Impact of Elasticity on the Transmission Behaviour of Thin Ring Gears

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Fachbereich 6

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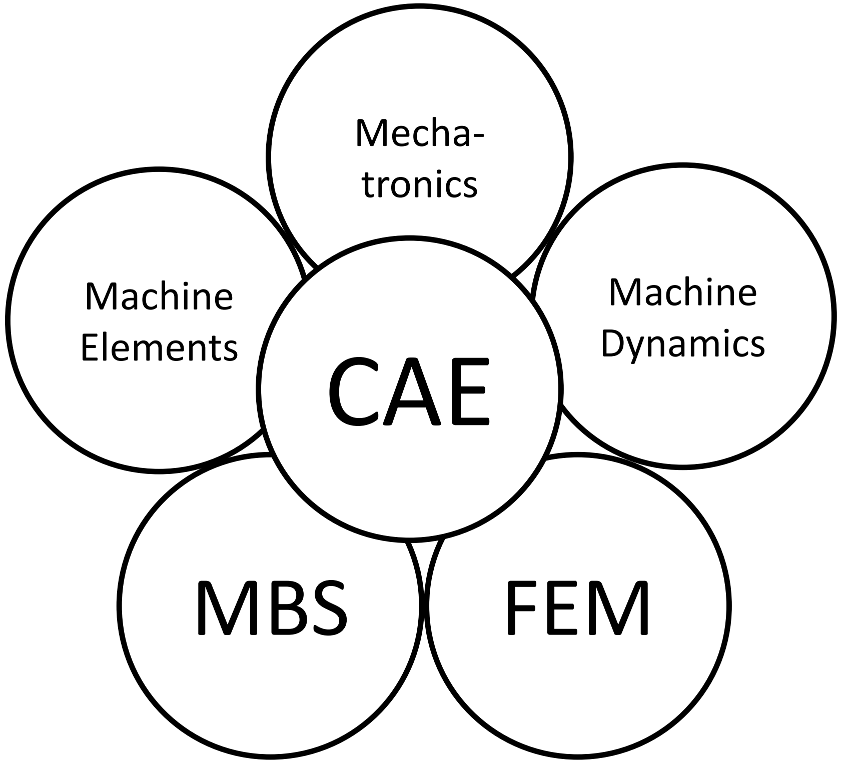
Research

Research Activity and Focus

- Holisitic analysis of static and dynamic behaviour of mechatronical drivetrains
- Strength and fatigue calculations using analytics and numerics



1. Research

2. Motivation

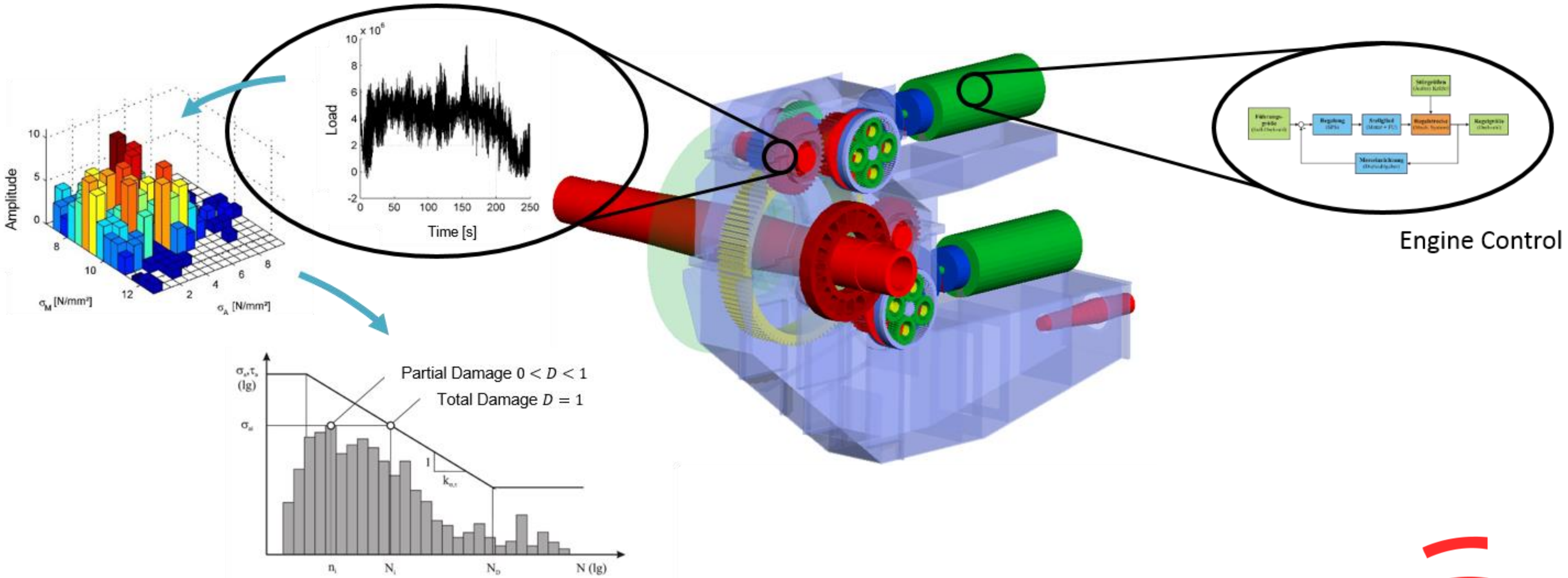
3. Modelling setup

4. Results

5. Conclusion

Research Activity and Focus

- Predictive Maintenance using MBS and FEM to:
    - Analyse current system status (real and virtual condition monitoring)
    - Calculate durability on demand (offline) and realtime (online)
    - Active and passive control systems predicting system behavior (L-/NMPC)



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Motivation

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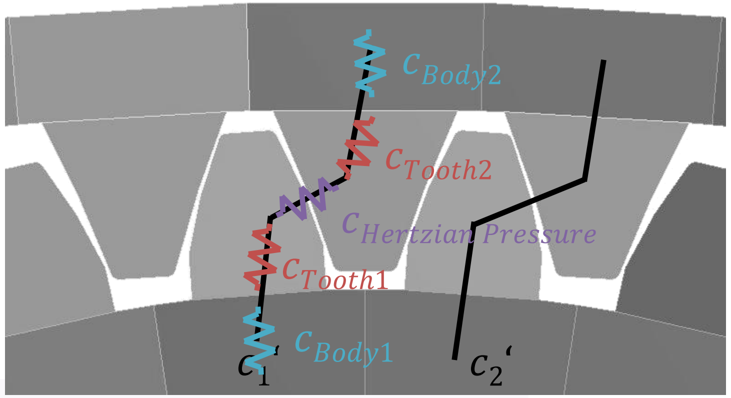
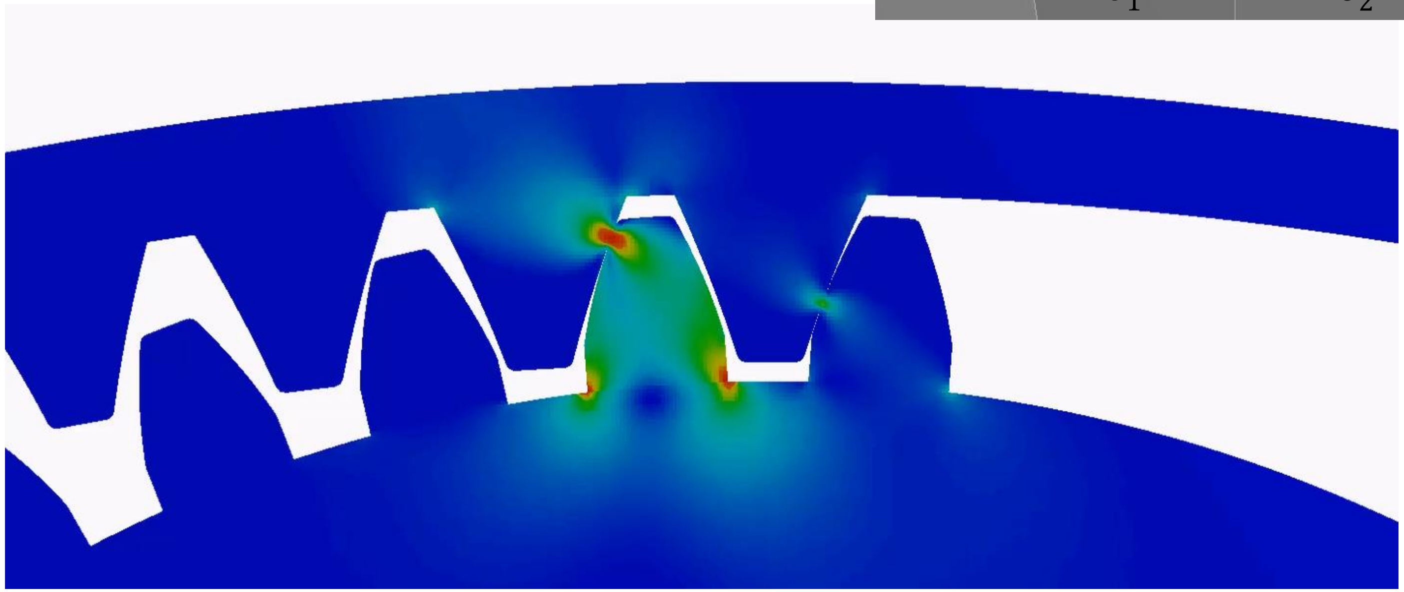
Transmission behaviour of a gear stage

- Influenced by geometry and material
  - Stiffness of tooth body
  - Stiffness of tooth bending
  - Stiffness due to Hertzian pressure





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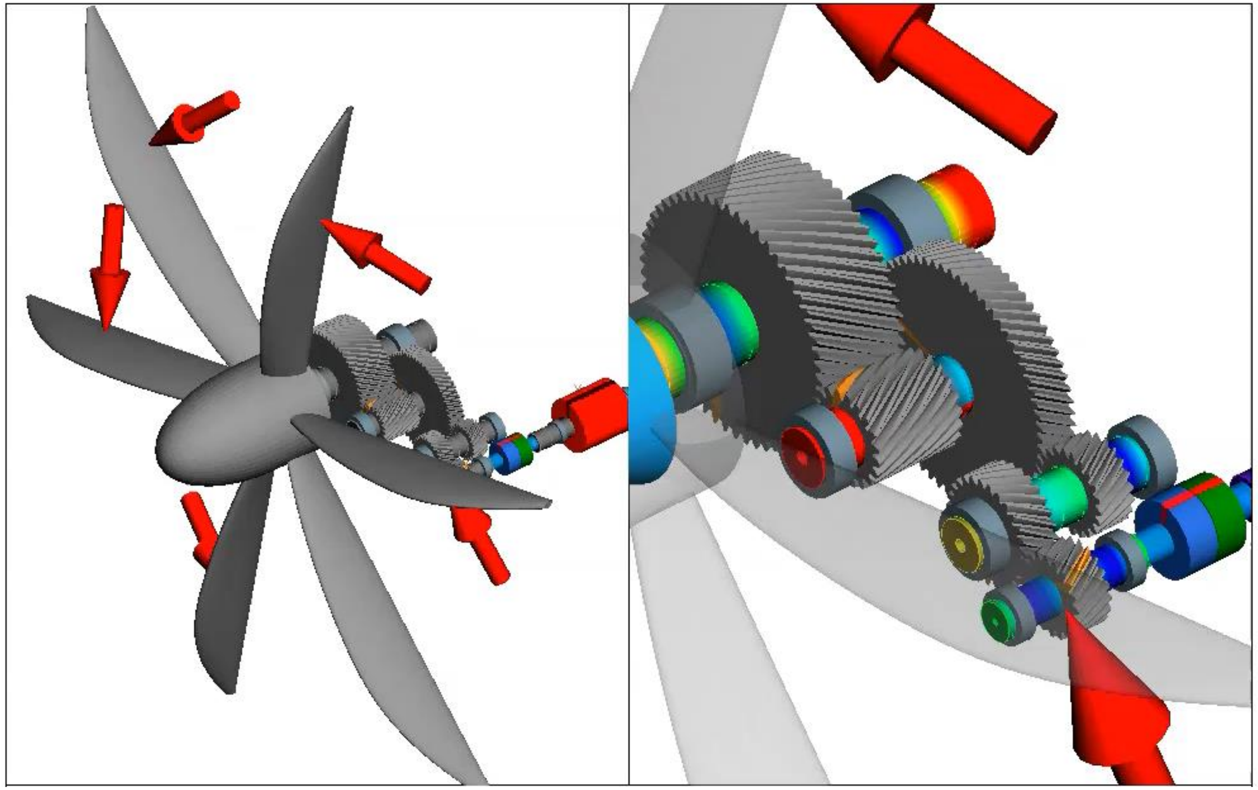
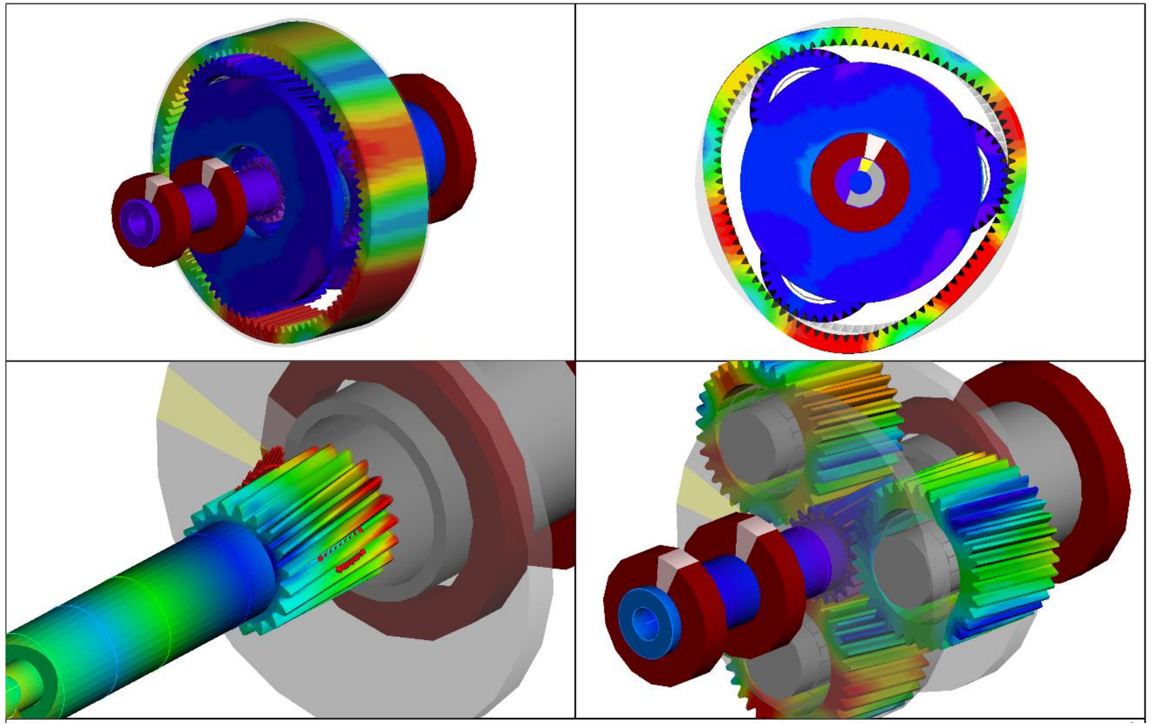
Different approaches for simulation of gearboxes

- Rigid gear wheels
  - No deformation of gear wheels
  - System stiffness combined in force element



Different approaches for simulation of gearboxes

- Flexible gear wheels
  - System stiffness is combination of force element and bodies (modal)
  - Consideration of eigenmodes
  - Calculation of load distribution



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When should one use which approach?

- When does the deformation of the gear wheels affect the transmission behaviour of the system?
  - Correlation between basic gear wheel parameters and deformation?

- Analyses at typical planetary gearboxes of wind turbines having thin ring gears
- Usage of fully flexible, parametrized FE-models
  - Automatic structured mesh generation

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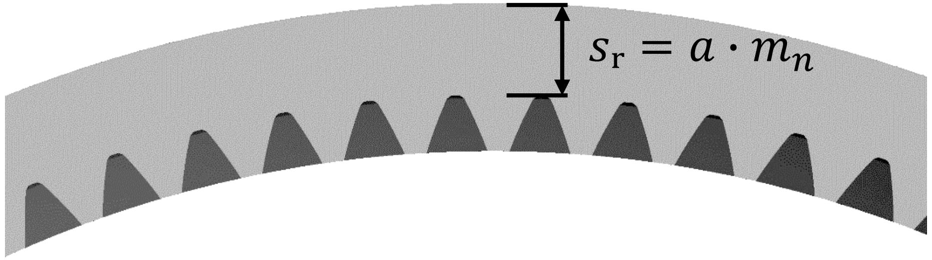
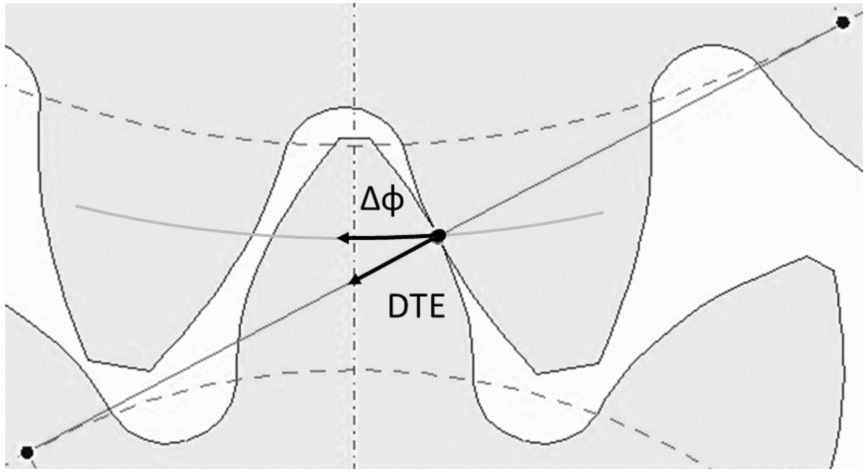
Modelling Setup

Usage of independent parameters for evaluation

- Ring thickness s_{r} depending on module m_n (parameter of geometry)
- Transmission error (parameter of system behaviour)





Definition of design parameters and their variation

- Variable parameters:
  - i_{21} Gear ratio
  - z_1 Number of teeth on ring gear
  - m_n Module
  - s_r Ring thickness
- Fix parameters:
  - $x_1 = x_2 = 0$ Shift factor
  - $\beta = 0°$ Helix angle
  - $b = 10\ mm$ Tooth width

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Definition of parameters and their variation

i_{21}

i_{21}	-4	-5	-6

m_n

m_n	2	3	5	8

s_r

s_r	$1{,}5 \cdot m_n$	$2 \cdot m_n$	$3 \cdot m_n$	$5 \cdot m_n$

z_1

i_{21}	z_{1_1}	z_{1_2}	z_{1_3}	z_{1_4}
-4	-120	-112	-104	-96
-5	-120	-115	-110	-105
-6	-120	-108	-96	-84

Number of Calculations

i_{21}	m_n	s_r	z_1	$\prod$
3	4	4	4	192

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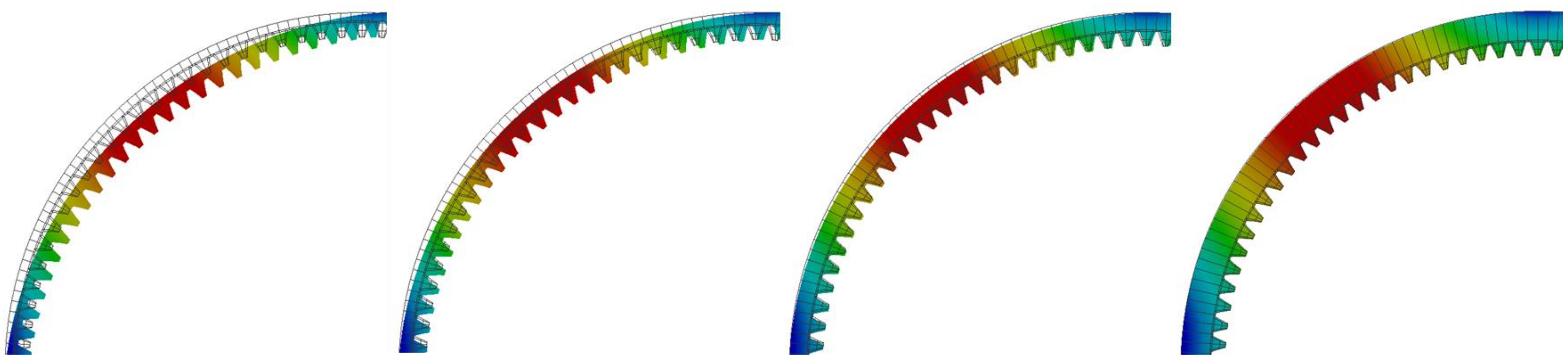
Results

Deformation of ring gear depending on ring thickness

- Deformation of ring gear decreases with increasing ring thickness

$1{,}5 \cdot m_n$ $2 \cdot m_n$ $3 \cdot m_n$ $5 \cdot m_n$



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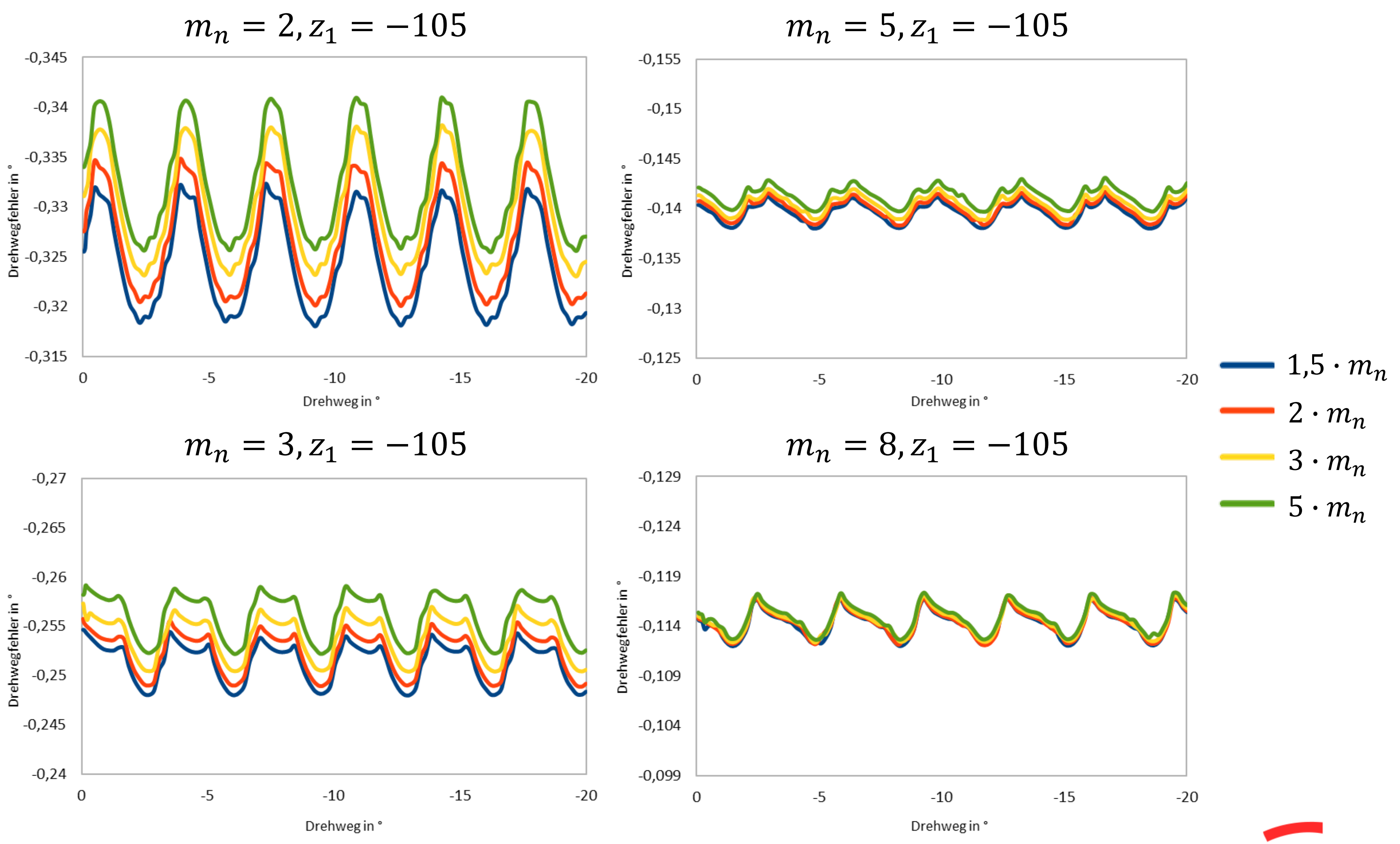
Transmission Behaviour – Transmission Error (Variation of Module m_n)



Transmission Behaviour – Transmission Error (Variation of Module m_n)

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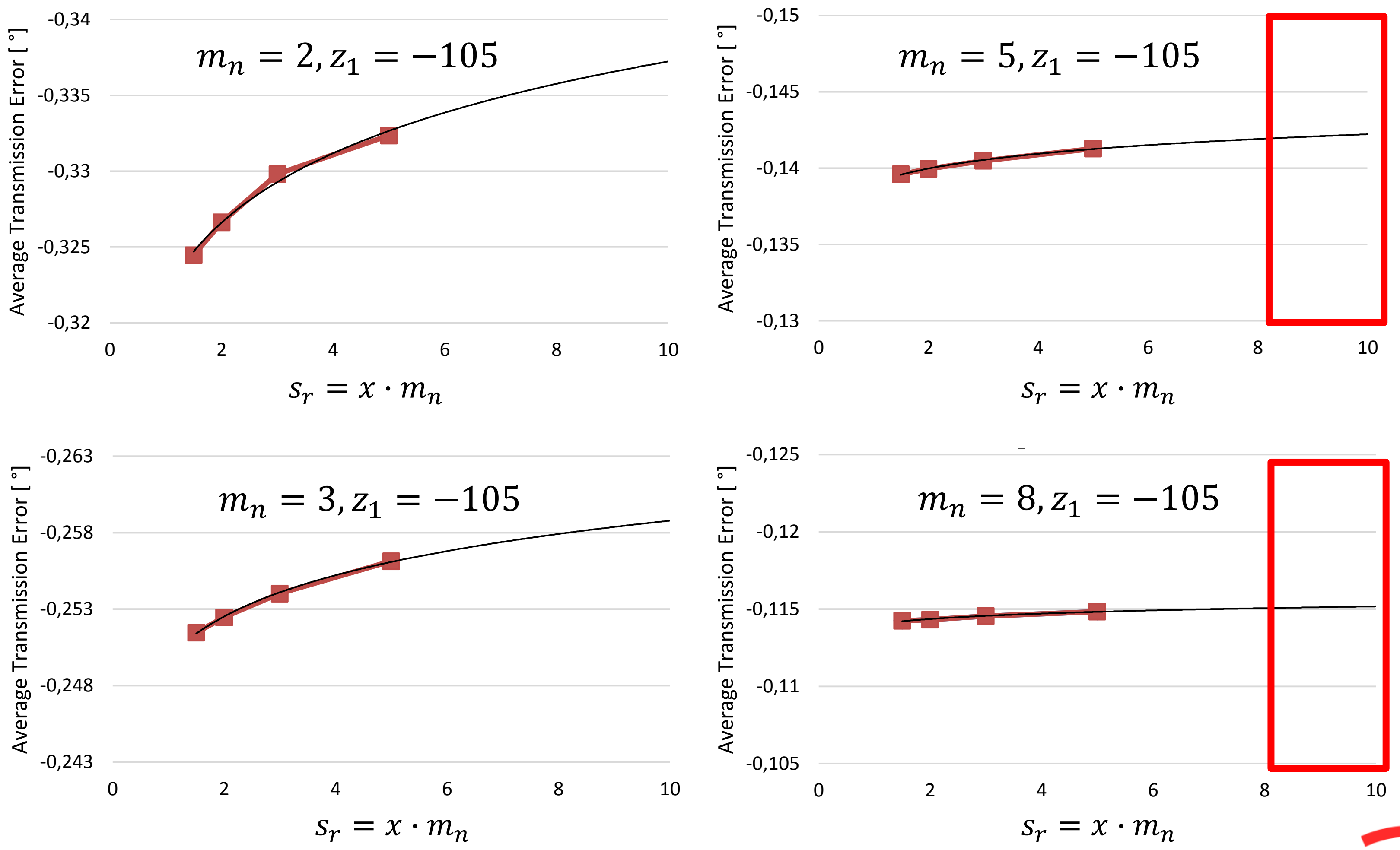

Transmission Behaviour – Transmission Error (Variation of No. of T. z_1)

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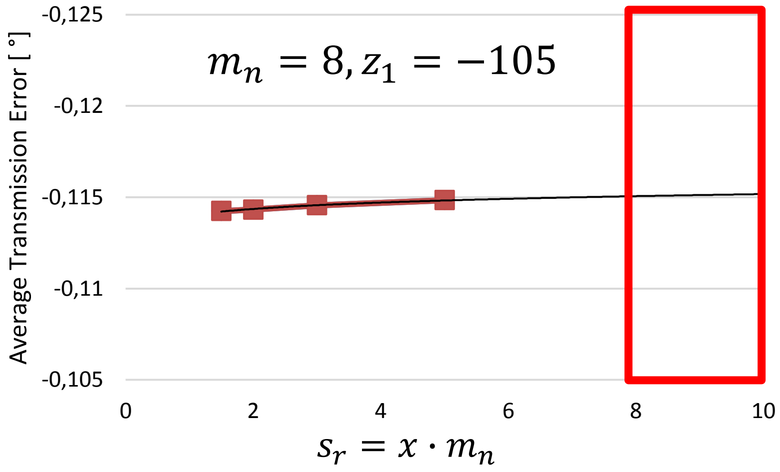

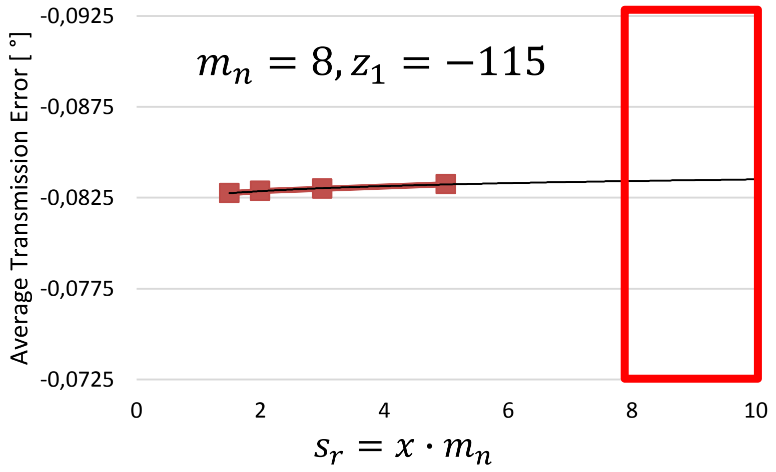

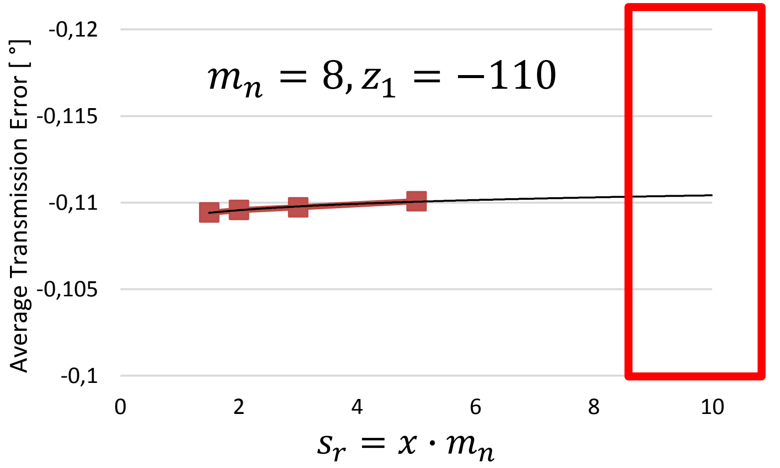

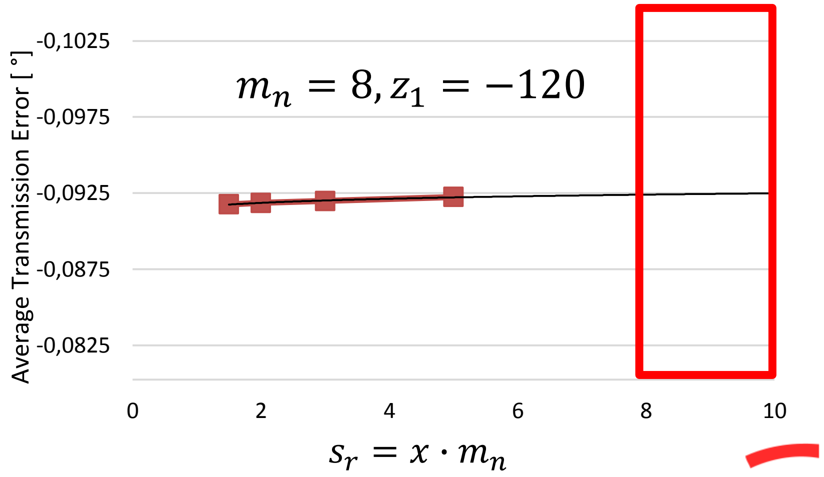

Transmission Behaviour – Validation of Results

- Comparison between theoretic TE and experimental TE

FEM	Weber/Banaschek (WB)
0,1142 °	0,113 °
100 %	99,12 %

Transmission Error [°], $i = -5, z_1 = 105, z_p = 42, m_n = 8, s_r = 1{,}5 \cdot m_n$

- Theoretic system stiffness, FE-stiffness and SIMPACK-stiffness

WB	DIN 3990	FEM	SIMPACK (WB)	SIMPACK (DIN)
14,52	15,71	14,67	14,52	15,31
100 %	108 %	101 %	100 %	105 %

Stiffness c‘ [N/mm(µm)], $i = -5, z_1 = 105, z_p = 42, m_n = 8, s_r = 1{,}5 \cdot m_n$

Conclusion

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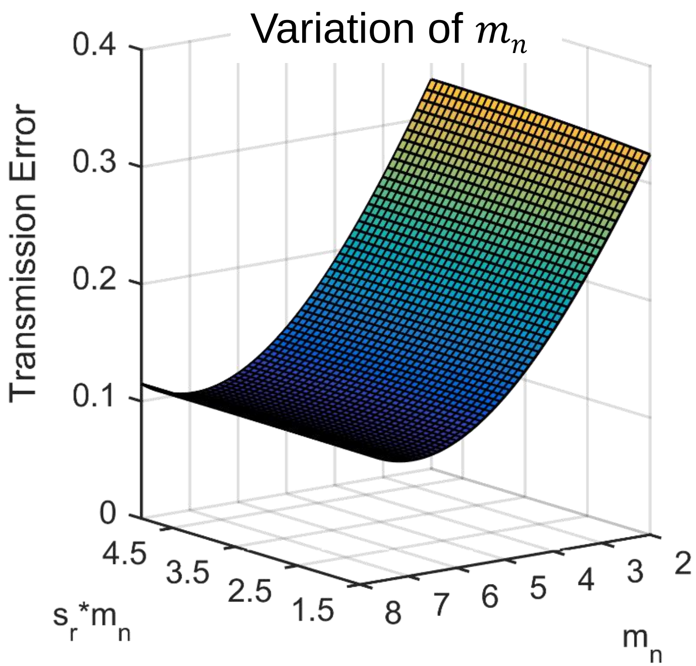
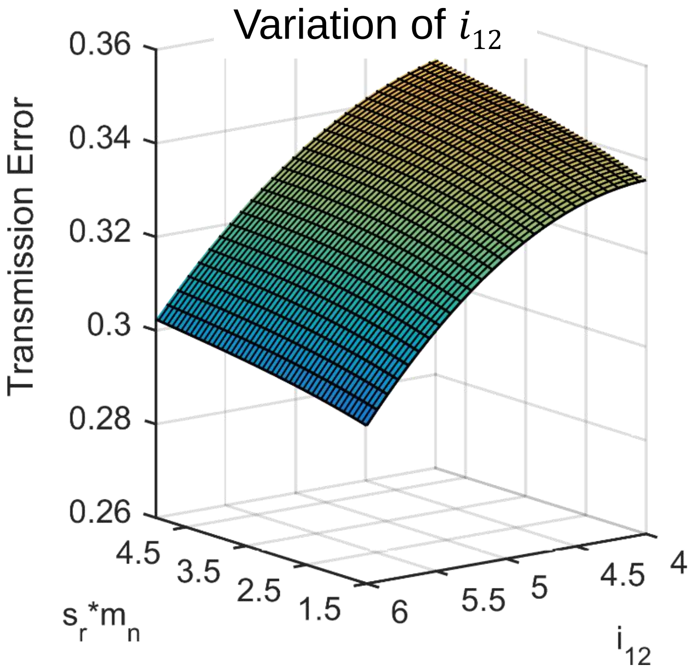
Conclusion

- Validated relation between choosen geometry and transmisson error (TE)
- Convergence of TE with increasing ring thickness
- Reduction of TE with increasing m_n and increasing i_{21}





Recommendations

- Flexible Approach recommended for ring thicknesses of $s_r < 7 \cdot m_n$

	FE-Results	
z	$\|z\| < 100$	$\|z\| > 100$
s_r $[mm]$	$7 \cdot m_n$	$8 \cdot m_n$

Thank You!

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