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Experiment Evaluation of Velocity Control in Linear Ultrasonic Motor Using a Link Twin Square Plate Vibrator

双正方板リンク形振動子を用いたリニア超音波モータにおける速度制御の実験評価

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1. Introduction

The single-phase drive ultrasonic motor (USM) using a linked twin square plate vibrator as shown in **Fig. 1** was proposed[1)]. When applying the driving voltage $V_D = V_A - V_C$ with a vicinity of the resonant frequency, the left side square plate vibrates with the breathing mode; and the top end of the V-link vibrates in the slant direction and a pressed slider is moved to the right direction. The moving in the opposite direction is obtained by switching the applied voltage terminal to V_B from V_A.

In this report, to control the slider average speed, we tried an intermittent drive using a ON-OFF gate signal which has a variable duty cycle. In the intermittent driving, time variations of the slider displacement were step-like. The average velocity of the slider was changed by the duty cycle; however, its relation was non-linear. Additionally, the remarkable audible noise occurred.

2. Experimental setup

The slider is pressed to the stator vibrator with 10N of the preload. In this experiment, the reverse operation driven by right side square plate is omitted.

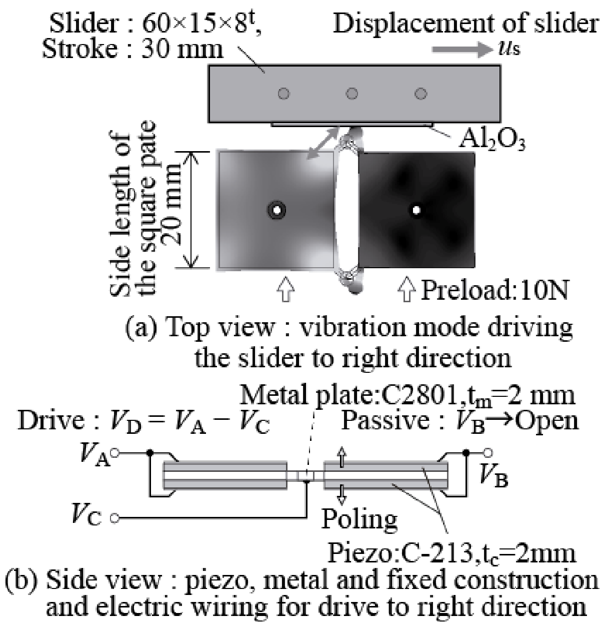


Fig.1 Structure and operation of the single-phase driven linear USM.

The driving signal is synthesized as shown in **Fig. 2**, and its signal is applied to the H-bridge circuit. The signal is based on the continuous wave of the frequency f_D = 91.65 kHz when the phase of the input admittance of the vibrator is nearly −15°. The continuous signal is limited at 5000 cycles to restrict the maximum slider stroke. Thus, the driving time is 55 ms. The gate-signal is changed its periodic time T_G (5, 8, 10.9, 16.4 ms) and duty cycle D (20 – 100%), and is applied to shut-down function of the FET-driver IC (IR2302). When the gate-signal is ON, the driving voltage V_D and input current waveforms are shown in **Fig. 3**.

The moving displacement of the slider u_s is measured using a laser displacement sensor (Keyence LK-G155), and the instantaneous velocity v_s is derived by the differentiation of the u_s.

The instantaneous sound pressure waveform P_{LA} as an audible noise is measured using a sound-level

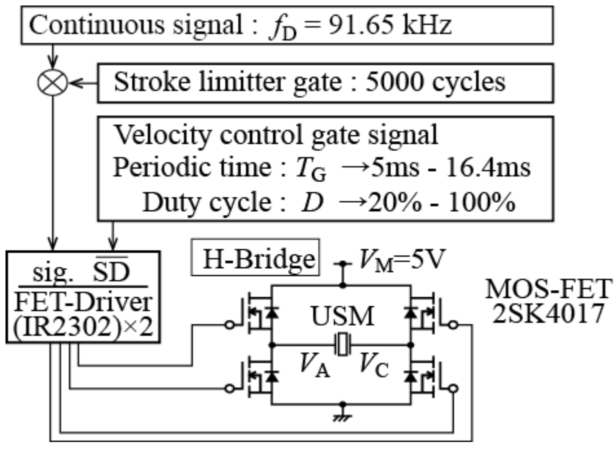


Fig.2 Driving signal synthesis and driver.

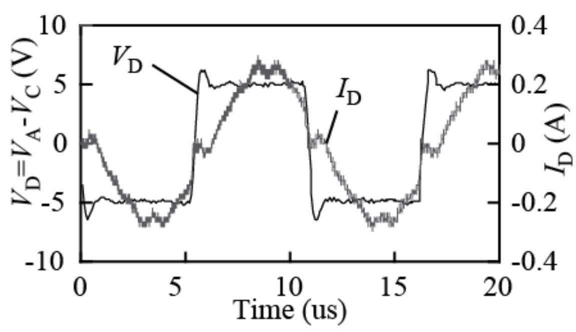


Fig.3 Driving wave form.

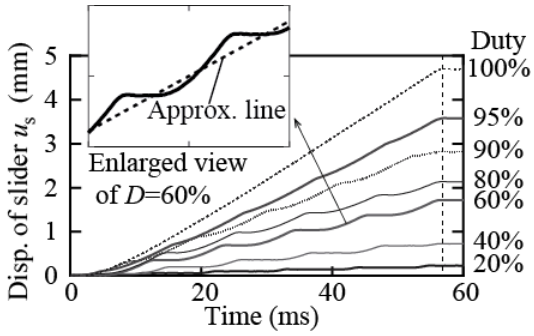


Fig.4 Displacement of the slider driven with T_G = 10.9 ms.

meter (Ono Sokki LA-5111) with the frequency correction of the A-weighting to consider a human auditory sensitivity. The microphone of the meter is positioned in 22 mm distance from the USM.

3. Experimental results

Figure 4 shows the time variation of the slider displacement u_s when the gate-period T_G is 10.9 ms. Except for D=100%, the slider displacements show stop-and-go time history.

However, if we regard the gradient of linear approximation of the displacement as an average velocity of the slider, the average velocity v_{avg} can be controlled by the duty cycle D as shown in **Fig.4**. The relationships between the v_{avg} and the D are not linear; however, the variable range of the v_{avg} is wide.

The smaller the T_G, the smaller the linearity; because the influence of the nonlinear characteristics in the rise time becomes large.

Figure 5 shows time variations of the v_s and the P_{LA}. After the falling edge of the gate-signal, the sound pressure amplitude becomes large as shown in Fig. 5(b). However, after the 5000 cycles driving when the D=100% as shown in Fig. 5(a), the sound pressure is not notably large.

The state of the H-bridge circuit is different between the 5000 cycles end in D=100% and the low-gate-time. When the low-gate-time, the USM is electrically opened by the shut-down function of the FET driver. On the other, after the driving in D=100%, the electrical drive terminals are equivalently shorted.

4. Conclusions

The intermittent square wave voltage causes the step-like displacement of the slider. The average velocity of the slider is changed by the duty cycle D of the gate-signal. When D=20%, the obtained minimum average velocity was 1.5% of the maximum velocity.

Hereafter, to obtain the electrically shorted condition even when under the gate-off-time, it is necessary to modify the driving circuit.

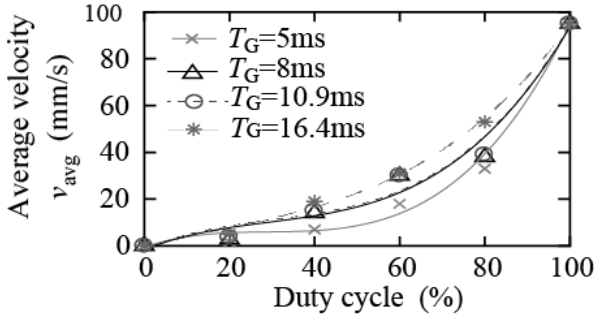
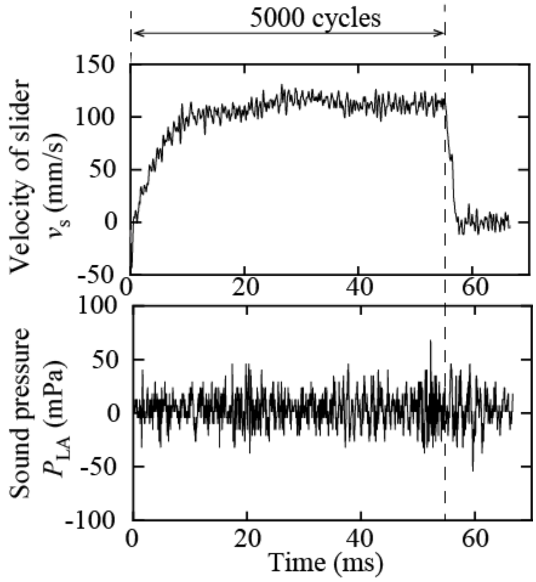
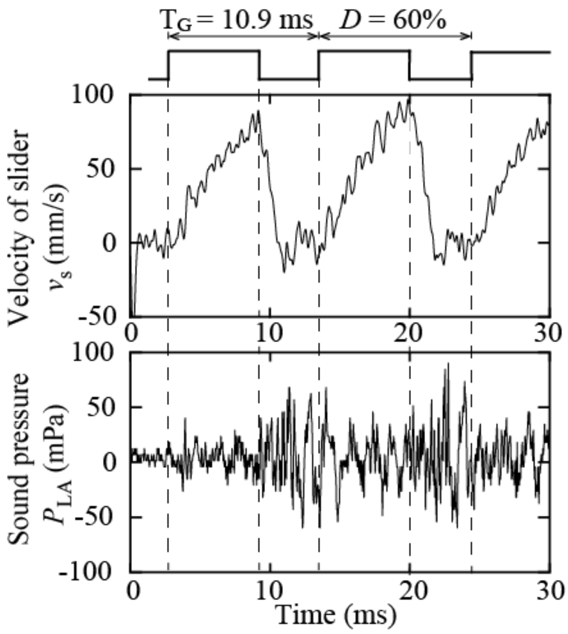


Fig.5 Average velocity characteristics.



(a) D=100%, entire time domain.



(b) D=60%, time domain of the beginning.

Fig.6 Velocity of the slider and sound pressure waveforms with T_G = 10.9 ms.

References

1. K. Yokoyama , *et al.*: Jpn J. Appl. Phys. Vol52, No7, 07HE03 (2013)