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Dynamic Simulation of a Coaxial Magnetic Gear Using Global ODE's and the Rotating Machinery, Magnetic Interface

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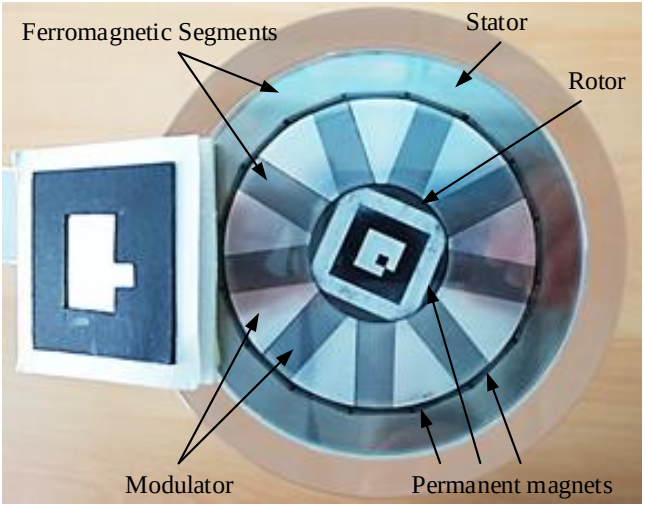
Motivation

- Dynamic simulation of the magnetic gear
- Magnetic and mechanical characteristics of the magnetic gear
- Finite element methods for a numerical solution
- Coupled multiphysics problem

Set-up of the magnetic gear



- Number of the pole pairs of the stator:

$$P_S = 8$$

- Number of the pole pairs of the rotor:

$$P_R = 1$$

- Number of the modulator segments:

$$P_M = P_S + P_R = 9$$

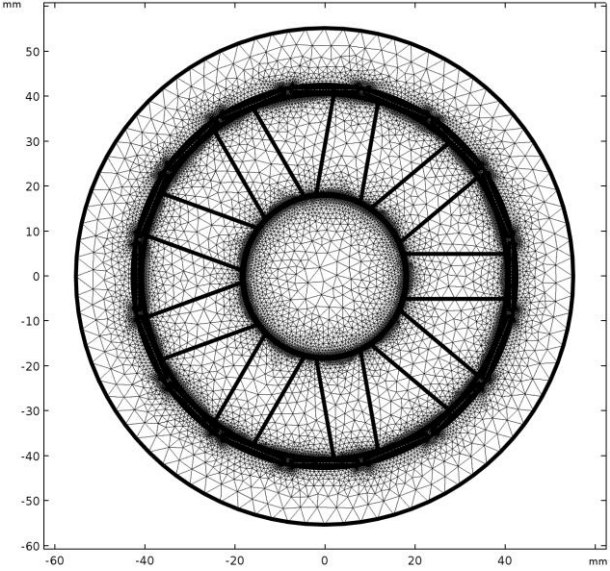
- Transmission ratio:

$$\eta_T = \frac{P_M}{P_R} = \frac{9}{1} = 9$$

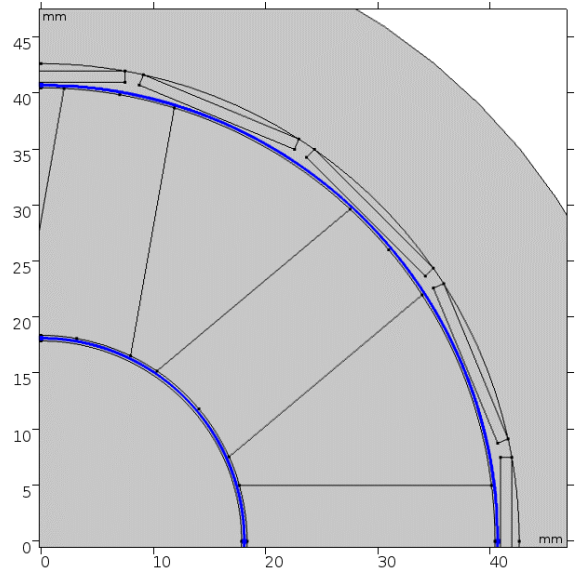
- Air gap – 0.5 mm

Numerical model

Discretization



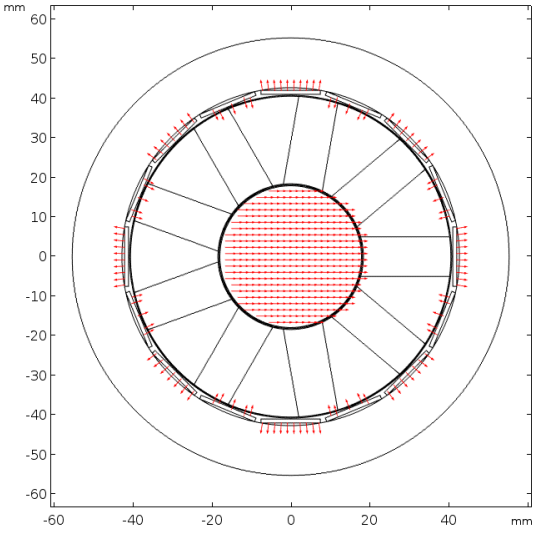
41873 domain elements



Identity pairs in the air gap

Numerical model

Rotating machinery, magnetic inteface (RMM)



$$\boldsymbol{B}_r = (\pm B_{rs,r}, 0, 0)$$

- Vector magnetic potential formulation

$$\boldsymbol{B} = \nabla \times \boldsymbol{A}$$

- Constitutive relations for permanent magnets

$$\boldsymbol{B} = \mu_0 \mu_r \boldsymbol{H} + \boldsymbol{B}_r$$

- φ_r and φ_m are predefined as prescribed rotation
- Nonlinear characteristic of the iron segments

$$\boldsymbol{H} = f(|\boldsymbol{B}|)\frac{\boldsymbol{B}}{|\boldsymbol{B}|}$$

- Continuity in the field variables on interior boundaries

Numerical model

Global ODE‘s inteface

- Modulator

  $\omega_m(t)$ is predefined

  $$\frac{d\varphi_m}{dt} = \omega_m \xrightarrow{\varphi_m}$$ to RMM interface

- Rotor

  Axial torque from RMM interface

  $$\boldsymbol{\tau} = \int_{\Omega} d(\boldsymbol{r} - \boldsymbol{r}_0) \times (\boldsymbol{n}T) dS \rightarrow \tau_{ax} = \frac{\boldsymbol{r}_{ax}}{|\boldsymbol{r}_{ax}|} \cdot \boldsymbol{\tau}$$

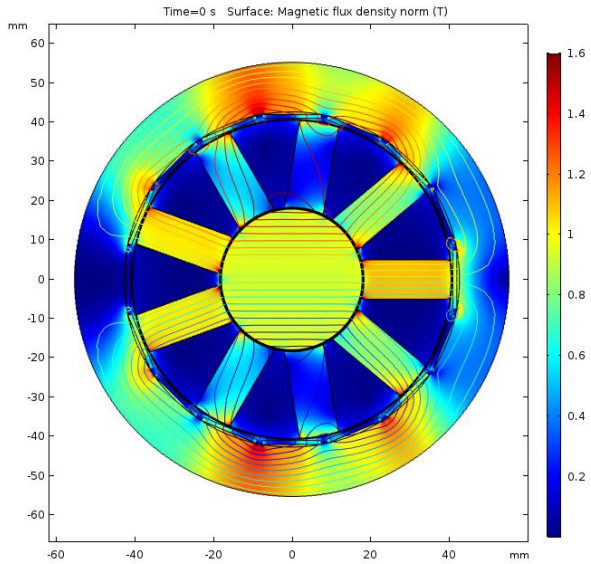
  Angular velocity of the rotor

  $$\frac{d\omega_r}{dt} = \frac{\tau_{ax}}{I} \qquad I = \int_V \boldsymbol{r}_{\perp}^2 \rho(\boldsymbol{r}) dV$$

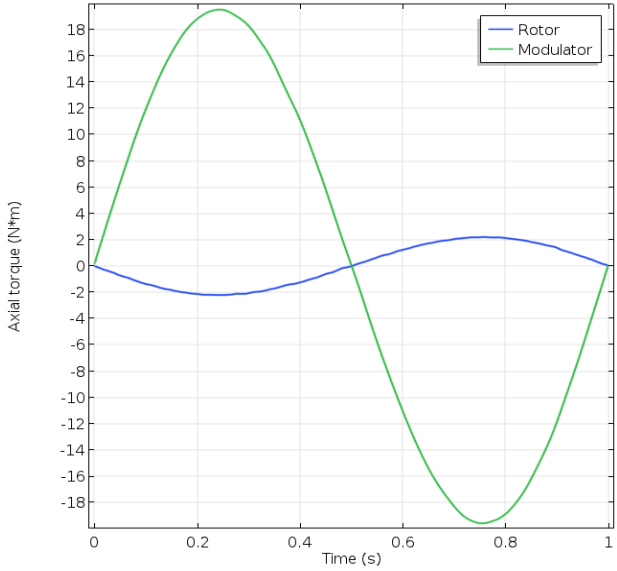
  Calculated angle of the rotor

  $$\frac{d\varphi_r}{dt} = \omega_r \xrightarrow{\varphi_r}$$ to RMM interface

Magnetic calculation results

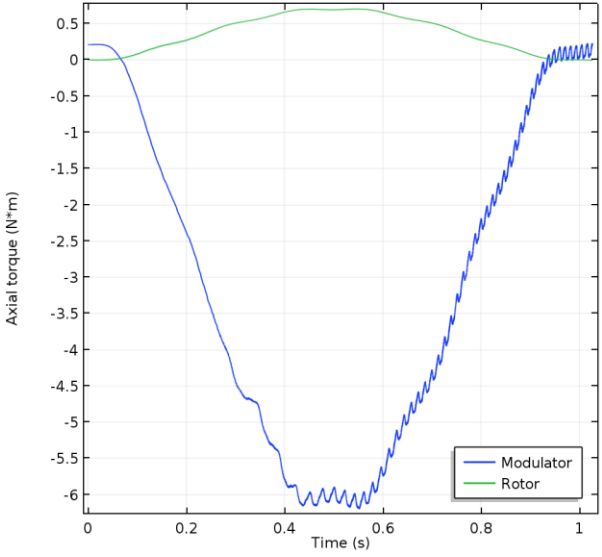


Magnetic flux density at initial time step

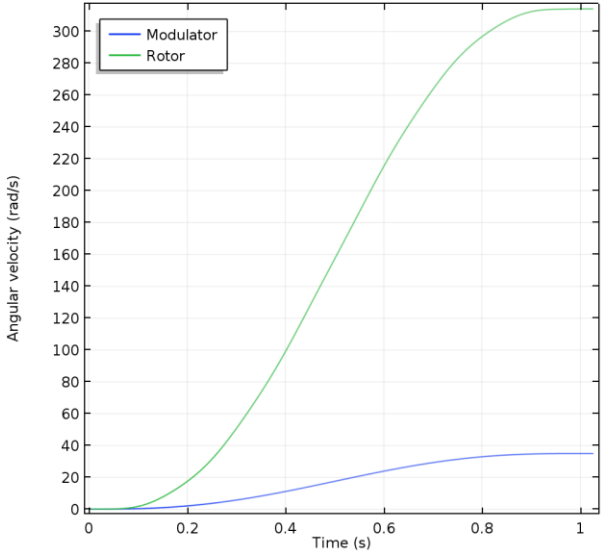


Axial torque

Mechanical calculation results

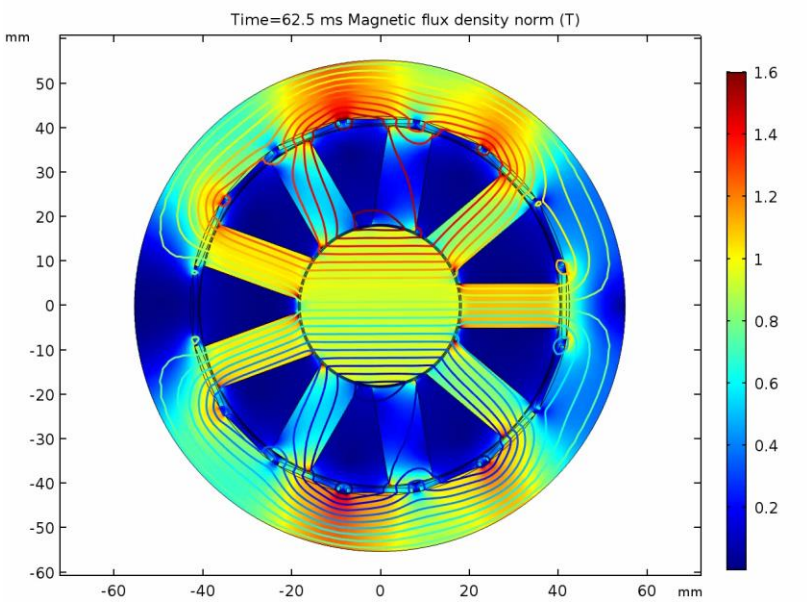


Axial torque



Angular velocity

Run-up process of the magnetic gear



Conclusions

- 41873 domain elements
- 86527 unknowns
- Physical memory: 1.88 GB
- Computation time 5 hours 35 minutes
- Intel Core I7-7770 at the 4 GHz