[KPA-15]
[BU-02]

Experimental Verification of Torque Ripple Suppression Method Using Coriolis Force Generated by Electromagnetic Oscillatory Actuator

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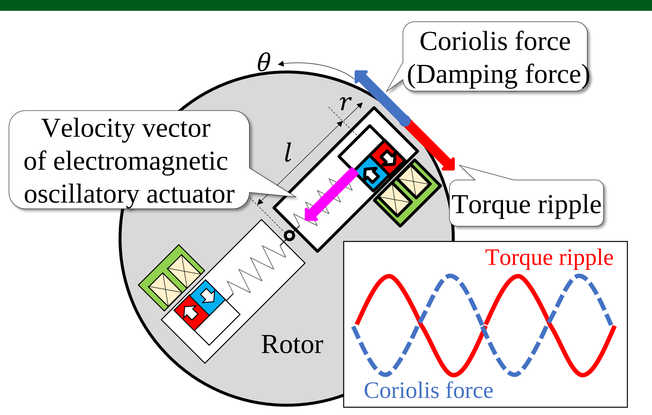
Introduction

- AC motors are used in various industrial and transportation equipment. Their intrinsic operational principle leads to inevitable torque ripples, resulting in noise and vibration.
- Authors have proposed a new torque ripple suppression method using an electromagnetic oscillatory actuator.

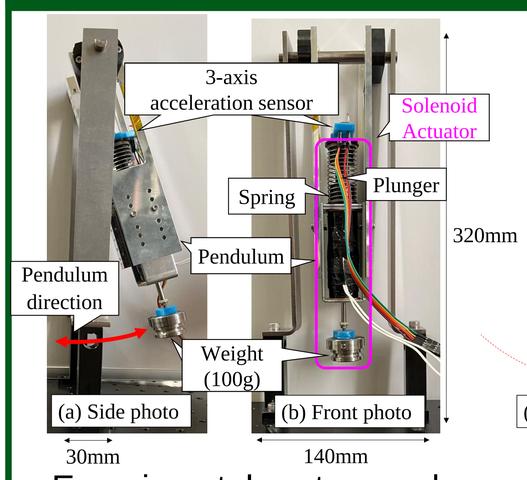
➢ Two problems on experimentally verification of the torque ripple reduction technique are existing: The power and signal transmission method, and the selection of the actuator.

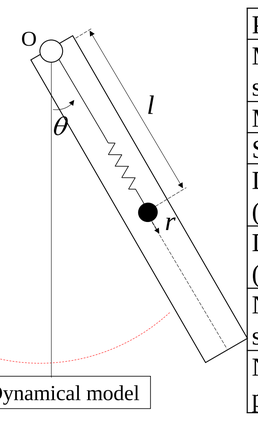
Aim of this study : Verify experimentally the new torque ripple suppression method using an elastic pendulum-type simple test apparatus focusing only on oscillating motion.



New torque ripple suppression method

Experimental system for torque ripple suppression





Parameter	Unit	Value
Maximum stroke of solenoid actuator	mm	35
Mass of plunger	g	105
Spring constant	N/m	61.25
Damping coefficient (θ-direction)	Nms/rad	0.9
Damping coefficient (r-direction)	Ns/m	0.3
Natural frequency of solenoid actuator	Hz	2.3
Natural frequency of pendulum	Hz	1.38

Experimental system and corresponding dynamical model (elastic pendulum).

- Equations of motion

Pendulum: $J\ddot{\theta} + m(l+r)^2\ddot{\theta} + \underline{2m(l+r)\dot{r}\dot{\theta}} + c_\theta\dot{\theta} + mg(l+r)\sin\theta = 0$

Coriolis force (Damping force)

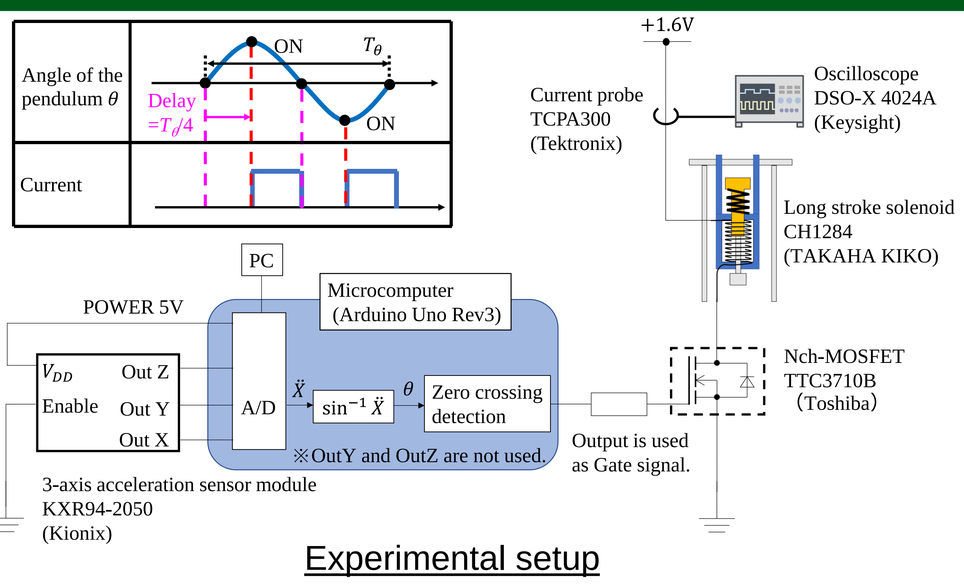
Centrifugal force (Excitation force)

Plunger: $m\ddot{r} + c_r\dot{r} + kr - \underline{m(l+r)\dot{\theta}^2} + mg(1-\cos\theta) = F_{sol}$

- Appropriate phase control of the plunger suppresses the swing of the elastic pendulum.

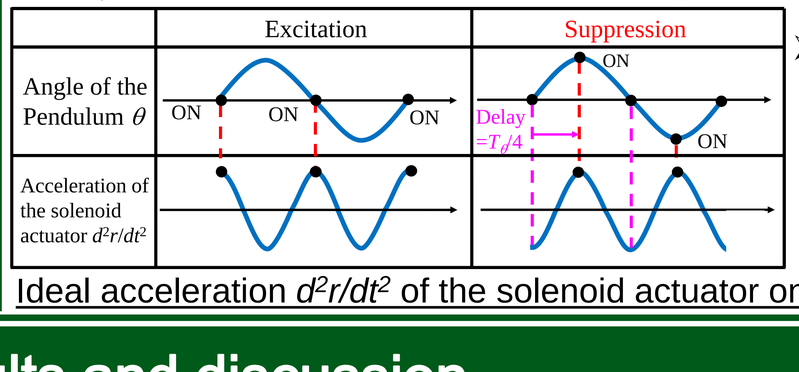
➢ This method is also understood as the parametric excitation.

➢ The following conditions must be satisfied for parametric excitation to occur: $\omega_l = 2\omega_\theta$



Experimental setup

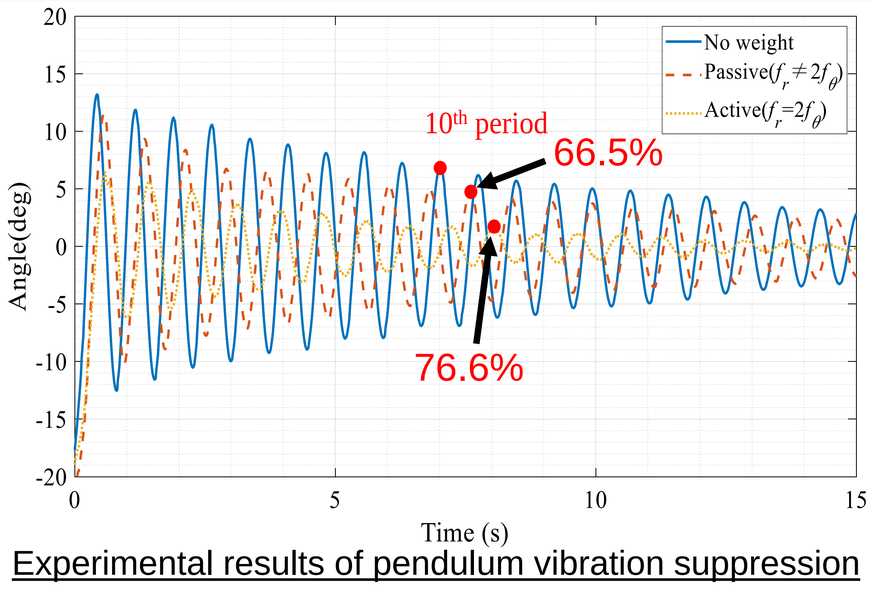
☐ Zero crossing of the angle θ turns off the MOSFET and turns on $T_\theta/4$ seconds after the zero crossing is detected.



Ideal acceleration d^2r/dt^2 of the solenoid actuator on ON/OFF controls

➢ This ON/OFF control can satisfy the conditions for parametric excitation, and the plunger is oscillated effectively

Measurement results and discussion

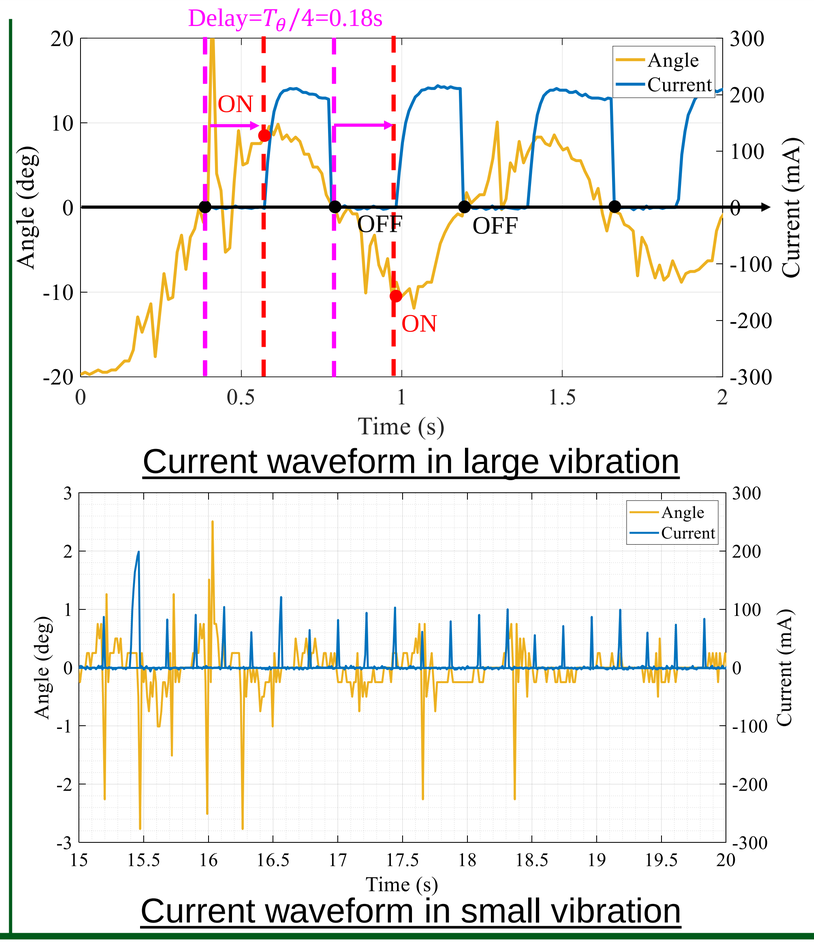


Experimental results of pendulum vibration suppression

☐ The active control suppressed the amplitude by 76.6% compared to the case without the weight

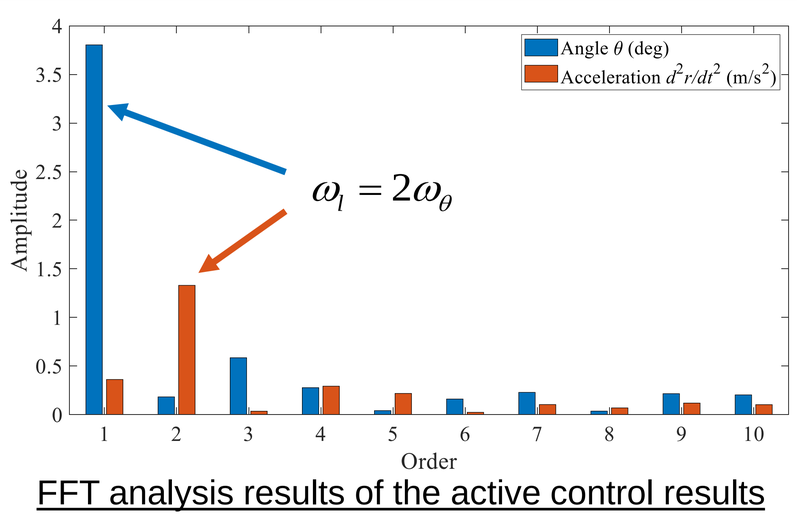
☐ The active control suppressed the amplitude by 66.5% compared to the conditions for parametric excitation is not satisfied.

➢ The proposed torque ripple suppression method was experimentally verified.



Current waveform in large vibration

Current waveform in small vibration



FFT analysis results of the active control results

☐ The proposed experimental system was not effective in small vibration.

➢ The cause is a tension in the wires of the acceleration sensor.

☐ The effectiveness of the proposed experimental system was verified in large vibration.

Conclusion

- We fabricated the elastic pendulum-type simple test apparatus using the solenoid actuator and succeeded the pendulum vibration suppression.
- The proposed method was verified experimentally because the proposed experimental system was effective in the large vibration.

✓ Further study on the wireless communication of the acceleration sensor will be implemented.

✓ An experiment using the experimental system including the LOA, its driver, and a motor will be conducted.

➢ The experiment system will use the motors that have sinusoidal and small torque ripple.

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