[PS1-62]

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Experimental Verification of Disturbance Compensation Control of Linear Resonant Actuator

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Introduction

Linear resonant actuator (LRAs) are actuators that reciprocate by alternating currents excitation.

○Simple structure, easy control, direct drive

◆ Problem

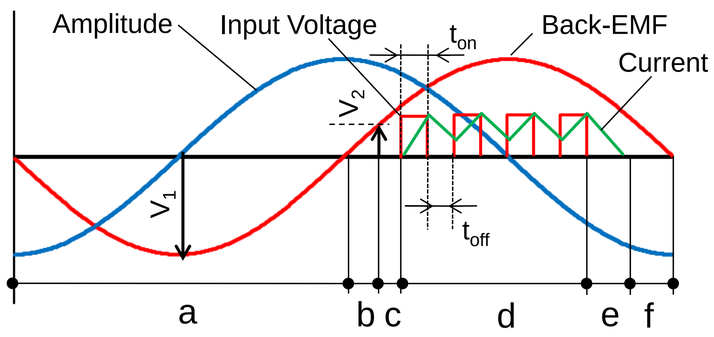
It takes much time until the amplitude of the LRA becomes steady state after it decreases once by external load.

◆ Purpose

- Propose a disturbance compensation control method which controls depression of the amplitude
- Propose a load device which is suitable to the actual LRA
- Verify the proposed control through measurements

Proposed Control

Load Estimation PWM Feedback Control



●Load estimation function

$$F' = \frac{K_a\{V_1 \exp(-\xi\pi) - K_v V_2\}}{2\{\exp(-\xi\pi)+1\}} K$$

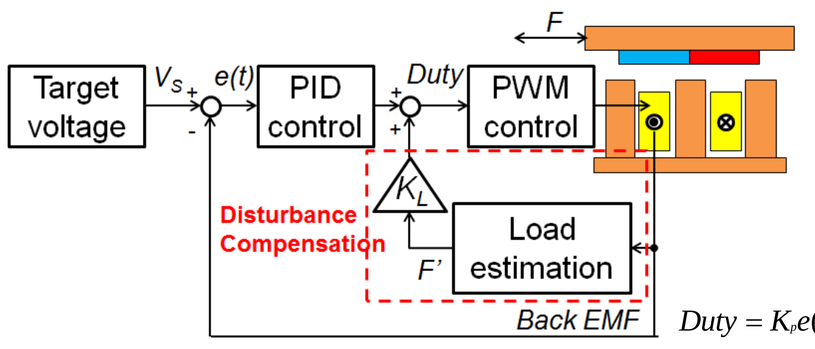
F' : estimated load

ξ : damping ratio

K_a , K_v : constants

Load estimation method uses two back-EMF signals: V_1 and V_2.

Disturbance Compensation Control

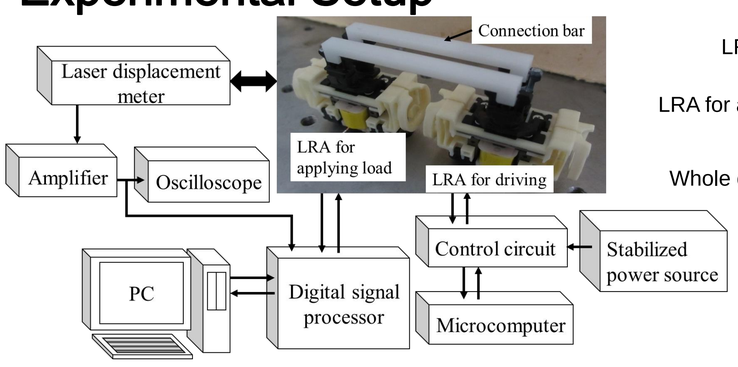


$$Duty = K_p e(t) + K_I \int e(t)dt + K_D \frac{de(t)}{dt} + K_L F'$$

Duty is determined by PID control and disturbance compensation control using estimated load.

Load Device Using Actual LRA

Experimental Setup



LRA for driving: $M\frac{d^2x}{dt^2} + C\frac{dx}{dt} + Kx = F_x$

LRA for applying load: $M\frac{d^2x}{dt^2} + C\frac{dx}{dt} + Kx = -F\,\mathrm{sgn}\left(\frac{dx}{dt}\right)$

Whole dynamic system:

$$M\frac{d^2x}{dt^2} + C\frac{dx}{dt} + Kx = \frac{1}{2}F_x - \frac{1}{2}F\,\mathrm{sgn}\left(\frac{dx}{dt}\right)$$

F_x : thrust

F : external load

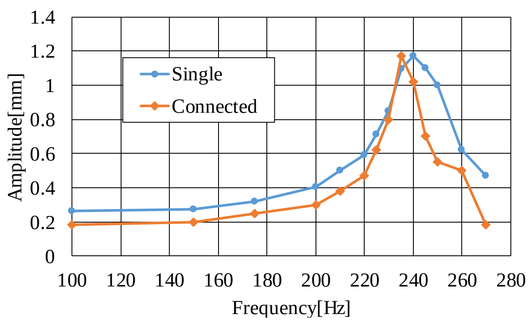
The same LRA is connected by rigid connection bars.
As the whole dynamic system, the thrust F_x and external load F are halved.
However, resonant frequency does not decrease.

●Current control method

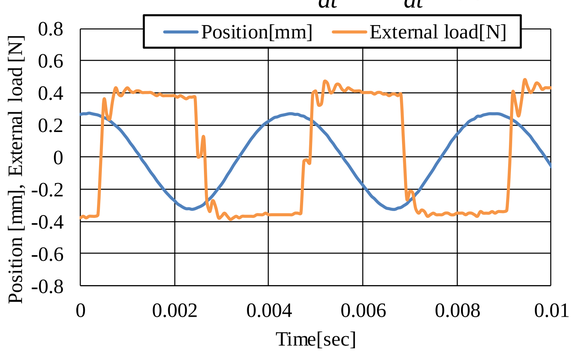
The target current is determined by equation (1).
DSP (Digital signal processor) calculates the input voltage as equation (2).

$$i = \frac{1}{K_t}F \quad (1)$$

$$V_{out} = Ri + L\frac{di}{dt} + K_e\frac{dx}{dt} \quad (2)$$



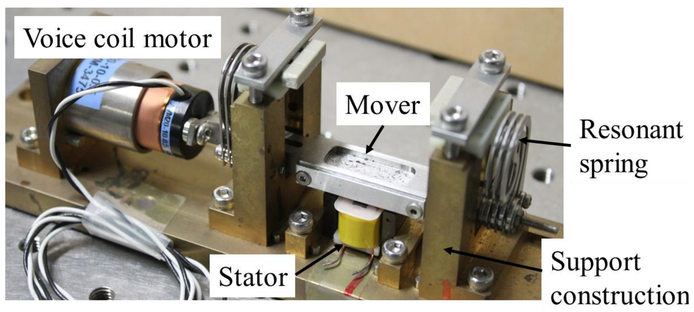
The frequency characteristics are measured.
As expected, there is little difference in resonant frequency between the single LRA and connected LRA.

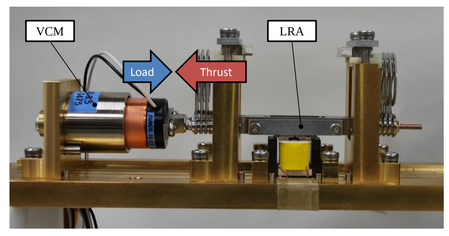


Dynamic characteristic is measured when external load is applied. The external load generated by current control is a little delayed.
However, the load is roughly synchronized to LRA's motion.

Experimental Verification Using Simple LRA

1-Mover LRA and VCM

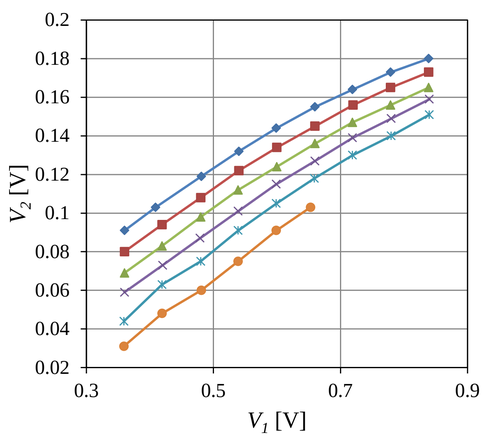




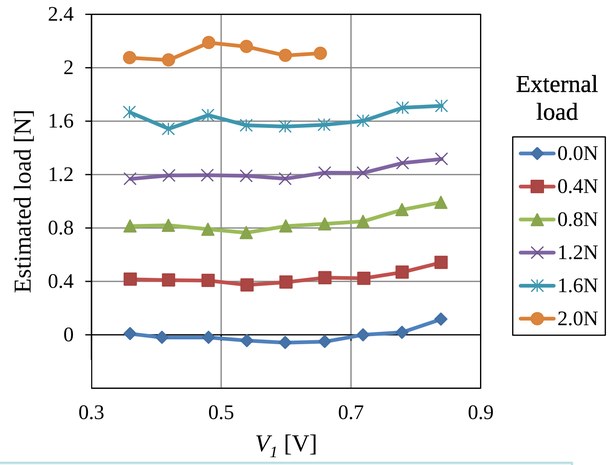
LRA and VCM are connected.
The external load is applied by VCM which is controlled to synchronize with the LRA's motion.

Load Estimation Results

Relationship between V1, V2, and external load

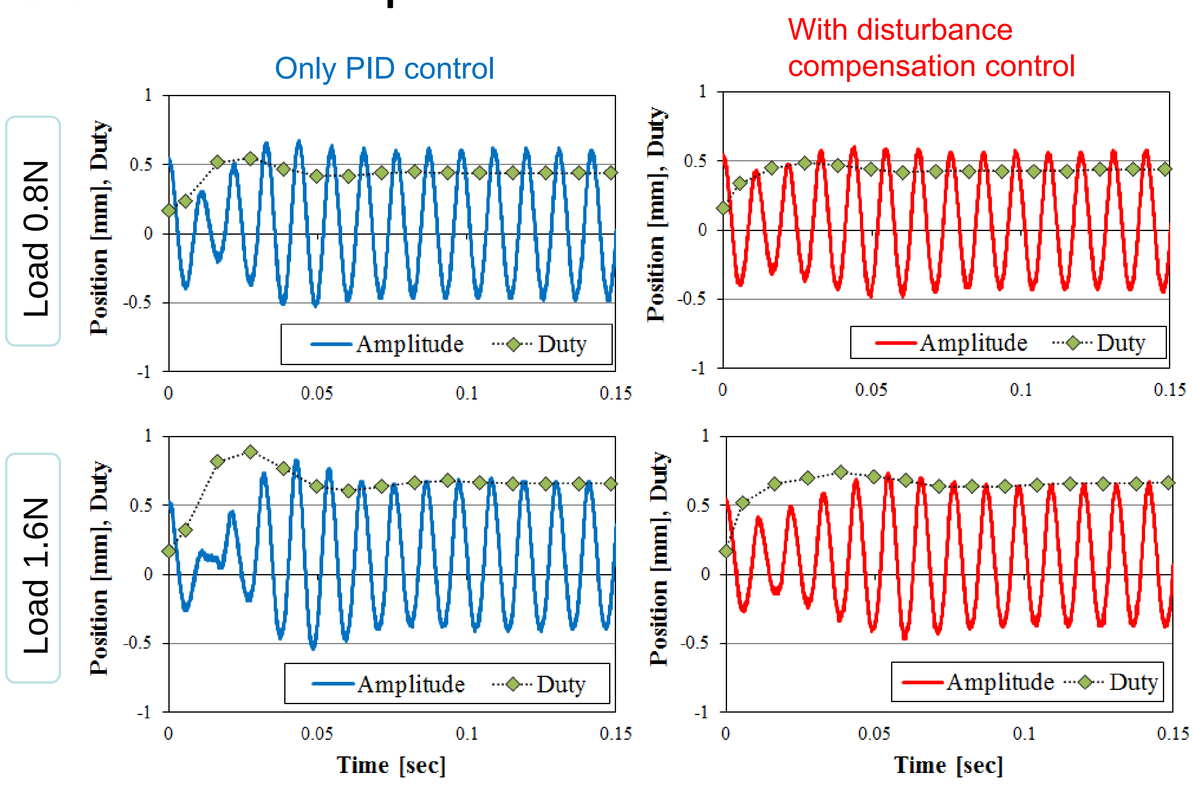


Estimated load



External load is estimated correctly without extra sensor.

Disturbance Compensation Control Results



Duty is increased quickly.
Decrease in amplitude is reduced by disturbance compensation control.

Conclusion

- We proposed a disturbance compensation control method which controls decrease in mover amplitude.
- We proposed a new load device which is suitable to the actual LRA.
- The effectiveness of the proposed control was confirmed to compare mover amplitude.

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