An Inchworm-type Microactuator Using Levitation Mechanisms

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Abstract

We propose an inchworm-type microactuator using levitation mechanisms. Since the proposed microactuator can realize linear displacement without friction, it is suitable for the use in a clean room. The vertical vibration of a piezoelectric element (piezo) levitates the mechanism. Horizontal piezos push and pull the levitation mechanism in air. In the experiment, the levitation was 20 μm and the step displacement was 10 μm.

1 Introduction

An inchworm-type microactuator using piezoelectric element (piezo) is one of the most useful actuators for precision engineering. We developed an inchworm-type microactuator which consists of electromagnets for clamping and piezos for thrusting [1]. A current energy source for the electromagnet and a voltage energy source for the piezo were needed. We then developed a microactuator without the electromagnet. The microactuator reduced a friction force by using vertical vibration [2]. The presence of the friction force sometimes interferes with the motion of the microactuator. In this paper, we propose an inchworm-type microactuator using levitation mechanisms. The levitation mechanism floating in air moves by the deformation of horizontal piezos so that no particle contamination is generated.

2 Structure

The levitation mechanism shown in Figure 1(a) is a key component of the microactuator we propose. The bottom plate is 20 mm in diameter and 3 mm in thick, and the counter weight is 30 g. A multilayer piezo (NEC-tokin, AD0505D16F) is inserted and glued between them. The length of the piezo is 20 mm, and it deforms 11.6 μm when the 100 V_{DC} is applied. The piezo vibrates in the vertical direction at an appropriate frequency. When two flat surfaces are separated by a compressible fluid film such as air, a dynamic pressure is generated in their normal direction by the oscillation of the surfaces. The vertical piezo oscillates the bottom plate, and the dynamic pressure is generated underneath the circular plate. The pressure, therefore, can lift the levitation mechanism from the operation surface.

Figure 1(b) shows the photograph of the proposed microactuator. The piezo (a-c) consists of the levitation mechanism (A-C). Three levitation mechanisms are connected with parallel leaf springs and horizontal piezos. The parallel leaf spring whose length is 20 mm is used as vibration isolators. The horizontal piezos (d and e) push and pull the levitation mechanisms.

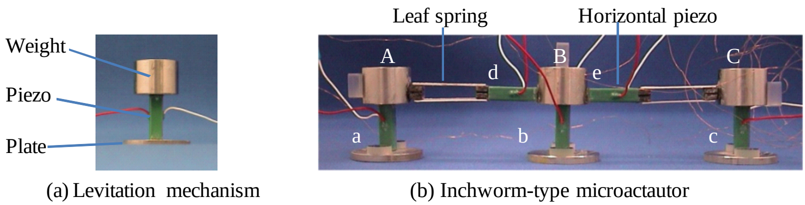

Figure 1: (a) Levitation mechanism and (b) proposed inchworm-type microactuator

3 Experiment

First, the height of the bottom plate of the levitation mechanism is measured. The sine wave with 100 V_{pp} amplitude and 50 V_{DC} offset is applied to the vertical piezos. The oscillating frequency is tuned experimentally in order that the equal levitation height is obtained. In the experimental conditions, the oscillation frequency is 11.0 kHz for the levitation mechanisms A and C, and is 11.2 kHz for the levitation mechanism B.

Figure 2 shows the levitation height. The levitation height was 15-20 μm. The levitation mechanisms reach the final height in 25-40 ms which restricts the control period of linear displacement. The mechanism B supported by two leaf springs shows the different characters, i.e. different operation frequency and rise time.

Next, the linear (horizontal) displacement is discussed. Figure 3(a) illustrates the principle. While one levitation mechanism is floating by the oscillation of the vertical piezo, other levitation mechanisms are landing on an operation surface, i.e. the levitation mechanisms float alternately. The levitation mechanism touching on the operation surface keeps its position by a friction force. The levitation mechanism floating in air moves by the deformation of horizontal piezos. In Figure 3(a), interval 1 is the initial condition. In interval 2, the levitation mechanism A, which is floating, moves by the extension of horizontal piezo d. The levitating mechanisms B and C move in interval 3 and 4, respectively. Interval 5 is the initial condition of the microactuator, which moves leftward. Figure 3(b) shows the voltage applied to the piezos. The vertical piezos vibrate intermittently at about 11 kHz. The horizontal piezos extend and contract after one levitation mechanism start levitating in air. The maximum voltage to the horizontal piezos is 100 V. A control period is 1 s and the horizontal piezos deform slowly, since the inertia force should be eliminated.

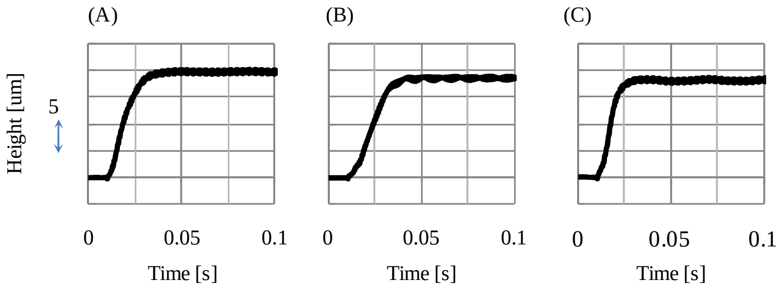

Figure 2: Levitation height of the levitation mechanisms

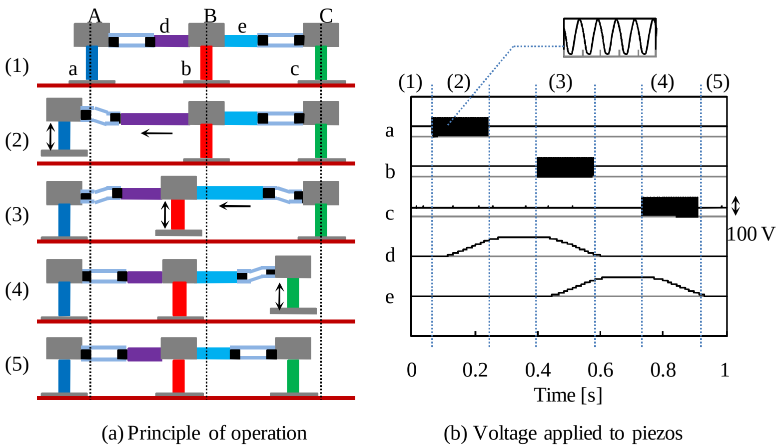

Figure 3: (a) Principle of horizontal displacement and (b) voltage applied to piezos.

Figure 4 shows experimental results. The microactuator moves rightward in Figure 4(a), and leftward in Figure 4(b). The horizontal displacement of the levitation mechanisms A-C is measured. The displacement in the right is expressed as positive. The voltages applied to the horizontal piezos d and e are also indicated. The leviration mechanisms shift about 10 μm per cycle in both directions. While one levitation mechanism is floating in air, it moves by the deformation of horizontal piezos and the other levitation mechanisms do not move. We believe that this fact eliminates particle contamination problem.

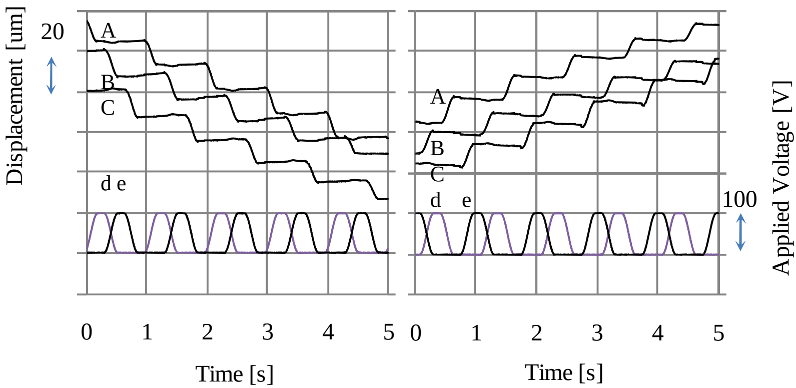

Figure 4: Displacement (left) leftward and (right) rightward

4 Summary and future work

This paper described an inchworm-type microactuator using levitation mechanisms. The microactuator consisted of the vertically vibrating piezos and the horizontally deformable piezos pushing or pulling the levitation mechanisms. After showing the levitation height, we demonstrated the linear displacement of the proposed microactuator. The horizontal step displacement per cycle is about 10 μm. We will validate the suitability of the microactuator for clean room application as part of future work.

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