Application of Surface Acoustic Wave Device to High Performance Linear Motor


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We have proposed to utilize a surface acoustic wave (SAW) devices for ultrasonic motors and demonstrated its possibility. A multi contact type slider using a silicon slider whose contact surface is micro machined have been proposed. Diameter and density of projections fabricated on silicon sliders were examined experimentally. Importance of elastic deformation control to obtain large output force with a surface acoustic wave motor is discussed in this paper. By adding pre-load to slider, stator and slider surfaces are deformed a few tens nano meter. Appropriate deformation in normal direction against normal vibration displacement amplitude of surface acoustic wave existed. By moderate deformation, the output force of the surface acoustic wave motor was enlarged up to about 10 N and no-load speed was 0.7 m/sec. By energy circulation drive, the efficiency was improved. Nano meter order step motion of this motor is also investigated. Stability 8 nm motion is already accomplished. Possibility of sub nano step motion is discussed.

POINT OF DISCUSSION

A schematic view of the surface acoustic wave motor[1] is illustrated in Fig. 1. RF electrical power (9.6 MHz) is transduced to elastic wave. The Rayleigh wave is excited at the interdigital transducer (IDT) with piezoelectric effect. By traveling wave propagation, the surface particles of the SAW device move in elliptical motion. Since the amplitude of the elliptical motion is 10 nm order, the contact condition of the slider is very critical. To control the contact condition, namely, the elastic deformation of the slider and the stator surface in nano meter order, a lot of projections are fabricated on a slider surface as shown in Fig. 2. The projection diameter was 20 mm.

In static condition, the elastic deformation and stress were evaluated with Hertz contact model in case of a single steel ball slider [2]. From this calculation and the simulation result [3], the friction drive mechanism of surface acoustic wave is illustrated as shown in Fig. 3. The wave crest is distorted, hence the elasticity has influence on the friction drive condition[4, 5].

Elastic deformation of the stator surface beneath the projection from the initial position were evaluated with the FEM at static condition. The maximum depression changed in proportion to the pre-load and contact pressure. In 4x4 mm² square area, the sliders had projections from 1089 to 23409. Depression value of the stator surface were 30 nm to 50 nm against 100 N pre-load.

DRIVING PERFORMANCE

Mechanical output of the motor such as no-load speed and output force were measured at the driving voltage of 125 V. At this condition, the vibration amplitude in normal to the stator surface was 21 nm. The vibration velocity of horizontal direction was 1.1 m/sec. The pre-load was changed up to 110 N. Hence, the maximum depression was changed up to about 2 times of the vibration amplitude.
No-load speed were plotted against the ratio of the maximum depression to the vibration displacement amplitude as shown in Fig. 9. No-load speed decreases with increase of the maximum depression, namely, increase of the pre-load. At low pre-load condition below the ratio of 0.5, the speed saturated. The maximum speed was 88% of the vibration velocity using 23409 projections slider.

The output force depended on the depression in spite of the projection density were different as shown in Fig. 10. The maximum output force was obtained when the maximum depression was from 1.0 to 1.5. This phenomenon was followed by different vibration amplitude. The maximum output force was 10 N when the highest projection density slider was tested.

Different diameter size sliders were tested. The diameters were from 5 mm to 50 mm. These sliders showed similar characteristics as 20 mm diameter sliders. Namely, the maximum output force was obtained when the maximum depression was almost same as vibration amplitude.

We also measured the stepping motion of the motor. When we drove 40 burst waves, the stepping displacement was about 8 nm as shown in Fig. 6. The driving time was only 4 µs. Much fine steps was available, but due to measurement technical matter, the sum nano motion steps has not confirmed yet.

**CONCLUSION**

The relation between the static elastic deformation by the pre-load and the mechanical output of the motor was examined. We found that the elastic deformation of the whole slider area have influence on the friction drive of the surface acoustic wave motor. We will improve the friction drive model to represent the experimental results discussed here. The stepping motion of 8 nm was measured.

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**REFERENCES**