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A study on fixing method of multiple degrees of freedom ultrasonic motor in the consideration of miniaturization and expandability

多自由度超音波モータの小型化と拡張性を考慮した固定方法に関する検討

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1.Introduction

Realization of a multi-degree of mottion by a single or double single-stators is an advantage to downsize actuators and to reduce the cost. An ultrasonic motor, that is multi-degree of freedom ultrasonic motor (MDOF-USM) achieves such a multi-degree of motion. Various MDOF-USMs have been proposed until now[1-4]. Pre-load structure is important to install MDOF-USM on a system. In this study, the authors have devised a degenerate MDOF-USM with a compact and simple preload mechanism in order to expand motion range and to install the MDOF actuator easily. To realize such features, the MDOF actuator is fixed at the bottom of the stator. Small pins are employed to fix the actuator in the preload systen in order to reduce the influence of the fixed mechanism on the free vibration mode.

2.Configuration of MDOF-USM

Figure 1 shows the configuration of the proposed MDOF-USM. The spherical rotor is sandwiched between two cylindrical stators which has comb teeth on a top surface. In order to simplify the structure, the preload mechanism structure consists of four parts which is made of brass in addition with a bearing and a shaft. The rotor is a steel ball in 12mm of diameter. Preload is applied to the rotor by a spring located on the opposite side of the stator. A motion range can be expanded by creating a space around the stator. The structure is advantage to expandability. The stator is attached to the preload structure by four small pins at the bottom. The four pins enables to prevent the stator rotation. Additionally, degenerated resonance frequency modes become almost same.

3.Operation of MDOF-USM

The proposed USM excites an elliptical locus at the top of the projects by generating the same of different two degenerated resonance modes simultaneously. The employed resonance degenerated modes are L, F and F' modes. L mode is a kind of longitudinal mode. F and F' are a kind of flexural mode. Figure 2 shows the combination of vibration modes to realize the rotation of each axis. The rotation axis X, Y and Z are also indicated. For the X axis rotation, an elliptical locus is obtained by generating the L and F modes. The supplied signal of L mode is sin ωt and the signal of F mode is cos ωt. Both supplied signals has to be applied simultaneously. For the Y axis rotation, the employed modes are almost same by generating F' mode instead of F mode.

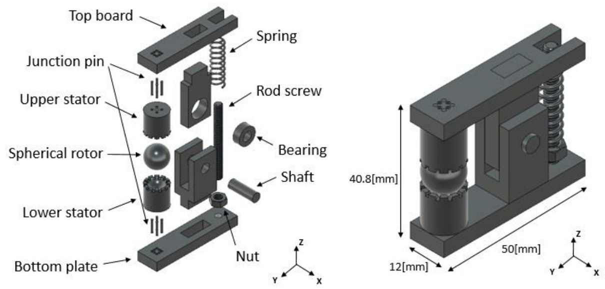

Fig.1 Structure of MDOF-USM

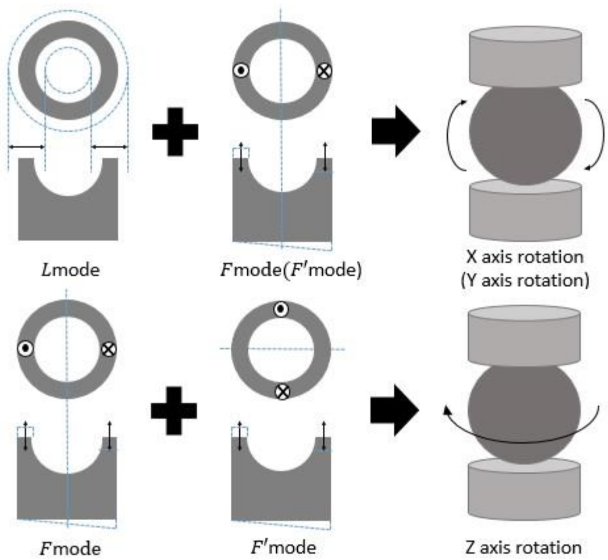

Fig.2 Driving principle of MDOF-USM

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Z axis rotation is obtained by generating F and F' mode. For supplying signal, F mode is cos ωt and F' mode is sin ωt.

4. MDOF-USM configuration

Figure 3 shows the shape of the stator and the arrangement of the electrodes and the piezoelectric elements. The stator body is made of duralumin (A2017). The seven copper electrodes and the six disc type PZT elements are sandwiched alternately. In Fig.3, upper two PZT elements generate L mode, of which electrode pattern on the PZT element is uniform. The sandwiched position is anti-nodal point of L mode. The lower four PZT elements generate F and F' mode. Among four PZT elements, upper two PZT elements pair generates F mode and lower two PZT elements pair generates F' mode. To generate flexural modes, the electrode pattern on PZT elements are divided two area in one side. Therefore, the direction of divided pattern of one PZT pair should be normal to the other PZT pair in the installation, The dimensions of the stator is designed using finite element method (FEM). Figure 4 shows the employed resonance modes.

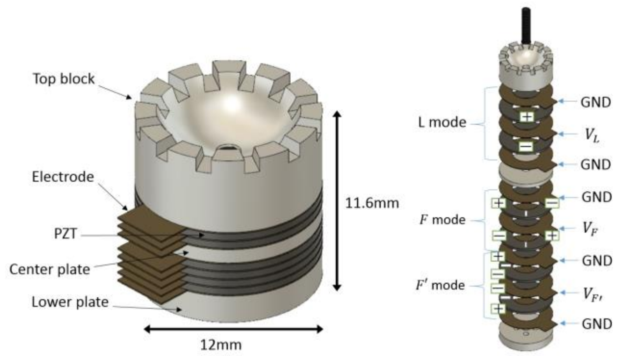
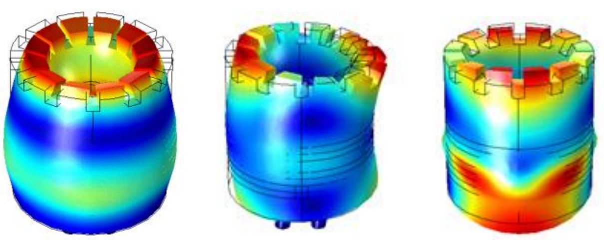


Fig.3 Structure of stator



(a) L mode (b) F mode (c) F' mode

Fig.4 Employed resonance frequency modes.

5. Admittance Characteristics and Discussion

Figure 4 shows the measured admittance -frequency characteristics of the stator. L mode characteristics is measured in connection with the electrode V_L shown in Fig.3. The measured resonance frequency is 144 kHz, comparing with 155kHz in the analysis. F mode and F' mode characteristics are measured in connection with the electrode V_F and $V_{F'}$ shown in Fig.3. F mode resonance frequency is 144 kHz and F' mode is 194kHz in the measurement, comparing with 147kHz in the analysis. In the measurement, F mode resonance is greatly different from F' mode resonance. The contact state of the PZT pairs causes the difference of the resonance frequencies.

In order to evaluate the operation feasibility of the ultrasonic motor, the vibration amplitude in each of the X, Y, and Z axis directions in the resonance frequency respectively. Using the analysis results, the elliptical locus on the top of the project is drawn as shown in Fig.6. Figure 6 shows the loci in the X axis and Z axis rotation. In each rotation, the loci on the project are almost circle. It is considered that multi-degree motions are able to be obtained by the proposed MDOF-USM.

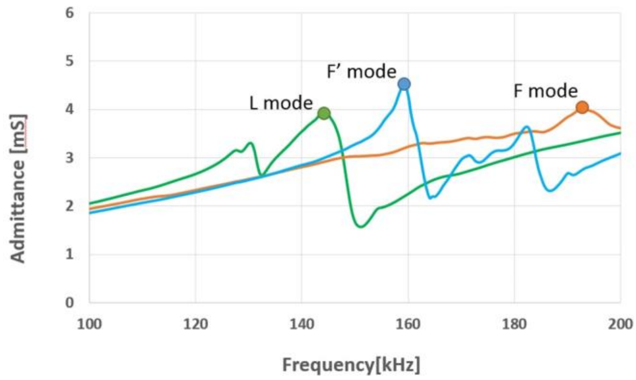
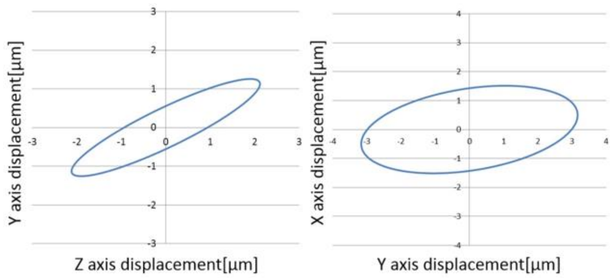


Fig.5 Admittance-frequency characteristics of stator



(a)X axis rotation (b)Z axis rotation

Fig.6 Lissajous curve in rotation driving

6. Conclusion

The MDOF-USM with the simple preload mechanism is investigated. In the future, the characteristics of the proposed MDOF-USM are measured to aim for improvement of performance.

References

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