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Single Phase Drive Ultrasonic Linear Motor Using a Linked Twin Square Plate Vibrator

双正方板リンク形振動子を用いた単相駆動超音波リニアモータ

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1.Introduction

For high torque ultrasonic motor (USM), it has been reported USMs with the V-shaped linked structures applied BLTs or multi-layered piezo-actuators.[1-2) The authors replaced the excitation part with square plates to obtain the structure of low-height and miniaturization, and the previous paper described its basic design and characteristics of a prototype of rotary type USM.[3)]

In this report, we applied the linked twin square plates to a linear motor, and the experimental characteristics were described.

2.Operation and structure

Figure 1 shows operation principle of the motor. When the half side of the square plate vibrates the breathing mode and another half side plate, called passive side, does not markedly vibrate, the top end of V-link vibrates in the slant direction and a pressed slider is moved by the frictional force.

The operation can be obtained by an effective elastic difference of the driving side and the passive side plates when the passive side is electronically opened as shown in **Fig.2**. Therefore, this linear USM is driven by the single-phase, and the slider motion in reverse direction is obtained by switching the driving terminal.

Figure 3 shows dimensions of the prototype structure that is designed using finite element method analysis.[3)] The linked plate is made by brass and bonded four piezo-ceramic square plates with an epoxy. The piezo-ceramic is C213 of Fuji Ceramic. The metal plate is grounded electrically. The z-surfaces of ceramic plates have electrodes, and the poling directions are directed to the outer electrode surface. The centers of both square plates are the node of breathing mode, and are used for the fixing with M2-screw; therefore, the ceramic plates are perforated to avoid the screw. One side of the top end of V-link is slit up and bonded an alumina rectangular chip as the friction material. The moving slider is BSP1560SL of Nippon Tompson Co., Ltd, of which travel range is 30mm. On the contact surface of the slider, ALTIC friction plate of 30×5×1mm^3 is bonded with an epoxy.

3.Experimental results

As a static characteristics without electrical power

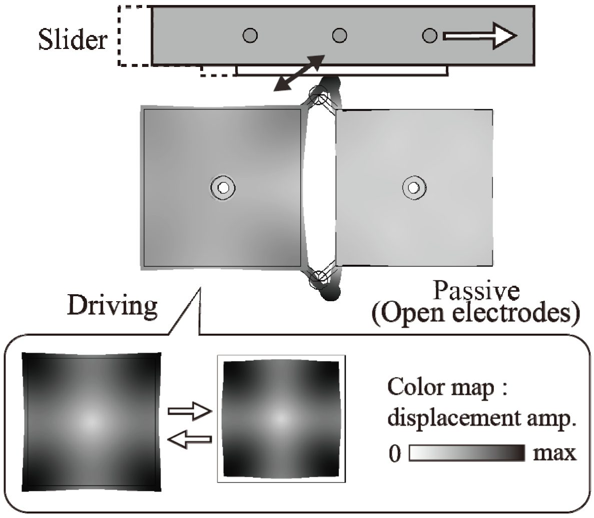

Fig.1 Fundamental operation of single-phase USM using breathing vibration mode.

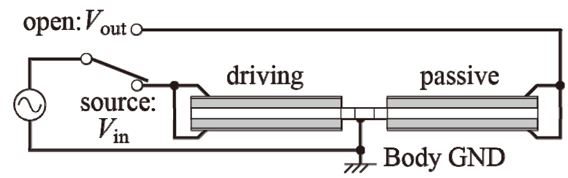

Fig.2 Driving method of the single-phase USM.

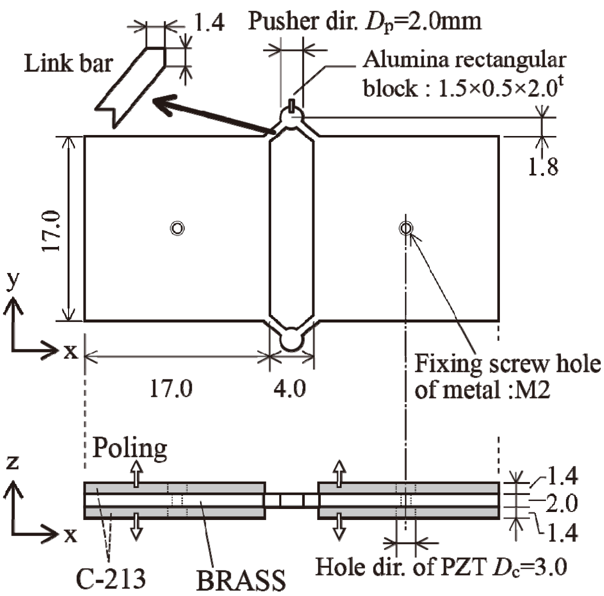

Fig.3 Experimental model of stator vibrator consists of a linked twin square metal plate and four piezoceramic square plates.

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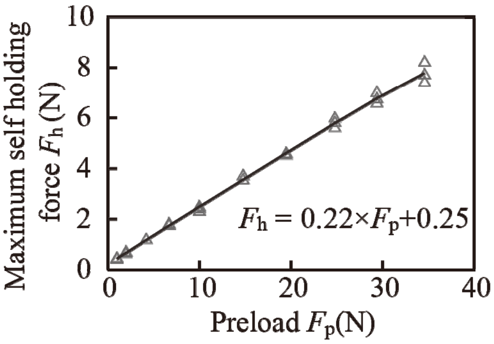

Fig.4 Characteristic of holding force vs. preload.

input, the maximum holding force as a function of the preload is shown in **Fig.4**. Static friction coefficient is estimated 0.22.

The velocity of slider and the thrust force of the USM are estimated from the measurement of transient response by applying burst voltage as shown in **Fig.5**. In this measurement, the driving voltage of 5,000 cycles is applied. The voltage and current waves are digitized, and those envelope curves are converted by Hilbert transformation to obtain the effective amplitudes $|V_{in}|$ and $|I_{in}|$. Simultaneously, moving displacement of the slider u is measured by laser displacement sensor (KEYENCE LK-G155), and its output signal is digitized. The velocity of slider v is calculated from a differentiation of the displacement.

When the voltage of $5.5V_{rms}$ is applied with the preload of 8N, non-loading characteristic is shown in **Fig.6**. The current rises immediately, and the velocity reaches steady state of 350mm/s after 19ms.

To measure the load characteristics as shown in **Fig.7**, the motor pulls up a weight of mass m against the gravitational acceleration g, and the thrust force is $m \cdot g$ N. The no-load velocity and input electric power are proportional to the driving voltage. However, the zero-speed thrusts are limited about 1.1N in each applied voltage, and the value is a half of the maximum holding force.

Additionally, we confirmed the moving operation in both directions by the switching drive-terminal.

4.Conclusions

We applied the linked twin square plates type stator vibrator to a linear USM, and measured the load characteristics. The motor can move the linear slider and be driven by low voltages of under $5.5V_{rms}$. When the preload is 8N and $|V_{in}|=3.8V_{rms}$, the motor provides no-load-velocity of 200mm/s and 1.1N of the maximum thrust force.

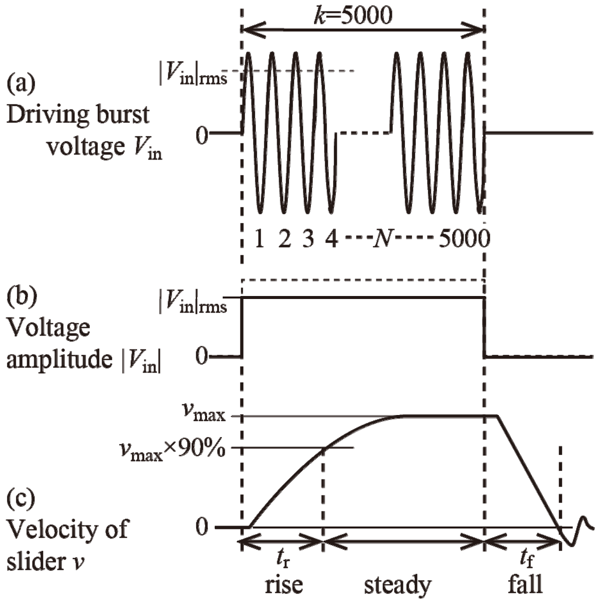

Fig.5 Definition of the burst voltage waveform (a), envelope of voltage (b), and slider velocity (c).

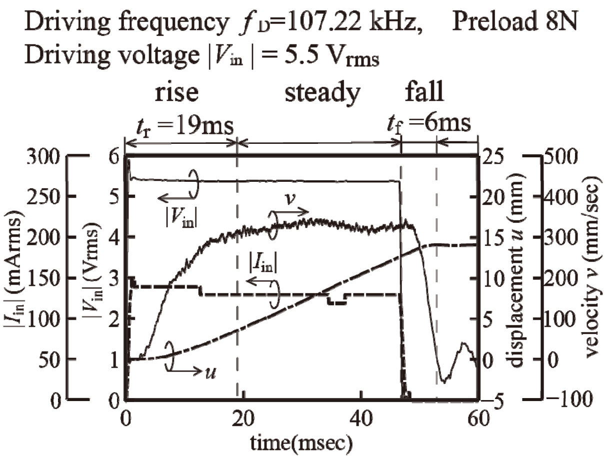

Fig.6 Transient response of USM without mechanical load when the preload of 8N is applied.

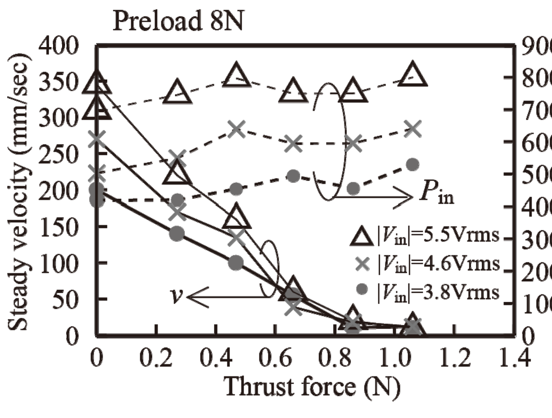

Fig.7 Moving speed and the driving power vs. thrust force with preload of 8N.

References

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