Introduction

Recently, linear resonant actuators (LRA) have been used in a wide range of applications because they have a lot of advantages: high efficiency, simple structure, easy control, and so on, however, they have a problem that the amplitude severely decreases in response to an external load.

To control this, a feedback control is adopted where the back EMF of the coil is detected to control the current duty.

We propose the numerical analysis method for predicting dynamic characteristics of LRA with two movers under PWM feedback control employing the 3-D FEM. And, the effect of a link-spring on each mover motion is clarified when a single mover is operated with load.

Analysis method

### Motion analysis

This actuator is composed of two movers linked together by link-springs, and the motion equations and the spring forces are given as follows:

\[
M_1 \frac{d^2 z_1}{dt^2} + C_1 \frac{dz_1}{dt} + F_{kt1} = F_{t1}
\]

\[
M_2 \frac{d^2 z_2}{dt^2} + C_2 \frac{dz_2}{dt} + F_{kt2} = F_{t2}
\]

where:

- \(M_1, M_2\): The mass of movers
- \(z_1, z_2\): The displacement of movers
- \(F_{kt1, kt2}\): Trust
- \(F_{t1, t2}\): Spring force
- \(C_1, C_2\): Viscous damping coefficient
- \(k_m\): Main spring constant
- \(k_i\): Link-spring constant

### Effect of Link-Spring

Link-springs recover the amplitude by the motion of the other mover while the amplitude of one mover is decreased by an external load. The horizontal load of 0.4N is applied to a single mover under unloaded steady-state condition.

A decrease in the amplitude of the loaded mover is controlled, and an increase in the amplitude of unloaded mover is also well controlled.

Conclusions

We proposed the dynamic analysis method of a linear resonance actuator with multi-movers under PWM control employing the 3-D FEM. The effectiveness of this method was shown by the comparison with the measured results. Moreover, the effect of link-springs on amplitude control was clarified.