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A Study on Half-Ring-Shaped Ultrasonic Motor for Simple Mounting
簡易装着可能な半円環形超音波モータの検討

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1. Introduction

Many ideas of ultarsonic motor have been reported.[1] In recent years, the multi degree of freedom ultrasonic motors are developed by many research groups.[2-4] In the developement of the multi degree of freedom ultrasonic motor, the configuration of the preload structure is a sever problem. To solve the problem, the configuration that the rotor is sandwitched by two traveling type ultorasonic motors is already proposed. But the size of the stators in that configuration are considerable large. On the contrary, our group propose a half-ring-shaped motor for multi degree of freedom actuation. Generally, the ball shaped rotor is employed in the multi degree of freedom ultrasonic motor. Hence, it is considered the half-ring-shaped stator is suitable for preload structure of multi degree of freedom. In this report, half-ring-shaped motor is developed for simple mounting. The fundamental characteristics of the motor are measured. The operation of the motor is confirmed.

2. Operation principle of the motor

Figure 1 shows the configuration of stator. PZT element which deforms in the lateral effect attached to the center of out profile of half-ring-shaped stator. There are two projects in the inner profile of stator. The rod or the ball shaped stator contact with the two projections. Two projections of the stator contact the rotor. Figure 2 shows the composition of the stator and the rotor. The employed resonance modes of the stator are shown in Fig.3. Figure 3 also shows the vibration directions of the projections in each vibration mode. In the vibration mode of "stator A" shown in upper Fig.3, we call "flexural vibration mode", the edge of projections vibrations at the oblique to the radial direction. Thus, the rotor rotates owing to the projection vibration as shown in Fig.3. In the vibration mode of "stator B" shown in lower Fig.3, we call "longitudinal vibration mode", the edge of projections vibrates along the radial direction. Thus, the projection vibration reduces the friction between the rotor and the stator. In the motor operation, two stators are employed. One stator rotates the rotor and the other stator reduces the friction between the stator and the rotor. When the two stators vibrate simultaneously in each mode,

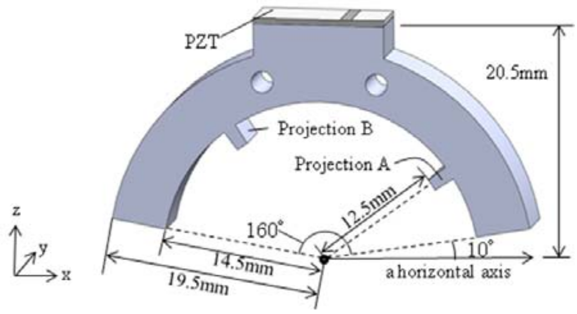

Fig.1 Configuration and dimensions of the half-ring-shaped stator.

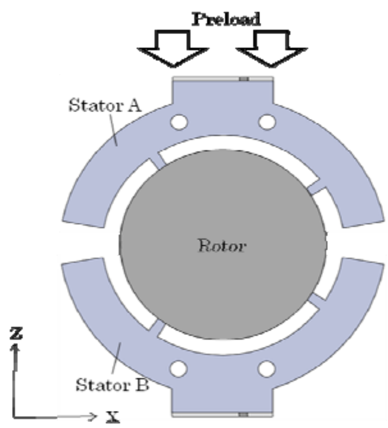

Fig.2 Composition of the stator and the rotor.

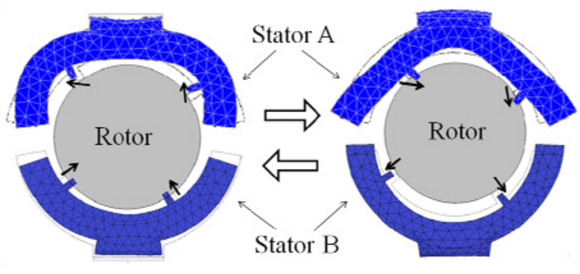

Fig.3 Vibration direction of the projection against the rotor ; (a) in the flexural mode, (b) in the longitudinal mode.

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the rotor rotates in the one way direction. To achieve the reverse rotation, the vibration mode of each stator is exchanged.

3. Configuration and dimensions of the stator

In order to design the projection vibration as principle, modal analysis of the stator is carried out by finite element analysis (FEM). The trial-made stator dimensions are shown in Fig.1. The dimensions of the stator are 19.5 mm with outer radius, 14.5 mm with inner radius as shown in Fig.1. The stator body is arc of 160 degrees with central angle, 5mm with thickness and 5mm with width. The dimension of two projections is 2 mm height and the width of projection is arc of 5 degrees. In the result of FEM, the resonance frequency of the flexural mode is 50.6kHz and the frequency of the longitudinal mode is 71.8kHz. The position of one projection, we call "projection A" is 35 degree from the horizontal direction and the position of the other one, we call "projection B" is 125 degree. Two holes for supported shaft are opened at the node of the flexural mode as shown in Fig.1.

4. Characteristics of the motor

Figure 4shows the admittance characteristic of stator A and stator B. The resonance frequencies of the stator A are 46.96kHz in the flexural vibration mode and 65.55kHz in the longitudinal vibration mode. And those of the stator B are 47.10kHz and 65.47kHz. Both resonance frequencies are almost same as the FEM results. Figures 5 and 6 show the vibration amplitude of the projection in each stator. The vibration amplitude is measured by Laser Doppler Vibrometer. Figure 5 shows the vibration amplitude in the radial direction of the flexural mode when stator A is employed. Maximum vibration amplitude of projection A is slightly different from that of projection B. Vibration amplitude is around 4 $\mu m_{p\text{-}p}$ at 200 V of applied voltage. Figure 6 also shows the vibration amplitude in the same direction of projections of the longitudinal mode when stator B is employed. There is also slight difference between projection A and B of stator B. Vibration amplitude is around 2 $\mu m_{p\text{-}p}$ at 200 V of applied voltage, which is smaller than that of flexural vibration mode. In the motor operation as principle, the motor rotation is confirmed. Maximum speed of rotation is 60rpm and stall torque is 7.1mNm. When vibration mode of stator A and B is exchanged, the reverse rotation is also confirmed. However, the rotation speed is very low comparing to the other direction.

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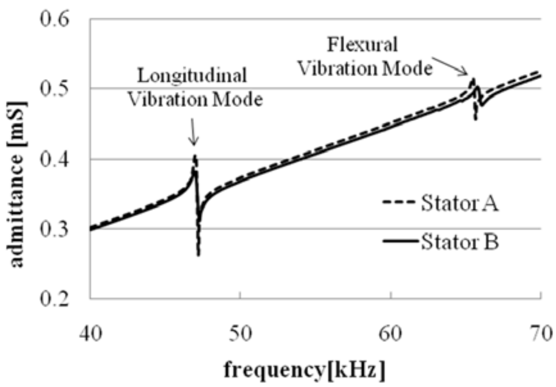

Fig.4 Admittance characteristics of the stator.

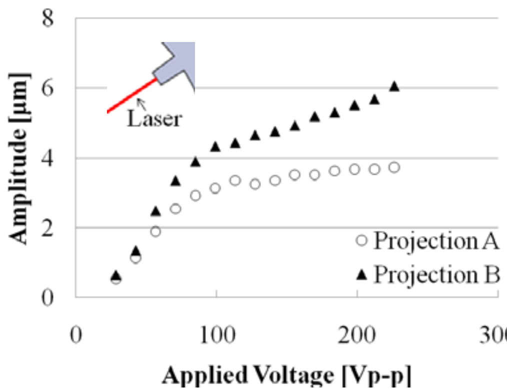

Fig.5 Vibration amplitude of the flexural mode of stator A against the applied voltage.

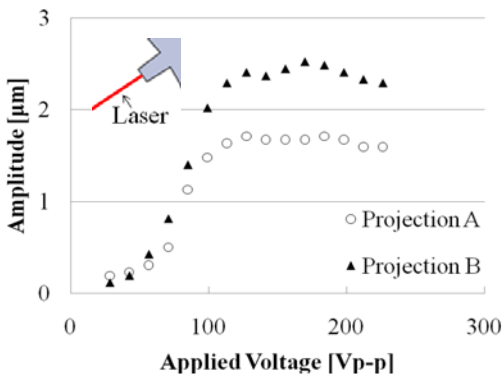

Fig.6 Vibration amplitude of the longitudinal mode of stator B against the applied voltage.