

The image shows the exterior of a building with a dark blue facade. A white rectangular sign is mounted on the wall, featuring the 'ebmpapst' logo in blue, lowercase letters. The building is partially obscured by green tree branches in the foreground. The sky is blue with some light clouds.The 'ebmpapst' logo is displayed in blue, lowercase letters within a white rectangular box. The box is positioned in the lower right area of the image, overlapping the building facade and the yellow footer.The slogan 'engineering a better life' is written in white, lowercase letters on a blue horizontal bar. This bar is located at the bottom of the white box containing the logo.

*Björn Winter*

# Tolerance analysis of a Vernier-Design

9 / 2024

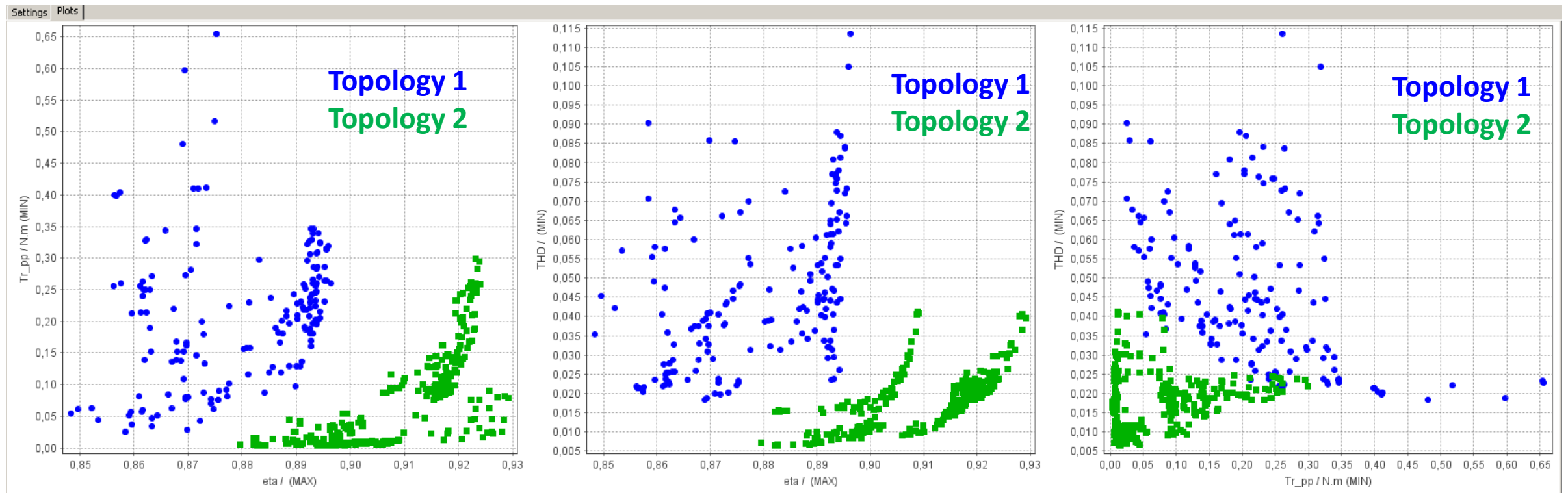
- 1** History
- 2** The „Problem“
- 3** Root cause analysis
- 4** Solution
- 5** Results

# History - Simulation

A new, „Low Speed Motor“ should be developed.

A Vernier-Design was analysed and promised very good performance.

Samples of the selected Variant of Topology 2 were build.

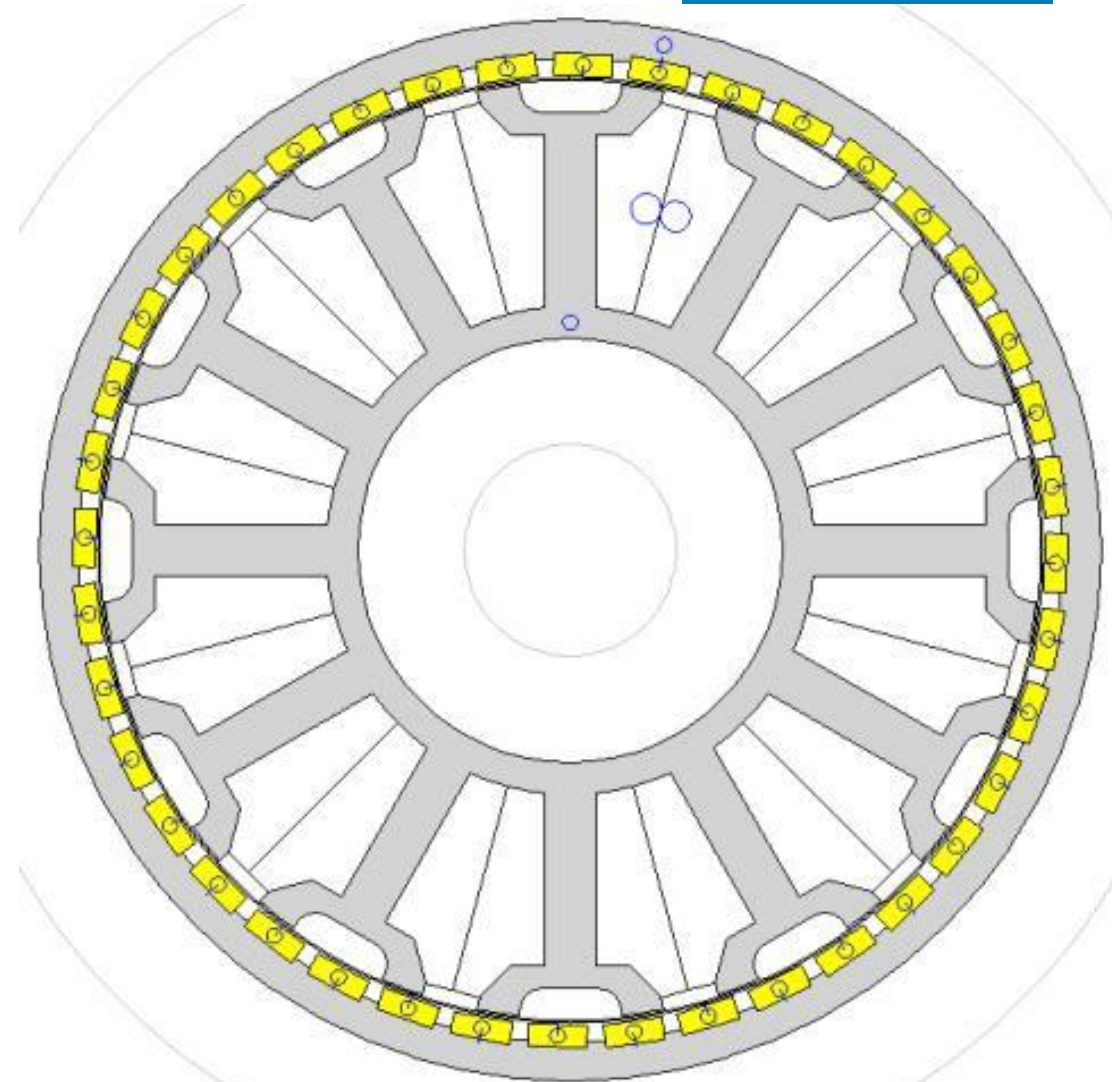
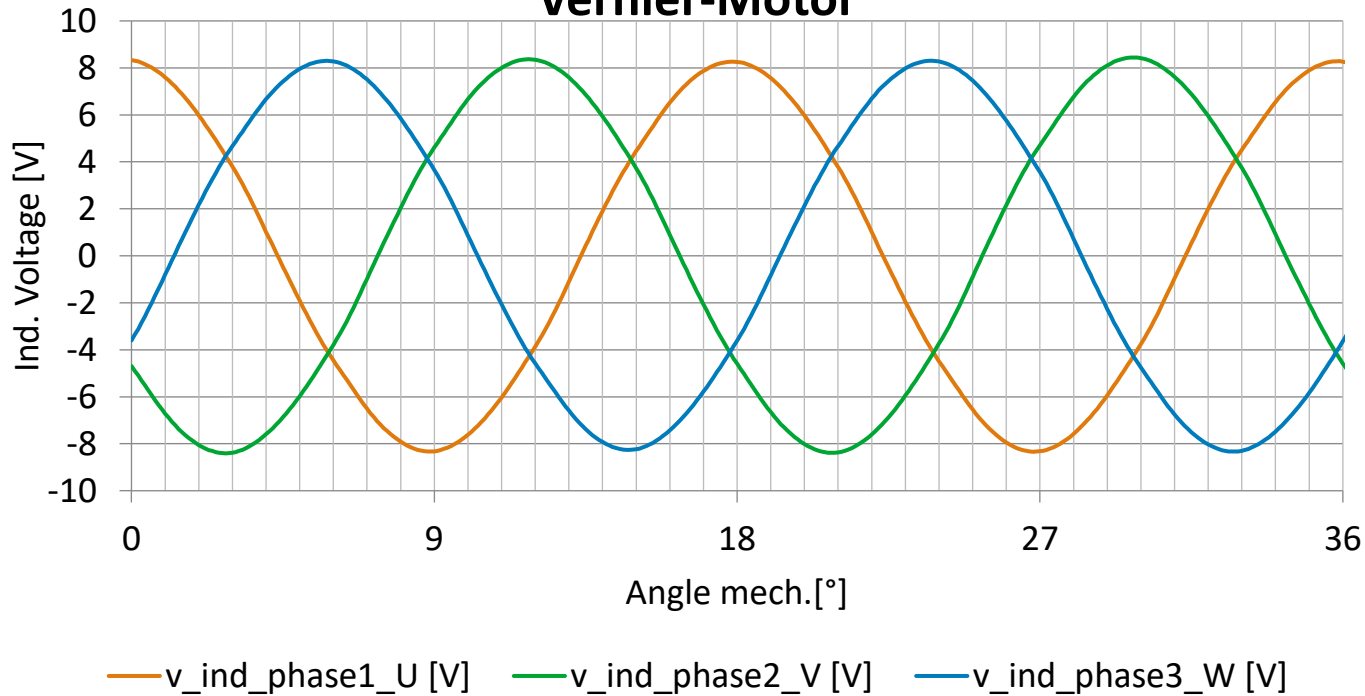


# History - Simulation

First Tests „on the point“ regarding

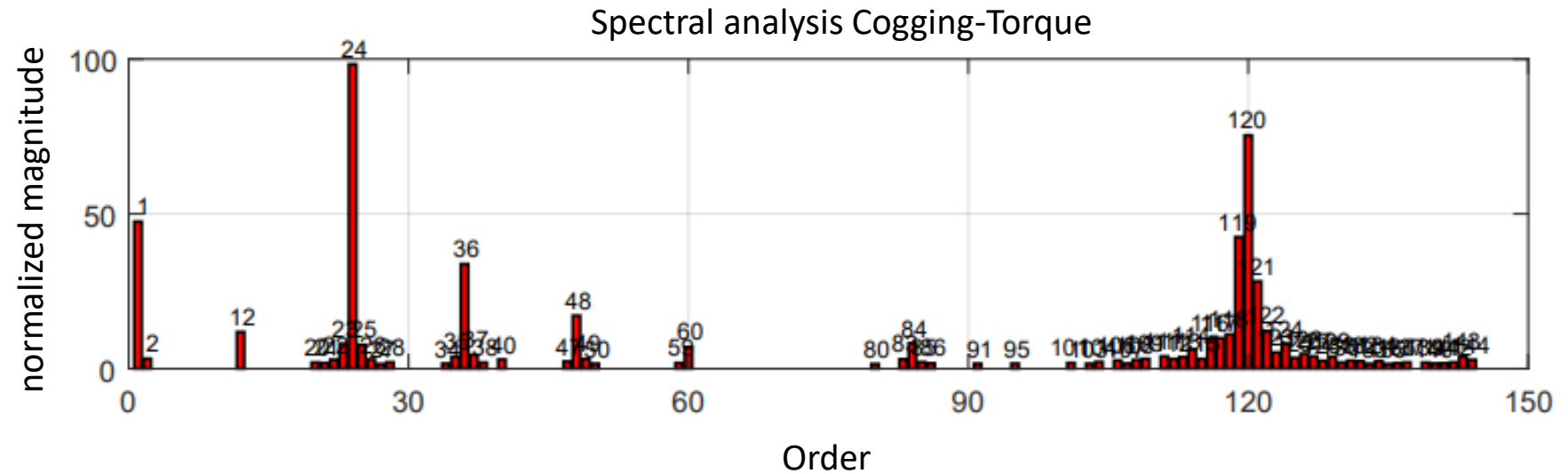
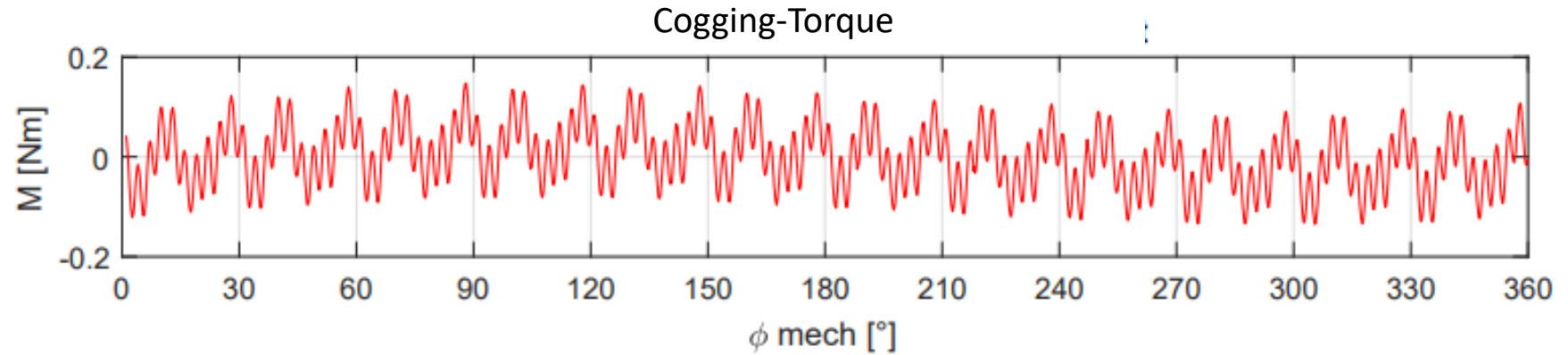
- Ind. Voltage (shape and magnitude)
- Poweroutput / Efficiency

**Vernier-Motor**

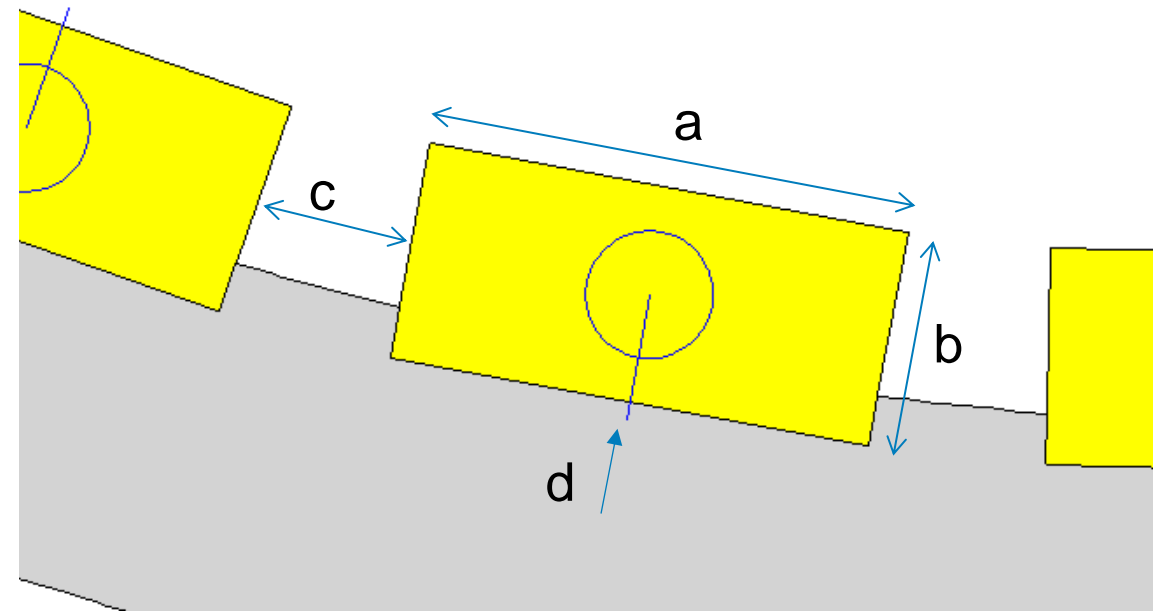


# The Problem

- Cogging Torque, much too high

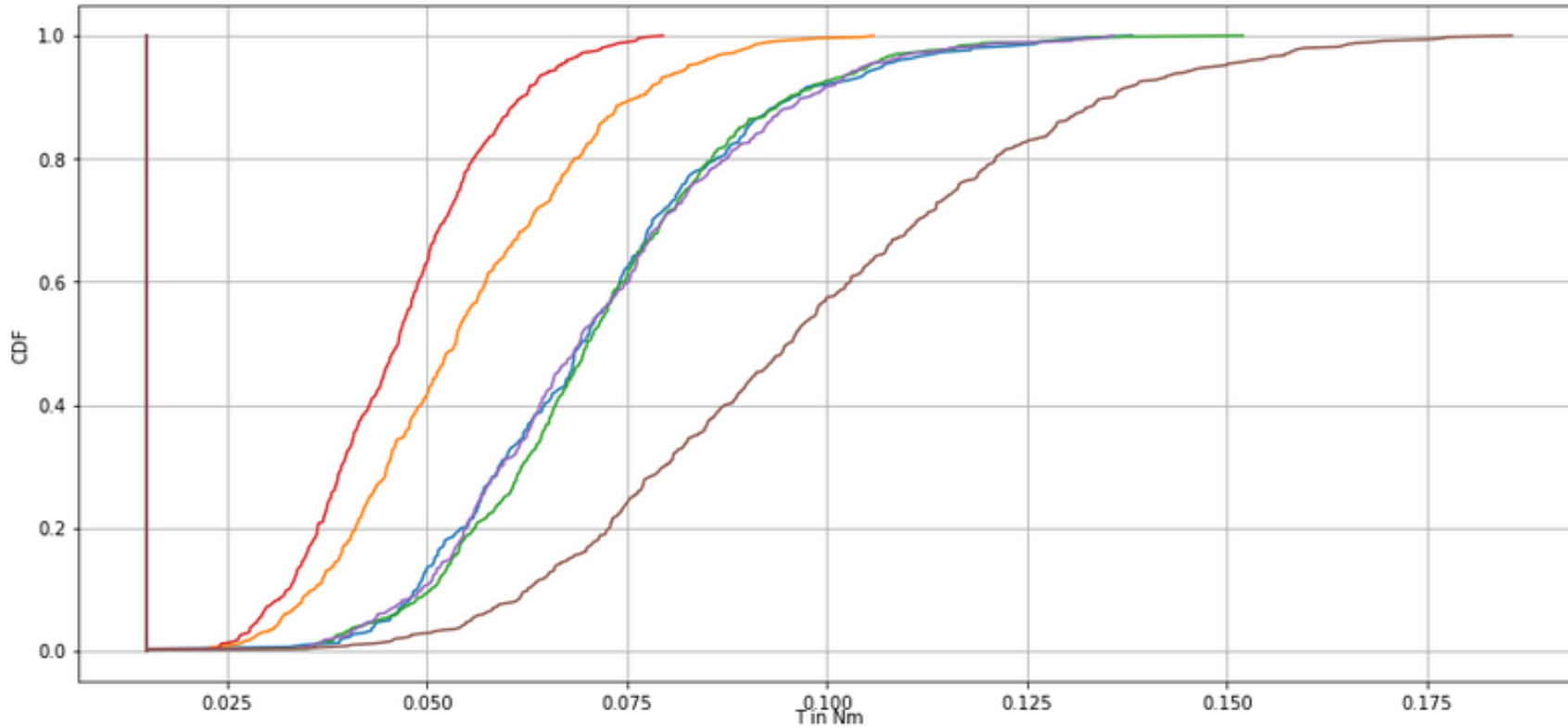


- In cooperation with the LCM/EAL, the mech. tolerances of the magnets and their positioning in the rotor are identified as the main cause of the excessive cogging torque.
- After the calculation models were extended with regard to the following tolerances, the dependencies of the cogging torques on individual tolerances could be represented.
  - a) Magnet Width Tolerance
  - b) Magnetic Height Tolerance
  - c) Tangential Position Tolerance
  - d) Radial Position Tolerance



# Root cause analysis

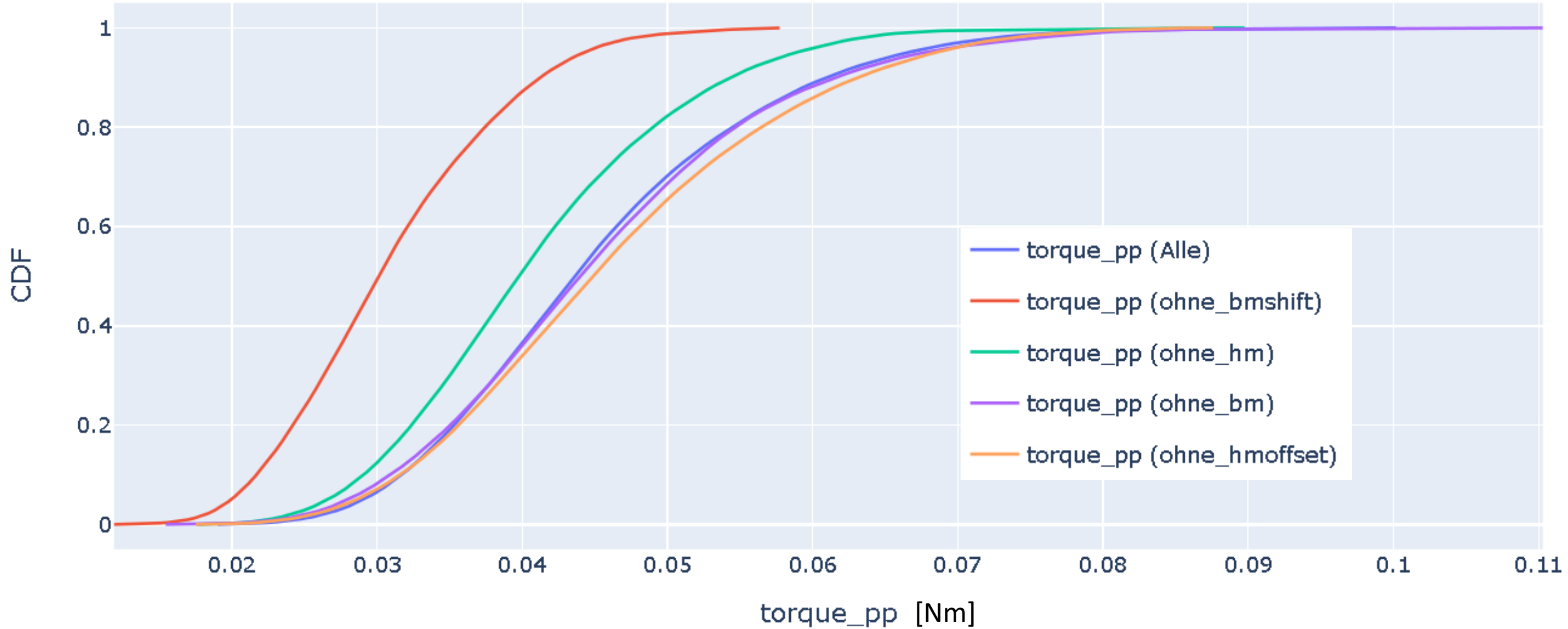
cumulative distribution function (CDF)



- VernierMuster2.noLoad\_postrrocessing.torque\_pp[Fx|bm]
- VernierMuster2.noLoad\_postrrocessing.torque\_pp[Fx|shiftb]
- VernierMuster2.noLoad\_postrrocessing.torque\_pp[Fx|bm(alt)]
- VernierMuster2.noLoad\_postrrocessing.torque\_pp[Fx|hm]
- VernierMuster2.noLoad\_postrrocessing.torque\_pp[Fx]
- VernierMuster2.noLoad\_postrrocessing.torque\_pp[Fx01]

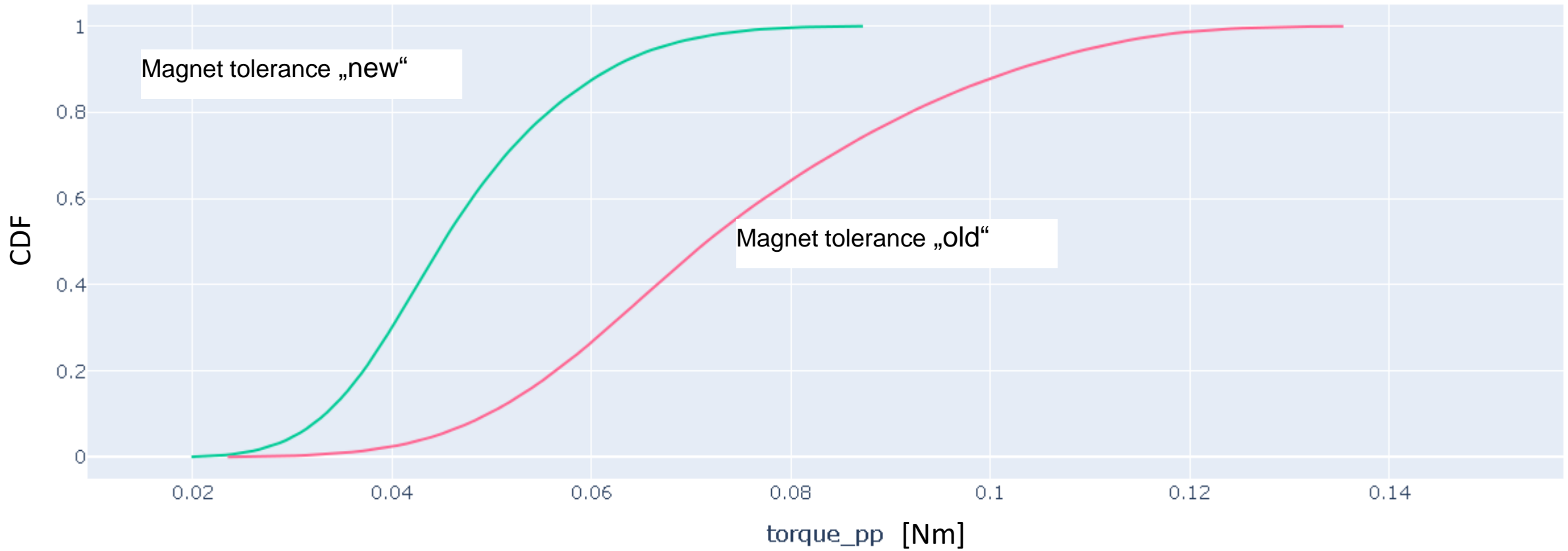
Without height tolerance (b)  
Without side offset (c)  
Without width tolerance (a)  
With all tolerances

# Solution – optimized Geometry incl. tolerances



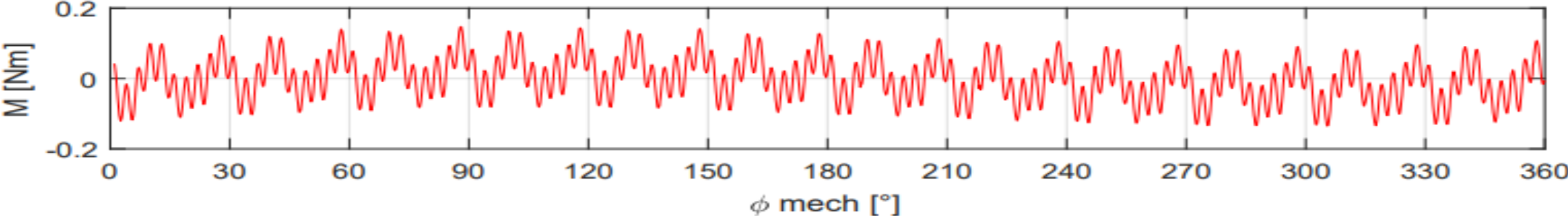


# Solution - Component tolerances

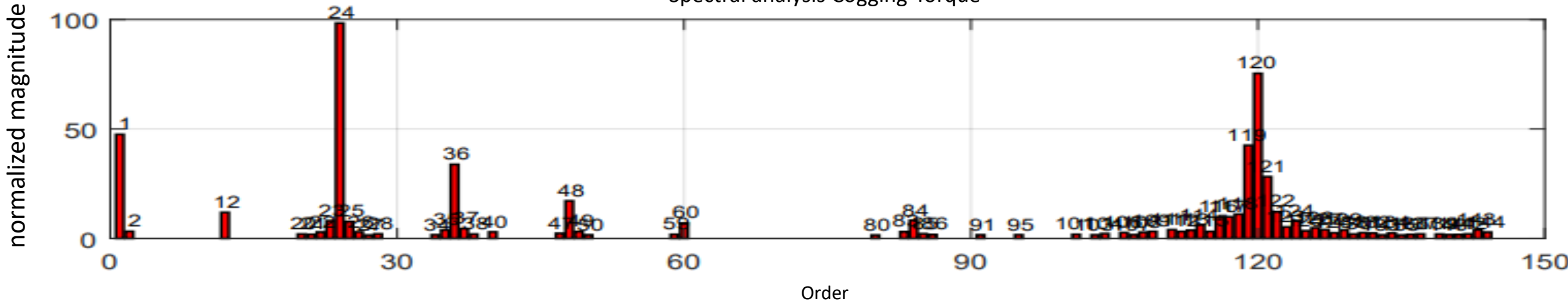


# Results – old design

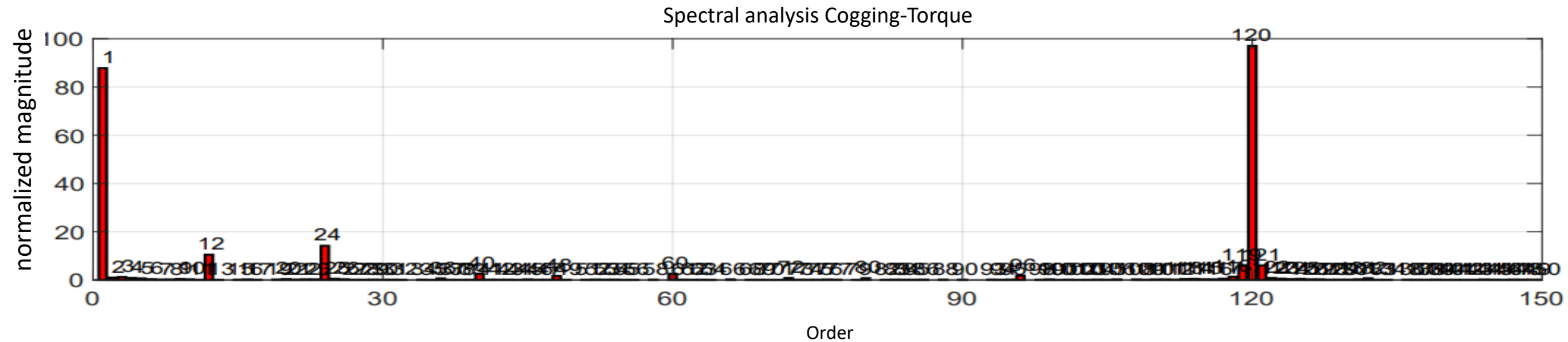
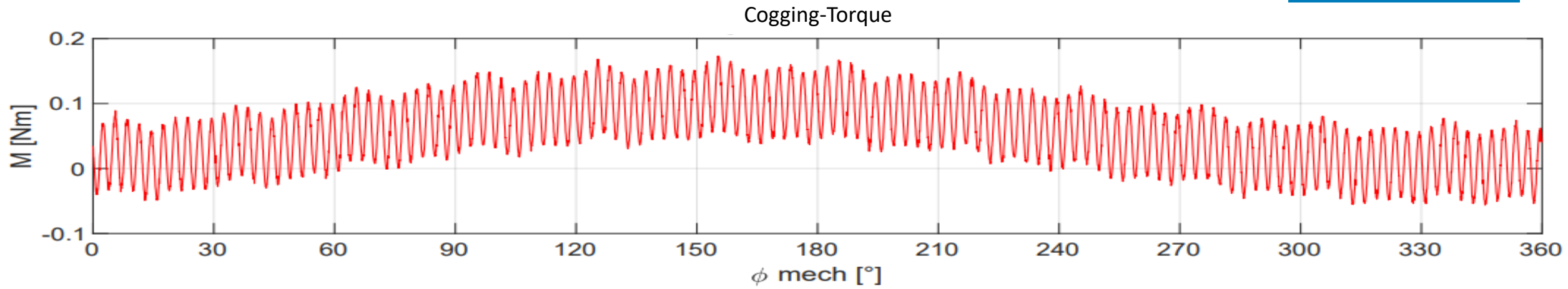
Cogging-Torque



Spectral analysis Cogging-Torque



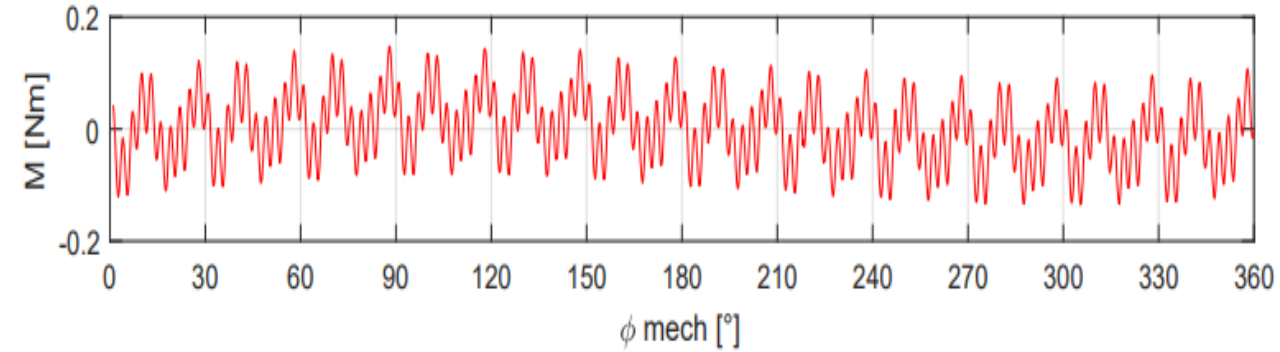
# Results – optimized design



# Results - comparison

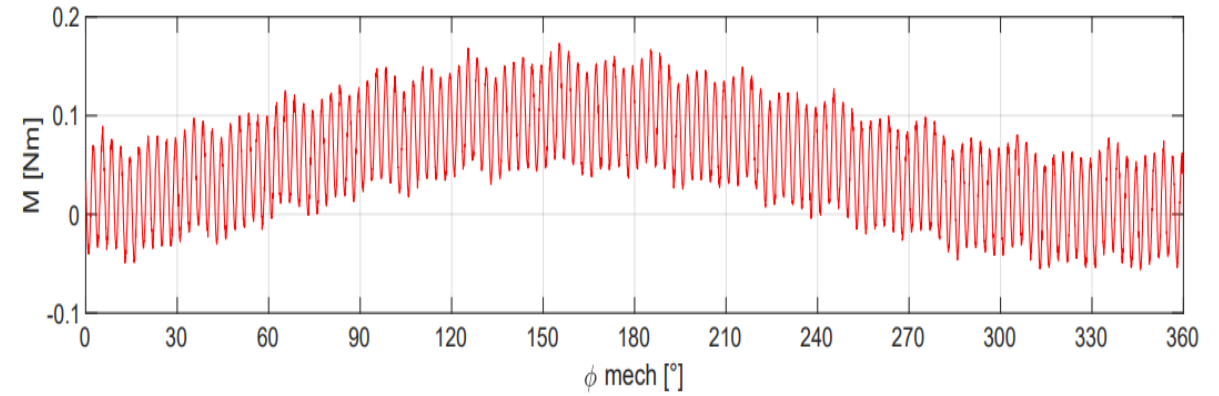
## Old design

Cogging-Torque

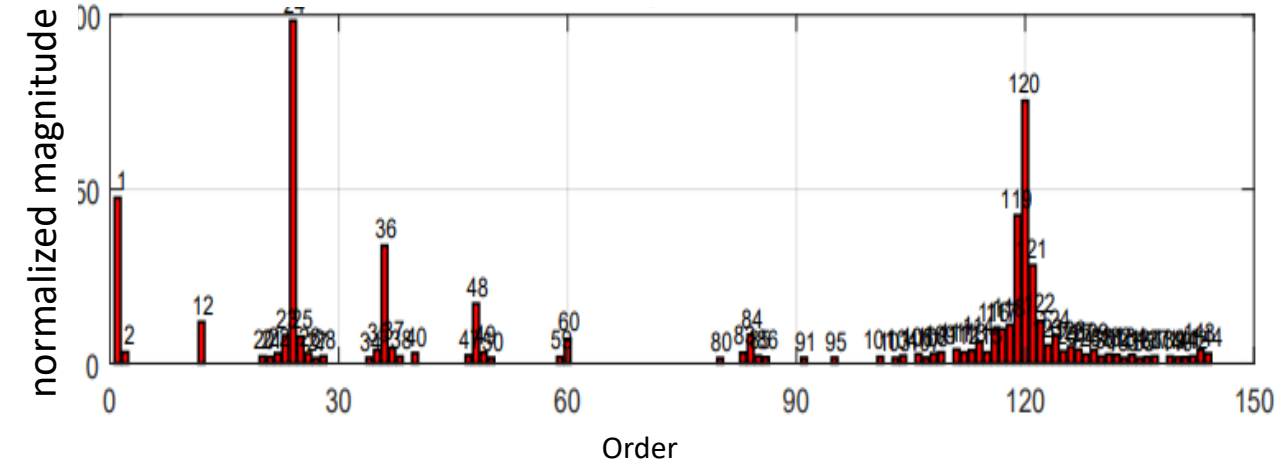


## Optimized design

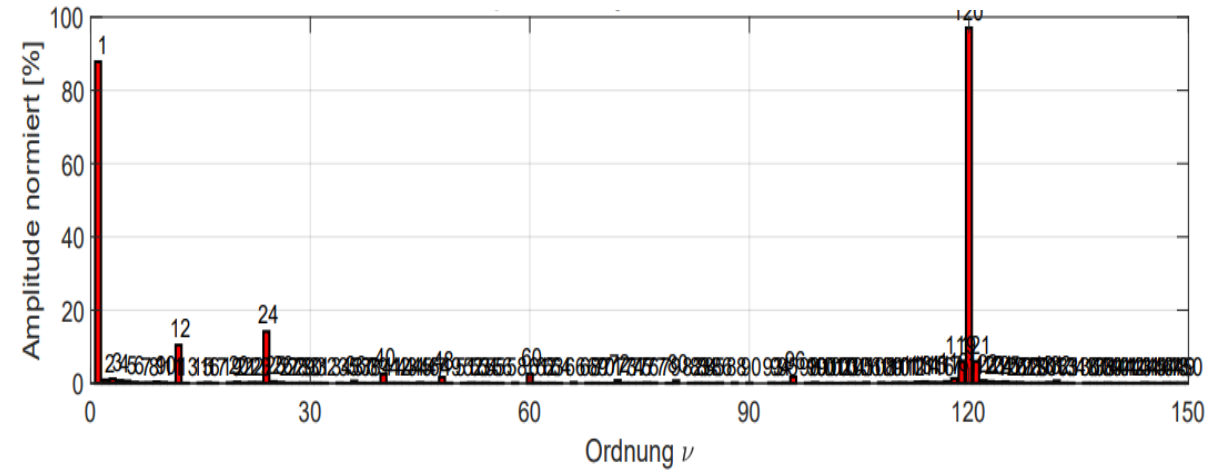
Cogging-Torque



Spectral analysis Cogging-Torque



Spectral analysis Cogging-Torque



# Thank You

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