CONFIGURATIONS OF AN ULTRASONIC MOTOR USING A CIRCULAR VIBRATION DISK WITH THREE LONGITUDINAL TRANSDUCERS

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Abstract

Vibration and load characteristics of an ultrasonic motor using a circular vibration disk with three longitudinal transducers are studied. Three bolt-clamped Langevin type longitudinal transducers of 20 mm diameter are installed along the circumference of the circular disk and transverse vibration rods are installed normally in the center of the circular disk. Three transducers are driven simultaniously using three power amplifires with phase difference of 120 degrees. A rotor disk installed on the free edge of the transverse vibration rod is pressed statically to a driving surface using a system for inducing static pressure. Maximum torque over 0.12 Nm were obtained under static pressure of 1.7 MPa. Maximum rotation and efficiency over 190 rpm and 0.83 % were obtained under static pressure of 1.5 MPa.

Introduction

Characteristics of an ultrasonic motor using a circular longitudinal vibration disk with three longitudinal transducers are studied.

Ultrasonic motors have superior characteristics such as large torque at low speed and no magnetic field compared with conventional electric motors. Various types of ultrasonic motor have been presented such as (a) ultrasonic motors using a progressive wave, (b) using a nonresonant type longitudinal transducer and resonant type torsional one, (c) using resonant type longitudinal and torsional transducers and (d) using a longitudinal-torsional vibration converter [1]-[3]. To obtain the motor with strong structure, the ultrasonic motor using a circular vibration disk which is driven by longitudinal vibration systems is proposed.

The ultrasonic motor consists of a circular disk part (63 mm in diameter), three bolt-clamped Langevin type longitudinal PZT transducers (20 mm in diameter) and complex transverse vibration rods (18 mm in diameter). Three BLT transducers are installed around the circular disk. Three transducers are driven simultaneously using three transformers and three 500 W static induction transistor power amplifiers with phase difference of 120 degrees, and an elliptical locus is obtained at vibration frequency of 65.2 kHz.

Rotating torque, revolution, electric input power, Mechanical output power and efficiency were measured. Maximum torque, rotation and efficiency over 0.12 Nm, 190 rpm and 0.83 % were obtained.

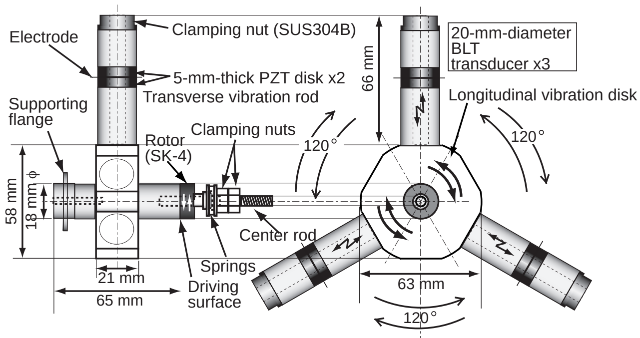

Figure 1. Configuration of a circular-disk-type ultrasonic rotary motor that consists of a longitudinal vibration disk with three bolt-clamped Langevin type PZT longitudinal vibration transducers and complex transverse vibration rods.

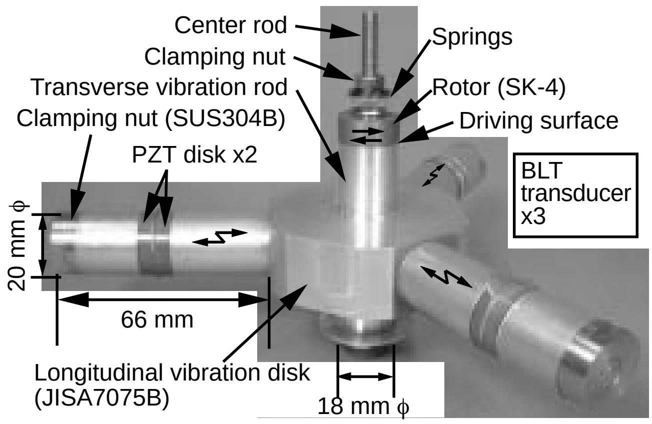

Figure 2. Configuration of an ultrasonic rotary motor using a longitudinal vibration disk with three bolt-clamped Langevin type PZT longitudinal vibration transducers.

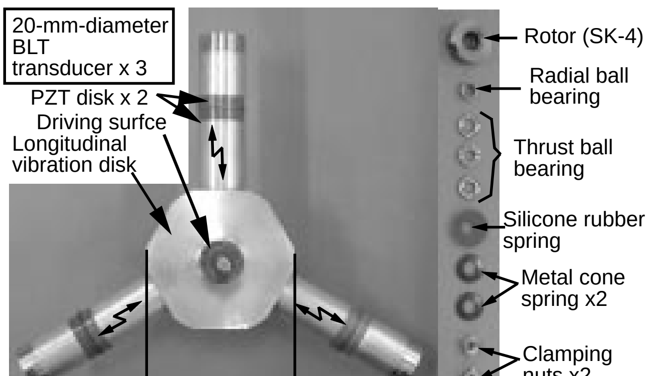

Figure 3. Elements which compose the ultrasonic rotary motor using a longitudinal vibration disk with three bolt-clamped Langevin type PZT longitudinal vibration transducers.

Configuration of an ultrasonic motor

The ultrasonic motor using a circular vibration disk with three longitudinal transducers is shown in Figure 1, 2 and 3. The ultrasonic motor consists of a circular disk part (63 mm in diameter and 21 mm thickness), three bolt-clamped Langevin type longitudinal PZT transducers (20 mm in diameter) and complex transverse vibration rods (18 mm in diameter). The transverse vibration rods are installed normally in the center of the disk at each side. The circular disk has six flat surfaces for installing the transducers that cut along the disk circumference and the distance between opposite surfaces is 58 mm. Three BLT transducers are installed around the circular disk using clamping bolts.

The complex transverse vibration rods are driven transversally by the longitudinal vibration at the center of the longitudinal vibration disk, and the transverse vibration rods are driven in elliptical locus when the three transducers are driven simultaneously with phase defference of 120 degrees.

The Rotor is made of steel (SK-4) and installed on the free edge of the transverse vibration rod and pressed statically to a driving surface using a system for inducing static pressure. The driving surfaces were ground to flat using 2000 mesh polishing powder. The metal rotor is driven directly by the metal driving surface.

Vibration characteristics of the ultrasonic motor

Free admittance loops of the ultrasonic motor

Figure 4 shows free admittance loops of the ultrasonic motor in the cases without rotor and with a rotor under static condition. In the case where the rotor is installed, resonance frequency is 67.3 kHz, motional admittance is 2.35 mS and Quality facter is 350. In the case where the rotor is not installed, resonance frequency is 69.1 kHz, motional admittance is 3.53 mS and Quality facter is 451.

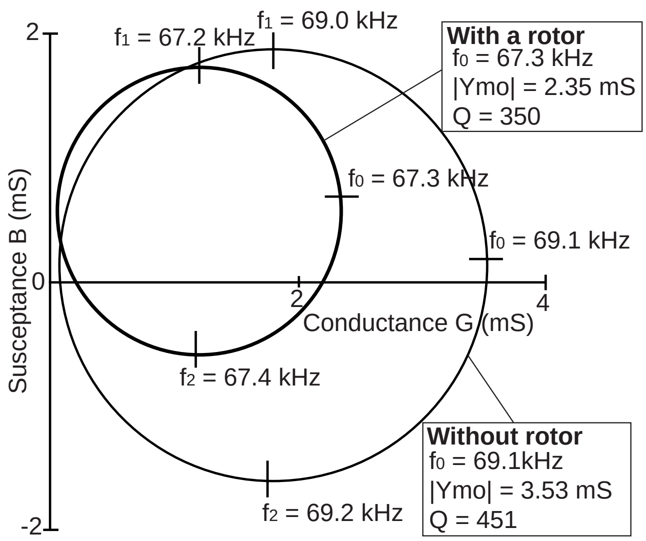

Figure 4. Free admittance loops of an ultrasonic motor without and with a steel rotor.

Transverse vibration distribution along transverse vibration rods

Transverse vibration distribution along the complex transverse vibration rods is shown in Figure 5. Three BLT transducers are driven. Longitudinal vibration is converted to transverse vibration at the center part of the disk. Driving voltages of the transducers are kept at 10 Vrms. The transverse vibration rods vibrate in a transverse vibration mode at each side of the longitudinal vibration disk.

Radial vibration distribution along the longitudinal transducer and normal vibration distributions across the circular disk and the end surface of the transverse vibration rod

Figure 6 shows radial vibration distribution along the longitudinal transducer and normal vibration distribution across the circular disk and the end surface of the transverse vibration rod. Three BLT transducers are driven. Driving voltages of the transducers are kept at 10 Vrms. Radial vibration loop exists in PZT disk part. The driving surface of the transverse vibration rod vibrates normally to the surface at the circumference of the rod. Normal vibration is produced by transverse vibration.

Torsional vibration distribution along transverse vibration rods

Figure 7 shows torsional vibration amplitude distribution along transverse vibration rods. Torsional vibration distribution is measured along a narrow plane surface cut normally to the circumference of the transverse vibration rods. It is shown that torsional vibration has loop parts at the edge of the clumping nut and the driv-

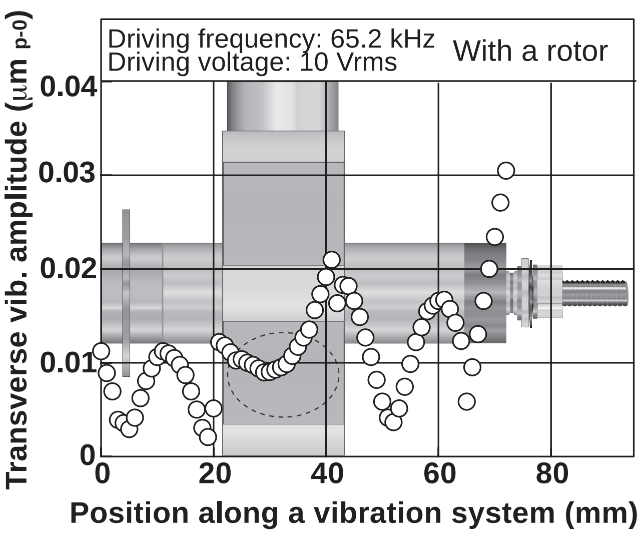

Figure 5. Transverse vibration distribution along upper and lower uniform transverse vibration rods installed in the center of the longitudinal vibration circular disk in the case where three transducers are driven.

ing surface. Torsional vibration amplitude at the driving surface is 1.5 times compared with near the circular disk.

Vibration locus at the driving surface

The combination of normal vibration component and torsional vibraton component produces elliptical vibration locus at the driving surface of the transverse vibration rod. Figure 8 shows a vibration locus at the driving surface without rotor in the case where three transducers are driven simultaneously and driving voltages of the transducers are kept at 10 Vrms. The vibration locus is measured using two laser Doppler vibrometers that detect normal and torsional vibrations independently. Measured vibration locus is elliptical at vibration frequency of 65.2 kHz.

Vibration distributions at the driving surface

Tranverse vibration distribution at the free edge of the transverse vibration rod is measured along the circumference of the circumference of the transverse vibration rod. The vibration distribution is shown in Figure 9. Three BLT transducers are driven. Driving voltages of the transducers are kept at 10 Vrms.

Normal vibration distribution at the free edge of the transverse vibration rod was measured along the circumference of the driving surface. The result of the measurement is shown in Figure 10. Three BLT transducers are driven. Driving voltages of the transducers

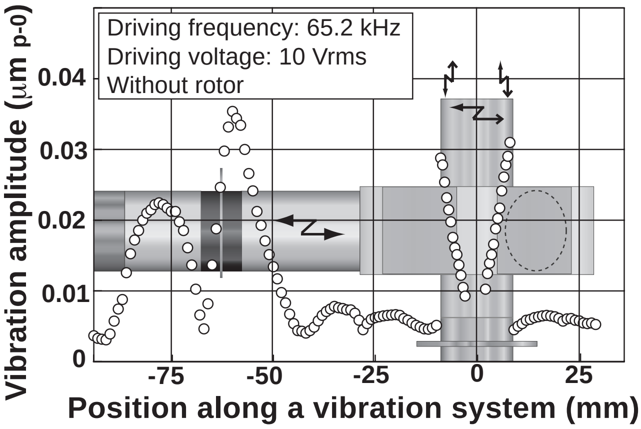

Figure 6. Radial vibration distribution along the longitudinal vibration transducer and normal vibration distributions across the longitudinal vibration disk and the end surface of the transverse vibration rod in the case where three transducers are driven.

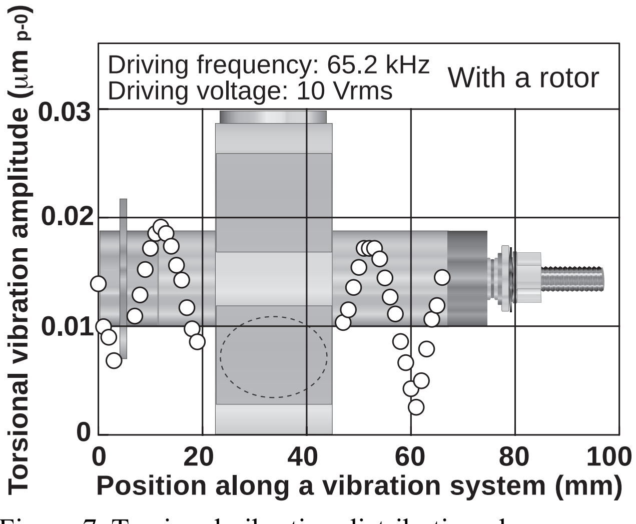

Figure 7. Torsional vibration distribution along upper and lower uniform transverse vibration rods installed in the center of the longitudinal vibration circular disk in the case where three transducers are driven.

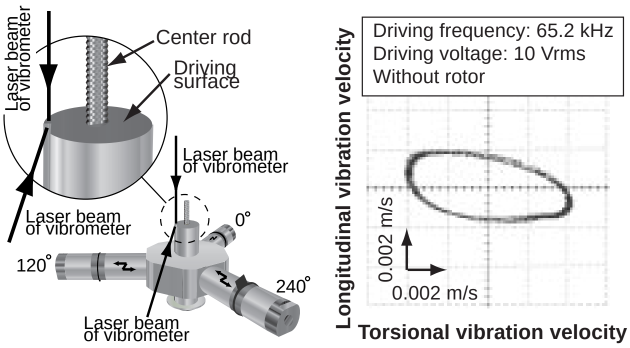

Figure 8. Vibration locus at a driving surface without rotor in the case where three transducers are driven.

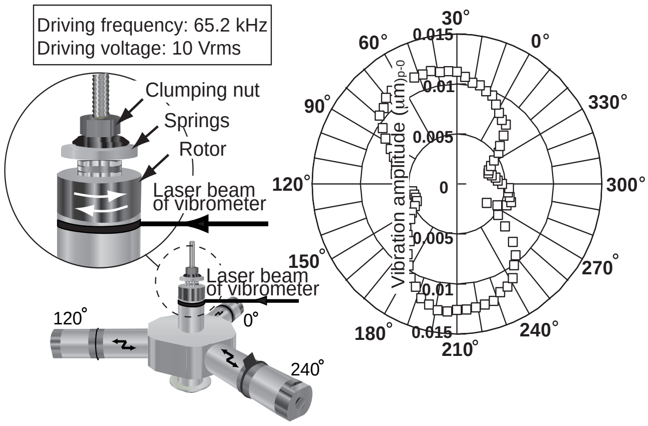

Figure 9 . Radial vibration distribution at a free edge of the transverse vibration rod measured along a circumference of the transverse vibration rod in the case where three transducers are driven.

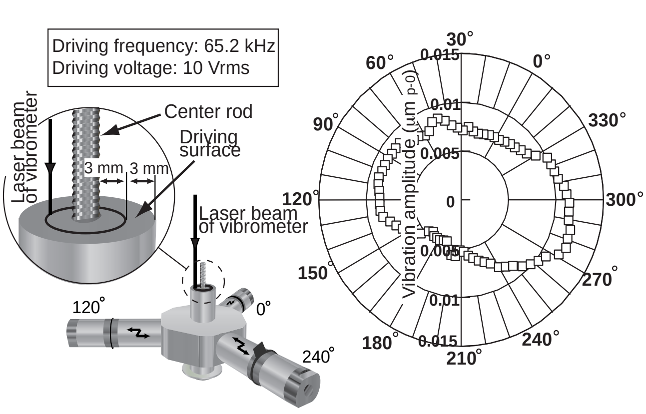

Figure 10. Vibration distribution at the free edge of the transverse vibration rod measured along the circumference of the driving surface in the case where three transducers are driven.

are kept at 10 Vrms.

It is desirable that vibration distribution at the driving surface is a complete circle. Normal vibration distribution measured is nearly circular, but not a complete circle.

Load characteristics of the ultrasonic motor

Load characteristics of the ultrasonic motor using a circular vibration disk with three longitudinal transducers are measured altering load torque by a powder brake. Torque and revolution are measured by a torque meter and a rotation meter. Input power is measured by a power meter using a electric current probe and a current-voltage multiplier. Mechanical output power is calculated from torque and revolution values measured at various load torques.

Figure 11 shows relationships between torque, revolution, electric input power, mechanical output power and efficiency of the ultrasonic motor under static pressure of 1.7 MPa. Maximum torque, revolution and efficiency of the ultrasonic motor are 0.12 Nm, 170 rpm and 0.66 % with driving frequency of 65.2 kHz.

Figure 12 shows load characteristics of the ultrasonic motor under static pressure of 1.5 MPa. Maximum torque, revolution and efficiency of the ultrasonic motor are 0.09 Nm, 190 rpm and 0.83 % with driving frequency of 65.2 kHz.

Conclusions

Vibration and load characteristics of an ultrasonic motor using a circular vibration disk with three longitudinal transducers were studied.

To obtain the motor with strong structure, the ultrasonic motor using a circular longitudinal vibration disk which are driven by three longitudinal vibration systems was proposed.

The ultrasonic motor consists of a circular disk part (63 mm in diameter), three bolt-clamped Langevin type longitudinal PZT transducers (20 mm in diameter) and complex transverse vibration rods (18 mm in diameter).

Three BLT transducers are installed around the circular disk. Three transducers are driven simultaneously using three transformers and three 500 W static induction transistor power amplifiers with phase defference of 120 degrees, and an elliptical locus was obtained.

The rotor is made of steel and installed on the free edge of the transverse vibration rod and pressed statically to a driving surface using a system for inducing static pressure.

Under static pressure of 1.7 MPa, maximum torque, revolution and efficiency of the ultrasonic motor were 0.12 Nm, 170 rpm and 0.66 % at driving frequency of 65.2 kHz.

Under static pressure of 1.5 MPa, maximum torque, revolution and efficiency of the ultrasonic motor are 0.09 Nm, 190 rpm and 0.83 % at driving frequency of 65.2 kHz.

The load characteristics may be improved by adjusting resonance frequencies of the consisting elements to be almost same.

References

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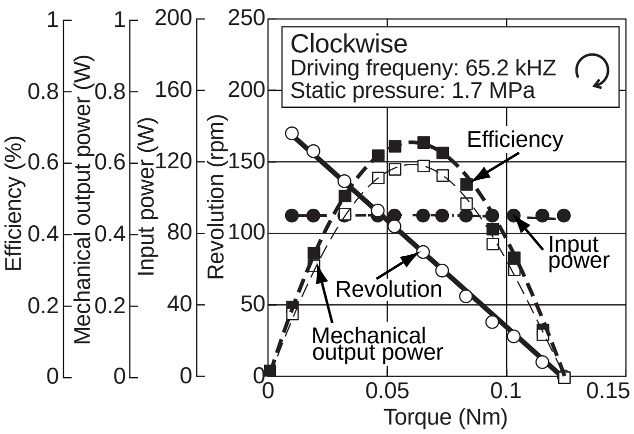

Figure 11. Load characteristics of the circular-disk-type ultrasonic rotary motor using multiple BLT transducers under static pressure of 1.7 MPa.

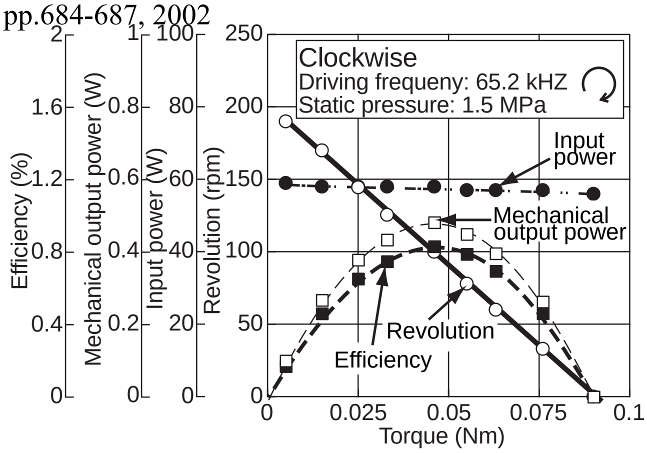

Figure 12. Load characteristics of the circular-disk-type ultrasonic rotary motor using multiple BLT transducers under static pressure of 1.5 MPa.