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Miniaturization of case-type Multi-degree-of-freedom Ultrasonic motor
ケース型多自由度超音波モータの小型化

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1. Introduction

In recent years, the multi degree of freedom ultrasonic motors are developed by many research groups. In the developement of the multi degree of freedom ultrasonic motor, the configuration of the preload structure is a sever problem. Our group propose MDOF-USM has a small and simple preload structure actuation. Motor authors aim is MDOF-USM has a small and simple preload structure. The MDOF-USM of the form which inserted the ball rotor in the inside of a single stator was examined. The fundamental characteristics of the motor are measured. The operation of the motor is confirmed.

2. Principles of MDOF-USM

Figure 1 shows the configuration of USM. The stator consists of a vibrator of an octagon pillar, and a foundation of the fixed end. Takes the XY axis parallel to the stator, take the Z-axis vertically. Elliptic motion on a stator are obtained through the combination of longitudinal vibration mode and flexural vibration mode . The ball rotor which touches inside a stator is rotated to the circumference of arbitrary axes by a friction drive. From Figure 1(a), By combining longitudinal vibration mode and flexural vibration mode, the rotation about the X-axis and the Y-axis is attained. From Figure 1(b), By combining flexural vibration mode and 90 degrees out of phase flexural vibration mode, the rotation about the Z axis is attained. Figure 2(a) shows the configuration of preload structure. The rotor is in contact with the internal stator, which is supported by a roller ball on the bottom. Advantage of the preload structure, preload mechanism so that all can be stored inside the stator, is that suitable for miniaturization. Furthermore, since the uniform preload to a rotor is given, it is a point which the stable drive can expect. By applying spring preload to the slider, rotor are pressed against the inside stator. Preload can be varied in adjusting the spring compression with a single screw. Figure 2(b) shows the configuration of electrode arrangement. Electrode set A, B, C, and D along the Z axis each electrode. PZT is polarized in the radial direction, respectively.

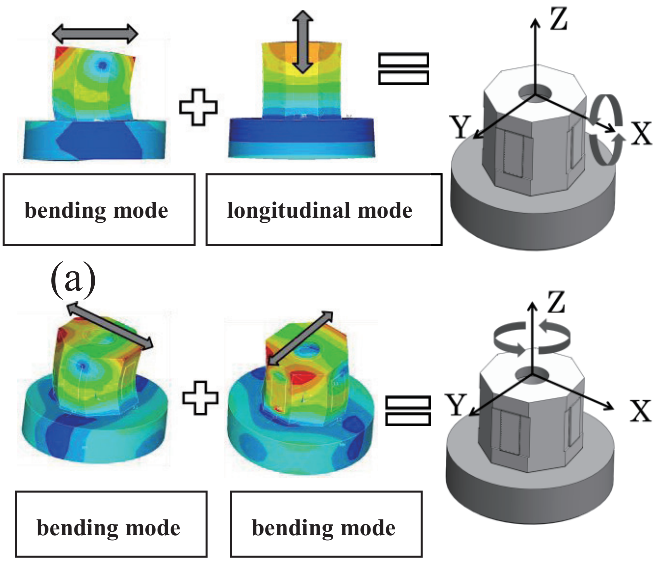

Fig 1.Priciple of operation of MDOF-USM

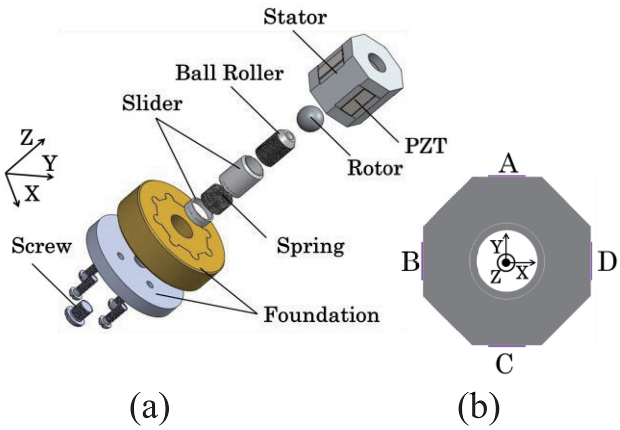

Fig 2.Preload structure and electrode disposition

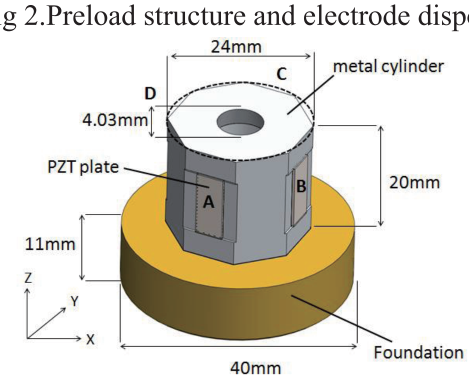

Fig 3. The size of a stator

3. Structure of the stator

The Dimensions of the stator is shown in Fig.3. In order to realize the vibration of the stator as principle, free vibration analysis is carried out by the finite element method using ANSYS. Dimensions of the octagonal prism stator, whose resonace frequency of the bending-vibration mode and longitudinal-vibration mode is same, are investigated by varying the diameter of the stator. The dimensions of the stator are 12 mm with circumscribed circle diameter, 5 mm with inner radius, 20mm with height. Foundation are 20 mm with Outer diameter, 5 mm with inner radius, 11mm with height. Primary longitudinal-vibration mode of the resonance frequency is 64.1kHz, and the primary bending-vibration mode of that is 64.6 kHz. The foundation consists of brass with high rigidity, in order to use a stator as a fixed end.

4. Characterization results

Figure 4 shows the admittance characteristic of stator. The resonance frequencies of the Electrode A are 63.1kHz in the flexural vibration mode and 61.66kHz in the longitudinal vibration mode. Between the electrodes, the resulting differences of admittance. As the cause, it is considered that the adhesion of the PZT layer is different between the electrodes. Next, The vibration in each direction amplitude is measured by Laser Doppler Vibrometer . Measurement of the amplitude point is the apex portion of the stator. fig 5 shows displacement Z and displacement Y induced by X-axis rotation. 100Vrms input voltage ,the maximum displacement about the Z-direction is 0.6μm while it is 0.4μm about the Y-direction. fig 6 shows displacement Z and displacement X induced by Y-axis rotation. 100Vrms input voltage ,the maximum displacement about the Z-direction is 0.45μm while it is 0.32μm about the Y-direction. Frequency was 63 kHz and it set voltage to 100Vrms. In this case ,the maximum no-load speed x axis is 56rpm while it is 60rpm about the y axis. As shown in Fig. 6, two or more frequency which Z axial rotation carries out was checked. Maximum speed of Z-axis rotation is 280rpm and resonance frequency is 88.4kHz. Moreover, CW and CCW of X, Y, and Z axial rotation have been checked.

5. Conclusion

The authors have examined the miniaturization of the multi-degree-of-freedom ultrasonic motor having a preload mechanism. When the stator is designed using FEM and the motor is made as an experiment, X axial rotation, Y axial rotation, Z axial rotation, and each CW-CCW as expected are checked. However, there is the problem with the contact portion of the rotor on the drive axis Y (X). Displacement in Z direction and the radial displacement is not the elliptical orbit but about the same phase, and rotation of the sphere rotor axis is tilted. From now on, we try to improve the variance of two resonance frequencies and the contact surface between the stator and the rotor to realize the motor.

References

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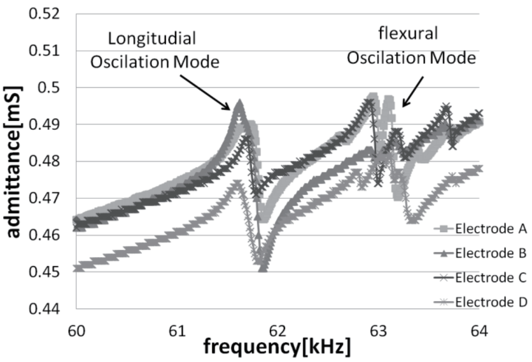
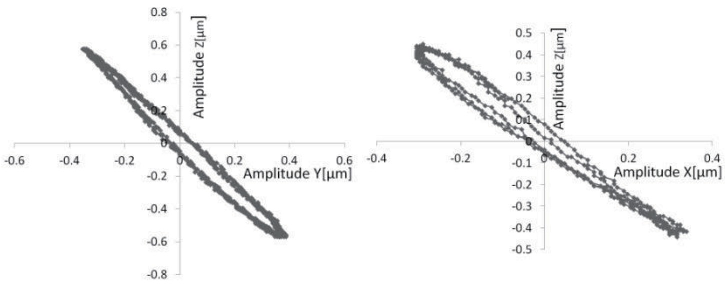


Fig 4. The admittance characteristic of stator



(a) (b)

Fig 5.(a) The amplitude of the rotation axis X
(b) The amplitude of the rotation axis Y

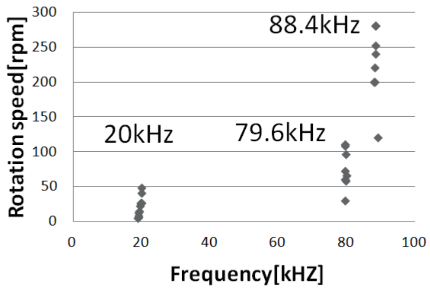


Fig 6. Rotation speed distribution rotation rotor.

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