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Proceedings of Symposium on Ultrasonic Electronics, Vol. 34 (2013) pp. 437-438
20-22 November, 2013

Investigation of SAW Motor Output Power and Efficiency
弾性表面波モータの機械出力と効率

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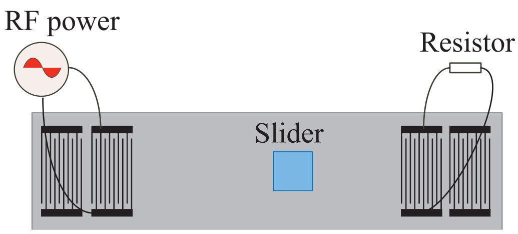
1. Introduction

We are investigating high speed and high power density linear motor using traveling wave of Rayleigh wave[1)-5)]. Estimation of conversion power from electrical input to generated wave power and mechanical motor output of the surface acoustic wave (SAW) motor was carried out. The motor efficiency from the electric driving power to the motor output power was 11 % without energy circulation. In case of energy circulation, the motor efficiency was estimated to be 15%. As for a traveling wave linear motor, the efficiency more than 10 % is much better result than ever.

2. SAW Device for Stator

A stator device was 90x13x1 mm^3 lithium niobate 128-degree-rotated-y x-propagation substrate Rayleigh wave SAW element. Two sets of IDT with reflector IDT were alocated at both end of the LN plate. In case one IDT was driven by an RF electrical source, the other IDT absorbed the propagating wave at impedance matching condition to avoid the generation of standing wave as shown in Fig. 1. The driving frequency was 9.61 MHz to generate the Rayleigh wave. The standing wave ratio was 1.2 at the condition of 68 Ω termination as shown in Fig. 2. By being tuned the space between the receiving IDT and the reflector IDT, a matching inductor for a damped capacitor of the IDT could be omitted.



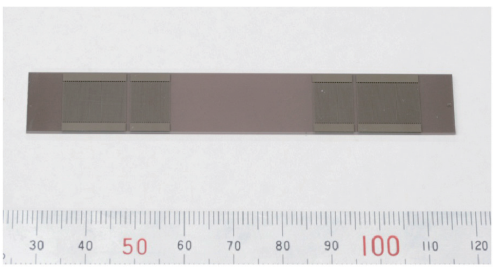
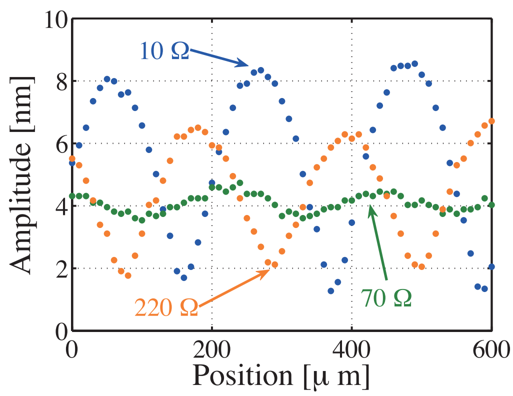


Fig. 1 Stator SAW device; electrode and connection (upper), and photo (lower).

3. Silicon Slider and performances of motor

Sliders made of silicon were used. The dimensions of the sliders were 5x5, 5x10 and 10x10 mm^2. The friction driven surface was surface machined with dry etching process to fabricate a lot of circular projections in order to contact with the waving stator surface. The projection diameter was 5 micron and the interval was 10 micron. The total number of the projections was 160,000 in 4x4 mm^2 area. The contact surface of the Si sliders was coated with SiC.

At the driving voltage of 60 V_{rms}, motor



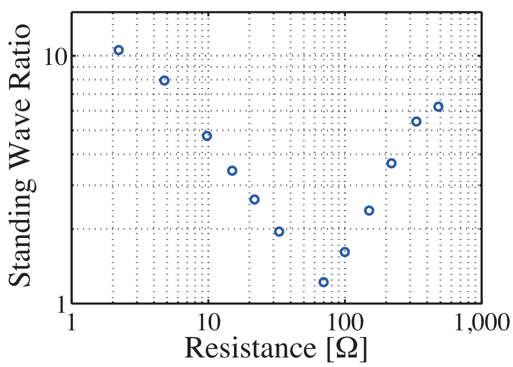


Fig. 2 Distribution of vibration amplitude (upper) and standing wave ration (lower)

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performances were measured. From the transient response of the motor, the no-load speed and output force were estimated for three sliders as shown in Fig. 3. Larger sliders had higher output force, but they were not in proportion to the slider contact area. This is because the distribution of the preload in the contact area. Uniform preload of the large contact area is difficult. However, 5x10 mm^2 slider was better performances than that of 5x5 mm^2 slider in speed and force at the same preload condition as can be seen from Fig. 3. Estimation of the efficiency was carried out with 5x10 mm^2 slider.

4. Mechanical Output Power and Efficiency

At the driving voltage of 40 V_{rms}, namely, the driving power of 19 W, and the various preload conditions, the motor performance was measured. The motor performance measurements were carried out from the transient responses of the motor. From the measurement, the efficiency of the motor was estimated as shown in Fig. 4.

When the preload was 40 N. the no-load speed and maximum output force of the motor were 0.55 m/s and 15 N. Then the maximum mechanical output power and the efficiency were 2.1 W and 11 %. In addition, if the circulated power of 4 W at the matching resister was taken into account for recyclable power, the efficiency was estimated to be 15 %.

5. Conclusion

The mass of the SAW device was only 5.5 g for the maximum output force of 15 N, no-load speed of 0.55 m/s and the maximum mechanical output power of 2.1 W. The efficiency was improved up to 11 %. The superior performance of the SAW traveling wave linear motor has been demonstrated successfully.

Acknowledgment

This work was supported by Grant-in-Aid for Scientific Research (B).

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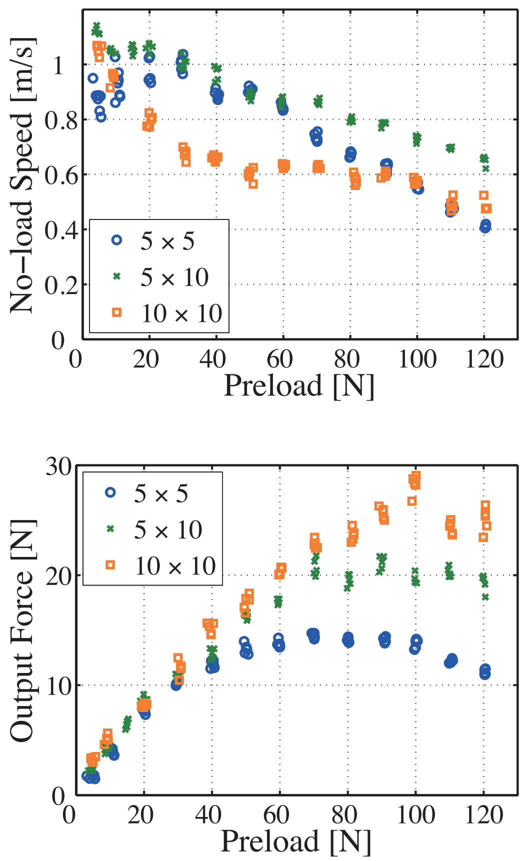

Fig. 3 Difference in motor performance by slider size at driving voltage of 60 V_{rms}; no-load speed (upper) and output force (lower).

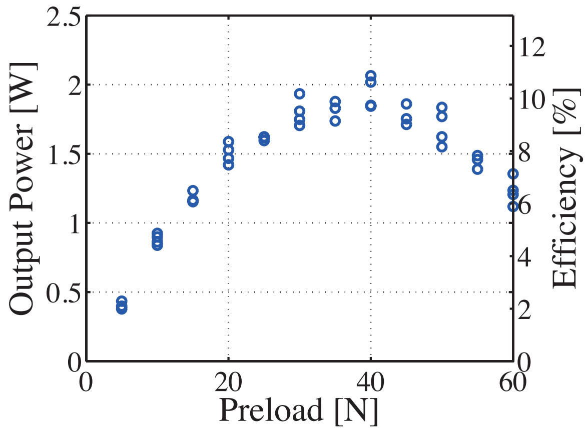

Fig. 4 Maximum output mechanical power and efficiency with change in preload; driving voltage of 40 V_{rms}, and 5x10 mm^2 slider.