Axial Magnetic Bearings in SyMSpace

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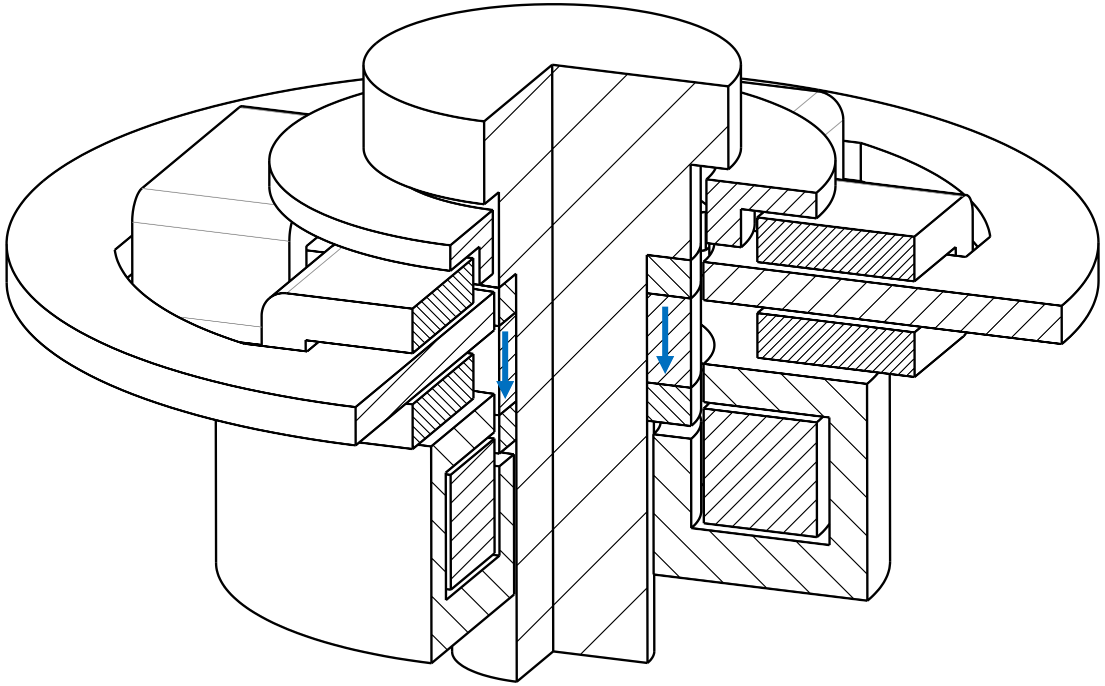
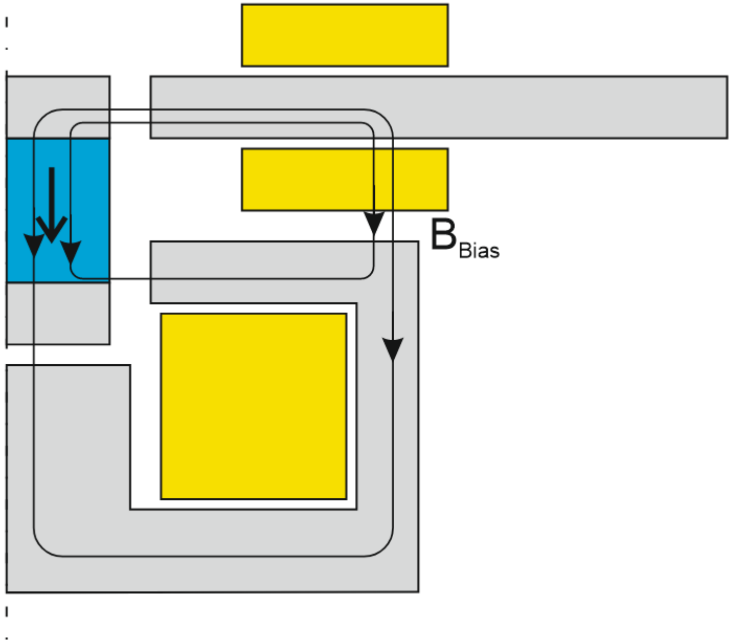
Application Example

Combined axial/radial magnetic bearing





3D FE: Radial forces → 2D FE used for optimization of axial force generation and radial bias flux

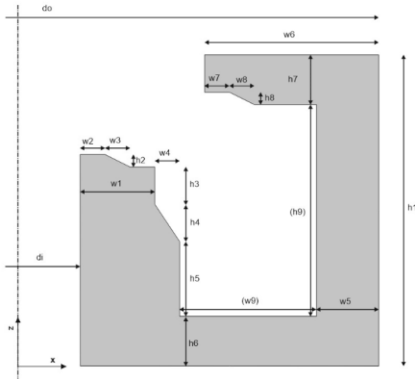
Axial Magnetic Bearing

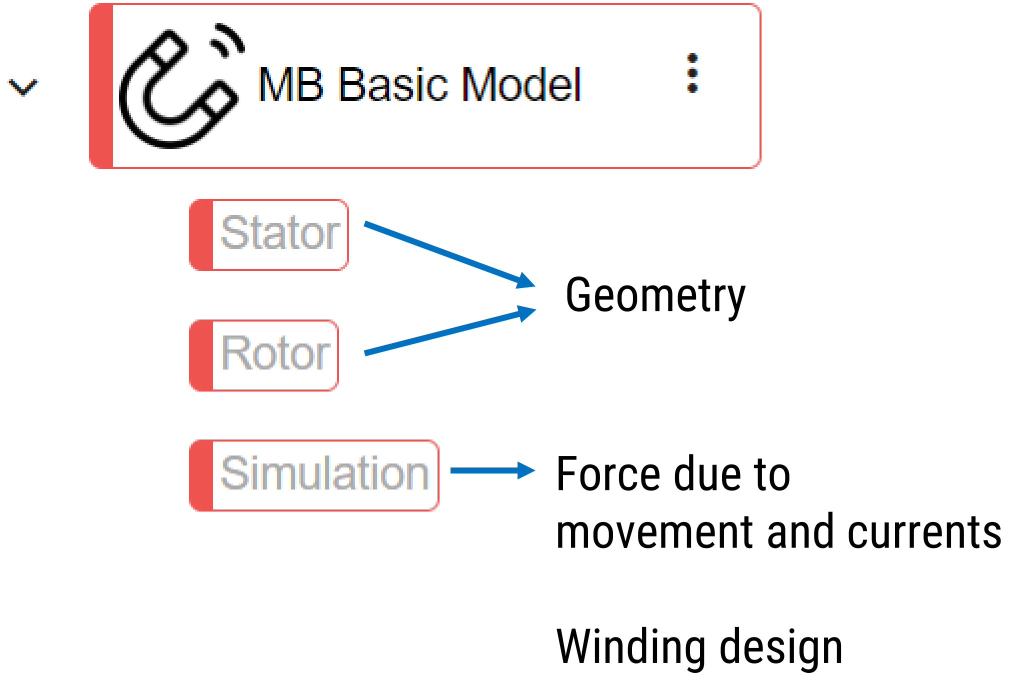
Basic Model

- Axisymmetric actuators (r-z coordinate system)

- FE simulations are done in FEMM

- Geometry based on script geometry





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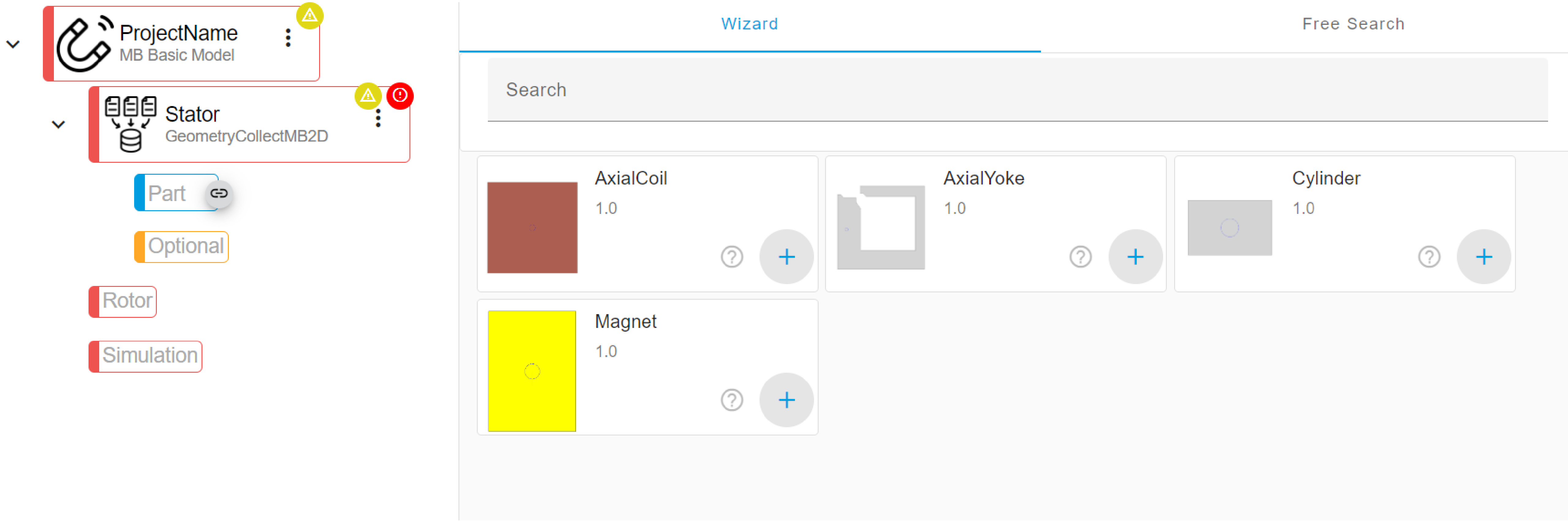
Axial Magnetic Bearing

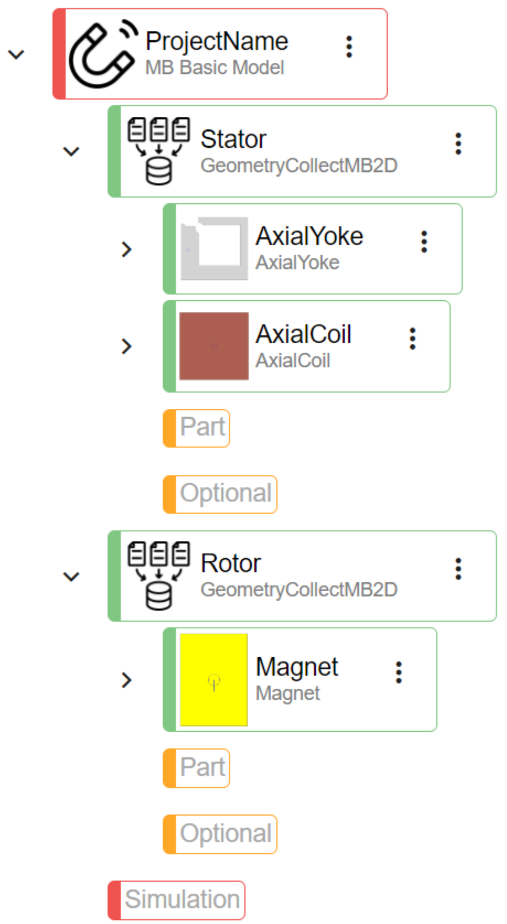
Stator Parts

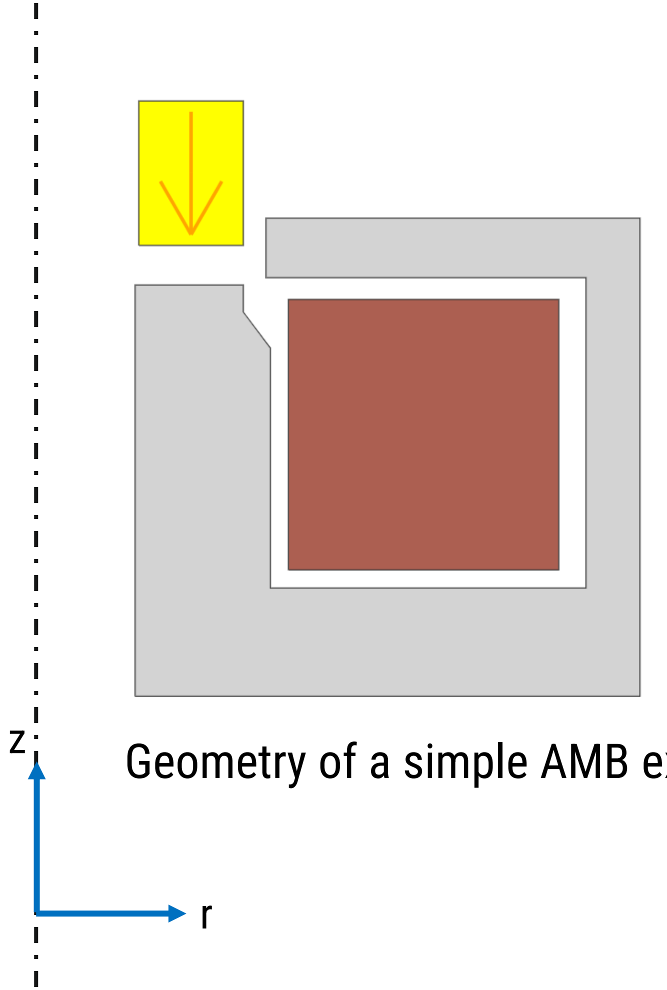
Implemented 2D geometries (rotationally symmetric)



Axial Magnetic Bearing

Example Geometry

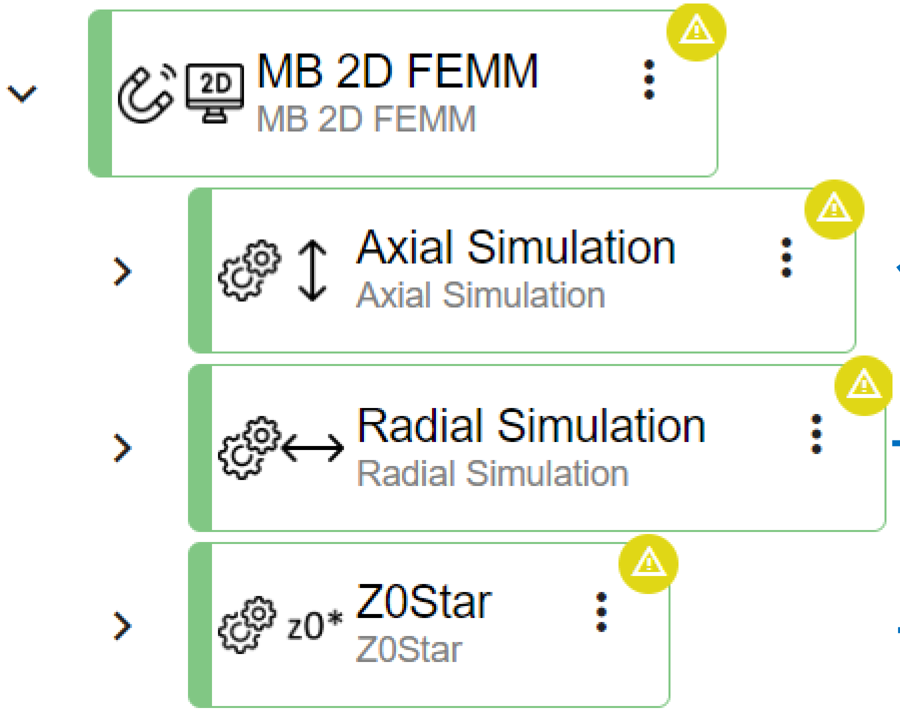




Geometry of a simple AMB example

Axial Magnetic Bearing

Simulation



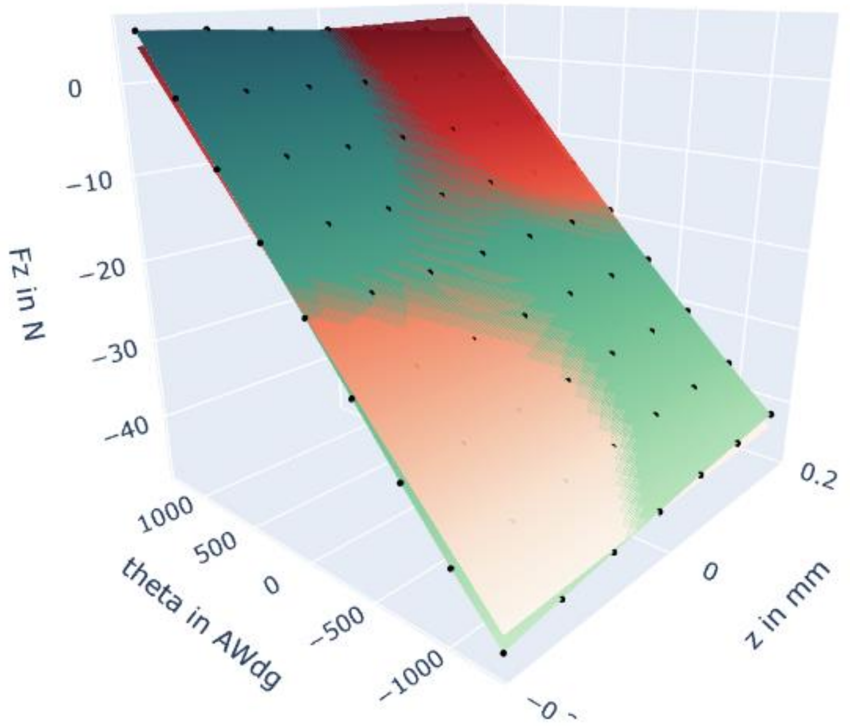
Results: force per current k_i
axial stiffness k_z
start current, …

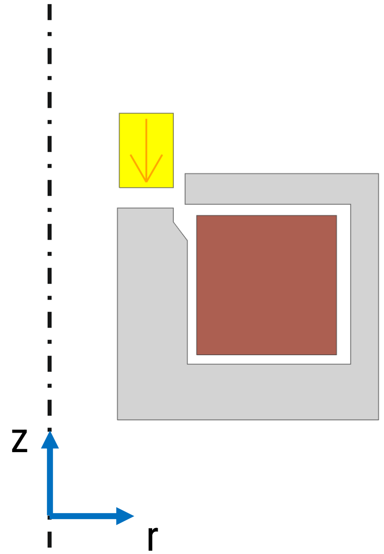
Results: approximation of radial stiffness k_r

Characteristic quantity for magnetic bearing dynamic / winding design

Axial Simulation Result

Preview example: Force = f (axial position, current)





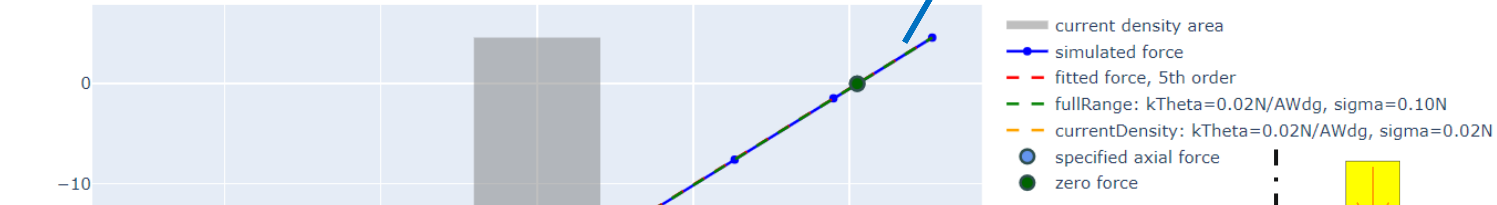
Axial Simulation

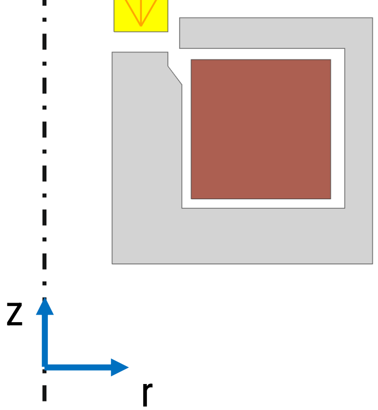
Preview example: Force = f(current) at middle position z=0mm

repulsive (positive) forces are also possible

Force at zero current due to magnet

axial force is usually compensated by an additional magnetic bearing component

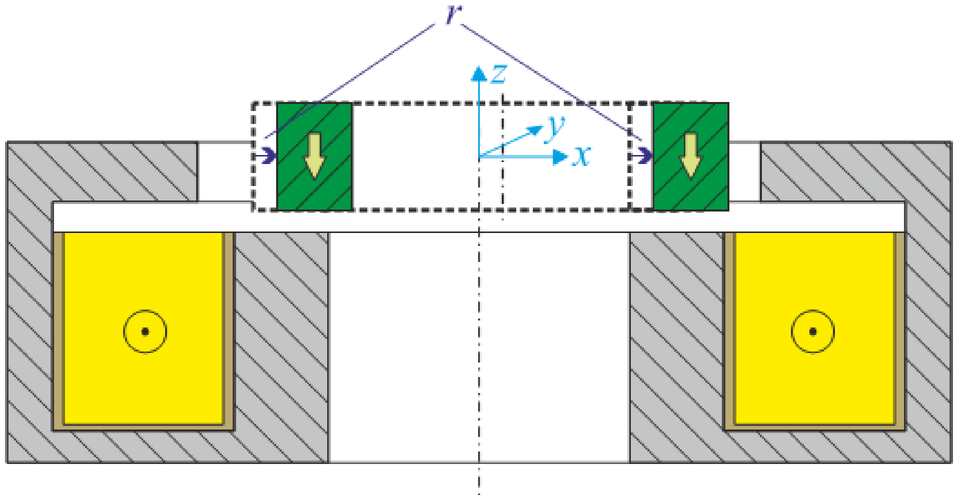




Radial Simulation

Approximation of the radial stiffness k_r using 2D FE simulation

Rotor moved by *r* in direction of *x*-axis



radial deflection of a magnet cross section at the circumferential angle φ

$$\Delta r = r \cdot \cos\left(\varphi\right)$$

Radial Simulation

Variation of rotor size allows estimation of radial stiffness

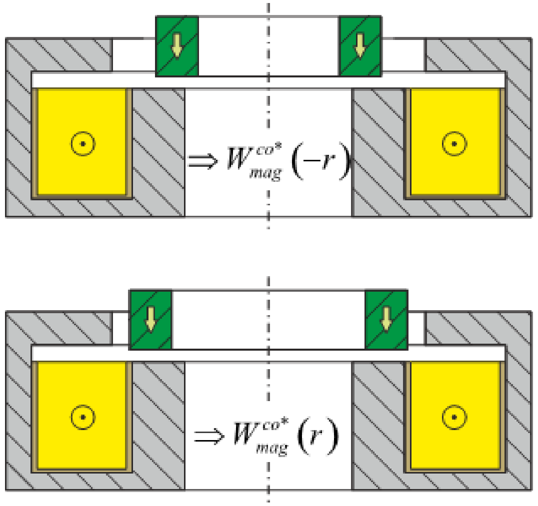
smaller magnet

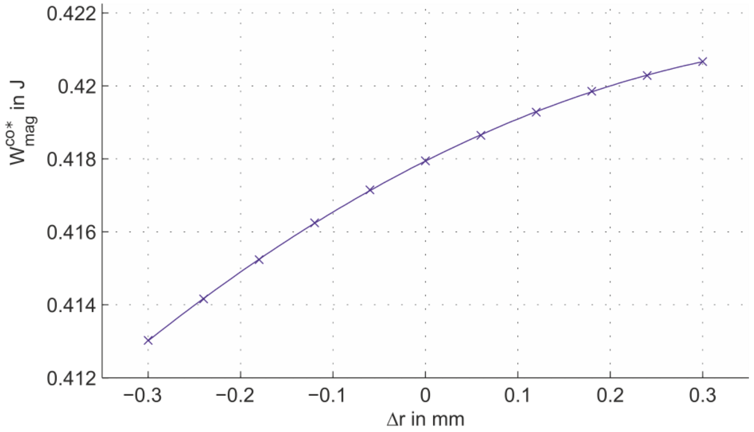
$\Delta r = -r$

⋮

bigger magnet

$\Delta r = +r$





$$W^{co*}_{mag}(\Delta r) = f_0 + f_1 \Delta r + f_2 \Delta r^2 + f_3 \Delta r^3 + \ldots$$

Approximation of magnetic conenergy of a rotor moved by *r* in direction of *x*-axis

$$W^{co}_{mag}(r) \approx \int_0^{2\pi} \frac{W^{co*}_{mag}(r \cdot \cos(\varphi))}{2\pi} d\varphi$$

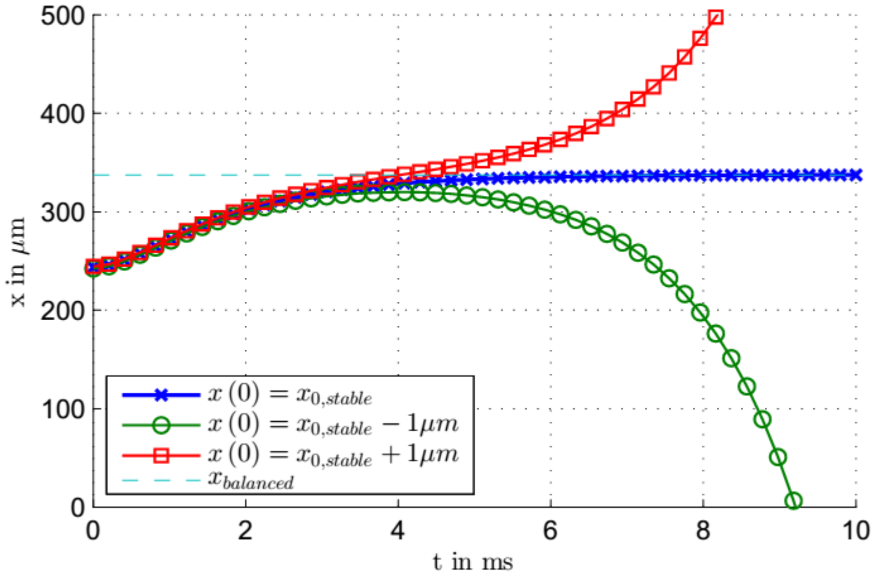
radial stiffness

$$k_r = \left. \frac{d^2 W^{co}_{mag}(r)}{dr^2} \right|_{r=0} = f_2$$

Ref: Jungmayr, G.; Marth, E.; Panholzer, M.; Amrhein, W.; Weidenholzer, G. Fast approximate calculation of the radial and tilt stiffness of magnetic bearings using magnetostatic 2D finite element analysis. *13th International Symposium on Magnetic Bearings*, 2012.

Characteristic quantity for magnetic bearing dynamic

Used for winding design



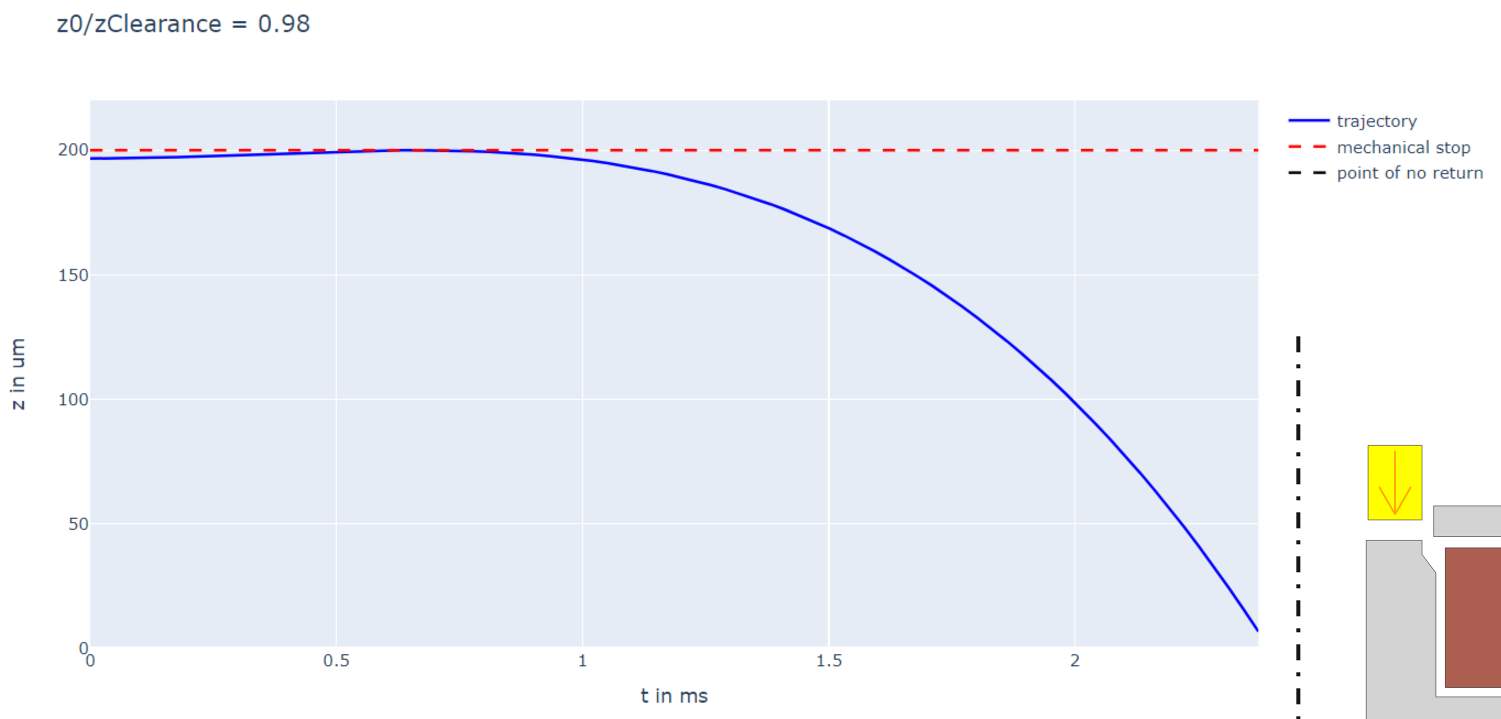
Maximum dynamic start position $x_{0,stable}$ can be calculated analytically

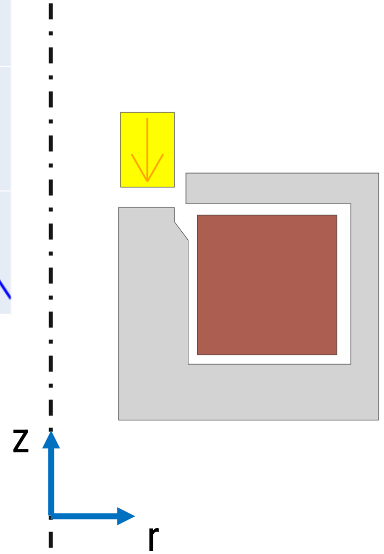
→ If the voltage $u = -u_{max}$ is applied at t = 0 s and the i.c. are x (0) <$x_{0,stable}$ and v_0=0 m/s the mass can pulled back to x = 0 µm

Ref: Jungmayr, G.; Marth, E.; Santner, R.; Amrhein, W.: Characteristic quantities of active magnetic bearings, *15th International Symposium on Magnetic Bearings*, 2016.

Characteristic quantity for magnetic bearing dynamic

Used for winding design





✔ Allows the determination of the magnetic bearing dynamics without setting up a control system

Science becomes **reality**

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