IEEE Intermag 2009, Sacramento, CA
May 8, 2009, GG-02

Novel bearingless motor concept with 26 poles and 24 slots

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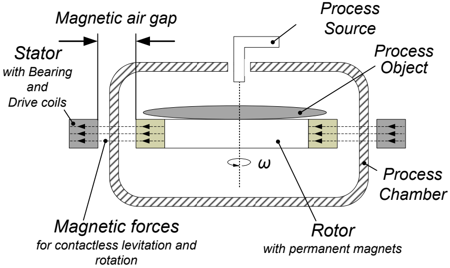
2009 INTERMAG

Motivation and applications of bearingless slice motors

Properties of bearingless slice motors

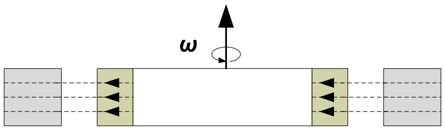
- Ultra compact setup
- Passive axial and tilting bearing
- Active radial bearing and PMSM
- Large air-gap possible
- High torque



Application

- Hermetically encapsulated rotor in process chamber
- For biotechnology, pharma and semiconductor industry

Basic principle: passive axial and tilting PM bearing



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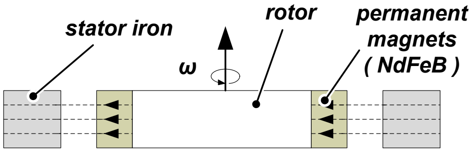

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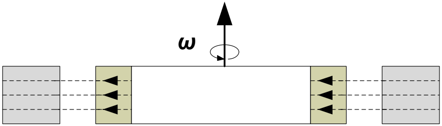

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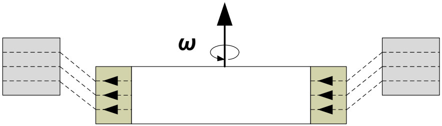

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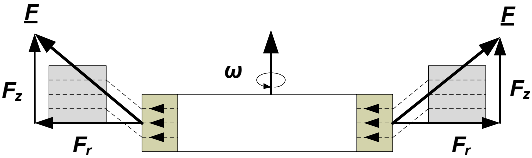

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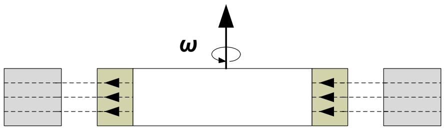

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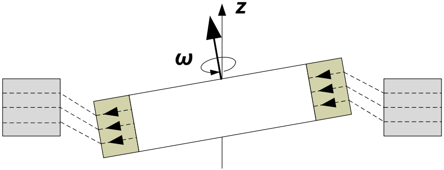

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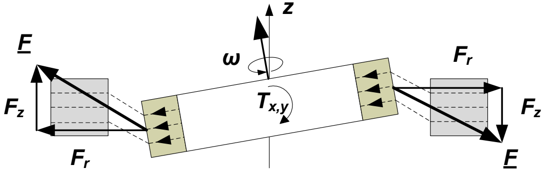

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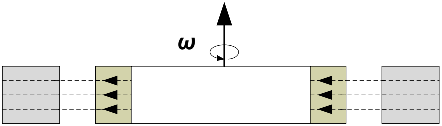
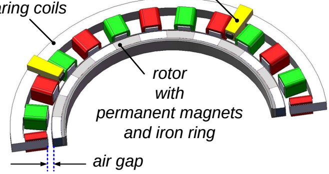


Basic principle: active radial bearing and motor drive



Principle

- Active radial magnetic bearing for Δx and Δy
- Permanent magnet synchronous motor (PMSM)

- **Stator** with bearing and drive windings...
- ...and position and angular sensors

- **Rotor** with permanent magnets and back iron

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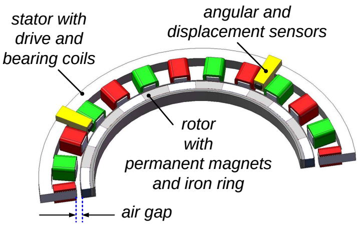

Key parameter

- Number of stator teeth: $N = 24$
  $\Rightarrow$ 12 motor teeth
  $\Rightarrow$ 12 bearing teeth
- Number of rotor pole-pairs: $p = 13$

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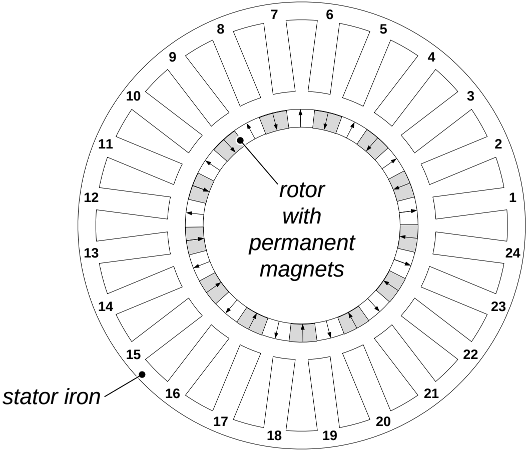

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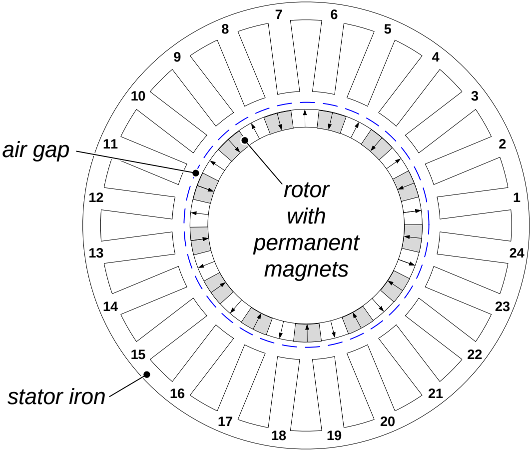

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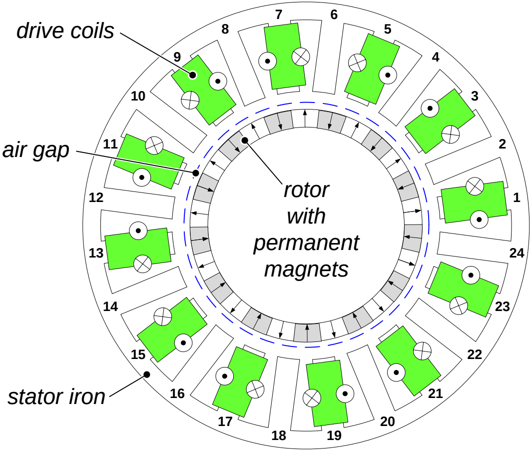

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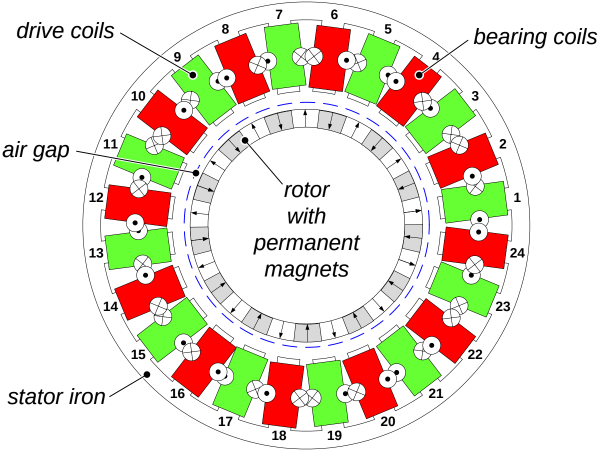

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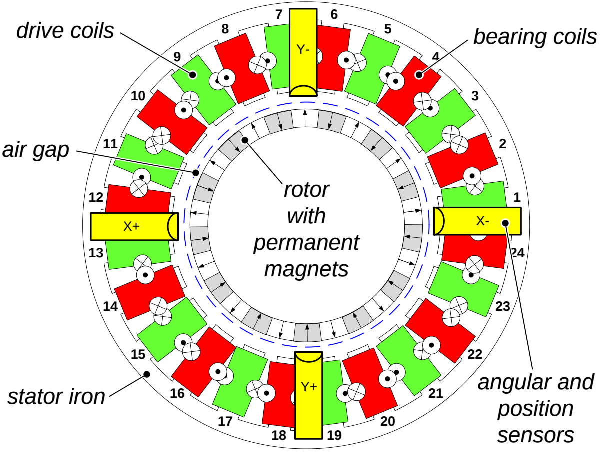
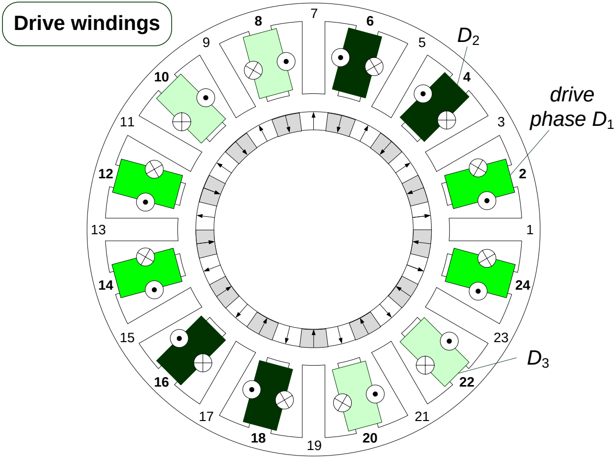


Permanent magnet synchronous drive



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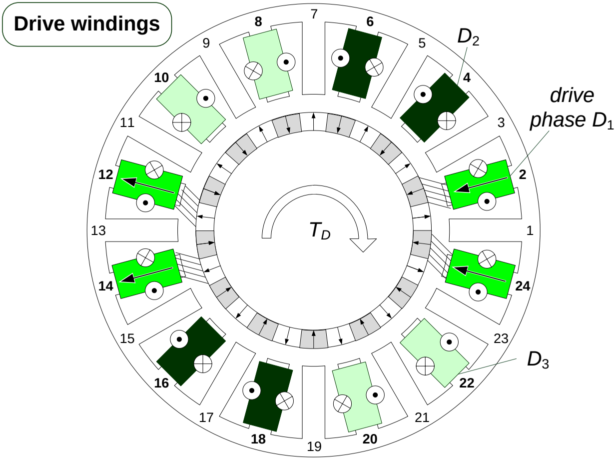

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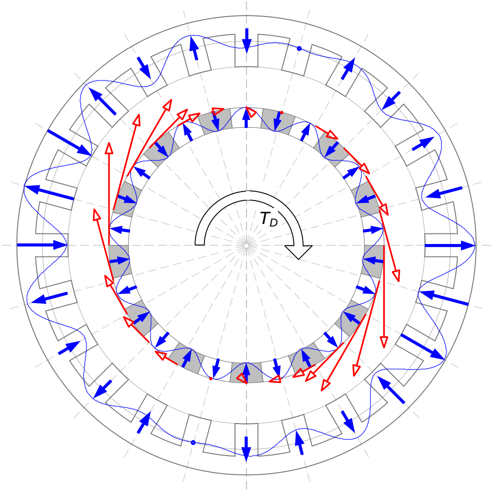
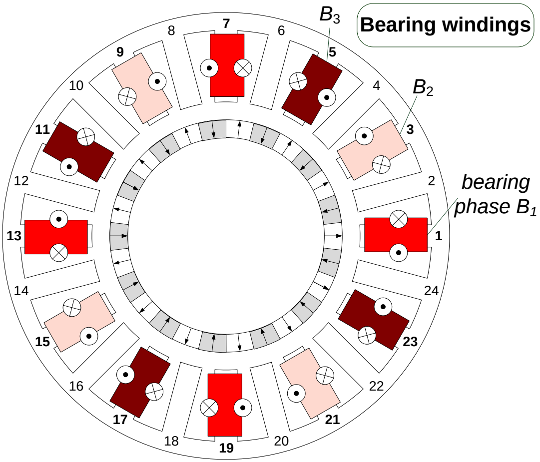


Active radial magnetic bearing



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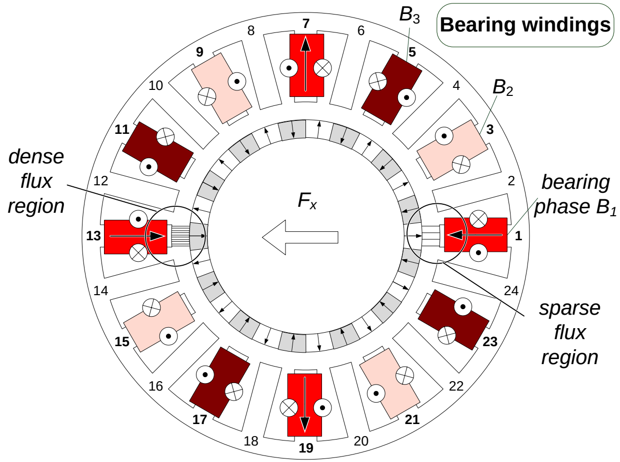

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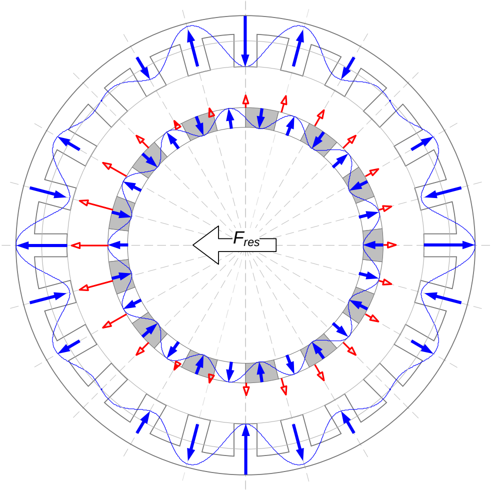


Parameter Optimization

Parameter to be optimized

- Rotor and stator length l
- Magnet thickness δ_{magnet}
- Magnet shape
- Tooth width w_{tooth}
- Number of windings

Criteria

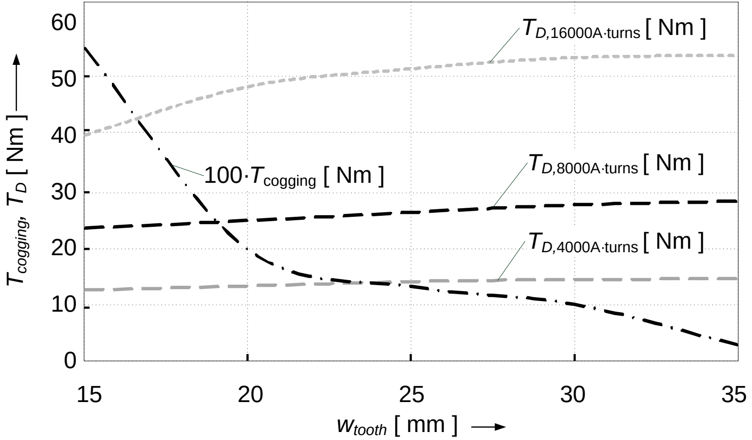
- Maximum motor torque T_M
- Minimum cogging torque $T_{cogging}$

- Maximum levitation F_x

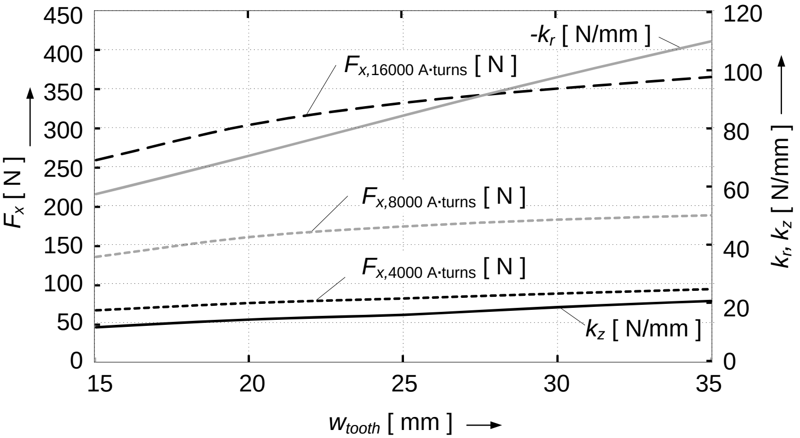
- Maximum axial stiffness k_z
- Minimum radial stiffness k_r

$\Rightarrow$ **Optimization using 3D-FEM simulation**

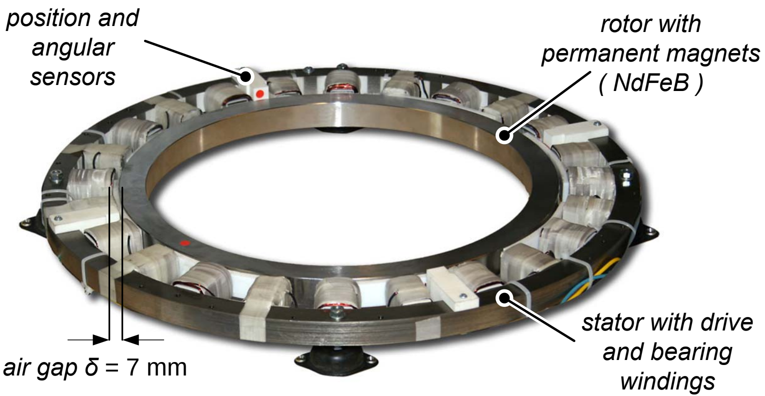
Motor torque optimization (example)



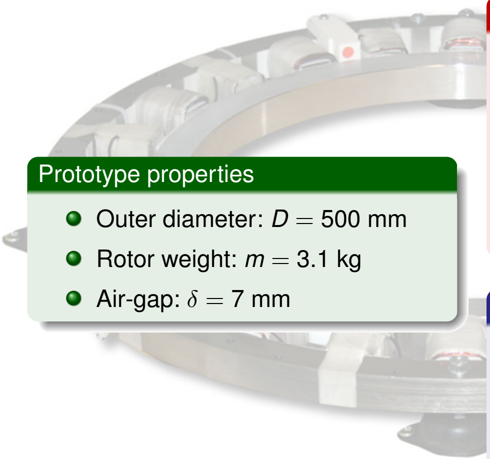
Bearing force optimization (example)



Laboratory Prototype



Performance Results



Prototype properties

- Outer diameter: $D = 500$ mm
- Rotor weight: $m = 3.1$ kg
- Air-gap: $\delta = 7$ mm

Bearing performance

- Max. bearing force: $F_x = 155$ N
- Max. displacment during acceleration: $\Delta x = 69\ \mu$m
- Radial stiffness: $k_r =$ -70.0 N/mm
- Axial stiffness: $k_z = 20.1$ N/mm

Motor performance

- Max. speed: $n_{max} = 1800$ rpm
- Acceleration time: $t_{0-1500} = 1.5$ s
- Rated torque: $T = 13.1$ Nm

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Thank you for your attention!
Please feel free to ask questions.
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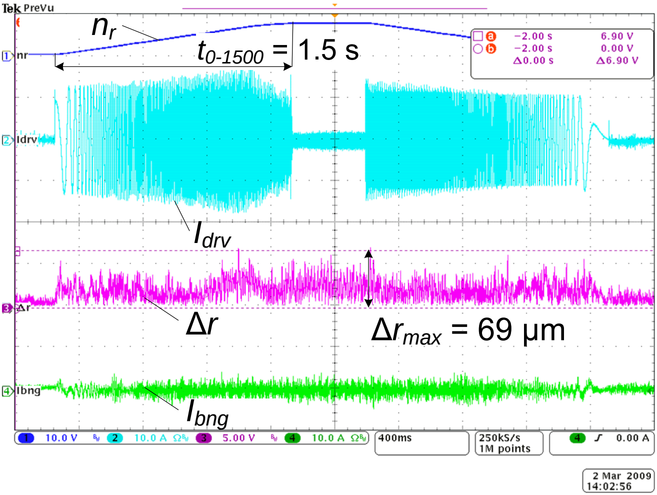
Motor Performance



Bearing Performance