Investigation into Friction-Induced Vibration Characteristics of Electromagnetic Brake in High-Load Logistics Robots

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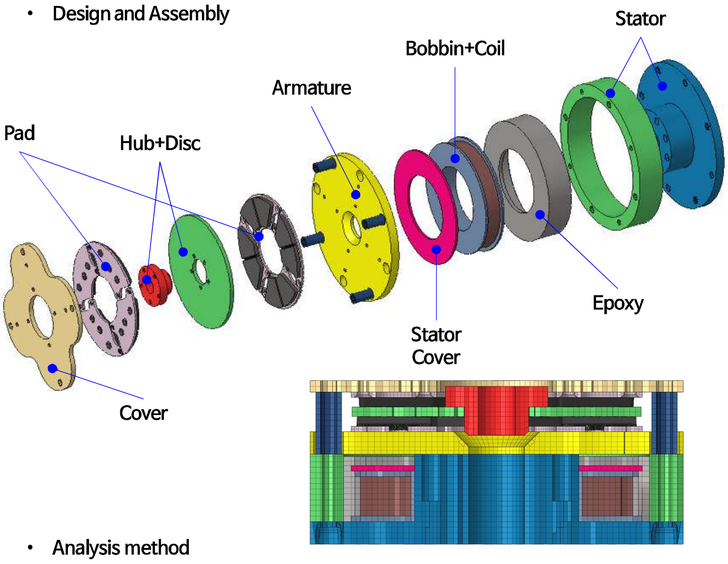
BACKGROUND

- Background
  - The acceleration of industrial machinery electrification, driven by the mandate to achieve net-zero carbon emissions by 2050, has triggered an unprecedented surge in demand for high-capacity logistics robots capable of handling payloads exceeding 2 tons.
- Core Mechanism
  - To ensure operational efficiency and human safety, these high-load robotic platforms employ a dual-braking architecture composed of regenerative braking for routine deceleration and power-off electromagnetic brakes as a critical fail-safe mechanism for emergency stopping and positional holding.
- Research Necessity
  - Despite the high criticality of these systems, the technical stability and vibrational reliability of power-off electromagnetic brakes under high-load conditions remain relatively underexplored, necessitating a comprehensive investigation into their mechanical behavior.

◎ Research objective: Investigating the frictional vibration behavior of electromagnetic brakes specifically designed for high-load logistics applications

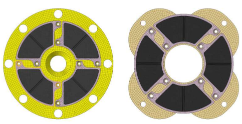
METHODS

- Design and Assembly

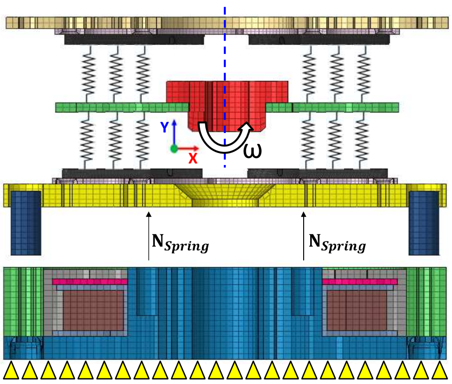


- Analysis method
  - Vibration instability analysis
    - Method: Complex eigenvalue analysis
    - Friction coefficient: 0~0.45
    - Force: 2,938.68 N (8 compression springs)

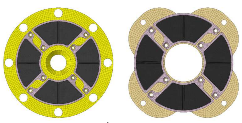
Case 1. Symmetry Pad



Armature pad   Cover pad

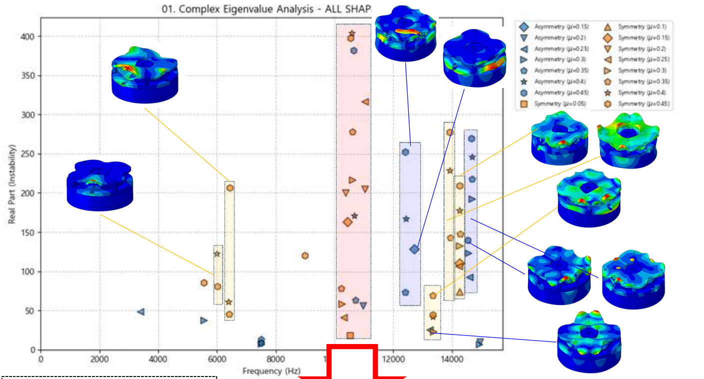


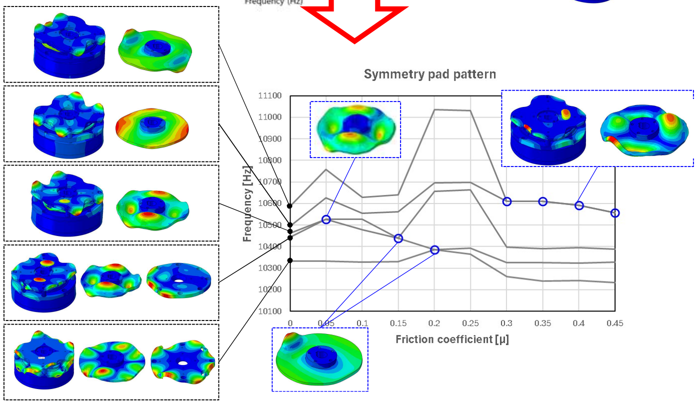
Case 2. Asymmetry Pad

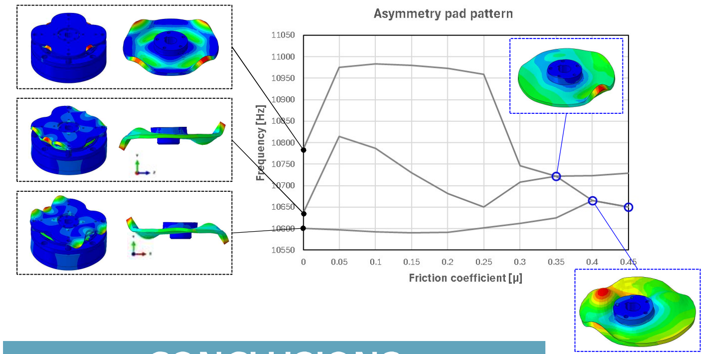


Armature pad   Cover pad

RESULTS/DISCUSSION







CONCLUSIONS

- Vibrational instability regions vary distinctly depending on the pad arrangement (symmetric vs. asymmetric) despite using identical friction materials.
- Finite element analysis identifies out-of-plane bending modes of the axisymmetrically assembled components (cover, disc, and armature) as the primary cause of instability.
- The symmetric configuration exhibits unstable modes over a wider frequency spectrum, suggesting that structural symmetry can paradoxically facilitate multi-modal coupling.
- The dominant instability mode occurs in the 10 kHz band due to friction-induced coupling between the disc's doublet modes, triggering severe mode localization and asymmetric wave distortion.
- The degeneracy of doublet modes is broken into a distinct frequency split, driven by geometric perturbations and structural asymmetries from the hub keyway and bolt-fastening boundaries.
- Future braking tests will evaluate the qualitative and quantitative correlations between numerical predictions and experimental vibration spectra.

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