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3D-FEM Simulation of a Transverse Flux Machine Respecting Nonlinear and Anisotropic Materials

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Introduction

The paper presents the three dimensional (3D) Finite Element Method (FEM) COMSOL model of a Three Phase Permanent Magnetic Excited Transverse Flux Machine (TFM). The model is fully parameterized and able to sweep over all parameters during design optimization process. The nonlinear BH curve of stator and rotor material as well as the anisotropy of the laminated rotor stack is considered. In order to reduce simulation time and computation effort model symmetries are respected and a mixed formulation with vector and scalar potential is used.

Transverse Flux Machine

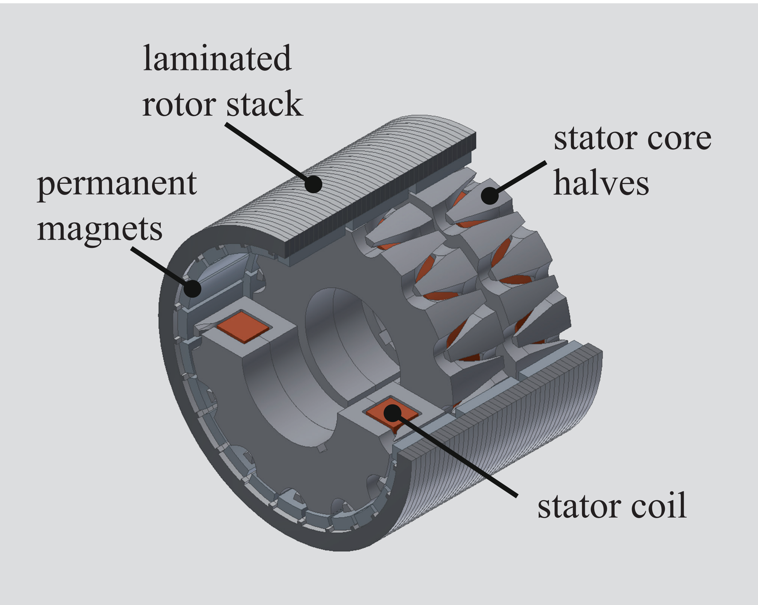


Figure 1: 3D model of the three phase transverse flux machine

- ring winding
- areas of magnetic flux and current guiding parts do not compete for available space
- high number of pole pairs
- high torque density at low speed

Computer-Aided Design

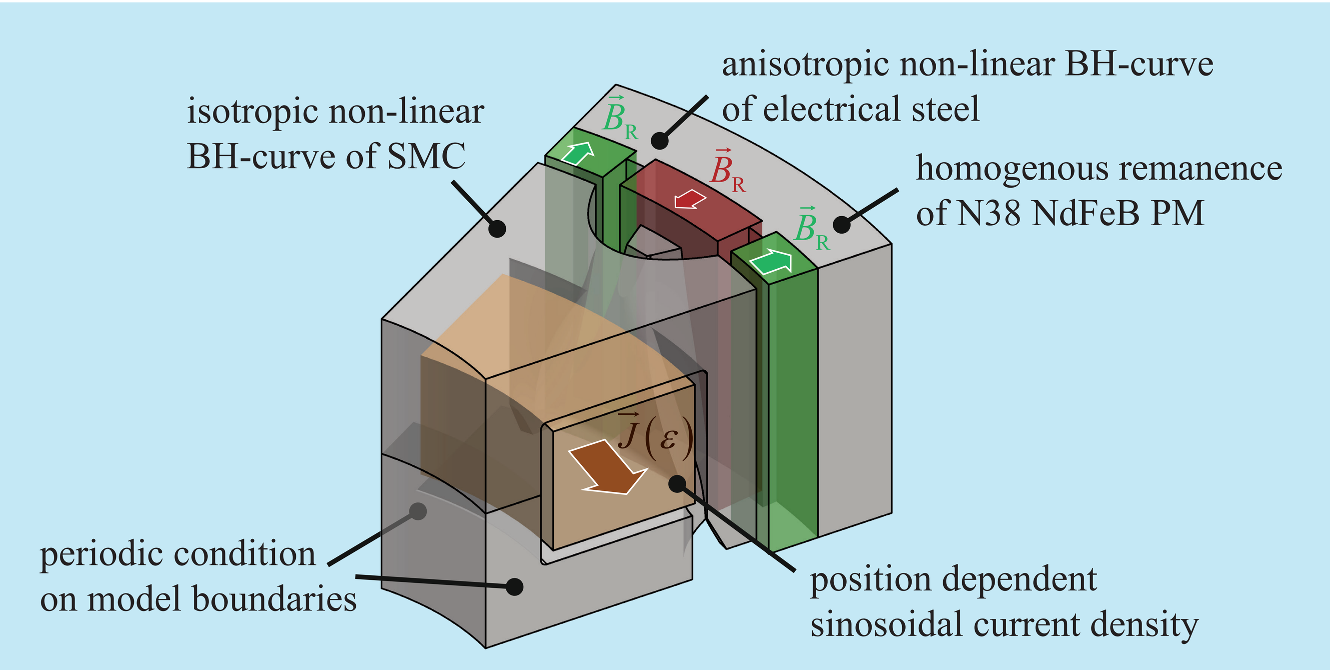


Figure 2: Model of one pole pair of one phase

- built in Autodesk Inventor 2016, imported via LiveLink™
- parameterized master drawing, components are derived from it
- COMSOL manipulates parameters during optimization

Problem definition

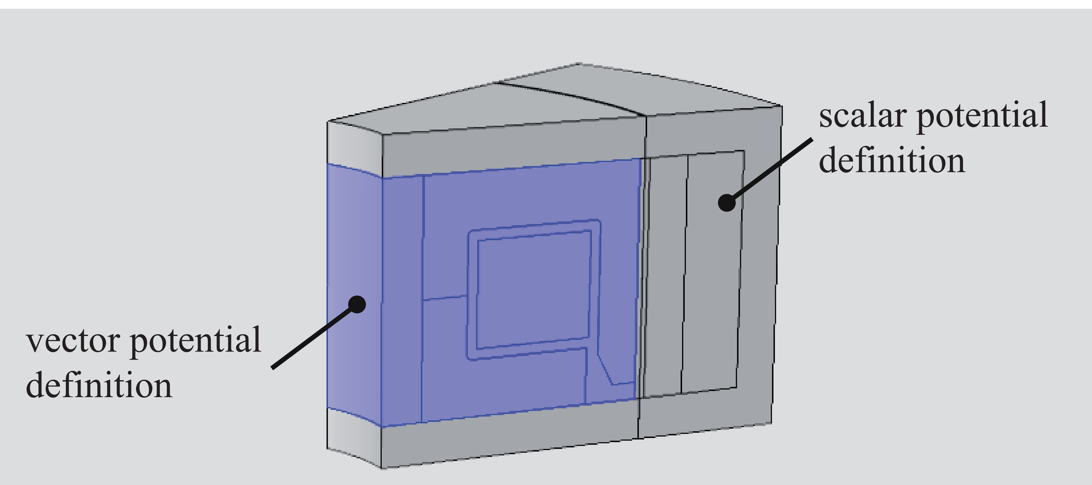


Figure 3: Model in COMSOL

- rotating machinary, magnetic
- mixed formulation: scalar and vector potential

$$\nabla \cdot B = 0 \qquad \nabla \times H = J$$
$$H = -\nabla V_m \qquad B = \nabla \times A$$

Laminated Steel

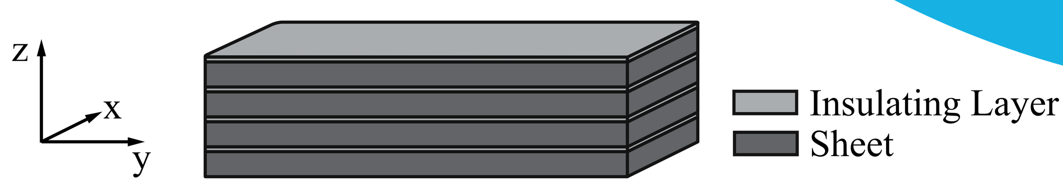
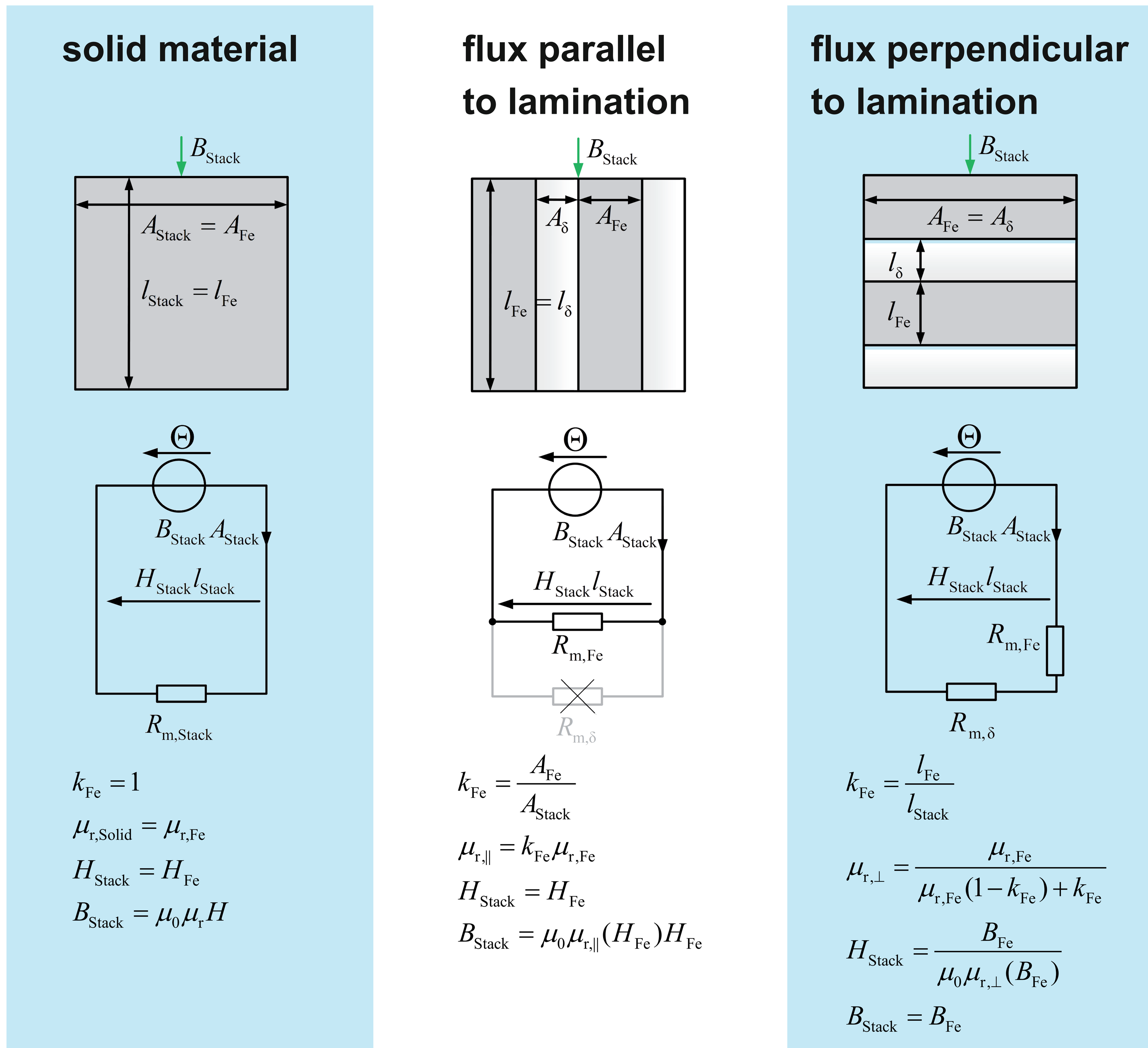


Figure 4: Stack of laminated steel sheets



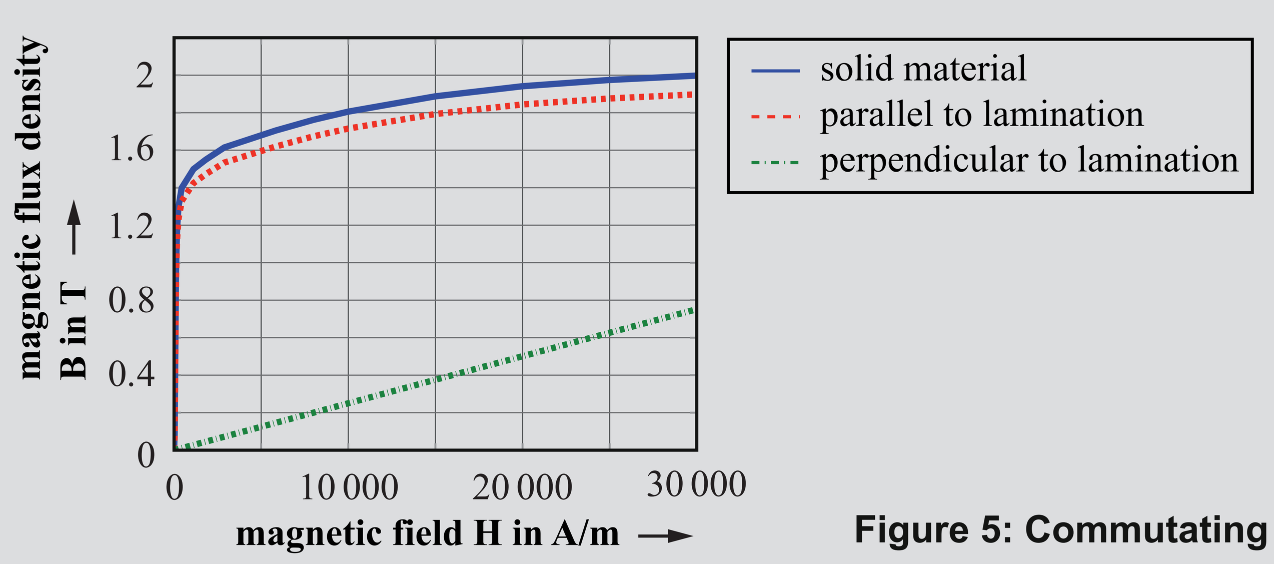


Figure 5: Commutating curves of steel

Results

- direct stationary solver (MUMPS)
- auxiliary sweep over 19 rotor positions
- linear presolving for the first position
- simulated and measured torque match very well
- optimization algorithm increased torque density by 20% and decreased torque ripple by 80%

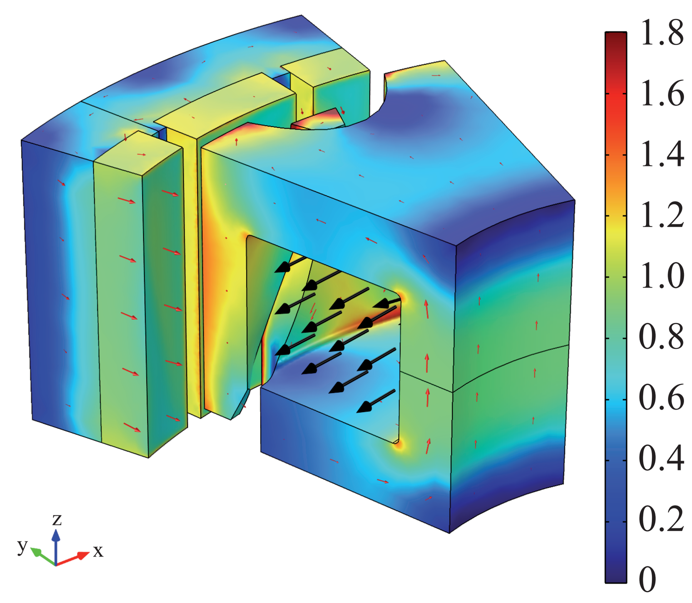


Figure 6: Absolute magnetic flux density in T, flux direction (red) and current direction (black), $\varepsilon_{el} = 90°$

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