

ALVIER MECHATRONICS

*Beyond Rare Earths: Rethinking Electric Motor
Design with Next-Generation Materials*

PRESENTER: Aleksandr Nadkin (ALEKSANDR.NADKIN@ALVIER.COM)

PRESENTATION FOR: CWIEME 2026, Berlin, Germany

DATE/TIME/LOCATION: 2026-05-19 / 15:45

SESSIONS: Advancements in Electrical & Mechanical Engineering and Automation;
Sustainability and Energy Efficiency

ALVIER MECHATRONICS

Presentation Outline

1

/ Introduction

2

/ Emerging Materials

3

/ Motor Concept

4

/ Electromagnetic analysis

5

/ Structural Mechanics

6

/ Prototyping and Assembly

7

/ Testing

8

/ Conclusions and Next Steps



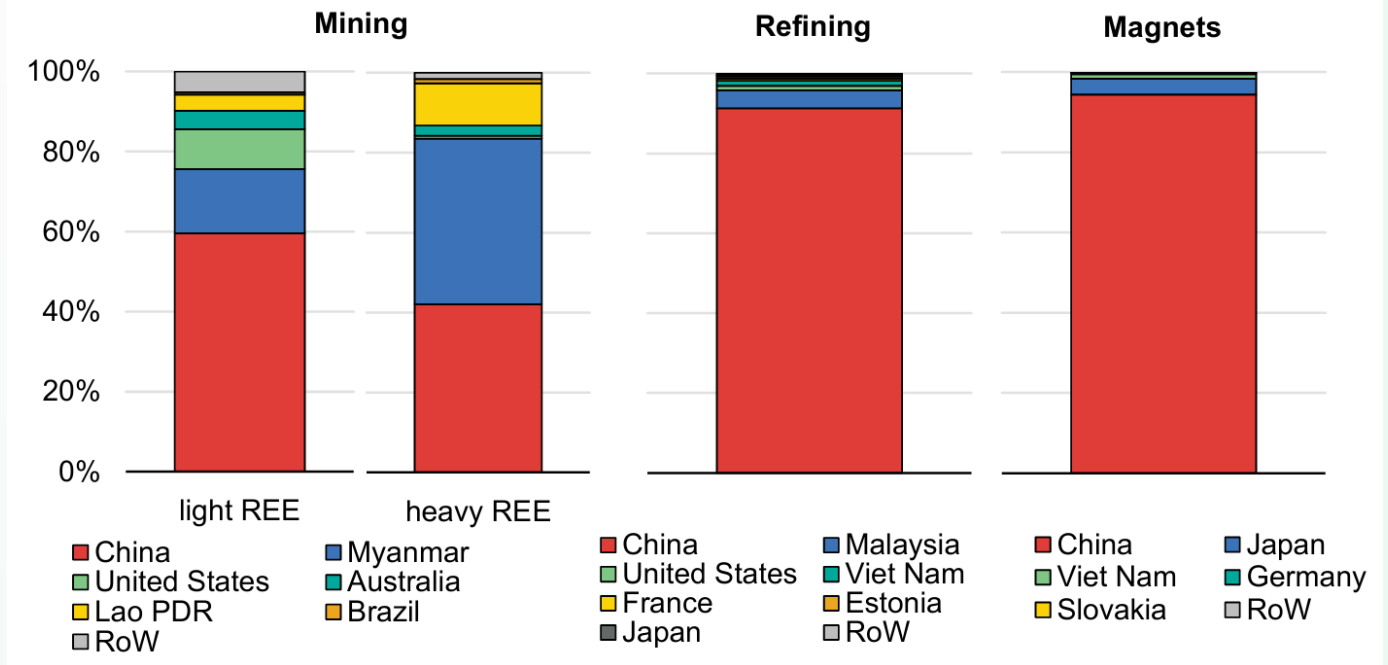
1. Introduction

Introduction

Background

- / High interest in high-efficiency electric motors with low environmental impact (without Rare Earth (RE) materials)
- / Addressable aspects
 - Resilient supply chains
 - Geopolitics (independence, risk mitigation)
 - Price volatility (strong fluctuation in RE materials pricing)
 - Sustainability

Geographical concentration of supply chain stages for rear earth magnets



Notes: REE – rare earth element, RoW – rest of world

Source: IEA (2026), Rare Earth Elements, IEA, Paris <https://www.iea.org/reports/rare-earth-elements>, Licence: CC BY 4.0

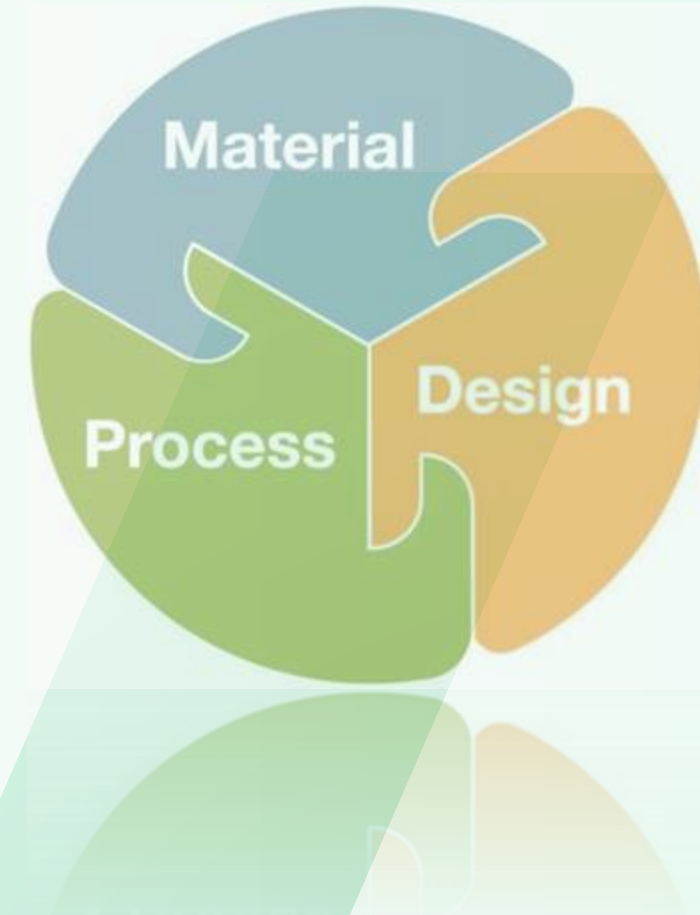
Introduction

Scope & Approach

- / **NOVEL MATERIALS** - Design, build and test a low power electric motor using FeN permanent magnets and SMC (Soft Magnetic Composite)
 - potential area in high-efficiency automotive and industrial applications < 10kW

- / **NOVEL CONCEPTS** - A SSAFM (Single Sided Axial Flux Motor) motor with an adapted new rotor design based on FeN magnets
 - Includes electromagnetics, structural mechanics, mechanical design as well as prototyping

- / **DESIGN OBJECTIVES**
 - Maximize torque output while respecting;
 - FeN magnet performance – safe operation without permanent demagnetization
 - Safe mechanical operation up to 6.000 rpm
 - Efficiency meeting market requirements



2. Emerging Materials



Emerging Materials

FeN permanent magnets

/ First new magnetic material in 40 years

- α'' Fe₁₆N₂
- Highest potential remanent flux density
- 100% free of rare earth minerals



/ Iron Nitride Properties

- High Remanence with moderate Coercive Force
- Very low reversible thermal coefficients
- Operating temperature >150°C
- Higher electrical resistivity than NdFeB (2X) and SmCo (5X)
- Density advantage
- FeN10B grade (first generation)

Emerging Materials

FeN permanent magnets

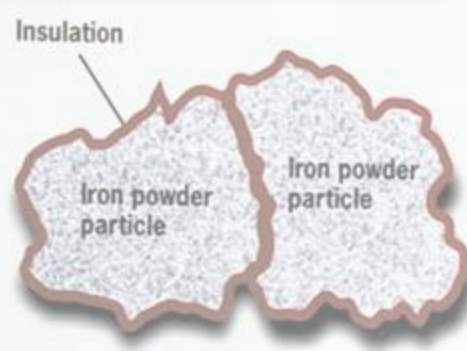
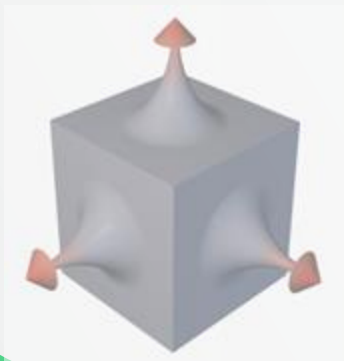
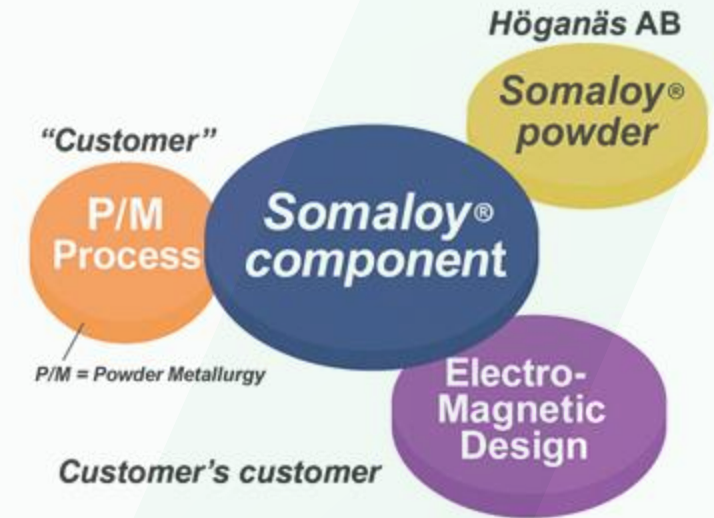
/ What does this mean for motor design

- Magnetic circuit designs with high permeance coefficients
- IPM rotor and spoke type IPM rotor designs (RFM and AFM)
- Flux concentration and intensification
- Transverse Flux Motor (TFM) designs
- Variable Flux Machine Concepts

Soft Magnetic Composite (SMC) material

/ The Somaloy® (SMC) concept

- A Somaloy® component is a result of three main parts - **material**, **design** and **component production**.
- The components are designed for efficient volume production (uni-axial compaction) at low cost.
- The anisotropic magnetic properties and the net shaping capabilities of the Somaloy® materials opens new opportunities to design compact, light and cost-efficient solutions
- Pure iron particles coated with a very thin inorganic coating



Emerging Materials

SMC component manufacturing process

/ Relatively new to the electric motor industry

Höganäs
Somaloy 110i 5P

Höganäs
Somaloy 130i 5P

Höganäs
Somaloy 700HR 5P

Product carbon footprint



Product information

Somaloy 700HR 5P is a 42-mesh SMC powder mix optimized for low core losses in the frequency range 0-1 kHz. It is based on pure iron powder, and the evolutionary SP coating enables heat treatment up to 650°C in nitrogen, which results in full stress relaxation for most motor applications. It provides a competitive alternative for cast iron, steel and rotating machines, such as electric shaft motors, pump shafts and compressors. The component shaping process and 3D properties offer greater design freedom than laminated electric steel. Therefore, Somaloy solutions can be optimized and integrated to a greater extent in the specific application.

The unique combination of high magnetic saturation and low magnetic losses results in increased efficiency and a reduction in size and weight.

Product Carbon Footprint

The Product Carbon Footprint (PCF) of Somaloy 700HR 5P is calculated according to the International Standard on Carbon Footprints of Products (ISO 14067:2018). The document is 1 kg of Somaloy 700HR 5P mix at Höganäs factory gate. For the mix an average composition of 0.34wt% lubricant is used. The result presents the Global Warming Potential (GWP) expressed in kg CO₂ equivalents (kg CO₂eq).

www.hoganas.com

Höganäs 



Press-ready mix



Uni-axial compaction

RT or heated die (max 100°C)

Pressure 600-800 MPa

Density > 7,3 g/cc



Heat-treatment

SMC = no sintering

Typically, 500-650°C

In air, N₂ or steam



Final component

Rule-of-thumb:
Up to 2-3 times
lower PCF than
laminated steel



3. Motor Concept

Motor configuration and targeting performance

Electric motor topology

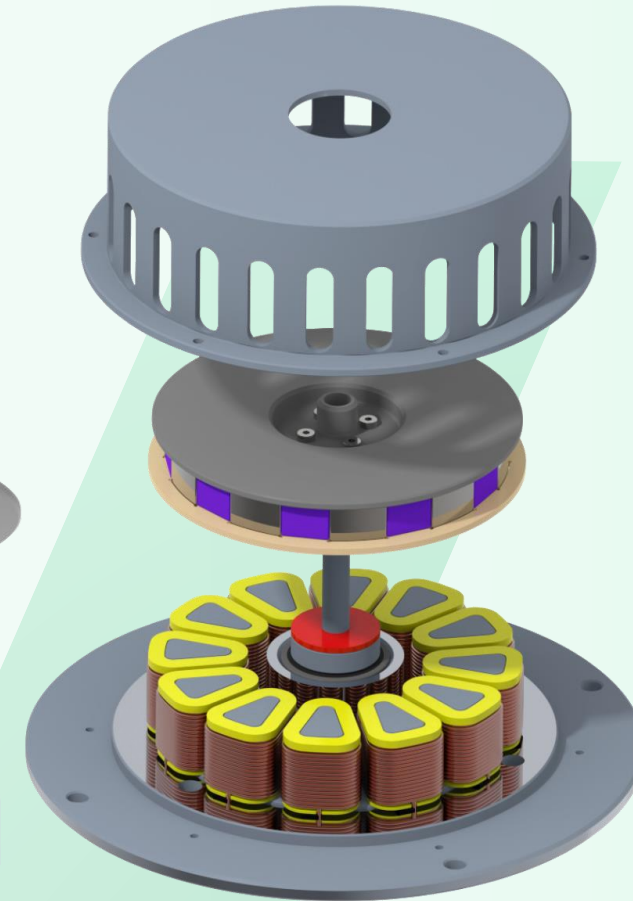
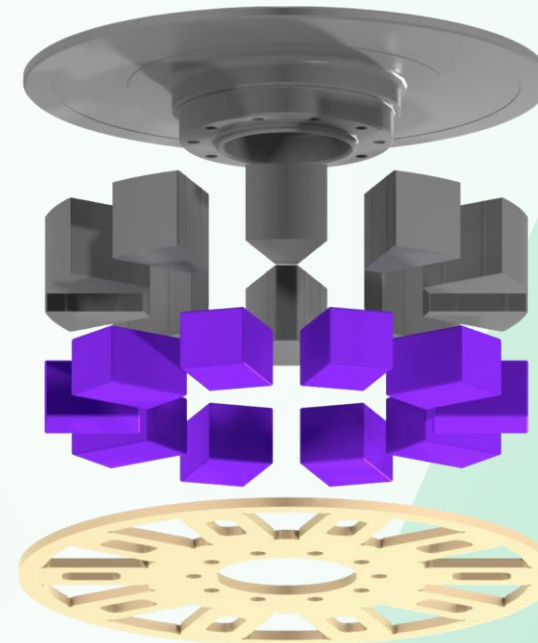
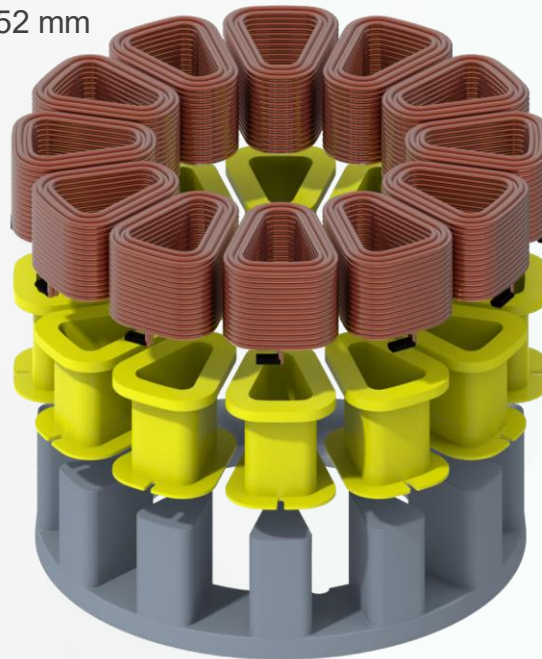
- Axial flux synchronous electrical machine with spoke type rotor and permanent magnet excitation
- A three-phase 12 slot / 10 pole layout with a concentrated winding

General dimensions

- Stator => OD 100 mm, ID 60 mm
- Total active axial length => 45 mm
- Housing => OD135 mm, axial length 52 mm

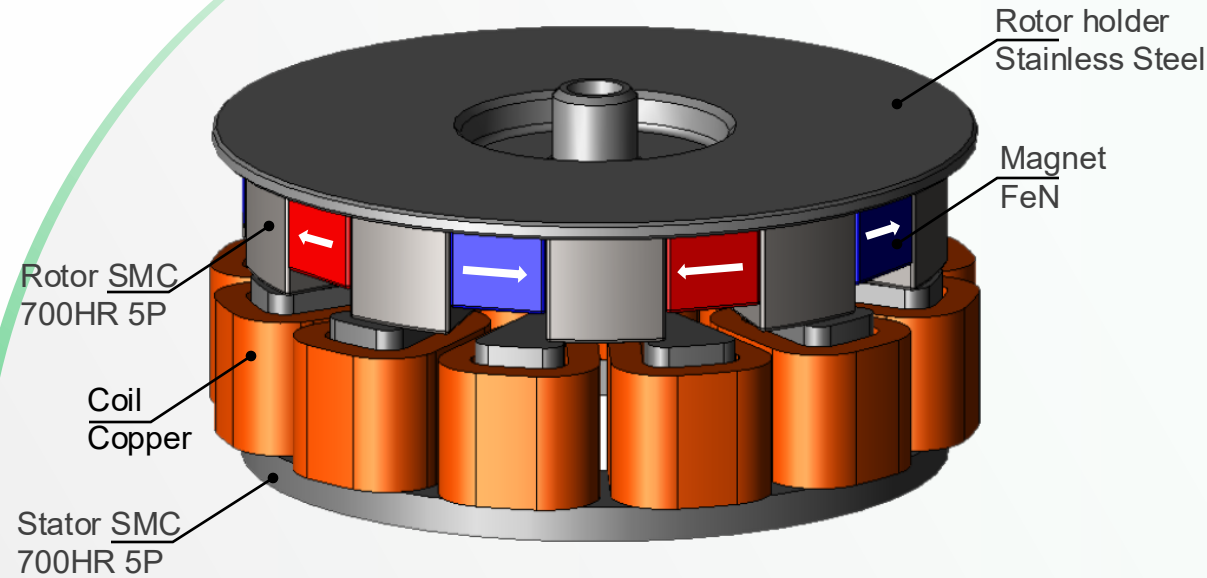
Targeted motor performance

- Rated torque $\geq 1,2$ Nm
- Peak torque ≈ 3 Nm
- Shaft speed up to 6000 rpm
- Rated current density 5 A/mm²
- Rated efficiency ≥ 90 %

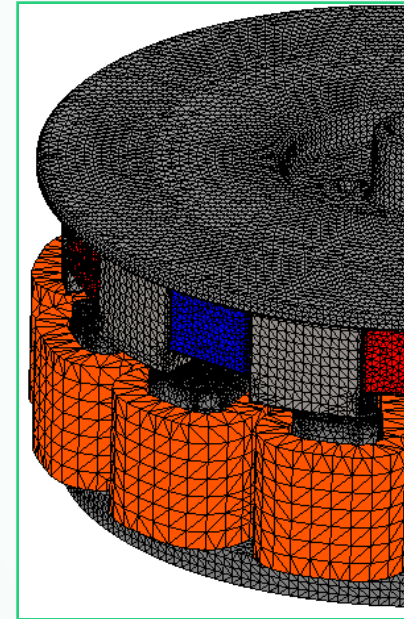


4. Electromagnetic analysis

Design and simulation model



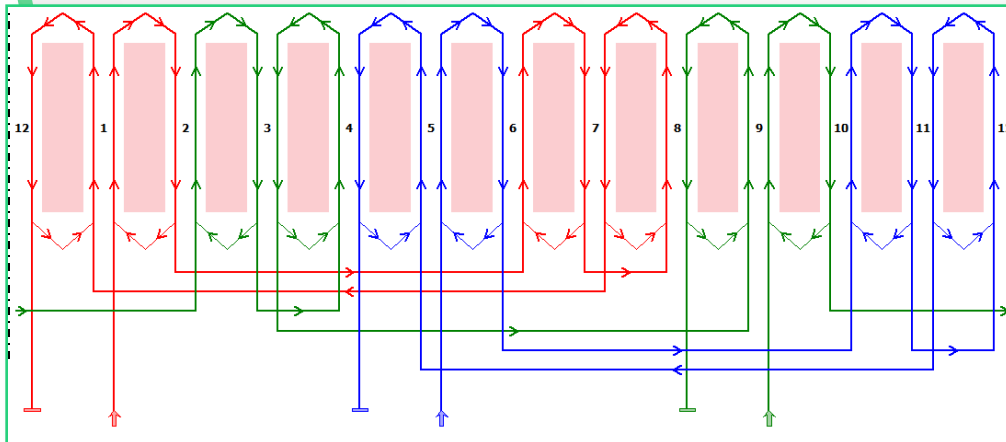
Model of electromagnetic system



Mesh in active components

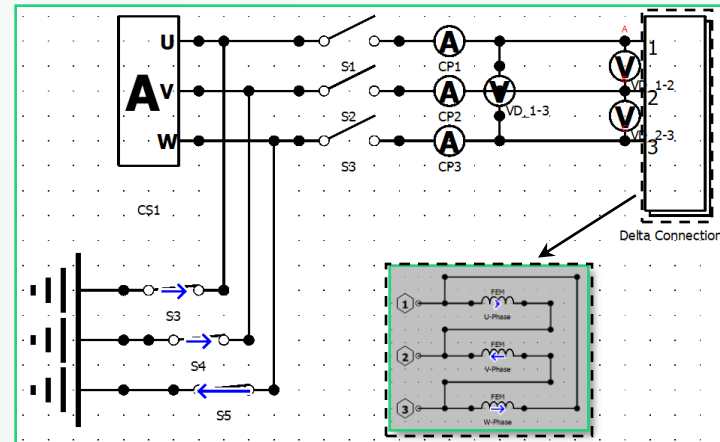
Assumptions in the simulation model:

- / Variable magnets with the nonlinear magnetic properties.
- / The magnets are assumed to be anisotropic.
- / Eddy currents in the magnets are neglected.
- / Temperature dependence of the magnetic properties is ignored, with all operating conditions assumed to occur at room temperature.
- / Core losses in stator and rotor parts are calculated in post-processing stage. Winding AC-losses, losses in magnets and drag losses are ignored.



Winding scheme

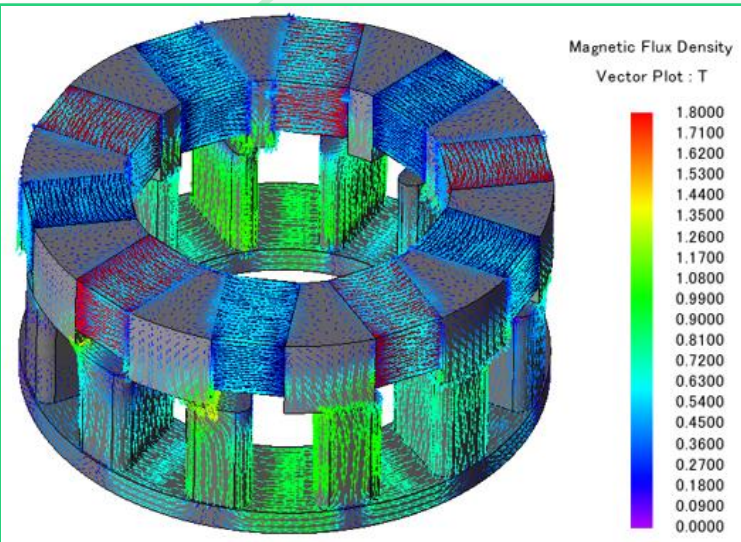
All coils are connected in series. The number of turns in each coil is 62, phase resistance is 0,321 Ohm at room temperature. Fundamental winding factor is 0,933.



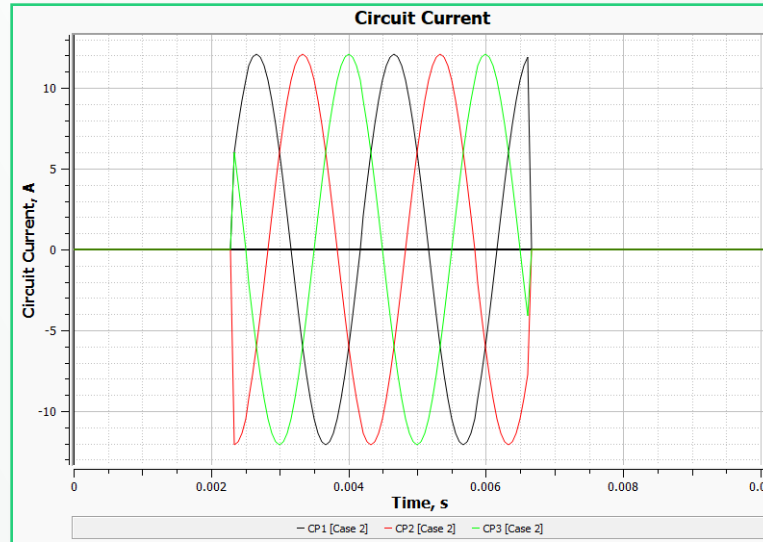
Motor control circuit

/ A set of switches allows the current source to be connected to the stator windings to supply current and generate torque. Disconnecting the current source enables the estimation of the back-EMF after loading, which serves as an indicator of demagnetization within the same simulation study.

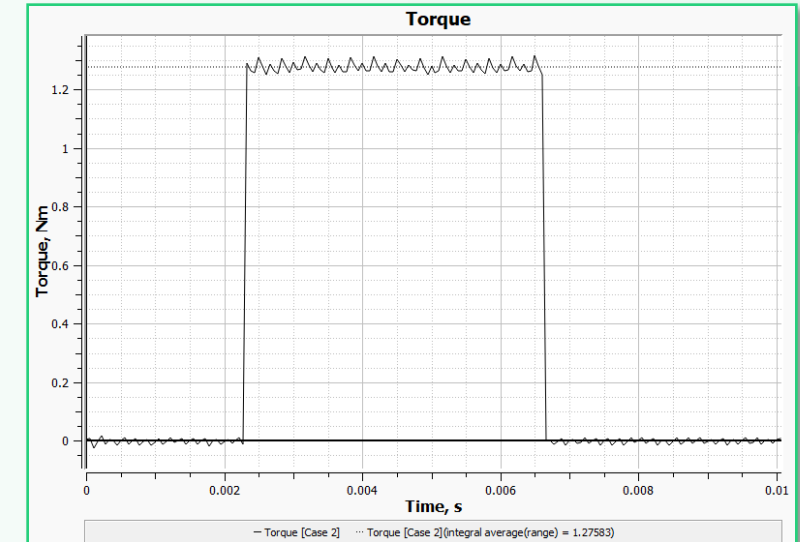
3D FE simulation



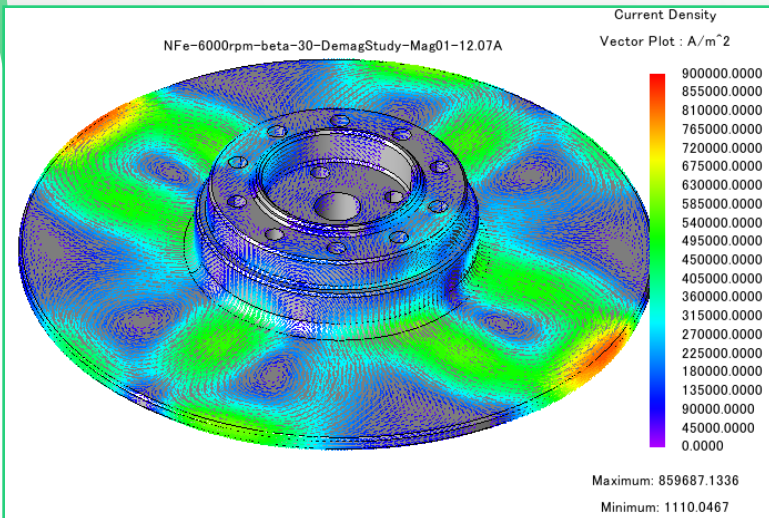
Magnetic flux distribution



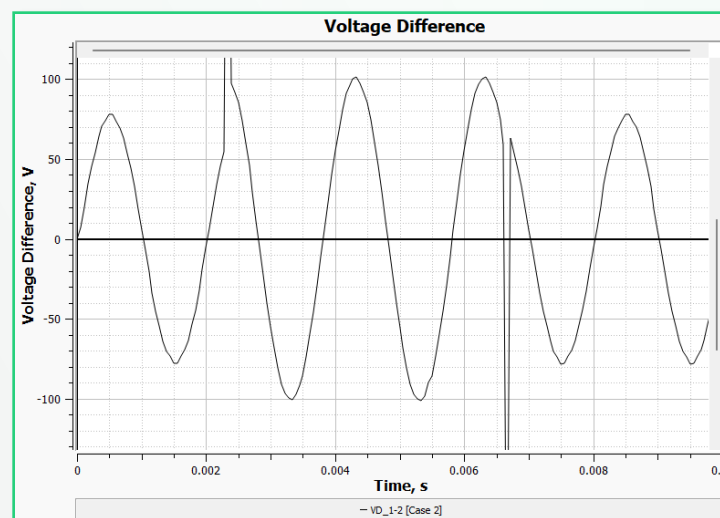
Current in winding



Electromagnetic torque



Eddy current distribution in holder



Back-EMF and voltage during simulation

/ Applied line current is 8.5 Arms and corresponding current density is 5 A/mm². Phase advance is set to 0 electrical degrees, meaning that only the I_q component is applied.

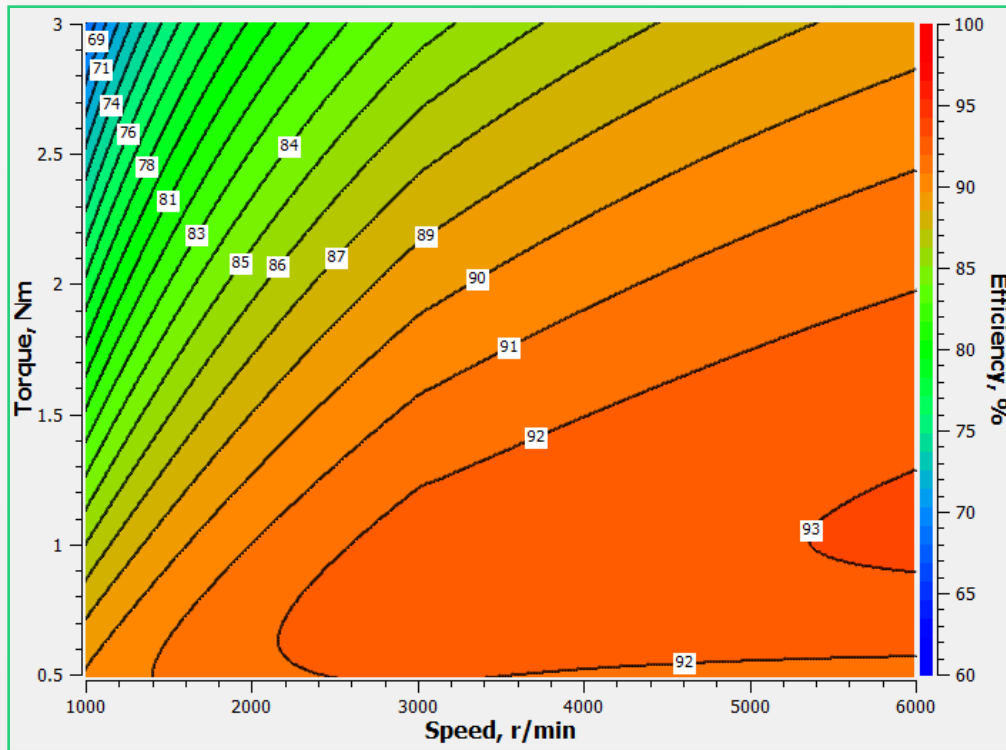
/ The equal values of back-EMF before and after the load indicate that the magnets did not change their magnetization state during operation at a current density of 5 A/mm².

/ Average torque in illustrated case is 1.276 Nm.

/ Due to the specific holder geometry eddy currents are minimized, however, they are still present and have a measurable impact on overall torque production.

Electromagnetic analysis

Simulation results – motor efficiency



Simulated Efficiency Map

/ The maximum efficiency of the motor is approximately 93%. Region with efficiency above 90% corresponds to wide range of operating modes from 1000 rpm to 6000 rpm and from 0.5 Nm to 2.8 Nm. To reduce simulation time, the rotor holder was excluded from the efficiency map calculation.

5. Structural Mechanics

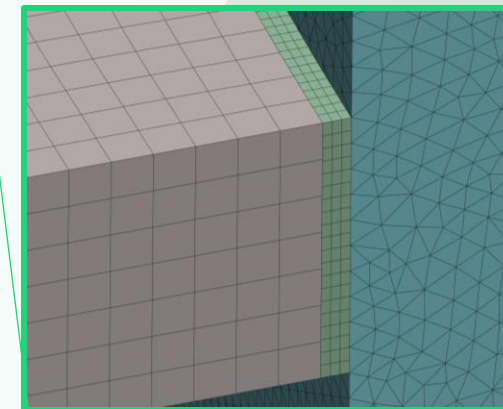
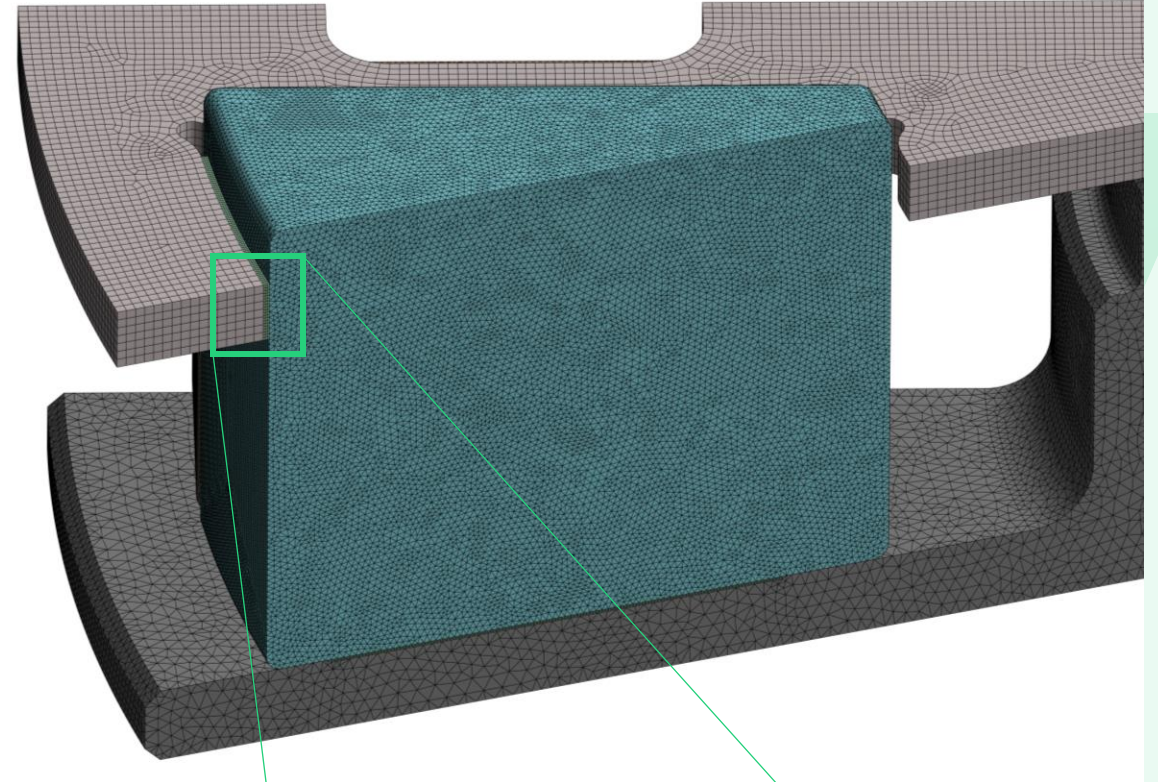
Structural Mechanics

Simulation Methodology

- / Simulated in Ansys Mechanical 2025 R2
- / 1/10 of the rotor with symmetry boundaries
- / Adhesive simulated as solids
- / Relevant load case:
 - Rotational speed 6000 RPM
 - Rotor temperature 120°C
- / Material parameters (selection below)

	CTE parallel [$\mu\text{m}/(\text{m}\cdot^\circ\text{C})$]	CTE perpendicular [$\mu\text{m}/(\text{m}\cdot^\circ\text{C})$]	Compressive strength [MPa]	Traverse Rupture Strength (TRS) [MPa]
SMC 700HR 5P	13,2	12,3	110	60
FeN Magnet	11,0	10,5	433, DOM* 368, 90deg to DOM*	45

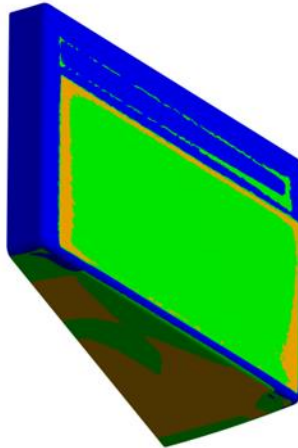
*) DOM – Direction Of Magnetization



Rotor stresses

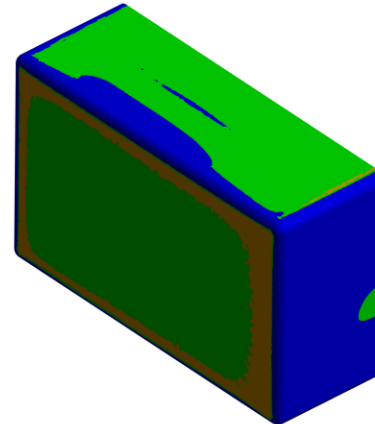
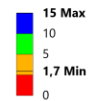
SMC 700HR 5P safety factor (Mohr-Coulomb Criteria) of SMC > 2.2

B: Rotor 1/10
SMC
Type: Safety Factor
Time: 1,
21.04.2026 11:31:04



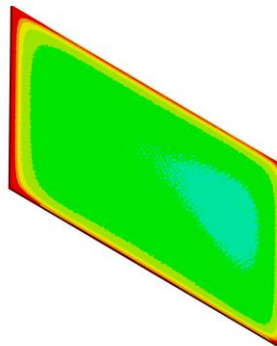
FeN Magnet safety factor (Mohr-Coulomb Criteria) of FeN magnets > 1,7

B: Rotor 1/10
FeN Magnet
Type: Safety Factor
Time: 1,
21.04.2026 11:51:05

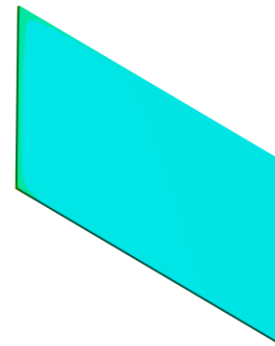
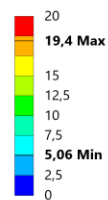


Adhesive between SMC and magnet: Average stress level within limits

B: Rotor 1/10
Adhesive
Type: Maximum Principal Stress
Unit: MPa
Time: 1, s
21.04.2026 11:53:46



B: Rotor 1/10
Adhesive
Type: Maximum Shear Stress
Unit: MPa
Time: 1, s
21.04.2026 11:54:01



- / Stress peaks at the ends of the adhesive
- / Global stresses in SMC and FeN Magnet low
- / For the adhesive, the stresses averaged over the surface are the most important

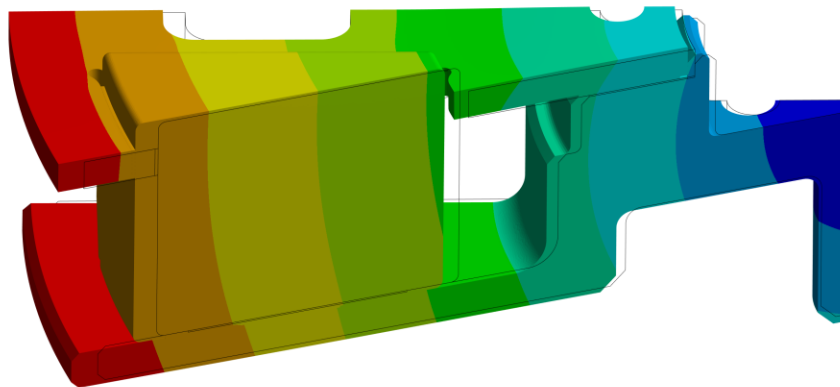
Rotor Deformation

Total Deformation

- / Mainly radial deformation due to temperature rise (thermal expansion) and rotational speed
- / Nearly no bending, as the rotor holder is designed for stiffness

B: Rotor 1/10
Total Deformation
Type: Total Deformation
Unit: mm
Time: 1, s
Deformation Scale Factor: 20,
21.04.2026 13:08:35

0,088 Max
0,079
0,07
0,061
0,052
0,043
0,034
0,025
0,016
0,0065 Min

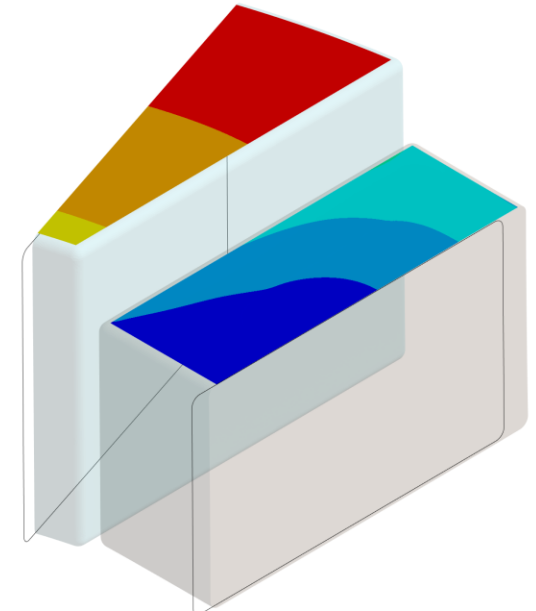


Axial Deformation

- / Only marginal change of the airgap

B: Rotor 1/10
Axial Deformation
Type: Directional Deformation(Z Axis)
Unit: mm
Global Coordinate System
Time: 1, s
Deformation Scale Factor: 20,
21.04.2026 13:05:05

0,011 Max
0,0096
0,0085
0,0073
0,0062
0,005
0,0039
0,0027
0,0016
0,0004 Min





6. Prototyping and Assembly



Motor parts

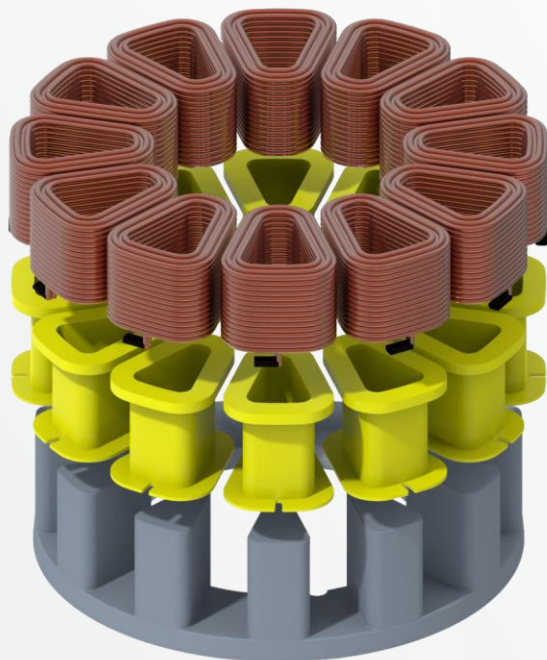


Fig 1. Stator

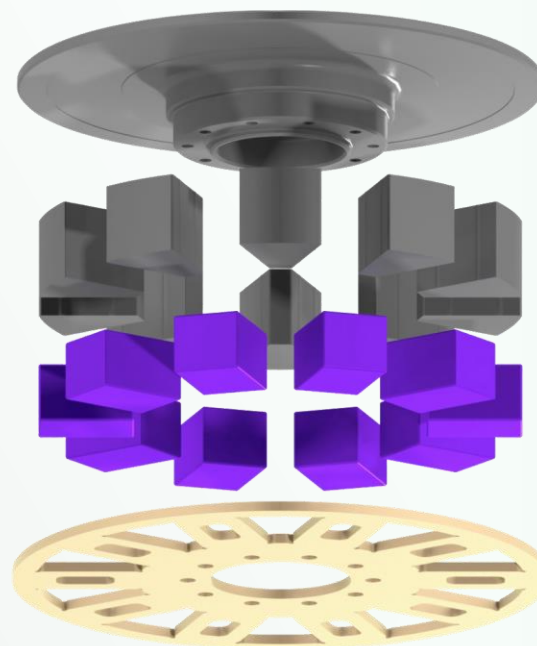


Fig 2. Rotor

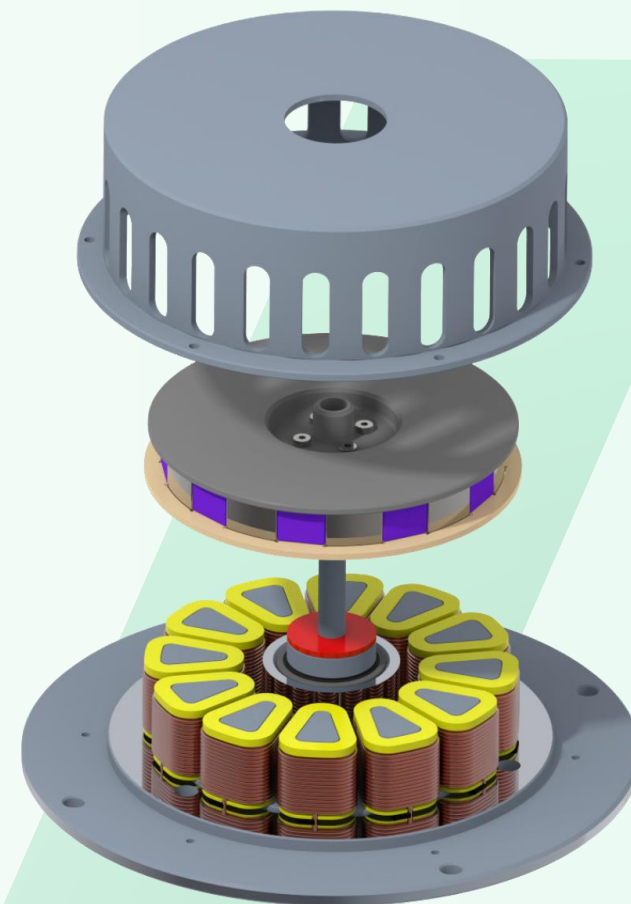
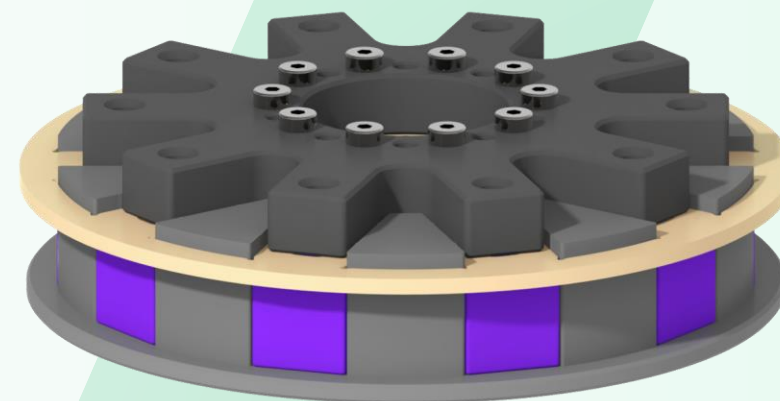
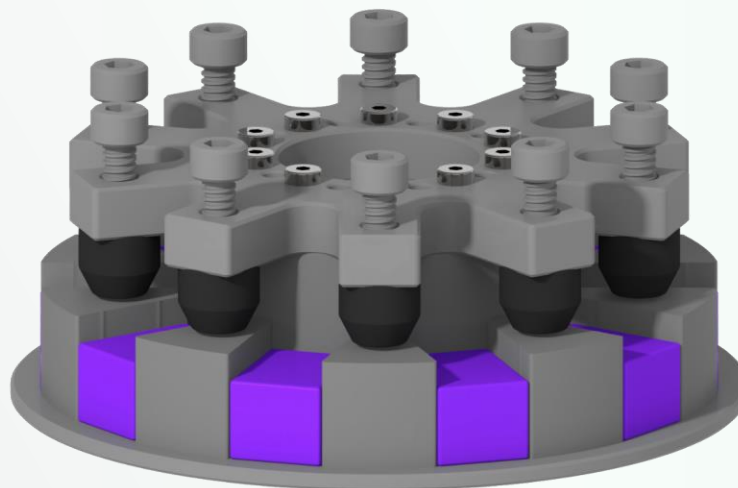
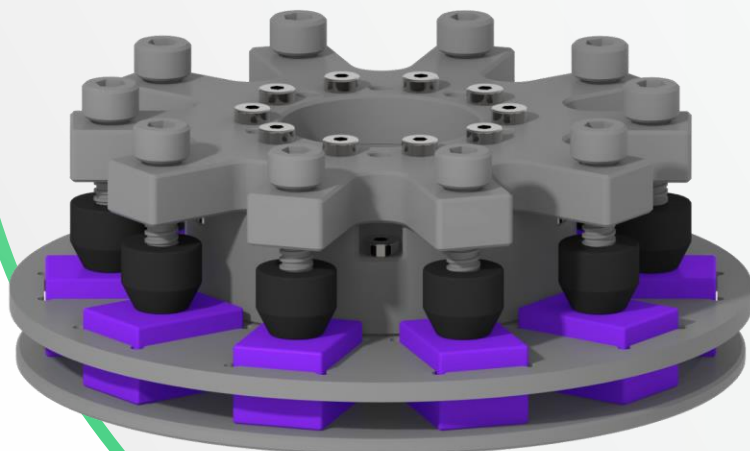


Fig 3. Stator & Rotor

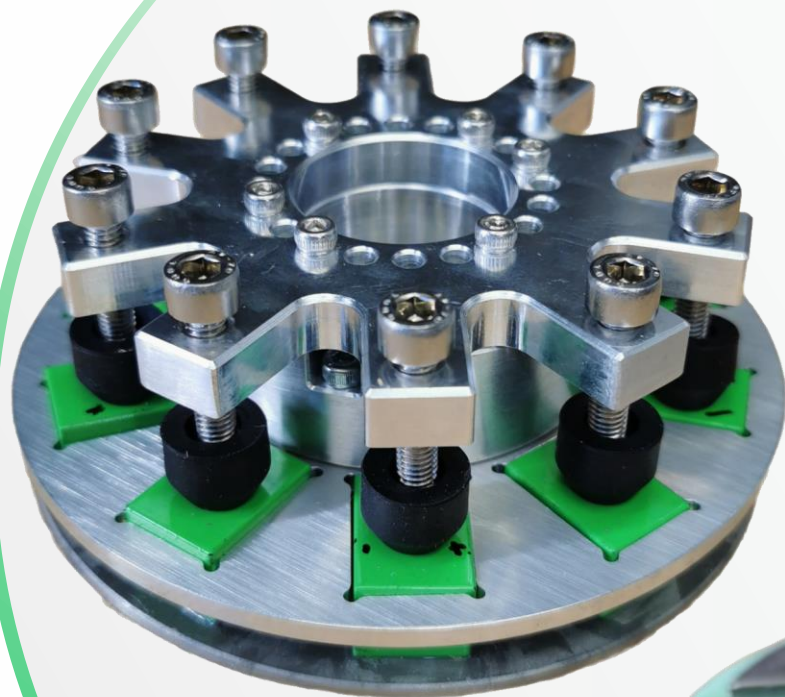
Rotor Assembly Process

/ Prototype build stage sequence

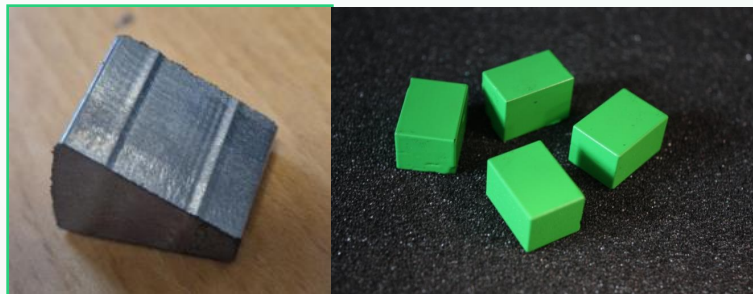
- 1. Magnets bonded to rotor disk with adhesive Permabond ET5401
- 2. SMC bonded to rotor disk & magnets with adhesive Permabond ET5401
- 3. Composite laminate bonded to rotor disk, magnets & SMC with adhesive Permabond ET5401 & ES558



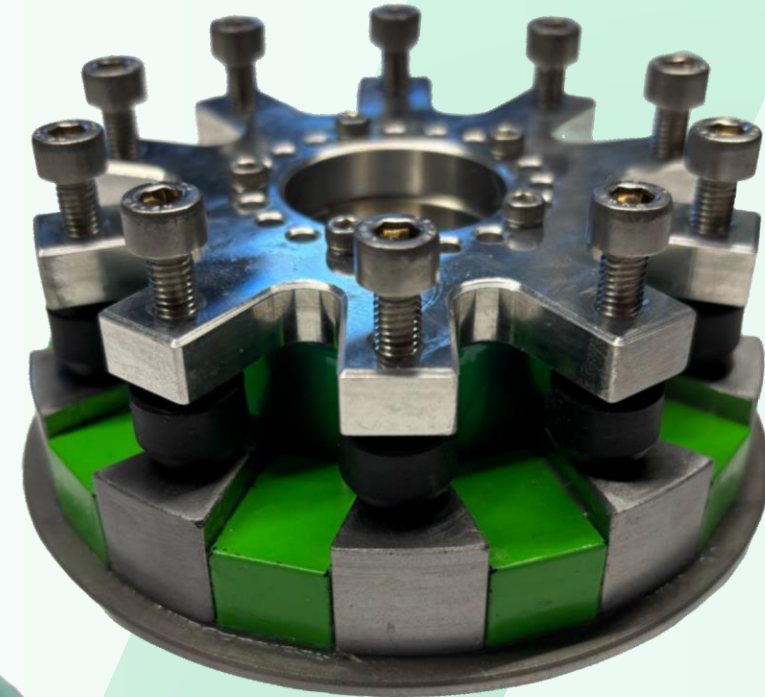
Rotor Assembly Process



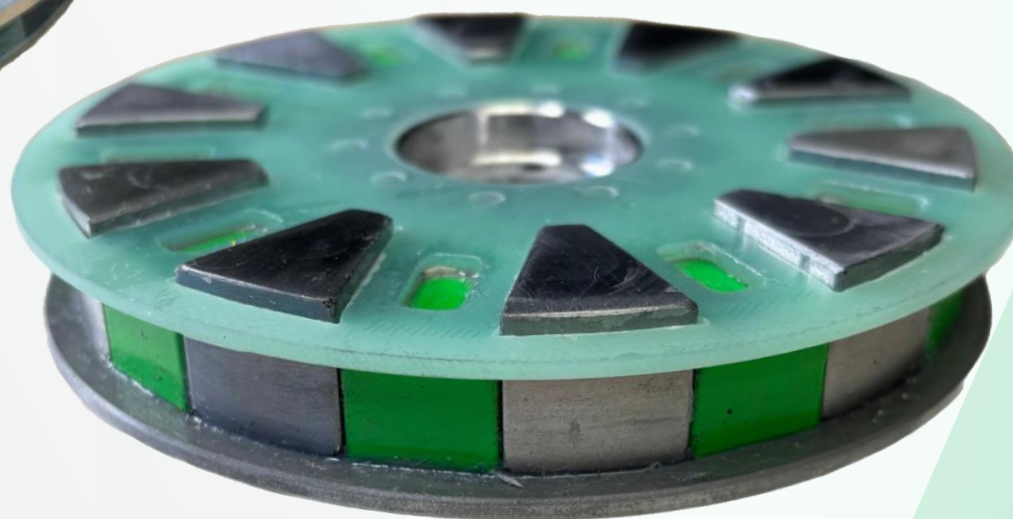
Magnet gluing (fixture)



SMC rotor pole piece
& FeN magnets



SMC gluing (fixture)



Final rotor assembly with GFRP retaining ring

The background of the slide features a complex financial chart with various data series, including candlesticks, line graphs, and numerical values like '+11,00.00' and '10 1 0'. The chart is rendered in a dark, semi-transparent style, allowing the title to stand out.

7. Testing

Testing

Motor under test

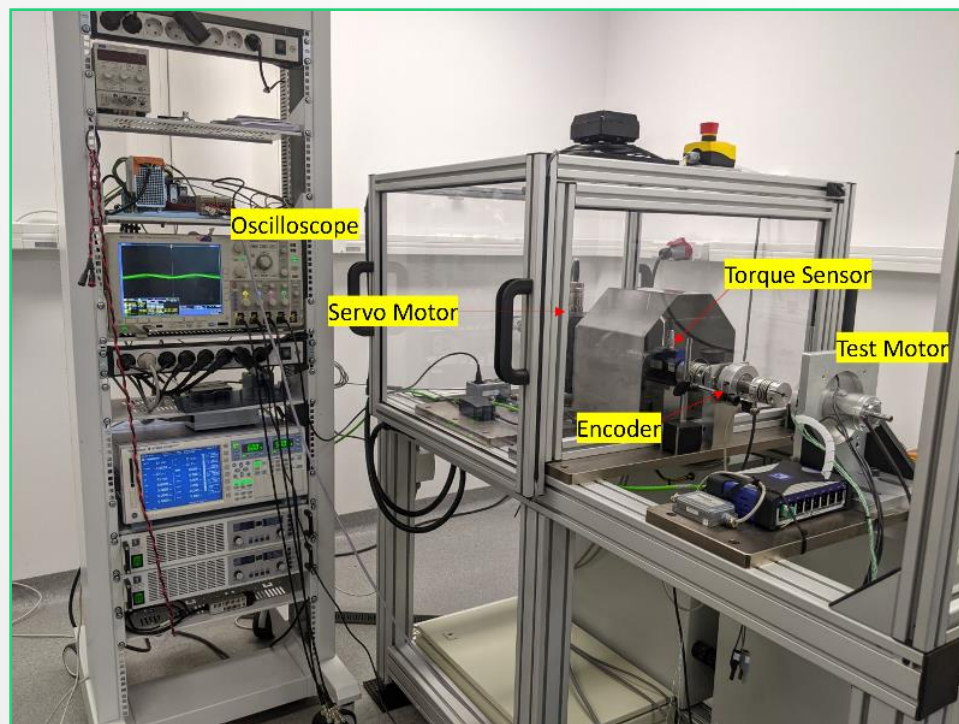
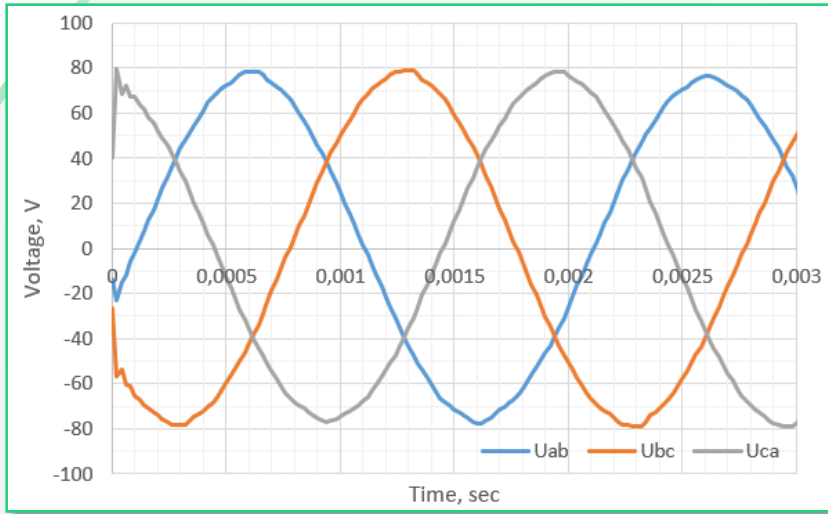


Fig 1. Dynamic test-bench



Fig 2. Highly sensitive cogging torque test-bench

Test results

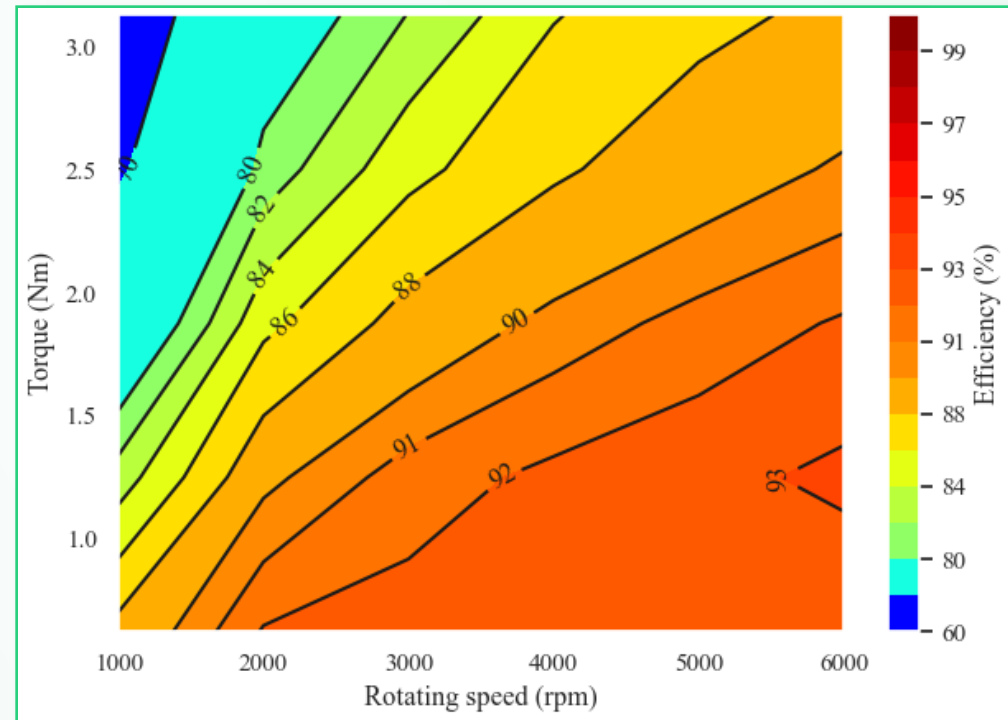


Measured Back-EMF

Line to line back-EMF at 6000 rpm is 54.5 Vrms. THD is 0.875 %

B-EMF imbalance

Speed, rpm	B-EMF _{AB} , Vrms	B-EMF _{BC} , Vrms	B-EMF _{CA} , Vrms	Imbalance, %
2000	18,122	18,231	18,207	0,598
6000	54,232	54,555	54,490	0,592



Measured Efficiency Map

- / The back-EMF imbalance is less than 1% across all tested conditions, indicating a symmetrical magnetic system and a uniform airgap.
- / THD of B-EMF is less 1% indicating a high degree of sinusoidality and confirms the good electromagnetic symmetry and quality of the motor and assembly.
- / At considered operation modes, the difference between simulation and measurement results is below 5% indicating good agreement.
- / Discrepancy may occur due to the simulation model accounting only for the major loss components.
- / Iron losses and their impact on torque are calculated in the post-processing stage, which can affect overall accuracy. Incorporating all loss components directly within the solver stage could improve simulation accuracy but would significantly increase computation time.



8. Conclusions and Next Steps

Conclusions and Next Steps

Conclusions

- High efficiency operation possible of > 90% in a wide operating area
 - targeting industrial drive systems with the first motor designed and built using FeN magnets and SMC stator and SMC rotor pole-pieces
 - FeN magnets sandwiched in flux concentrating (spoke type) arrangement between isotropic SMC rotor pole pieces
 - Stresses in all rotor parts (SMC pole pices, FeN magnets, GFRP retaining ring and adhesive joints) were simulated and found to be well within permissable stress levels with negligible deformation
- Internal development project from Alvier Mechatronics together with Niron Magnetics and Höganäs

Conclusions and Next Steps

Next steps

/ Potential next steps

- Different control strategies to increase output torque keeping high efficiency.
- Investigate novel electromagnetic system topologies for improved performance using SMC and FeN magnets (e.g. variable flux machines).
- Bottom-up technology and top-down application market analysis
 - e.g. refrigeration compressors, washing machines, pumps

INTERESTED TO LEARN MORE AND DISCUSS THE VALUES IN YOUR APPLICATION?
- please reach out to Alvier Mechatronics during the conference

THANK YOU – Q&A!

ALVIER MECHATRONICS –
AN ENGINEERING COMPANY

CONTACT: Aleksandr Nadkin

EMAIL: ALEKSANDR.NADKIN@ALVIER.COM