Positioning Characteristics of Ultrasonic Rotary Actuator with Two Mode Operation

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ABSTRACT

An ultrasonic actuator\(^1\) is expected to be successfully used as a precision positioning controller because of its features such as quick response, high torque at low revolution speed, etc.\(^1\). Using a trial-made rotary-type ultrasonic actuator, which consists of a longitudinal multilayered piezoelectric actuator (LMPA) and a torsional multilayered piezoelectric actuator (TMPA), the angular positioning characteristics were studied. The trial-made actuator is driven by two modes, that is, dynamic and static operations. Employing the two mode operations complementarily, the angular positioning has been successfully proved to be quickly controlled with an excellent accuracy of 1 arcsec±0.3 arcsec.

PRINCIPLE AND CONFIGURATION

Configurations of Trial Actuators

A trial ultrasonic rotary actuator is shown in Fig.1. The stator consists of a dumbbell-shaped bolted Langevin type torsional vibrator\(^1\) (20mm in diameter; 20mm in length) and a ring-shaped LMPA implanted to the vibrator with adhesive. The other side of LMPA contacts with the rotor by a coil spring to generate the frictional force. A holder is set at the center of the stator and two 6-layered TMPAs (inner radius, 3mm; outer radius, 5mm; thickness, 3mm) are implanted in each side of the holder.

Principle

The ultrasonic actuator is driven by two modes, that is, dynamic and static operations. In the former mode, the TMPA acts as a torsional transducer operating at the resonance frequency of 8.61kHz and the LMPA acts as a clutch as shown in Fig.2-1. The angular displacement can be controlled by the width of burst voltage applied to the LMPA and the TMPA, and the rotor can rotate quickly in wide range with an accuracy of about 10 arcsec. In the latter mode, the TMPA acts as a torsional displacement actuator, while the LMPA is rest as shown in Fig.2-2. The angular position in this case can be controlled by a static voltage applied to the TMPA and the rotor can move with high accuracy about.
more than 1 arcsec within narrow range of 40 arcsec even at 200V.

Figure 3 shows how to position the rotor to a target point P0 from a point X. First, the rotor is rotated to the position [P0±W] by the dynamic operation. Next, the position is adjusted to P0 by the static operation. The angular window width W should be more than the positioning accuracy of the rotor and less than the dynamic range of static operation. Employing the two mode operations complementarily, the angular positioning with an excellent accuracy of 1 arcsec±0.5 arcsec was aimed at.

Fig.3 Complemental use of dynamic and static operations for the precision positioning.

POSITIONING SYSTEM

The positioning block diagram is shown in Fig.4. The conditions of applied voltages to the LMPA and the TMPA are controlled by the personal computer through the GPIB while output pulse from the rotary encoder (128000 pulses/rev. 1 pulse=1 arcsec) which is mechanically coupled with the rotor, is counted by the personal computer through the I/O board. Here, the output pulse from the rotary encoder is denoted by P, target pulse number P0, hold time T, burst width of the applied voltage (applied cycle number) C and window width W.

Fig.4 Block diagram of the positioning system.

BASIC CHARACTERISTICS

Dynamic Operation

The dynamic operation is carried out under the following conditions: driving frequency f, 8.6kHz; applied voltage to TMA V, 50V±5; applied voltage to LMPA V, 1N±10V±5; phase between V1 and V, 30deg (clockwise) or 210deg (counter clockwise); the pre-load by the coil spring F, 10kgf.

The relations between burst width and average output pulse are shown in Fig.5. The curve partly approximated as dotted lines in the figure.

Fig.5 Average output pulses vs. burst width in the dynamic operation.

Static Operation

The relation between applied static voltage to the TMA V1 and output pulse (angular displacement) P from the rotary encoder is shown in Fig.6. The curve shows a hysteresis loop. A solid line shows the calculated curve using the piezoelectric constant d15 and V1. Figure 7 shows creep characteristics of the angular displacement of each applied voltage V1. The output pulse changes regardless of the constant applied voltage. So it is necessary that the applied voltage should be adjusted to keep the angular position constant.
Fig. 6 Output pulses vs. applied voltage in the static operation.

Fig. 7 Creep characteristics in the static operation.

Fig. 8 Flow chart of two mode operation programs.

Fig. 9 Positioning characteristics by the dynamic operation program.

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measured. Figure 10 shows the result under such a condition as P1=40 and T=50sec. Dotted lines were obtained with uncontrolled condition, and P1 is increasing because of the creep characteristics. Solid lines were obtained when the applied voltage is controlled and angular displacement is correctly controlled by the static operation program.

Then using two mode operations complementarily, the precision positioning characteristics were measured. Figure 11 shows the result under such conditions as P1=1296000 (just one revolution and T=50sec. Firstly, the rotor was moved to the position of P1=1296000 by the dynamic operation, and then the rotor was moved to the target position of P1=1296000 and kept there by the static operation. Consequently, this program is working correctly and the precision positioning can be realized.

CONCLUSION

The rotary type ultrasonic actuator which consists of the LMA and the TMBA was designed and precision positioning was studied. Two modes, that is, dynamic and static operations were employed. The dynamic operation is controlled by the burst width of the applied voltage and the static operation is controlled by the voltage applied to the TMBA. The precision positioning with accuracy of 1 arcsec±0.5 arcsec was successfully accomplished. We will be able to get more precise positioning, because the static operation can do it if a more precise rotary encoder is obtained. But the speed of positioning is not satisfactory. So we must study about speedup of the precision positioning process.

REFERENCES