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π shaped ultrasonic motor with multi-degree of freedom.
π形超音波多自由度モータ

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1. Introduction

Some transducers are necessary to obtain multi-degree of freedom motion, and complicated structure and difficulty to realize small size are the problems. In this report, we propose π-shaped ultrasonic motor with multi-degree of freedom motion.

Several structures have already been proposed to obtain multi-degree of freedom motion[1~2]. Newly desinged actuator is presented in this report.

Figure 1 shows the schematic view of the conventional π shaped ultrasonic linear motor[3]. Two multilayered piezoelectric actuators are used to drive the motor and bi-directional linear motion can be obtained.

Figure 2 shows the proposed π shaped ultrasonic motor using four multilayered piezoelectric actuators. Size of the multilayered piezoelectric actuators used for new motor is 5mm x 5mm x 9mm, same as the one used for the conventional motor. Cross-section for elastic body made of metal is 5mm x 5mm. Dimensions of the motor are about 48mm x 21mm x 22mm.

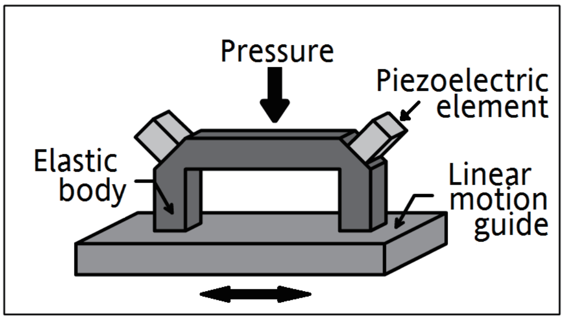


Fig.1 π shaped ultrasonic linear motor.

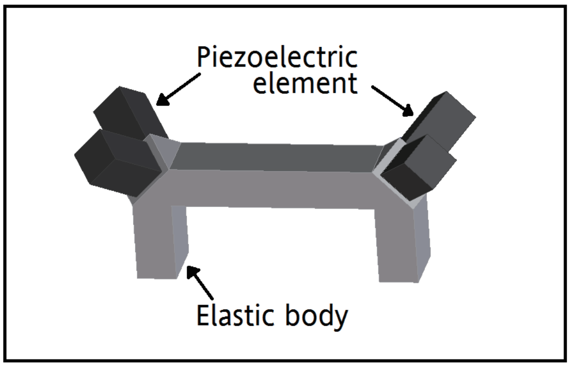


Fig.2 π shaped ultrasonic motor with multi-degree of freedom.

2. Driving principle

Driving principle of this newly proposed motor is similar to the conventional linear motor. Multilayered piezoelectric actuators are bonded with a tilt angle of 45 degrees as shown in **figure 2**.

Basic driving methods are explained by rotation of a boll. Two adjacent vibration modes, longitudinal and bending modes, are used to drive the motor. Driving frequency is set between these two vibration modes. Then the elliptical motion is excited on the contact surfaces of the motor.

Power supplies are connected to the multilayered piezoelectric actuators to obtain required longitudinal and bending vibration modes.

Longitudinal vibration mode and bending vibration mode along the Y-axis generate the elliptical motion at the contact surfaces shown in **figure 3(a)**, then the rotation around X-axis is realized. Another combination of longitudinal and bending vibration modes rotates the ball around the

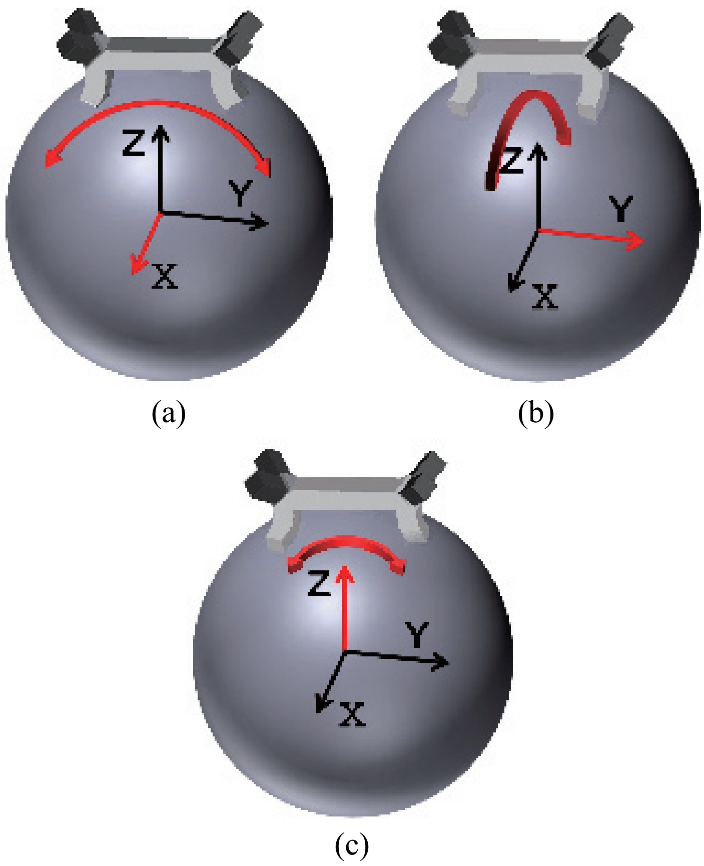
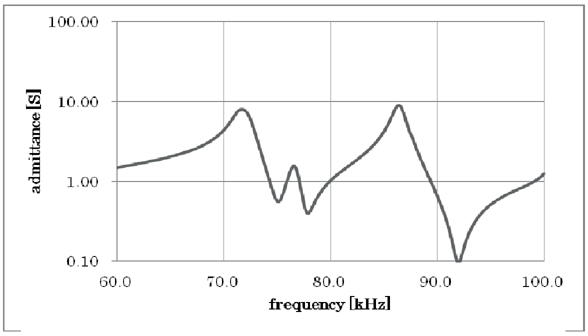
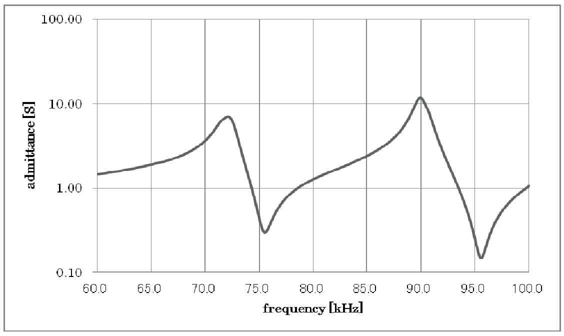


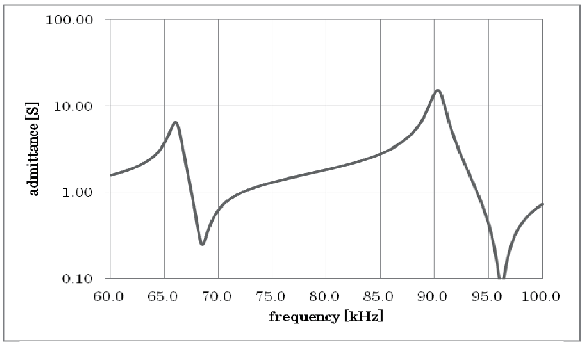
Fig.3 Driving principle



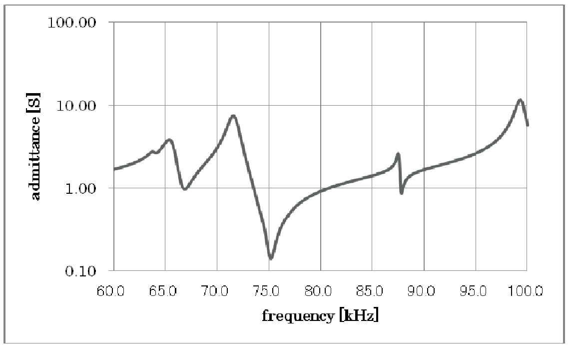
(a) Longitudinal mode



(b) Bending mode along Y-axis



(c) In phase bending mode along X-axis



(d) Out of phase bending mode along X-axis

Fig.4 Frequency characteristics of the admittance

Y-axix as shown in **figure 3(b)**. The rotation around the Z-axis is obtained by the combination of the longitudinal vibration and the out of phase bending vibration mode as shown in **figure 3(c)**.

3. Frequency characteristics

Frequency characteristics of the motor admittance are measured and the results are shown in **figures 4(a), 4(b), 4(c)** and **4(d)**.

Resonance frequencies of the longitudinal vibration mode is about 87 kHz, bending vibrasion mode along the Y-axis is about 90 kHz, in phase bending vibration mode along the X-axis is about 90 kHz and out of phase bending vibration mode along X-axis is about 87 kHz, as shown in **figures 4(a), 4(b), 4(c)** and **4(d)**, respectively.

4. Load characteristic and Efficiency

Three kinds of rotations around the X, Y and Z axes are realized by the proposed actuator and driving methods.

Figure 5 shows the one example of the load characteristics of the motor around the Z-axis rotation.

Applied voltage is 3.5Vp-p, and applied preload is 1kgf. Maximum revolution speed of 66 rpm, maximum torque of 15.8 N・mm and maximum driving efficiency of 1.7 % are obtaind.

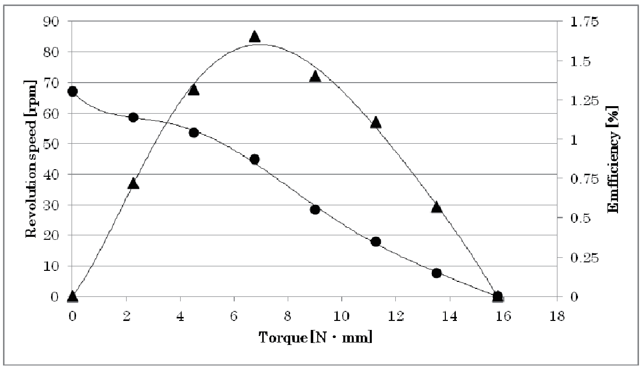


Fig.5 Load characteristics of the motor around the Z-axis

5. Conclusion

A newly proposed actuator with multi-degree of freedom is realized and some driving characteristics are obtained. The motor characteristics are not sufficient for practical use, therefore optimization of the design is required for future work.

6. References

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