A self-running standing wave type ultrasonically levitated linear guide
自走式定在波型超音波浮上リニアガイド

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1. Introduction

A self-running standing wave type ultrasonically levitated linear guide is discussed. The authors have been investigating the ultrasonically levitated sliding table [1]. In our previous work, the stator for the self-running ultrasonically levitated sliding stage having the rectangular aluminum frame and four PZT plates was proposed, and the noncontact movement of the stator was achieved. This traveling wave type stator could be moved by exciting the traveling wave along the stator’s beam because of the reaction forces of the acoustic radiation force, the inertial resistance and the viscosity resistance on the stator’s beam surface. However, the control of the stator’s thrust was particularly difficult since the condition, in which the traveling wave can be generated, strongly depends on the individual specificity of PZTs and the contact condition between the PZT and the beam. In this report, we proposed a novel self-running standing wave type levitated linear slider, and the levitation and thrust characteristics were investigated.

2. Standing wave type levitated slider

The standing wave type levitated slider consists of an aluminum plate (10.0×30.0×1.0 mm) and a PZT plate (10.0×10.0×1.0 mm, C-213 Fuji Ceramics) with a simple structure as shown in Fig.1. The polarization of the PZT plate was in the thickness direction, and the two components were attached using epoxy. By applying the input voltage to the PZT, the flexural vibration can be generated along the aluminum beam (Fig.1 (b)). The slider on the flat substrate can be levitated in z-direction by the acoustic radiation force radiated from own beam when the slider gravity and the radiation force are balanced. When the vibration distribution along the beam is asymmetric in x-direction, the acoustic field in the air gap between the flat substrate and the levitated slider will be also asymmetric, and the acoustic streaming will be induced along the air gap in the x-direction.

![Fig. 1 Noncontact levitated slider: (a) configuration of the slider, and (b) flexural vibration mode at 35 kHz predicted by FEA.](image)

The slider can be moved in the same direction to the acoustic streaming due to the acoustic viscosity force [2]. The size of the slider was determined using the FEM software ANSYS 11.0 (ANSYS Inc.) to obtain the large asymmetric vibration distribution in the x-direction for the high thrust and levitation performance.

3. Levitation and thrust characteristics

The slider driven with the input voltage of 80 V\text{pp} could be levitated at the driving frequencies of 35, 68 and 69 kHz, and could be moved at 68 and 69 kHz. The vibration distributions of the slider at 68 and 69 kHz measured by an LDV are shown in Fig.2. The position of the square PZT is 0 to 10 mm in x and y-direction. The vibration amplitude of the beam on the right side, 10 to 30 mm in x-direction, is larger than one of the left side, 0 to 10 mm, attached with the PZT. The vibration modes of the slider’s beam at 68 and 69 kHz were the lattice-shape vibration mode and the complex mixture mode of the flexural and the lattice mode. The slider could be moved to the negative and positive direction in x-direction with the thrust force of 2.1 and 1.1 mN at 68 and 69 kHz, respectively. The slider’s moving direction, therefore, can be switched by controlling the driving frequency even though the frequency difference is only 1 kHz. The relationship between the vibration distribution of the slider and...
The moving direction is under consideration. The levitation characteristics were investigated by using a digital microscope. Fig. 3 shows the relationship between the levitation distance of the slider and the vibration displacement amplitude at 68 and 69 kHz. The measurement points of the slider’s levitation distance were the ends of the slider in the x-direction, x=0 and 30 mm. The levitation distance on x=0 mm at 69 kHz could not be measured because of the small levitation distance compared with the microscope resolution. The larger levitation distances \( h \) could be obtained with the larger displacement amplitude \( u \) at both frequencies. The levitation distance at x=30 is approximately ten times larger than one at x=0 since the vibration displacement amplitude is larger: the slider leaned at approximately 0.1º in x-axis when the slider is levitated. The relationship between the levitation distance and the weight per unit area was measured by setting different masses above the slider’s beam noncontactly. As shown in Fig. 4, the larger levitation force can be obtained with the smaller levitation distance. The thrust of the slider was measured with changing the weight per unit area. The larger thrust could be obtained with larger weight as shown in Fig. 5. From the experimental result in Fig.4, the large weight decreases the levitation distance of the slider. Therefore, the larger thrust can be obtained with the smaller levitation distance of the slider.

4. Conclusion

The slider for the standing wave type ultrasonically levitated linear guide was proposed. The slider consists of the aluminum plate and the PZT plate. The slider could be levitated and be moved by exciting the asymmetric vibration mode in the length direction. By changing the driving frequency, the slider’s moving direction could be switched.

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References


Fig. 3 Relationship between the levitation distance and the vibration displacement amplitude of the beam at 68 and 69 kHz.

Fig. 4 Relationship between the levitation distance of the slider and the mass of weight at 68 kHz.

Fig. 5 Relationship between the thrust and the weight of the slider at 68 kHz.