An Analytical Solution Method for Magnetic Fields using the Fourier Analysis and its Application for Ferrofluid Driven Electric Machines

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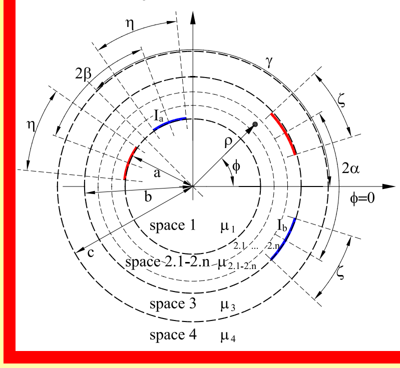
Introduction

A method to increase the forces and thus the efficiency of electric machines by filling the gap between rotor and stator with ferrofluid is presented. The magnetic field and torque in a simplified model of an electric motor are calculated using orthogonal expansion. The magnetic field is described with sums of orthogonal functions. The continuation of the field at the boundaries of the subspaces is guaranteed by fulfilling continuation requirements.

Geometry and ansatz of the radial n-layer model



vector potential:

$$A_{z,i}(\varrho,\varphi) = \sum_{j=1}^{n} \left(\frac{\varrho^j}{a^j} A_{j;i} + \frac{a^j}{\varrho^j} B_{j;i} \right) \cdot \sin(j\varphi)$$

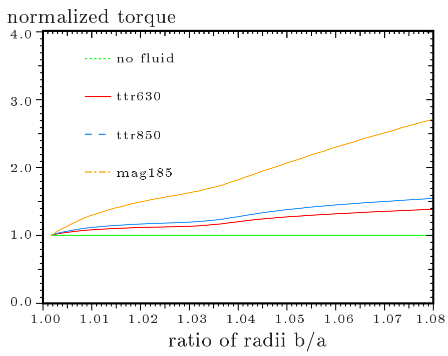


Bild 1: Normalized torque versus the ratio of radii at constant inner radius a for 3 different ferrofluids.

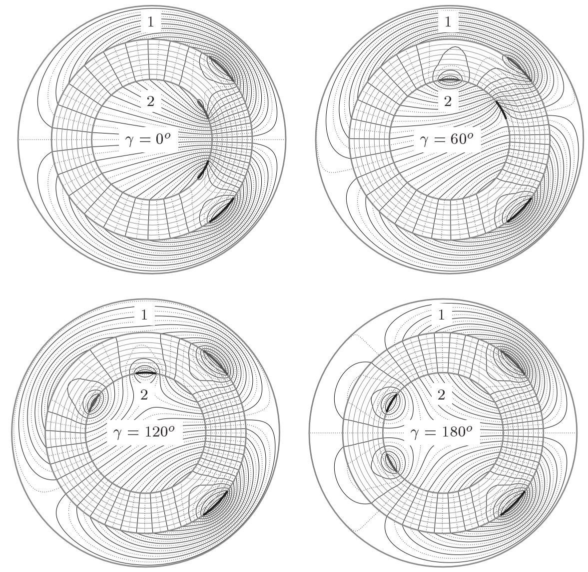
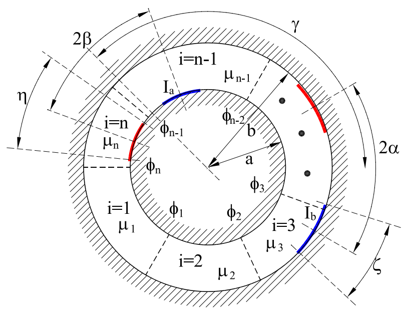


Bild 2: Magnetic lines of forces for the n-layer model (8 layers in the gap between stator and rotor) for 4 different angles γ between the currents (1 stator, 2 rotor). The concentric circles mark the subdivision of the gap area, which is here excessively wide for a better view. Due to the nonlinear behaviour of the ferrofluid as well as the steel applied in the stator and the rotor the permeability and the magnetic field are determined in a recursive procedure. From these magnetic field the torque can be calculated applying the Maxwell tensions.

Geometry of the azimuthal n-section model



First the eigenvalues and eigenvectors for the intersected gap area have to be found using the continuation requirements at the intersection boundaries. Then the field is calculated applying the excitation of the current sheets.

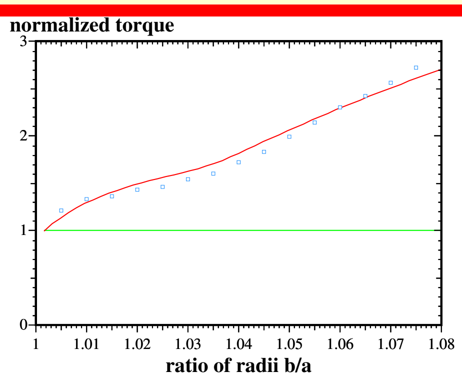


Bild 3: Normalized torque for the radial n-layer (solid line) and the azimuthal segmented gap (squares).

Conclusion and prospects

Both types of calculations give a good impression of the effect of ferrofluids in the layer between stator and rotor and ensure the capacities for development resting on this technology.
The very promising results have to be proved in a real experimental setup. This is an electric motor which has to be able to enclose the ferrofluid between the stator and the rotor. It remains a technological challenge to develop a reliable enclosure mechanism.