between horizontal displacement Δx and horizontal holding force F when suction pressure p_v was changed. As shown in the figure, the maximum horizontal holding force F_{max} increases with suction pressure p_v increases, and the maximum value is obtained when p_v = -3kPa. As shown in this result, the holding force in the horizontal direction could be increased by performing suction, however it can be seen that there is an optimum value for the suction pressure p_v.

4. Conclusions

In this study, we have investigated characteristics of the squeeze chuck and the following conclusions were drawn.

[1] The vibration amplitude of the tip of the chuck increases quadratically with respect to oscillating voltage V_{amp}, however the value does not change when offset voltage V_{off} is changed.

[2] Floating height of the holding object increases with increase of the vibration amplitude of the tip of the chuck.

[3] The holding force of the proposed non-contact chuck in the horizontal direction could be increased by performing suction, however there is an optimum value for the suction pressure p_v.

5. Reference

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[2] Yoshimoto,S.,Sekine,H.,Miyatake,M, "A non-contact chuck using ultrasonic vibration: analysis of the primary cause of the holding force acting on a floating object", Proceedings of the Institution of Mech. Eng., Part C: Journal of Mech.Eng.Sci. ,Vol 224, Issue 2, 2010

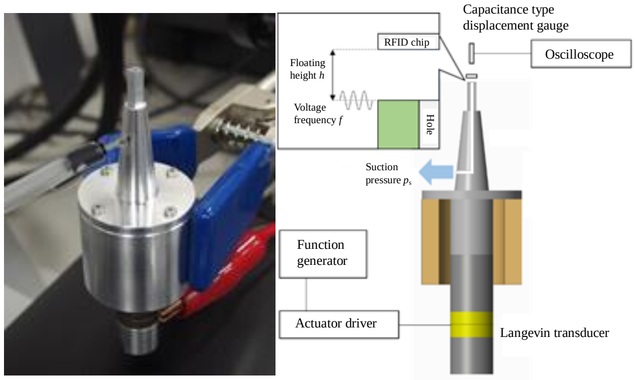

Fig.2 schematic view of the experiment apparatus

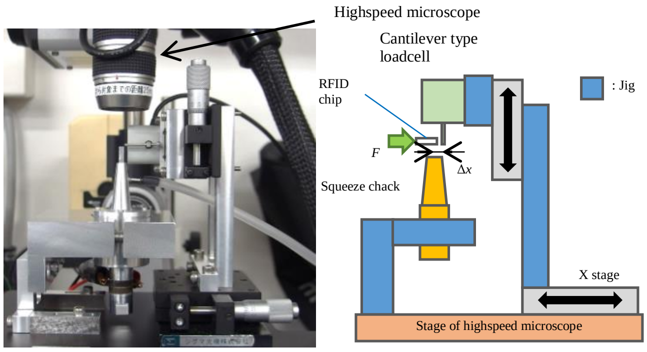

Fig.3 schematic views of the experimental set up for measurement of horizontal holding force

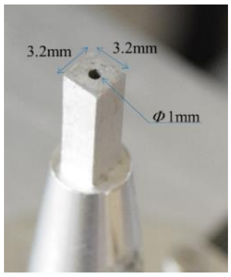

Fig.4 Tip of non-contact chuck with suction hole

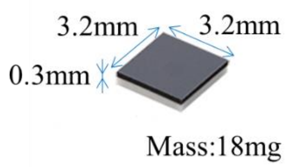

Fig.5 RFID chip used in this study

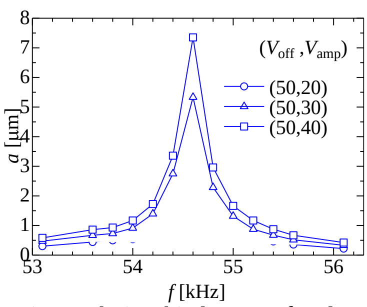

Fig.6 Relationship between f and a

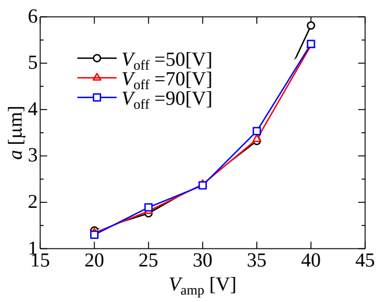

Fig.7 Relationship between V_{amp} and a

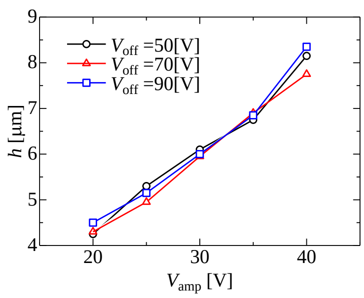

Fig.8 Relationship between V_{amp} and h

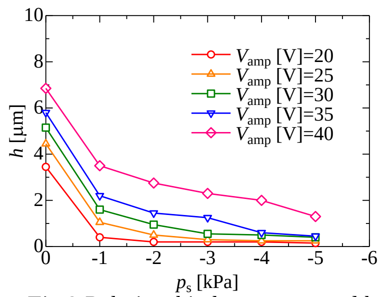

Fig.9 Relationship between p_v and h

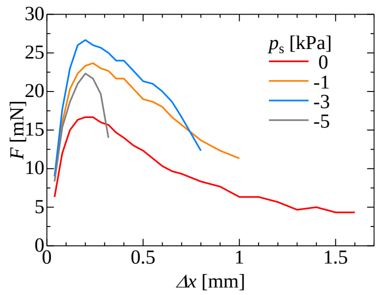

Fig.10 Relationship between Δx and F