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Improvements of Controllability in Ultrasonic Linear Motors Using Longitudinal-Bending Multilayered Transducer with Independent Electrodes and Their Applications to Mirror Holders

独立励振積層振動子を用いた超音波リニアモータの制御性向上とミラーホルダへの応用

Masahiro Takano[1‡], Kenichi Hirosaki[1], Mikio Takimoto[2], Satoru Ichimura[3], Kentaro Nakamura[4]
([1]Industrial Research Institute of Ishikawa, [2]Nikko Company, [3]Sigma Koki Co., Ltd, [4]Tokyo Inst. of Tech.)
高野 昌宏 [1‡], 廣崎 憲一 [1], 滝本 幹夫 [2], 市村 悟 [3], 中村健太郎 [4]([1]石川工試; [2]ニッコー, [3]シグマ光機, [4]東工大)

1. Introduction

Ultrasonic linear motors have the advanced characteristics such as small in size, high resolution and large holding torque for actuators of optical system. However, the nonlinearity in the speed-voltage characteristics arouses problems for precise control. Various types of control methods have been proposed to eliminate the nonlinearity[1-3]. The nonlinearity is related to the shape of vibration locus at the friction head of the transducer. For the low speed region, the vibraiton component in the preloading direction for the frictional force controll declines as the vibration component in the feeding direction used as driving force. This causes the dead zone and the nonlinearity. To improve the linearity and apply ultrasonic motors to optical system, we proposed a multilayered rectangular plate transducer with independent electrode structure for the 1st longitudinal mode and the 2nd bending mode. In this report, we described the controllability of this motor and the applications to mirror holders.

2. Basic configuration

Figure 1 shows the configuration of the motor. A friction head is bonded on the end of the transducer, and is in contact with the slider or rotor surface. The vibration component in the normal direction is produced by the 1st longitudinal mode (L1-mode) and that in feeding direction is produced by the 2nd bending mode (B2-mode) as shown in Fig. 2. Fig. 3 shows the independent electrode structure for the L1-mode and the B2-mode. A cross-shaped electrode is located in the center (L1-electrode) to excite only the L1-mode, while four ones are located in the corners (B2-electrode) to excite only the B2-mode. Therefore, we can controll the amplitude and phase of each vibration component in preloading and feeding direction independently. The transducer consists of 24-laminated layeres of thin piezolectric ceramics in order to enable us a low-voltage drive. The inner electrode pattern has the same shape among all piezoelectric layers except for small area for connecting to the outer electrodes.

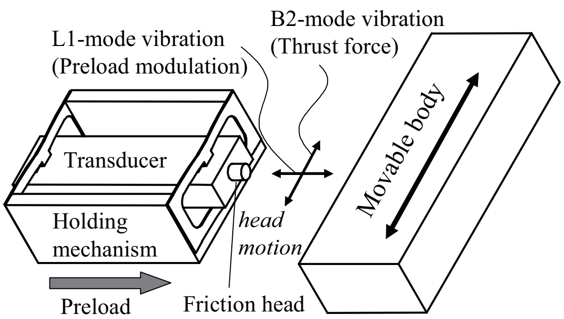


Fig. 1 Basic configuration of the motor.

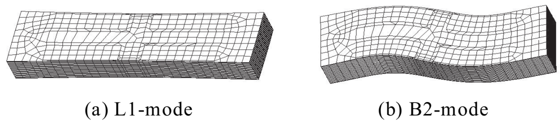


Fig. 2 Mode shapes calculated using finite element analysis.

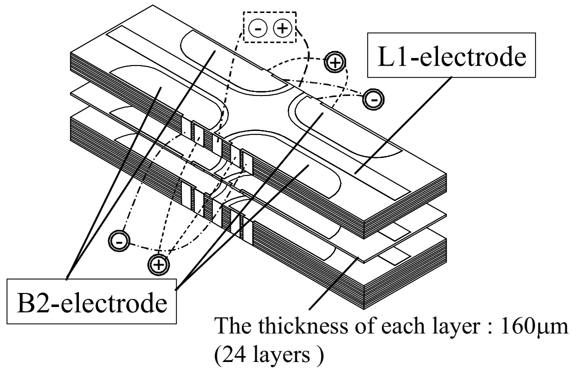


Fig. 3 Independent electrode structure

3. Controllability

Speed characteristics of the motor were measured as functions of the B2-electrode volatages as shown in Fig. 4. The pressing force to the slider was about 40 N. The driving frequency and the phase difference between the L1-electrode and

B2-electrode were 56.5 kHz and 90°. When the L1-electrode voltage was fixed to 16 $V_{0\text{-}p}$, the speed characteristics showed good linearity and no dead-zone. On the other hand, when the L1-electorode voltage was equal to the B2-electrode voltage as like in conventional ultrasonic motors, the speed-voltage courve showed nonlinear characteristics and deadzone. The results suggest that the linearity in the speed-voltage characteristics subject to the vibration amplitude of the L1-mode. Fig. 5 shows the speed response to the sinusoidal change in the amplitude of the B2-electrode voltage. Since the L1-electrode voltage was fixed to 16 $V_{0\text{-}p}$, the speed response showed a sinsoidal shape as same as the B2-electrode voltage. In the case of the drive B where the L1-electrode voltage was changed in proportion to the B2-electrode voltage, the speed did not follow the applied voltage amplitude. From these results, we confirm that the proposed motor has better controllability if the L1-electrode voltage is kept at proper value.

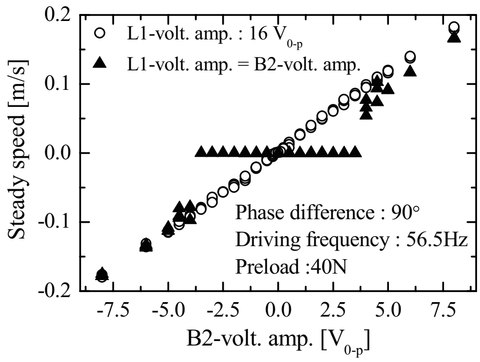


Fig. 4 Speed-voltage characteristics. Negative voltage means the phase difference of 180 degrees.

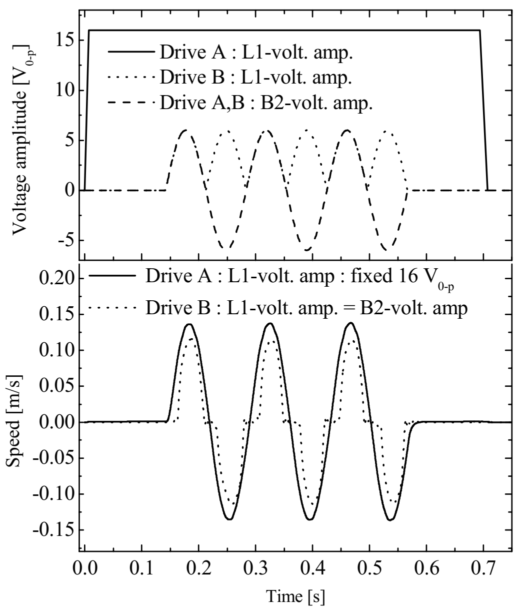
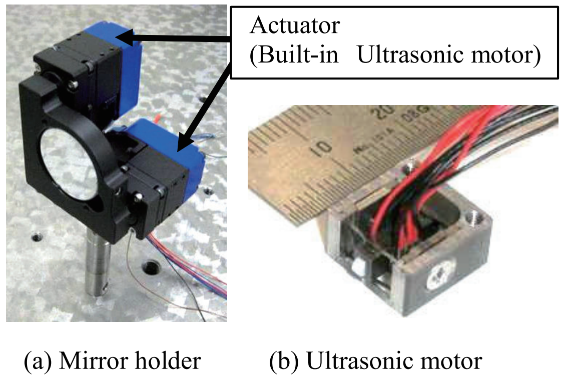


Fig. 5 Speed response to B2-electrode voltage of sinusoidal-wave. Negative voltage means the phase difference of 180 degrees.



(a) Mirror holder (b) Ultrasonic motor

Fig. 6 Trial mirror holder using the ultrasonic motor

4. Applications to mirror holders

A mirror holder actuator was developped using the proposed motor. Fig. 6 shows the mirror holder and the ultrasonic motor unit. The ultrasonic motor was made smaller than 15 mm. The mirror holder is the apparatus which adjusts the angle of mirror to deflect laser light in the optical system and suitable for use of ultrasonic motor. As compared with a holder using conventional electro-magnetic motors, the length is one third, and the position resolution is improved 5 times.

5. Conclusions

We proposed an ultrasonic linear motor using longitudinal-bending multilayered transducer with independent electrodes. The trial motor showed good controllability without dead-zone. A mirror holder actuator using the proposed motor was developed and showed good performance.

Acknowledgment
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