Magnetically levitated linear drive with repulsive magnetic guidance and nearly zero power emission

Markus Raab M.Eng; Prof. Dr.-Ing. Wolfgang Schinköthe

Introduction

Most levitation concepts use electromagnetism or the electro-dynamic effect.

- A constant electric current to compensate the force of gravity is required
  → **Power dissipation in the guidance**
- An active control in six degrees of freedom is required
  → **high amount of power and sensing electronics**

Goals

- **Magnetic levitation with nearly zero watts power emission**
  → Gravity compensation with forces of permanent magnets in repulsive configuration
- **Reduction of the power and sensing electronics**
  → Passive stabilization of three axes using repulsive forces of permanent magnets

Design

Passive stabilization of three axes

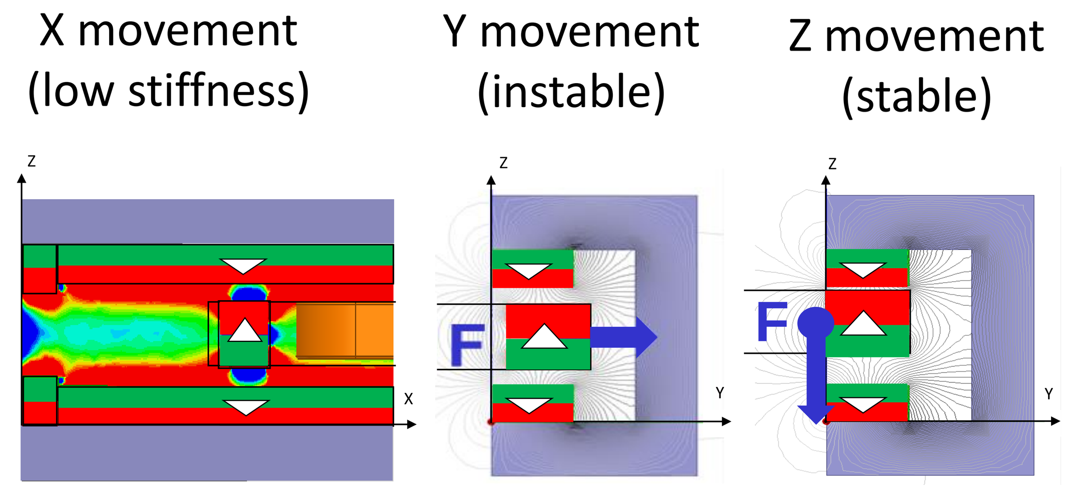
- The design uses two tracks of permanent magnets which are mounted on the stator.
- At the armature of the motor four permanent magnets are mounted in repulsive configuration.
- Three axes of the guidance are stabilized by a positive spring stiffness.
- The permanent magnet configuration is designed to achieve a positive stiffness in the Z axis of the motor of 9100 N/m. This results in a maximum load of 700 g of the guidance.

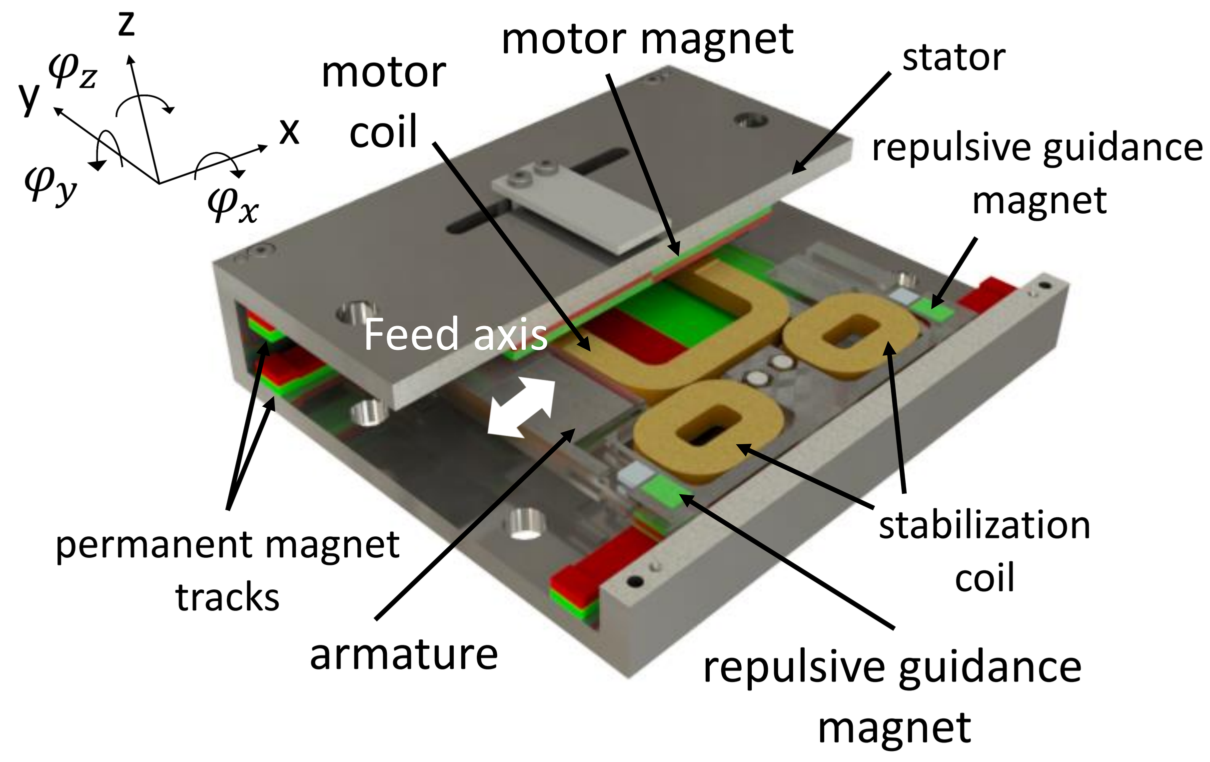
Stabilization of the remaining axes

- The repulsive guidance magnet creates a negative spring stiffness in the Y and φ_z 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.
- No parasitic reluctance forces created in the system.





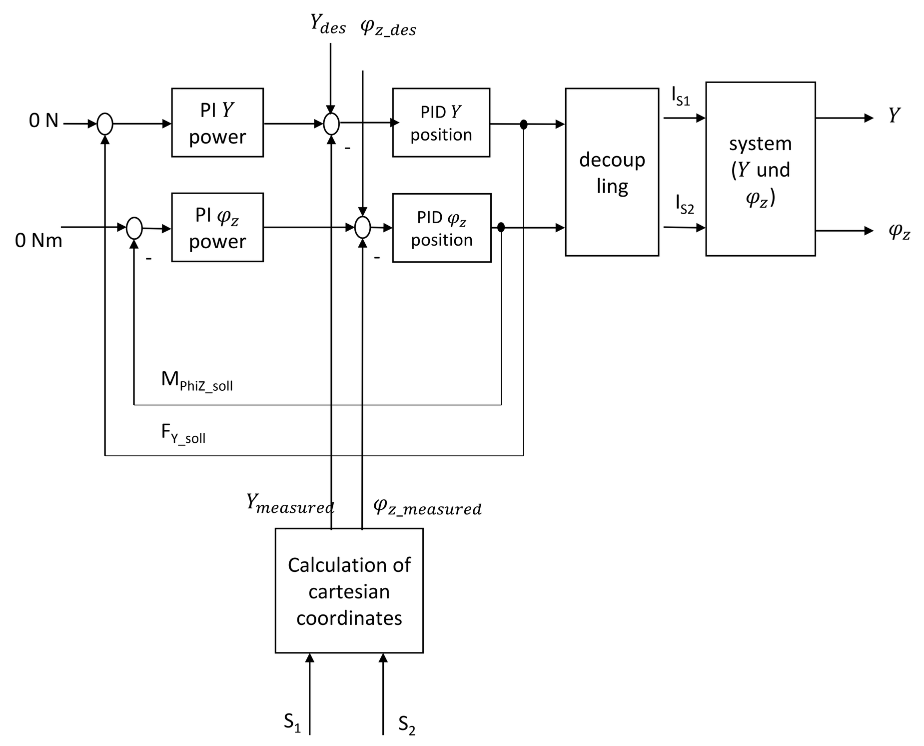
Control

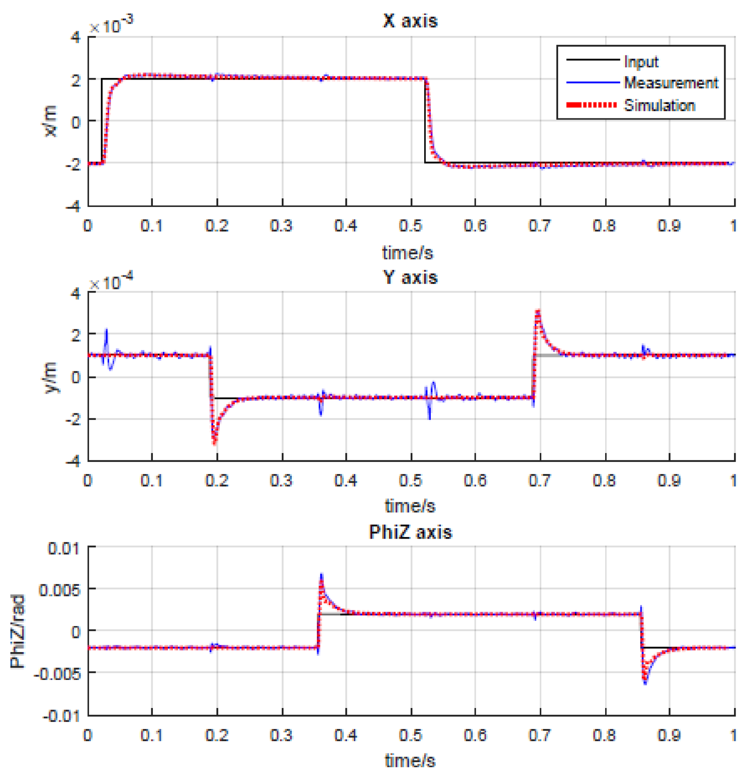
Position control

- The position control is done by a decoupled PID control algorithm.
- Two independent PID controllers for coordinates Y and φ_z axes are designed, using a model based design approach.
- A pitch and roll error occurs when the stage is moving due to disturbance torques created by the distance of force application and centre of mass

Zero power control

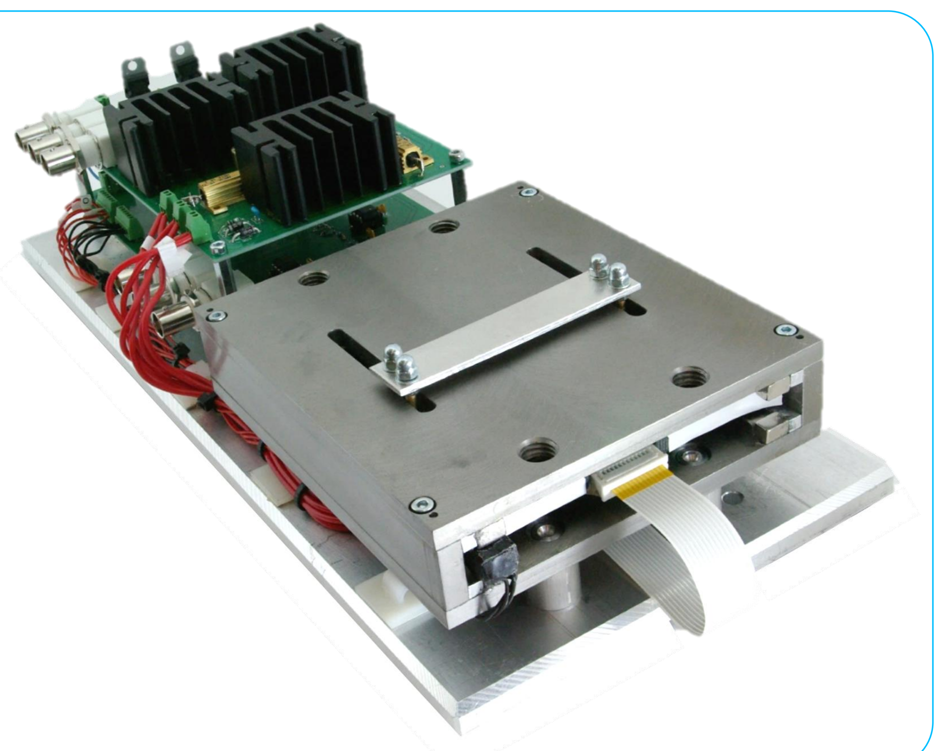
- No electrical current is required, when the armature is centred in the middle of the guidance
- This is done by an additional cascaded control loop
- A levitation power lower than one milliwatt is achieved.





Conclusion

A magnetically levitated linear motor with repulsive magnetic guidance and three controlled axes was presented. Using this concept magnetic levitation with almost zero watts power emission is possible. This makes the system power- and cost-efficient for industrial applications.



Contact

Markus Raab
University Stuttgart
Institute of Design and Production in Precision Engineering
Telefon: +49 (0)711 685-66408
markus.raab@ikff.uni-stuttgart.de