Magnetically levitated linear drive with zero watt power dissipation at a constant levitation height

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Introduction

- In magnetically levitated drives the force of gravity needs to be compensated. This leads to a constant electric current and Joule losses.
- For constant loads and constant position fixed permanent magnet forces are used to lower the Joule losses.
- When different loads are applied to a magnetic guidance and a constant position is required few solutions are available.

Goals

- **Magnecitally levitated linear drive**
- **Magnetic levitation with nearly zero watts power dissipation**
- **Constant levitation height for different loads**
- **Reduction of power and sensing electronics**

Design

Passive stabilization of two axes

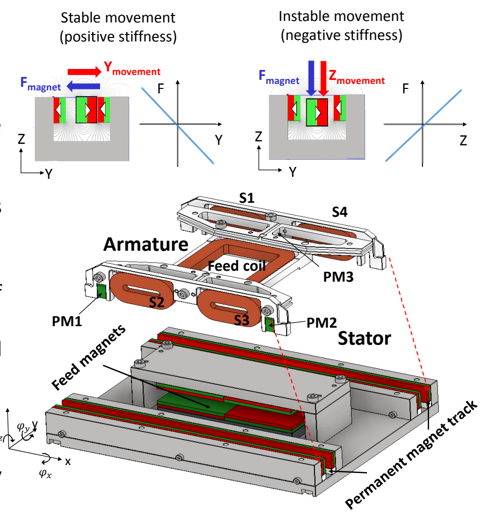
- The design uses two tracks of permanent magnets (PM) which are mounted on the stator.
- At the armature of the motor three permanent magnets are mounted in repulsive configuration.
- Two axes of the guidance are stabilized by a positive spring stiffness of 6.5 N/mm.
- The permanent magnet configuration is designed to have a negative stiffness in the Z axis of -10 N/mm.

Stabilization of the remaining axes

- The repulsive guidance magnet creates a negative stiffness in the Z and φ_x and φ_y axis of the guidance which requires an active control.
- The stabilization in the guidance is done by four coils which are placed in the magnetic field of the permanent magnet .
- Due to the Lorentz force of these coils the destabilized axes can be actuated.

Linear drive

- The linear motor is designed as a flat coils linear motor having movable coils and stationary magnets.



Zero power levitation at constant levitation height

Position control

- The position control is done by a decoupled PID control algorithm.
- Three independent PID controllers for coordinates Z and φ_x and φ_y are designed, using a model based design approach.

Zero power control

- No constant electric current is required when the permanent magnet forces in the Z axis are equal to the force of gravity.
- The control is done by an additional cascaded control loop which uses the control output of the position controller. When the control output of the position controllers is zero the power dissipation is zero (Figure 1).
- When a load is applied to the armature, it regulates its position in positive Z direction based on the linear negative stiffness of the PM guidance.
- A levitation power lower than 10 mW is achieved.

Zero power levitation at constant height

- Springs with the same stiffness than the PM guidance (but positive sign) are mounted over the repulsive PM. When a load is applied to the armature, the spring is compressed by the amount, the armature is lifted by the controller to achieve zero Watts levitation (Figure 2).
- The springs are build as flexure hinges (Figure 3).
- For loads up to 400 g the loads will levitate at a constant position and minimum power dissipation (Figure 4).

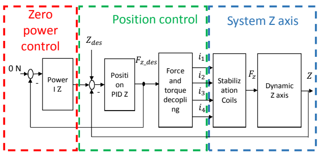


Figure 1: Control Structure

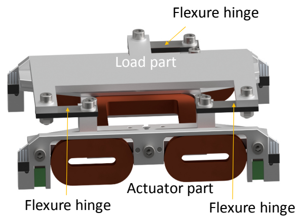


Figure 3: Armature design

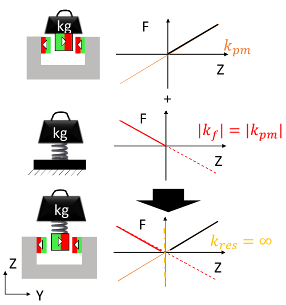


Figure 2: Spring and magnet arrangement

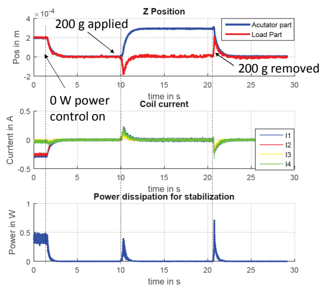
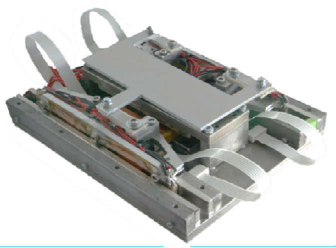


Figure 4: Measurement results

Conclusion

A magnetically levitated linear motor with repulsive magnetic guidance is presented. Using this concept magnetic levitation with almost zero watts power dissipation at a constant levitation height is possible. This makes the system power- and cost-efficient for industrial applications.



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