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Experiment Evaluation of Switching Drive Method Linked-Twin-Square –USM for Servo-positioning Control

双正方板リンク形 USM の位置サーボ制御のための スイッチング駆動方式の実験評価

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1 Introduction

The single-phase drive ultrasonic motor (USM) using a linked twin square plate vibrator was proposed. **Figure 1** shows the USM operation principle, when the slider moves to the right direction. Only left-side square plate vibrates with the breathing resonant mode, and the top end of V-link vibrates in the slant direction and pressed slider is moved. On the other hand, driving only right-side square plate causes moving the slider to the left direction. In both driving operation, piezo-electric terminal of the non-driving square plate must be opened to use the depolarizing-field effect. [1]

For using as a servo-motor, the moving-direction is many times inverted around the target position until the settling time. When the moving direction is inverted, in spite of the switching the driven plate side of the stator, the slider continues moving in the original direction for a while as an invert loss time.

In this study, we tried to reduce the invert loss time. We confirmed that inserting a vibration stop operation between the direction inverting is effective. Additionally, when the stop operation, treatment of the electric terminals of the stator resonator also contribute to reduce the slip of the moving slider.

2 Operation modes

Figure 2 shows the construction and electric terminals of the stator resonator. To move the slider for right direction, square pulse voltage of $7.2V_{p\text{-}p}$ with f_{DR}=107.26kHz was applied to the electric terminals between the Terminal-A and Common, and the Terminal-B was electrically opened. It is defined as the operation mode D_R in the **Table I**. Reversely, the slider was moved for left direction by using the operation mode D_L with f_{DL}=109.25kHz. The difference of the driving frequency is caused by the structure error of the stator resonator.

When the stop operation, the electric terminals-A and -B are electrically shorted or opened. The definition of the operation modes S_{nm} and these terminals conditions are shown in Table I.

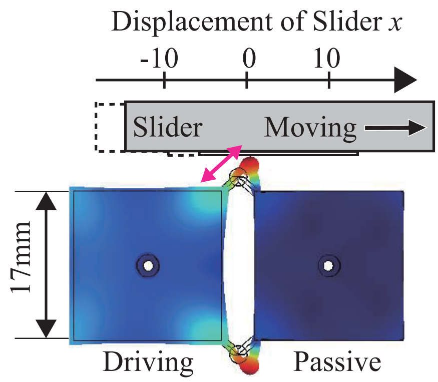

Fig.1 Top-view of the USM operation principle when the left-square plate was driven to move the slider to right direction.

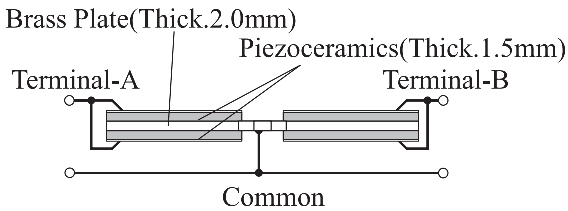

Fig.2 Side-view of the stator resonator construction and the electric terminals.

Table I Usage of the electrical terminals for the USM-operations.

Operation	Terminal-A	Terminal-B	Mode
Drive for Right	Apply-f_{DR}	Open	D_R
Drive for Left	Open	Apply-f_{DL}	D_L
Stop	Short	Open	S_{SO}
Stop	Open	Open	S_{OO}
Stop	Short	Short	S_{SS}
Stop	Open	Short	S_{OS}

The driving pulse voltage was applied by H-bridge switching driver. And the terminal-open was realized by the high impedance function of the H-bridge driver.[2] The H-bridge driver to set the operation modes was controlled by FPGA.

3 Experimental results

3.1 Transient response after the driving stop

At first, transient response of the slider displacement after the driving stop was measured. The slider displacement x was measured using a laser displacement sensor CD-33-120NV(OPTEX FA).

Figure 3 shows the result; the slider was stopping at the beginning, and the stator resonator was driven 40ms with mode D_R, after that the operation mode was shifted to the stop mode. After the driving stop, the slider slipped in the slipping time t_s with the slipping displacement x_s.

As a result, when using the stop mode S_{SS} as shown in Fig. 3(c), t_s and x_s are minimized.

3.2 The invert loss time with simple driving

Next, the invert loss time t_i was measured using the simple inverted driving method. To invert the direction of the slider continually, the operation mode D_R and D_L were repeated every 40ms. **Figure 4** shows the time variation chart of the slider displacement x.

The invert loss time t_i from the moment of changing operation-mode to the moment of the actually inverting the slider was obtained about 7.36-7.46ms. And the displacement x_i that occurred during t_i was about 2.88mm.

3.3 The method inserting a vibration stop operation

The slipping time t_s using the stop mode S_{SS} as shown in Fig. 3(c) is shorter than the invert loss time t_i using the simple inverted method as shown in Fig.4.

Therefore, to reduce the invert loss time, the stop operation S_{SS} is inserted between the inverted driving mode. The experimental result is shown in **Fig. 5**. The driving mode times were applied 36ms and the time of the stop mode S_{SS} were applied 4ms. Like the result of Fig. 3(c), the slider stopped after a driving stop in about 3.9ms.

4 Conclusion

For the servo-motion using the linked twin square plate type USM, we tried to reduce the invert loss time. It was confirmed experimentally that the introducing the stop mode between the inverted driving mode causes the improved invert loss time. Using the stop mode with both the electric terminals shorted, the minimized invert loss time of 4ms was obtained.

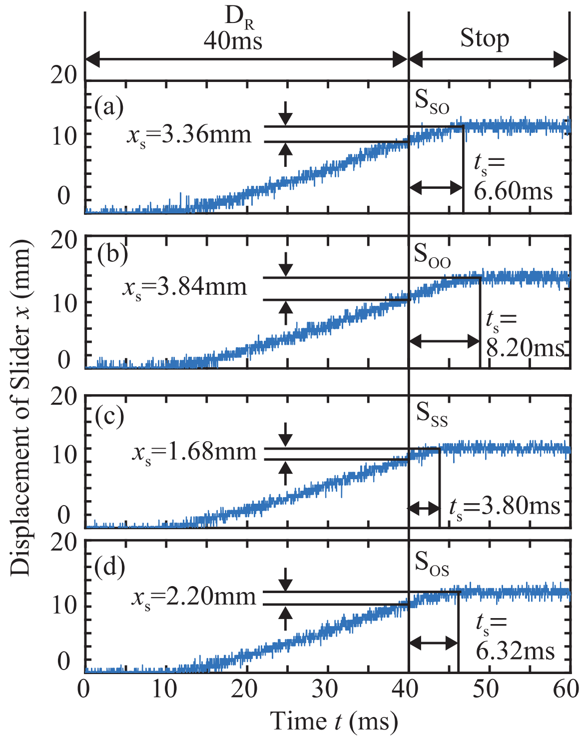

Fig.3 Transient response of the slider displacement.

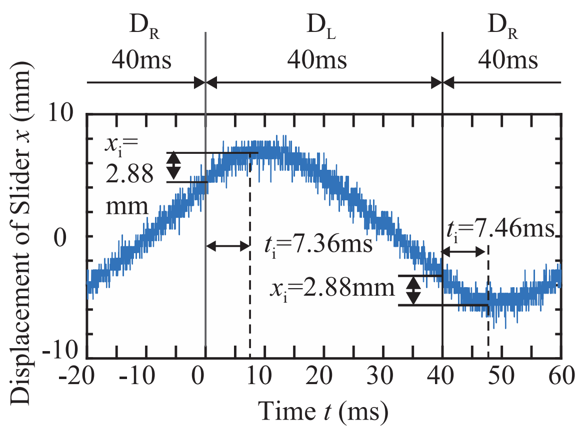

Fig.4 Slider disp. using the simple inverted method.

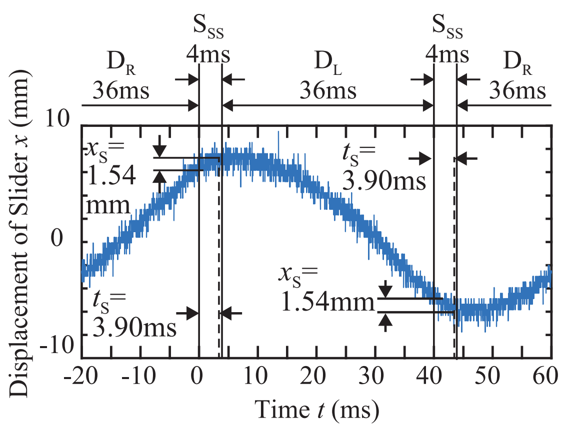

Fig.5 Slider disp. with inserting the stop operation.

Reference

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