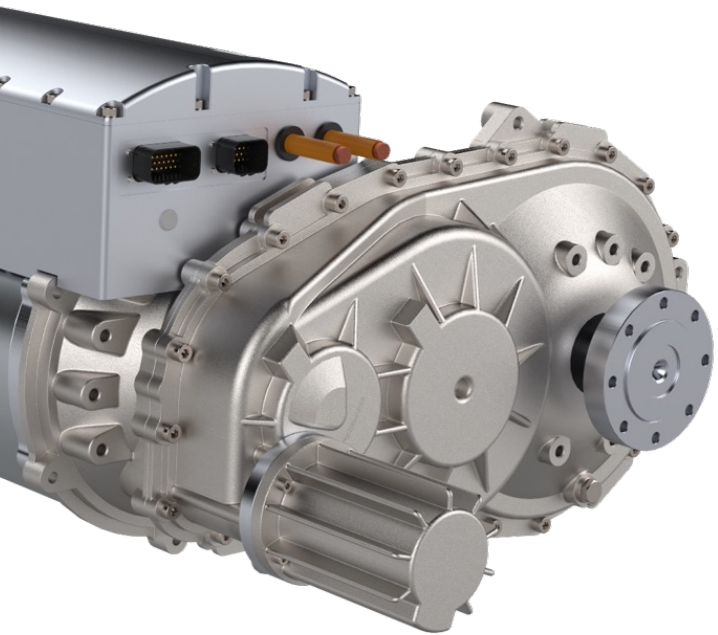

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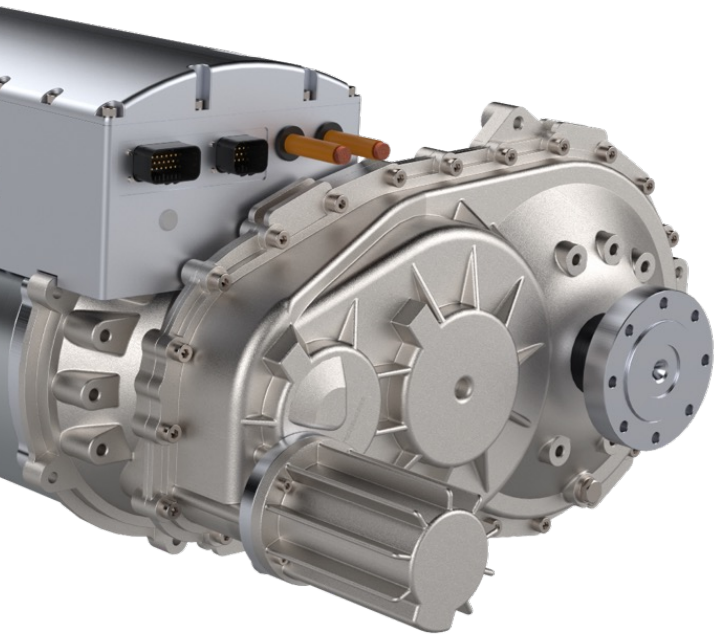
Top-down Validation Framework for Efficient and Low Noise Electric Driven Vehicles with Shiftable Gearbox

Steffen Jäger, Jonas Schätzle, Tilmann Linde
Furtwangen University, Germany

14.06.2022

Outline

- Introduction
- Top-down Validation Framework
- Model Implementation
  - 1D Tooth Mesh Simulation
  - 3D FEA Acoustic Simulation
- Physical Validation Environment
- Conclusion and Outlook



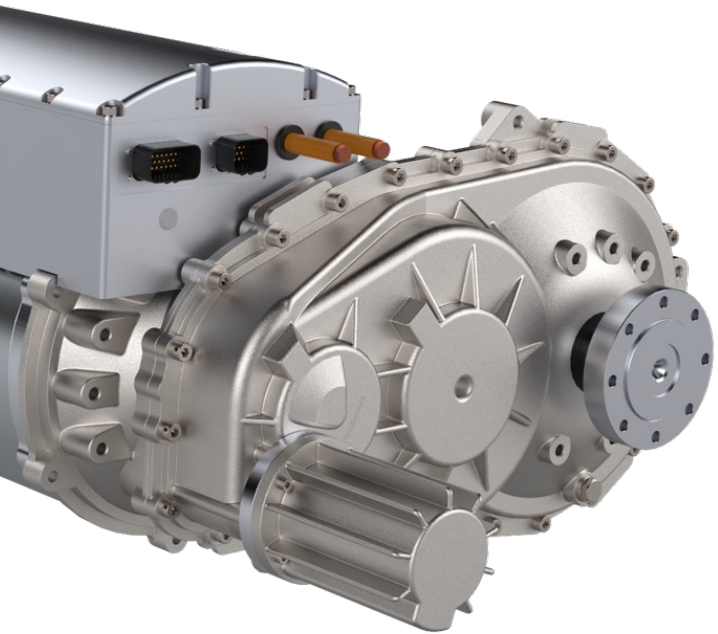
Introduction

Introduction

- **Project:** Efficient and Low Noise Electric Powertrain Systems

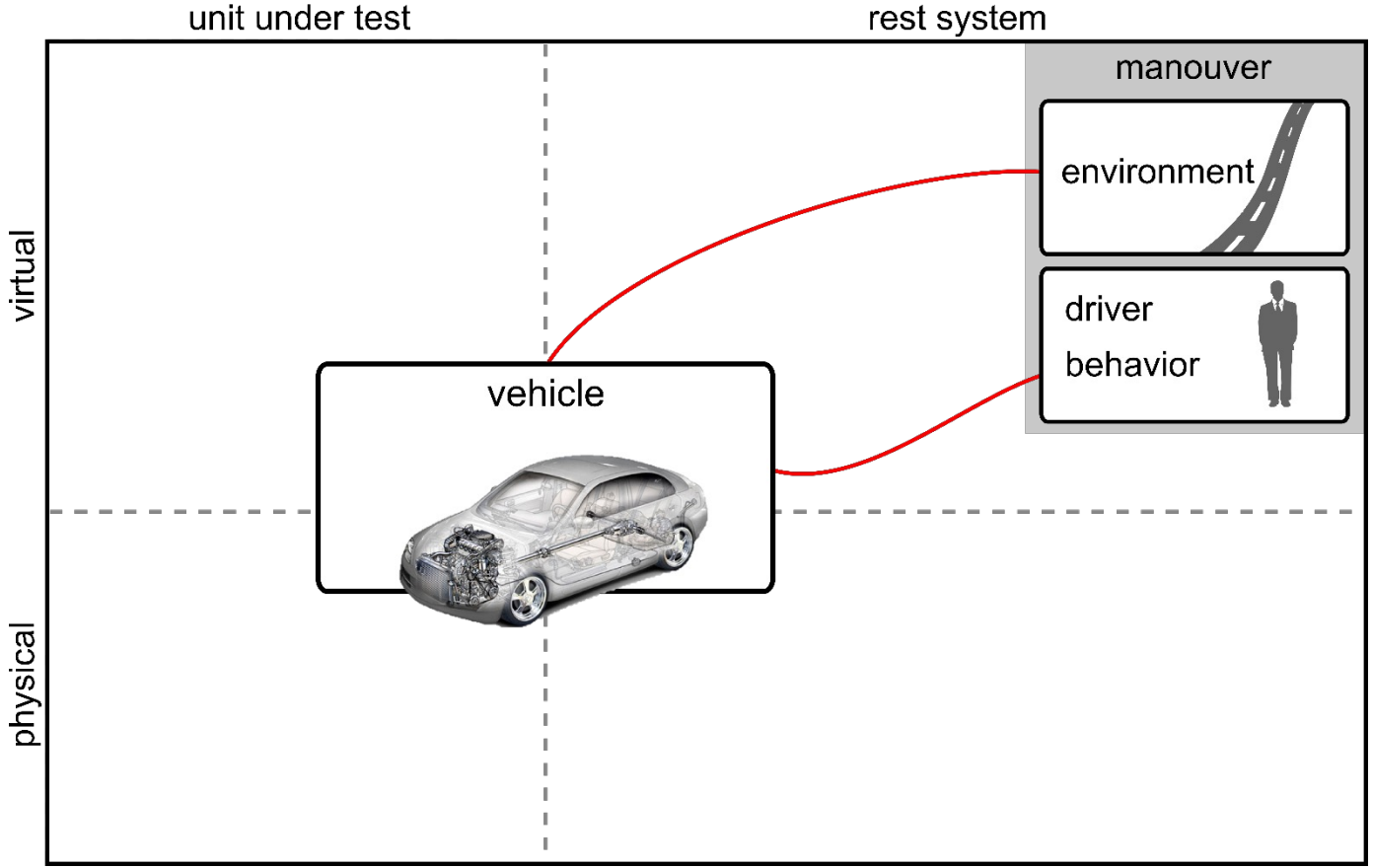
- **Motivation**
  - Using a shiftable gearbox to improve the efficiency of an electric drive system
  - Optimization of an existing powertrain system regarding to efficiency and sound emission
  - Supporting (smaller) automotive suppliers in the technological transformation by providing modern product development methods and process models

- **Approach**
  - Using top-down validation strategies to come to a real/virtual coupled XiL framework with different layers of validated (sub)models



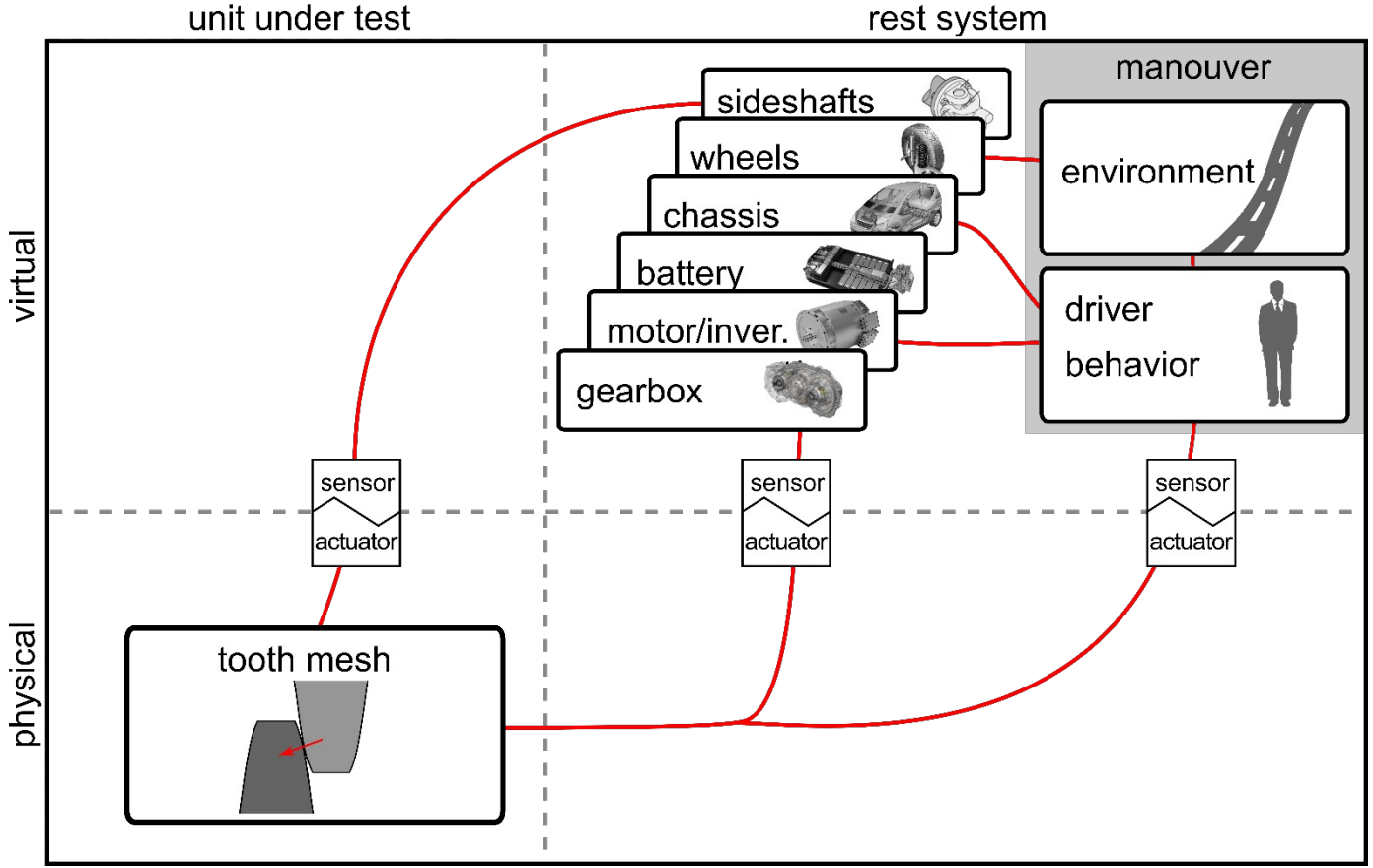
Top-down Validation Framework

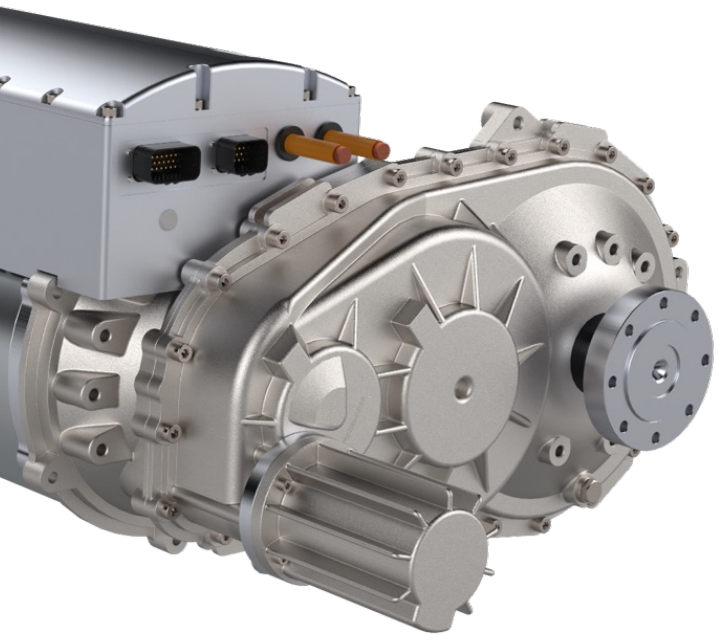
Top-down Validation Framework



Quelle: Albers, Geier, Jäger [Albers13]

Top-down Validation Framework



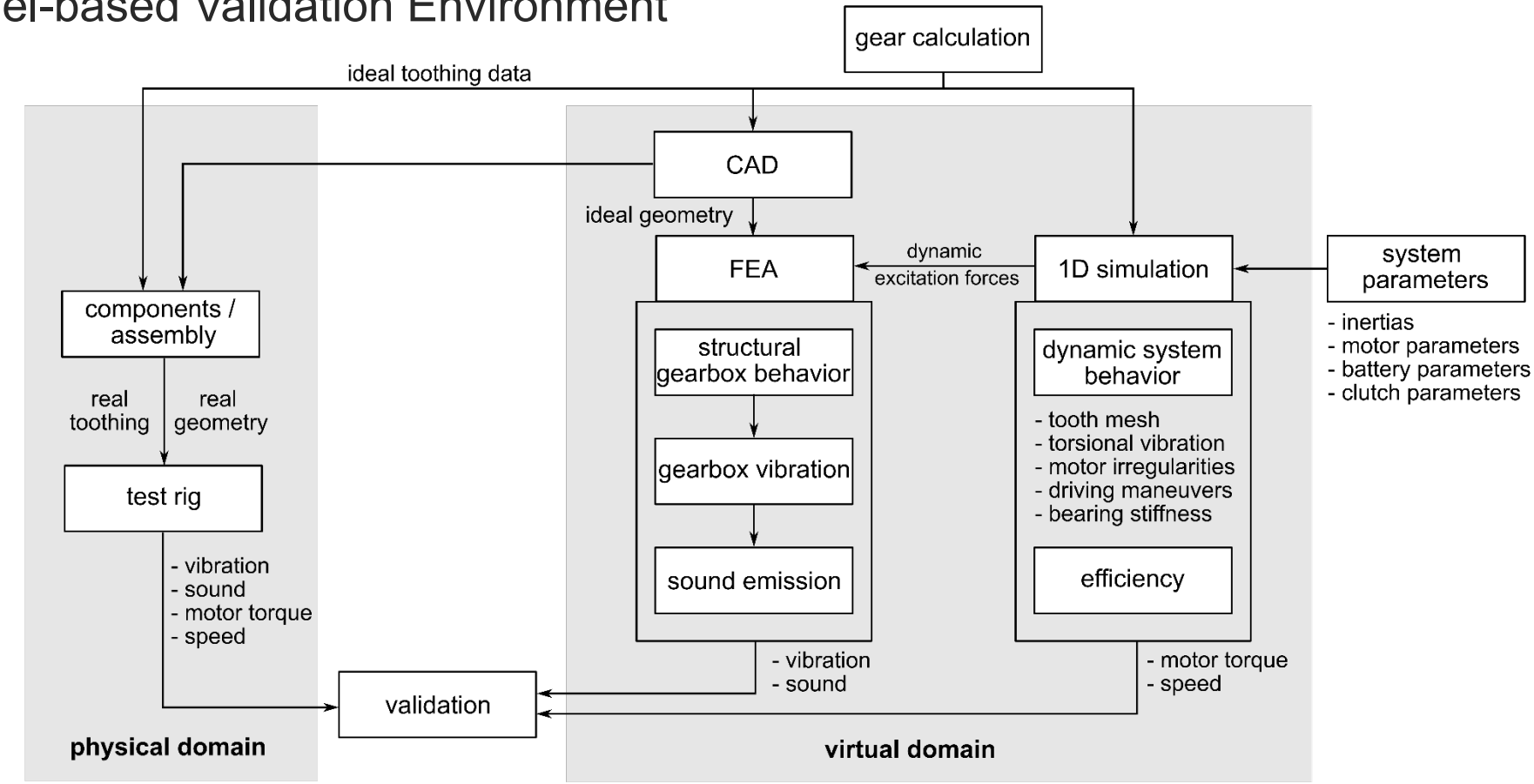


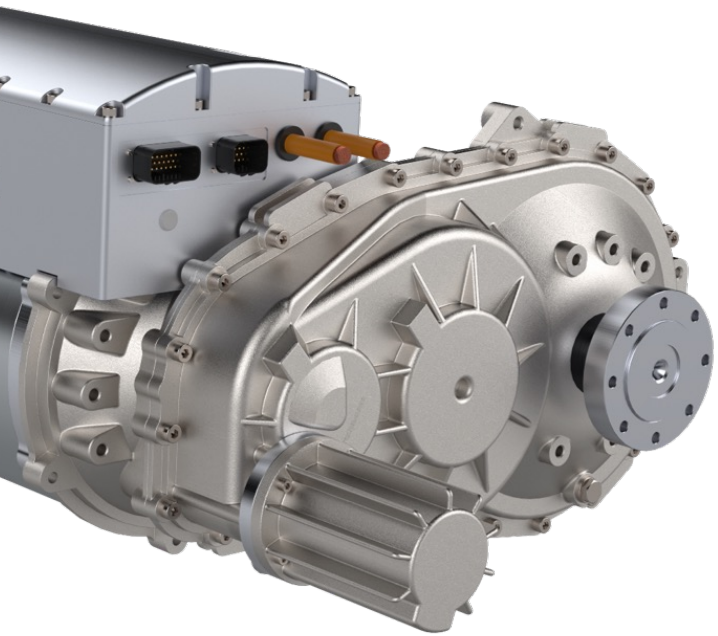
Model Implementation

Tooth Mesh Layer – Model Overview

Model Implementation

- Model-based Validation Environment



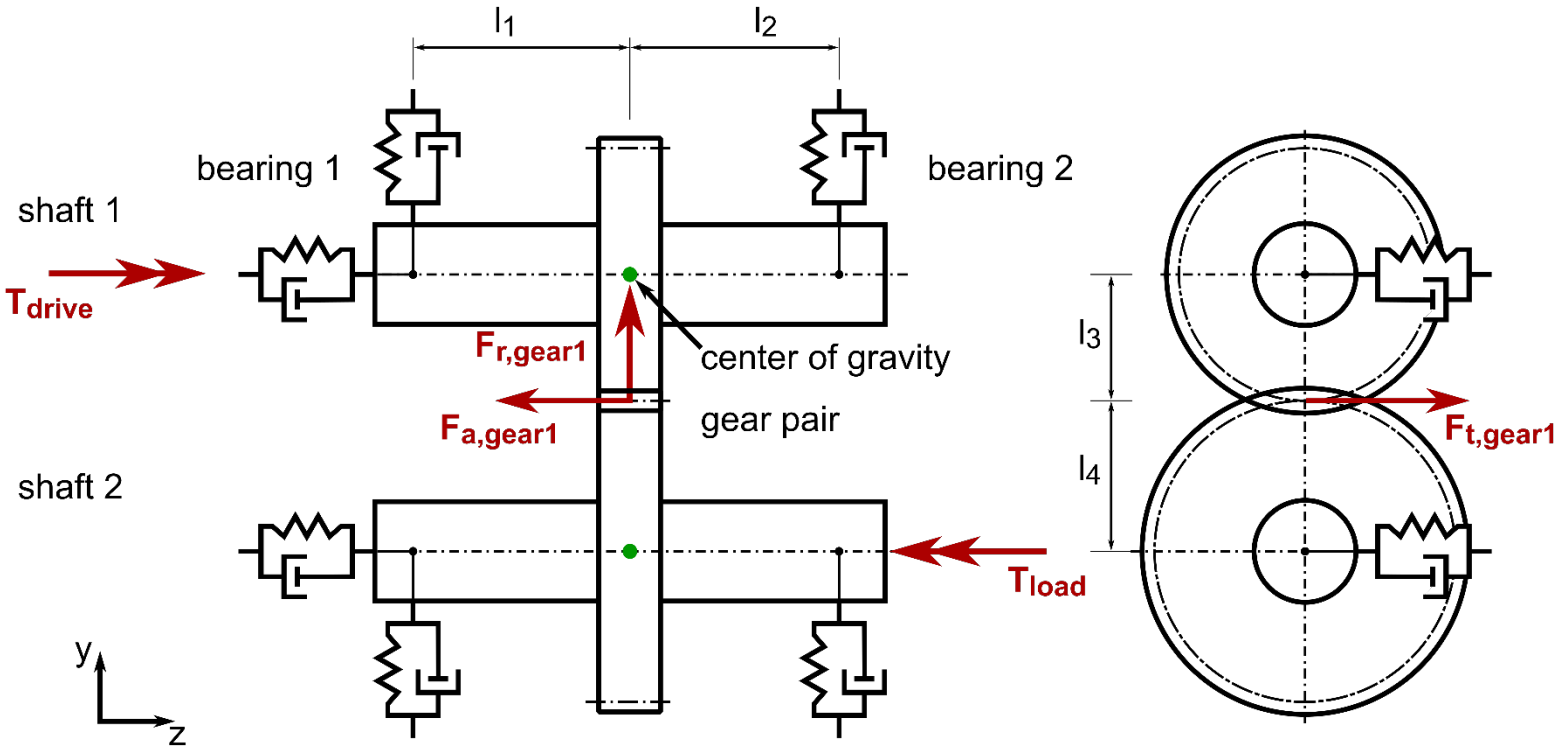


Model Implementation

1D Tooth Mesh Simulation

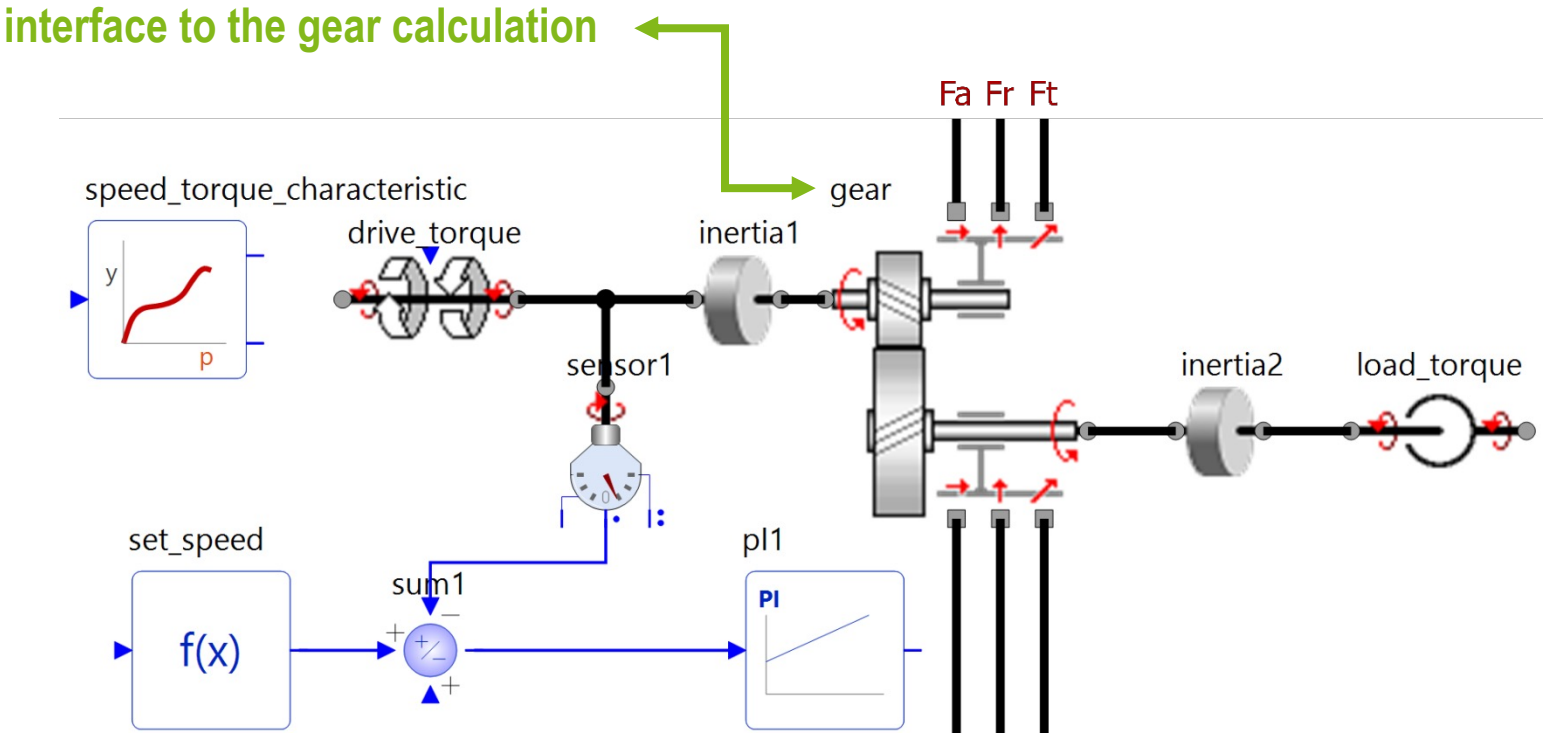
1D Tooth Mesh Simulation

- System overview



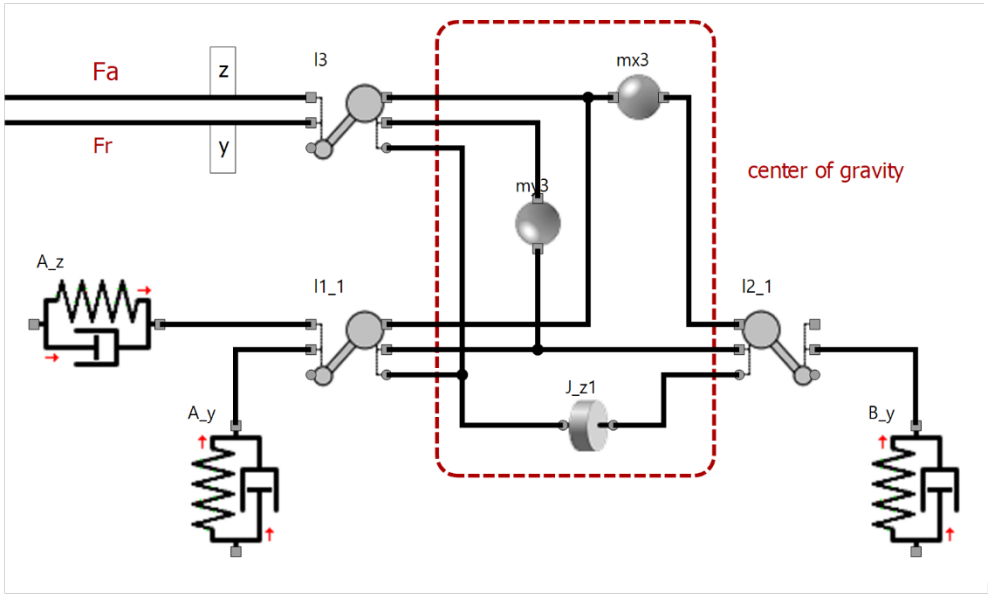
1D Tooth Mesh Simulation

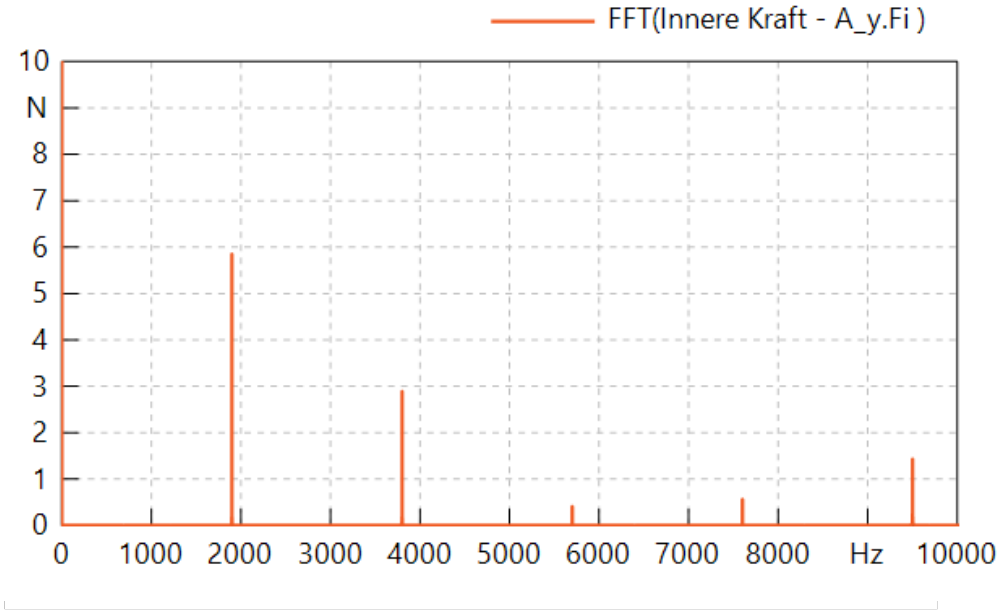
- Implementation – rotational system

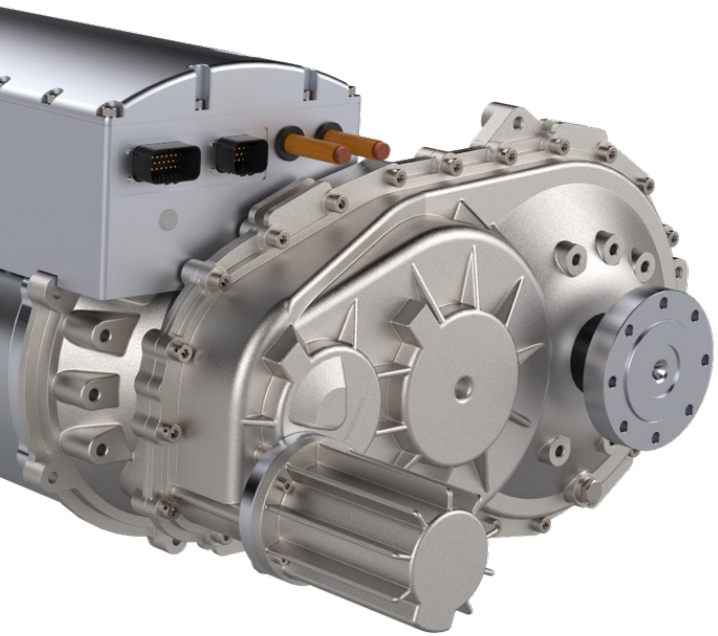


1D Tooth Mesh Simulation

- Implementation - translational system





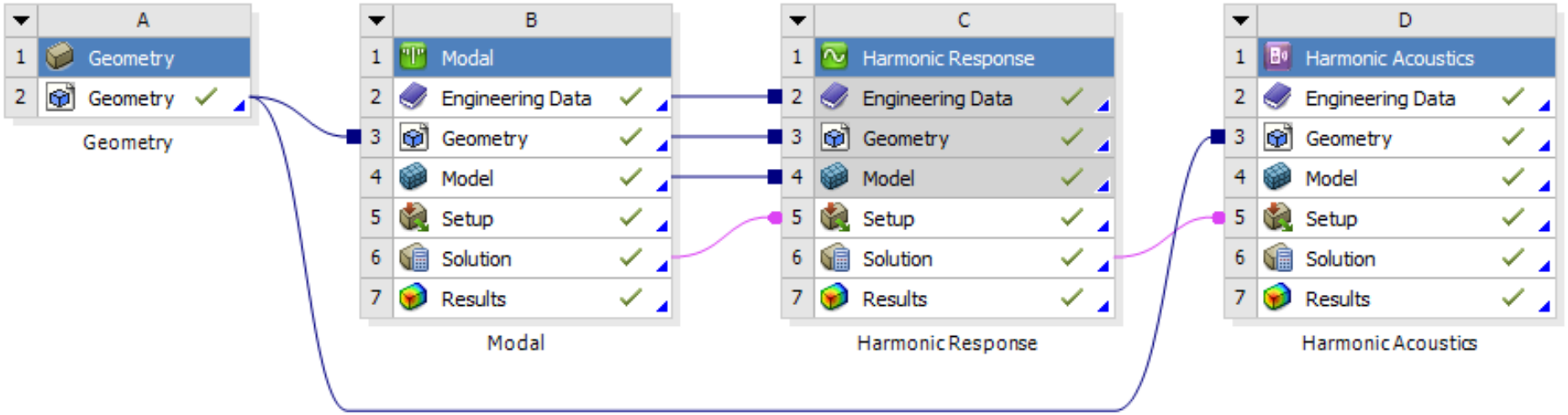


Model Implementation

3D FEA Acoustic Simulation

3D FEA Acoustic Simulation

- Model Implementation - Overview



- gearbox housing
- fluid domain

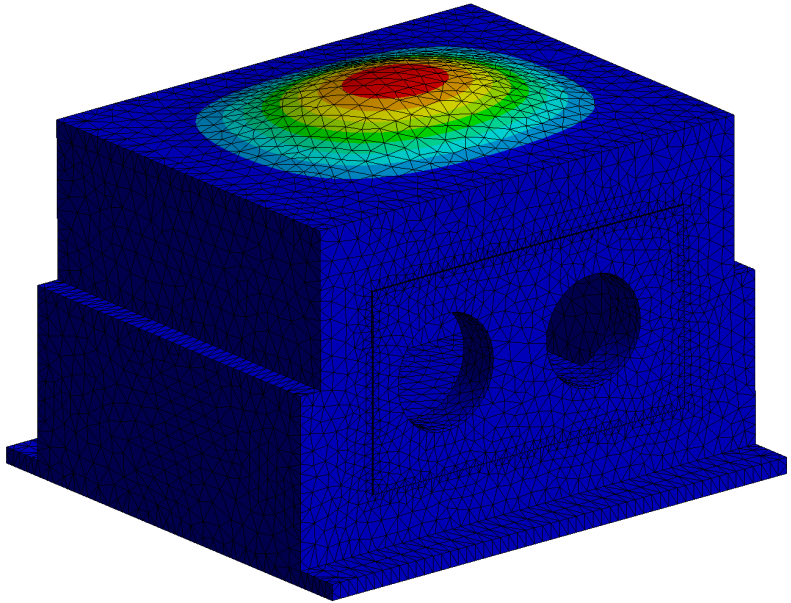
- eigenfrequencies and their shapes

- loads from 1D Simulation
- frequency response
- structure-borne sound

- acoustic parameter
- air-borne sound

3D FEA Acoustic Simulation

- **Modal Analysis** to determine the eigenfrequencies as well as their shapes of the gearbox housing (independent from load)

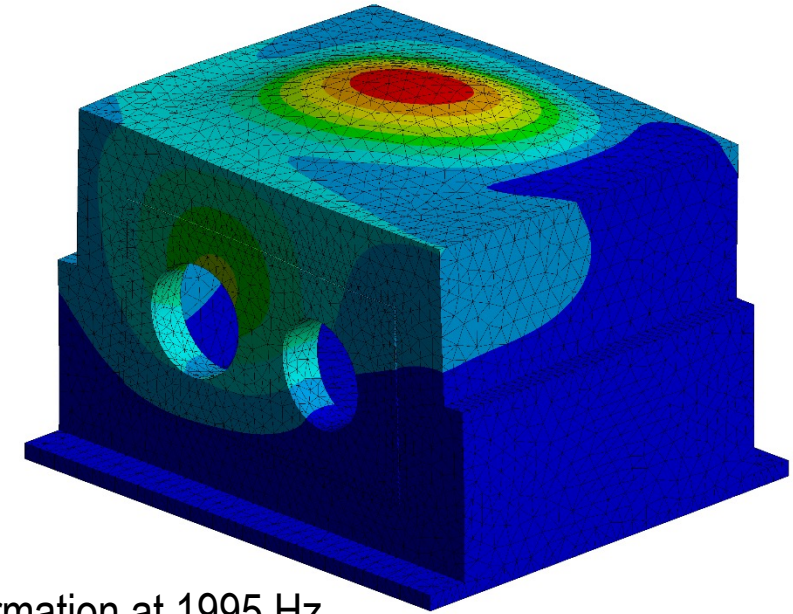


Eigenfrequency at 1995 Hz

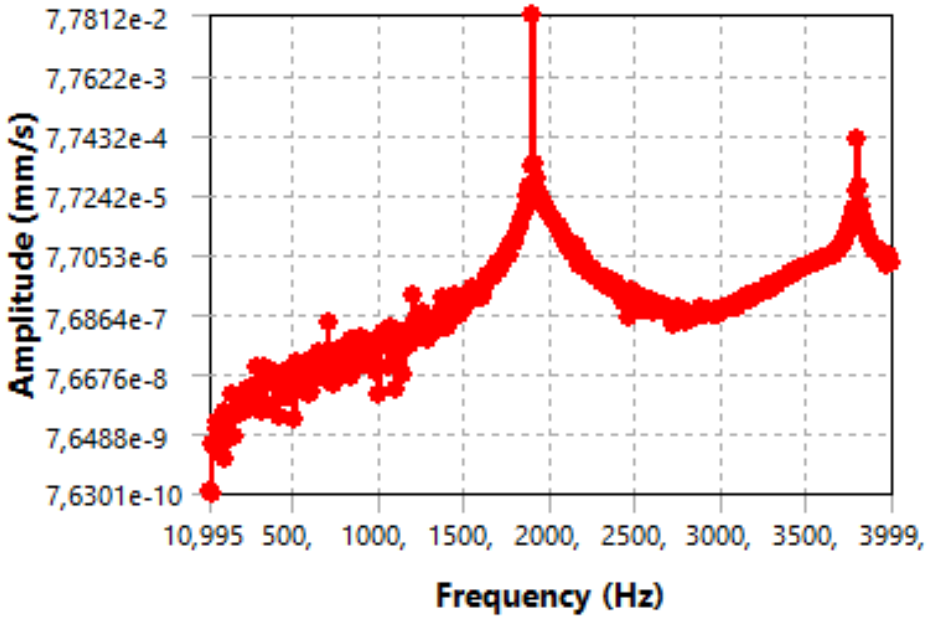
	Auswahlmodus	Frequenz [Hz]
1	1,	1995,3
2	2,	2270,2
3	3,	2438,7
4	4,	3391,
5	5,	3544,8
6	6,	3665,

3D FEA Acoustic Simulation

- **Frequency Response Analysis**
  - Considering the bearing loads from 1D Simulation
  - Shows the frequency response of the structure

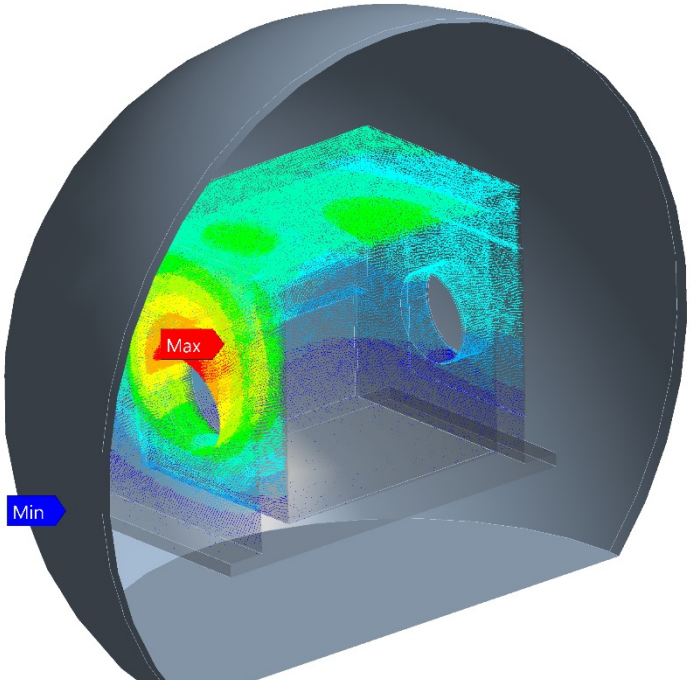


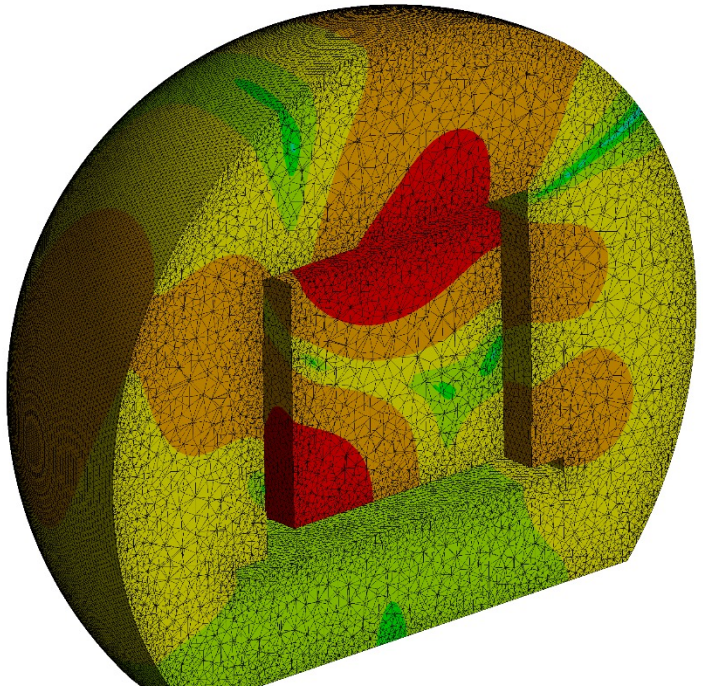
Deformation at 1995 Hz

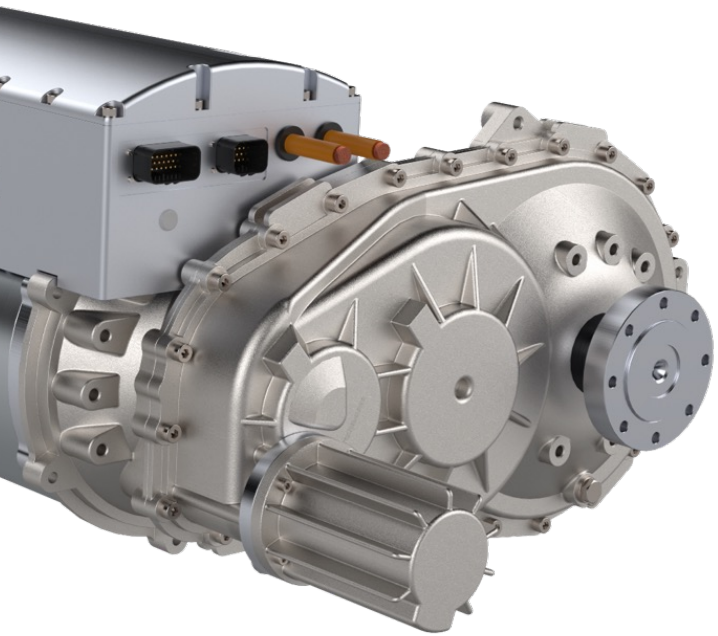


3D FEA Acoustic Simulation

- **Acoustic Simulation**
  - Based on the frequency response results
  - Gives information about the air-borne sound







Physical Validation Environment

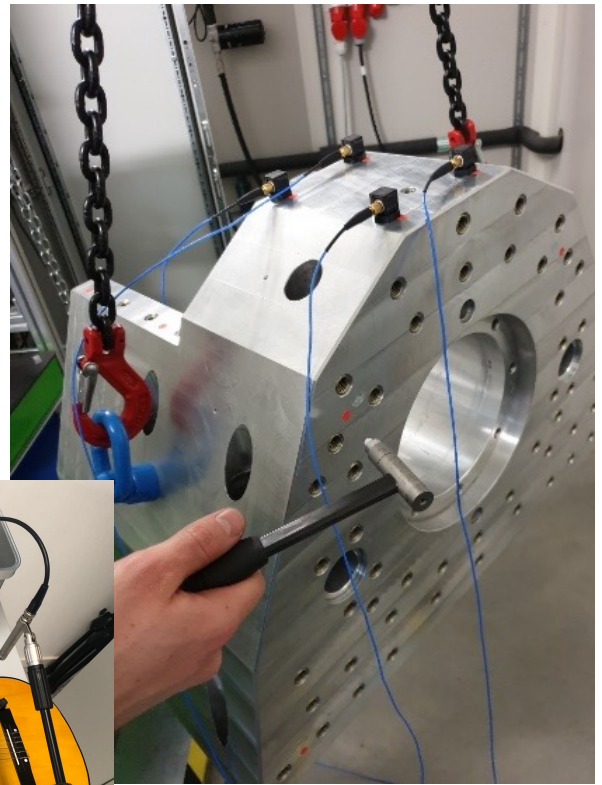
Physical Validation Environment

Component and Assembly Tests

- Modal Analysis
  - For the validation of the modal analysis simulation
  - Using impulse hammer and acceleration sensors

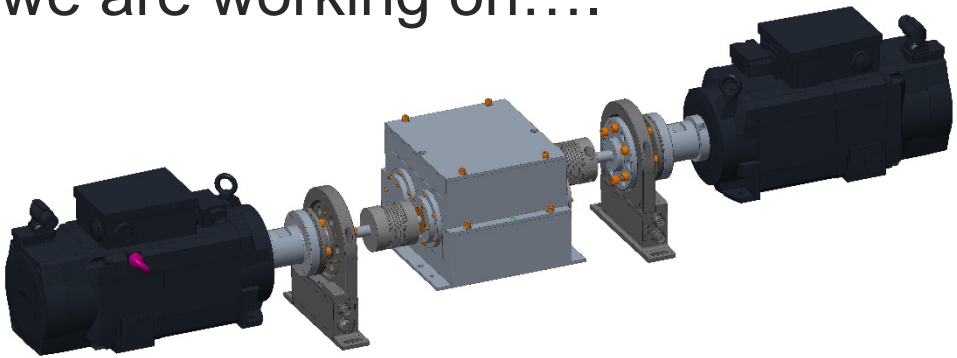
- Operating Deflection Shape Analysis (ODS)
  - To validate the frequency response simulation
  - Gear pair test rig in operation mode

- Acoustic Analysis
  - For the validation of the acoustic simulation
  - Using structure-borne sound sensors and microphones

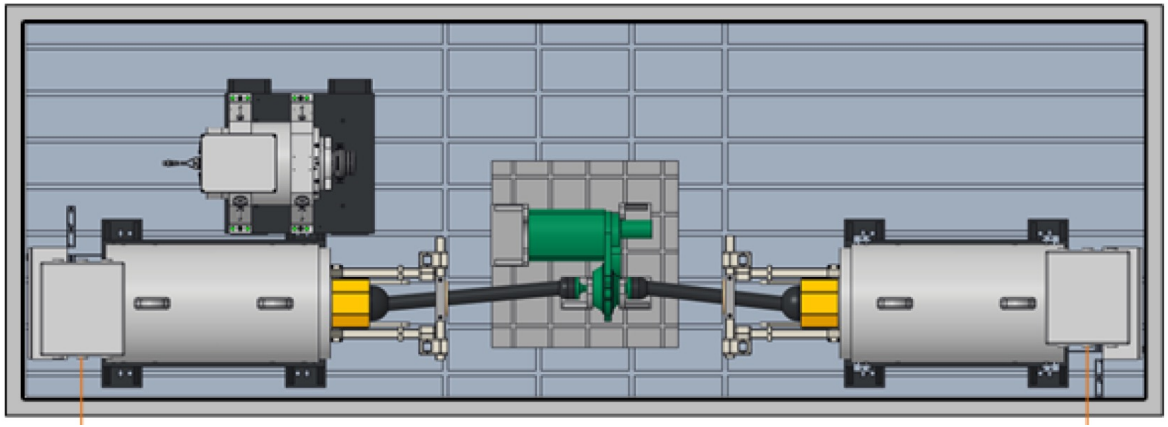


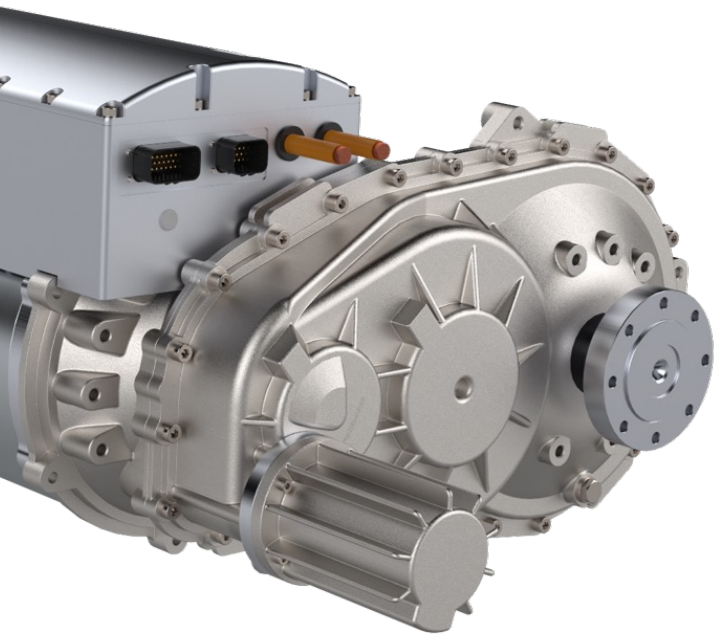
Physical Validation Environment

- According to the **XiL framework** we are working on….
  - … a two motor **gear pair test rig…**



  - … and an **electric powertrain system test rig** (for LCV performance levels)





Conclusion and Outlook

Conclusion and Outlook

- Based on the XiL framework a **physical-virtual coupled validation environment** for noise and efficiency studies is set
- On the tooth mesh validation layer **advanced simulation model** implementations are available
- The **validation** of the tooth mesh models and the acoustic simulation as well as the realization of the test rigs are ongoing processes

- The authors are very grateful for the financial support from the Federal Ministry of Education and Research of Germany (Grant No.13FH527KA9).

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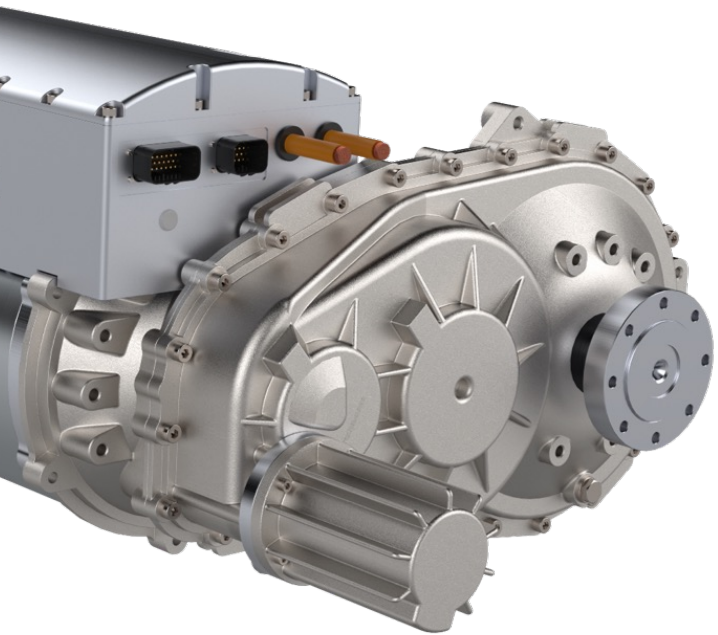

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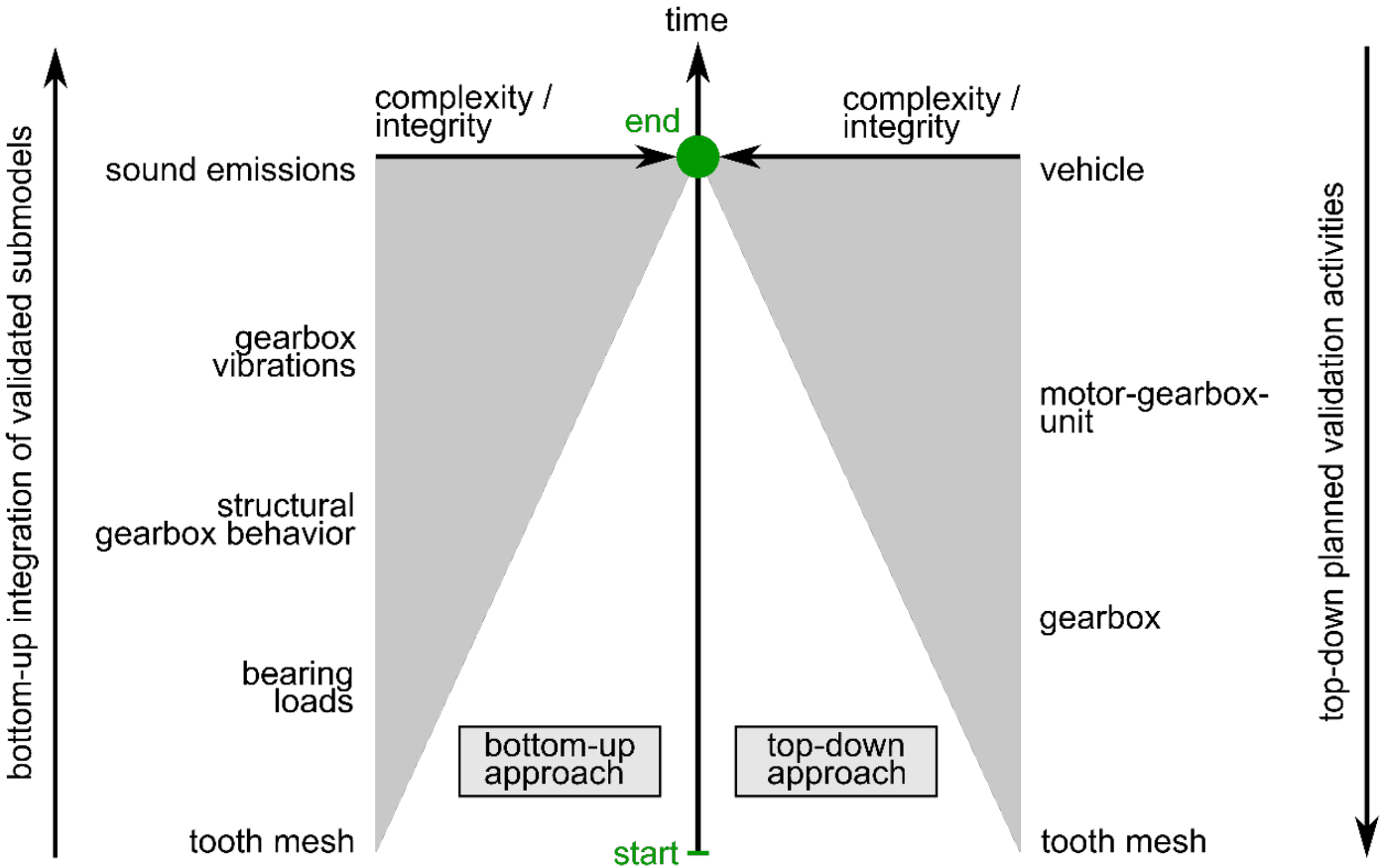
Extended Validation Approach



1D Tooth Mesh Simulation