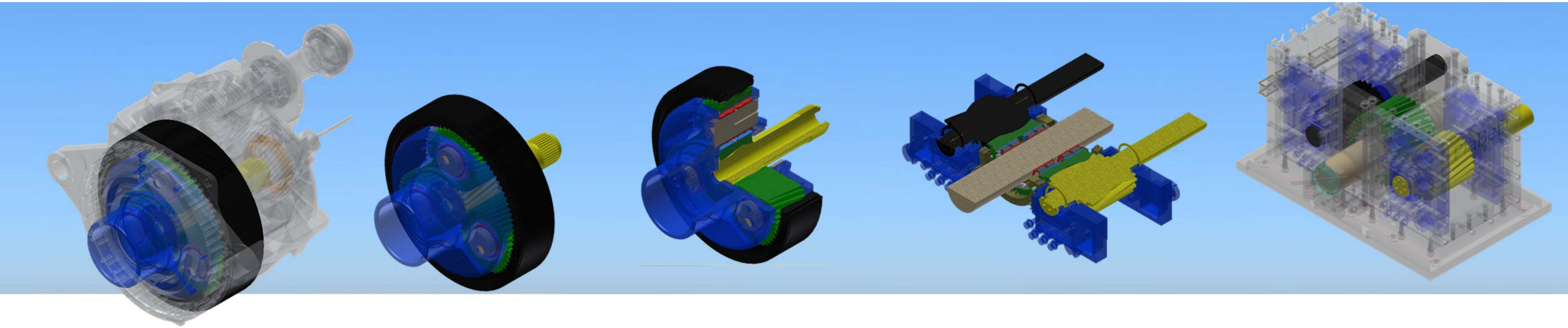

Development of an innovative component test bench for planetary bearings in wind turbine gearboxes

Project „PlaBeD“ – Planetary Bearing Design
Enhanced Design of Planetary Bearings in Gearboxes of Wind Turbines

09.11.2017
Valencia, Spain

Supported by:

Federal Ministry for Economic Affairs and Energy

on the basis of a decision by the German Bundestag

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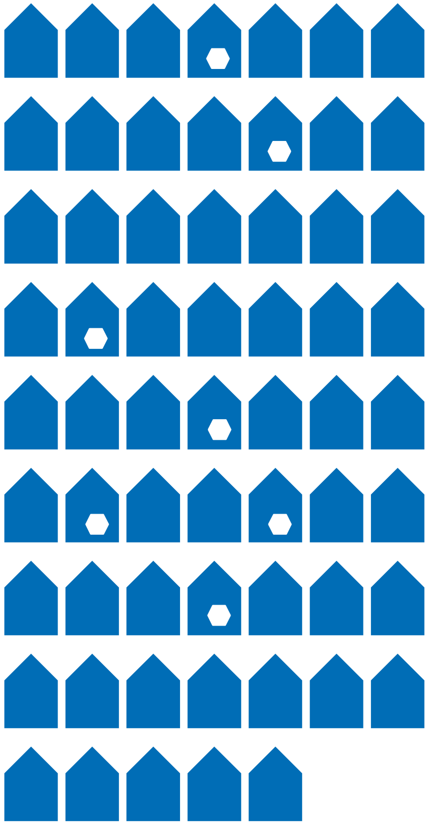
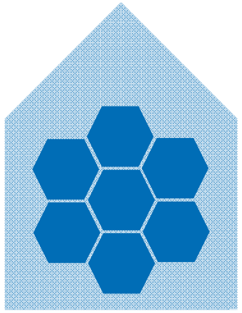
CWD Chair for Wind Power Drives
RWTH AACHEN UNIVERSITY

Overview

Center for Wind Power Drives – Concept and Integration



I3-Institute: Integrated Interdisciplinary Institute:
aerodynamics, control technology, electrical and mechanical engineering under one umbrella



CWD Center for Wind Power Drives

Directorate:	Abel, Brecher, De Doncker, Hameyer, Monti, Jacobs, Schröder
CTO:	Schelenz
Research Advisory Board:	Industrial Companies

Prof. Abel	Controls
Prof. Brecher	Gears
Prof. De Doncker	Power Electronics
Prof. Hameyer	Generators
Prof. Monti	Grids
Prof. Schröder	Aerodynamics
Prof. Stich	Logistics

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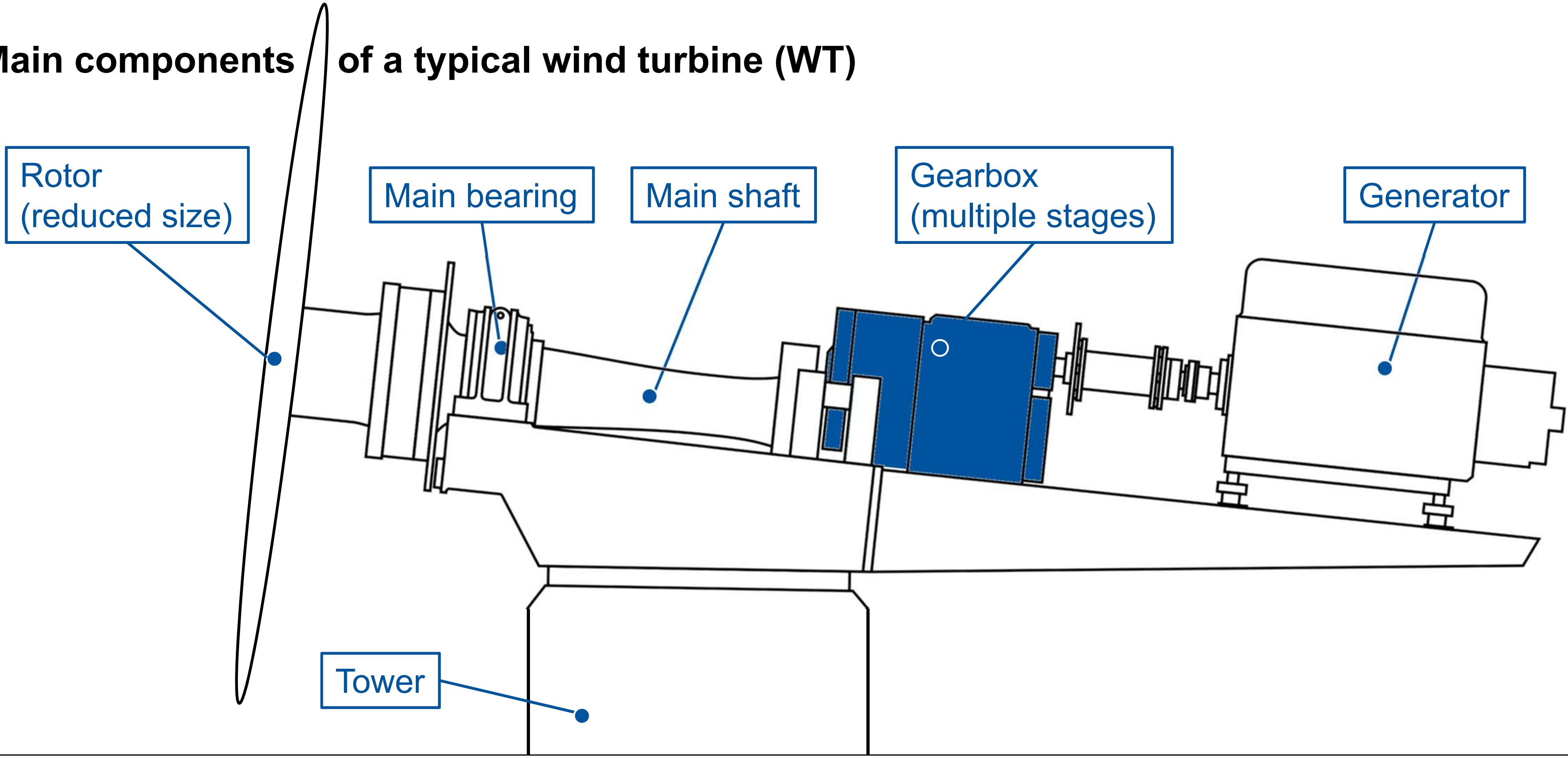
Prof. Jacobs	Chair for Wind Power Drives	Systemdesign & Test

Overview

System overview „wind turbine“

Main components of a typical wind turbine (WT)

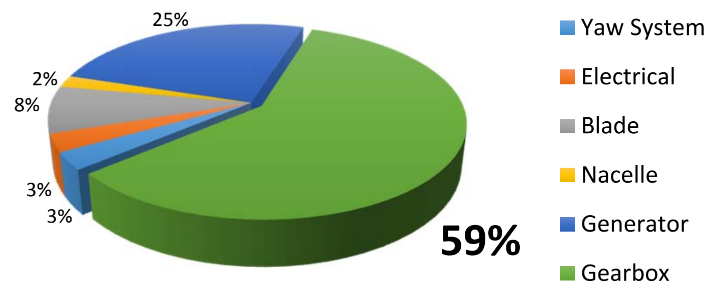


Motivation

Downtime of wind turbines / Gearbox failures

- About 90% of all WT have a planetary gearbox [1]
- Gearboxes cause about 60% of the downtime in WT [2]
- About 2/3 of these failures result from bearing damages [2]

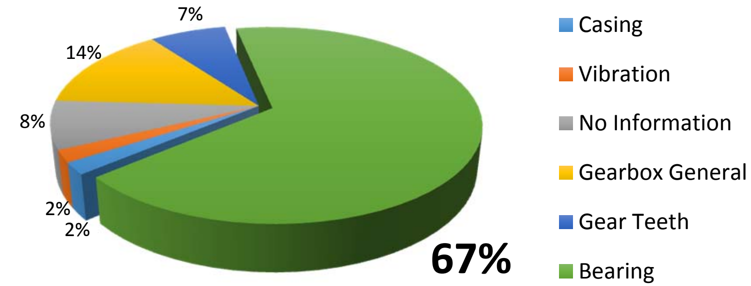
Reasons for down time of WT [2]



Planetary Bearings

- Highest loads in WT gearboxes appear in planetary bearings [3]
- Replacing a planetary bearing is very costly [4]

Reasons for gearbox failures in WT [2]



➡ More detailled understanding of failure mechanisms necessary

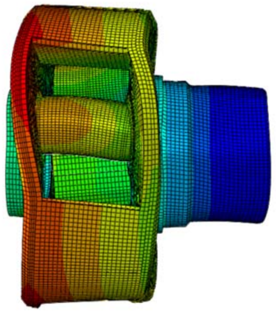
➡ Project „PlaBeD“ – Planetary Bearing Design
Enhanced Design of Planetary Bearings in Gearboxes of WT

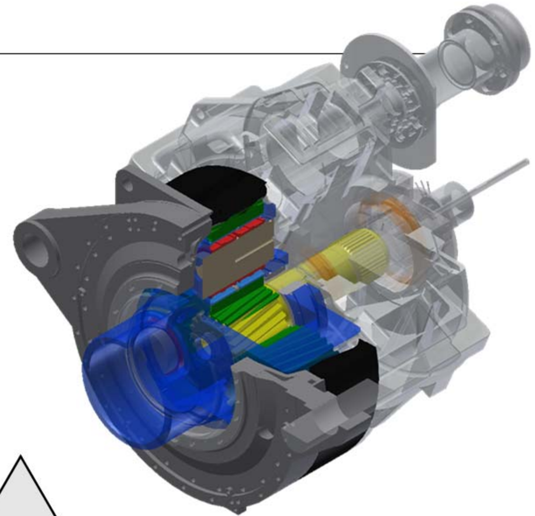
Project „PlaBeD“ – Planetary Bearing Design

Problem

- Unknown deformations in planetary stage
- Unpredictable bearing load conditions

➡ Premature bearing failures





Goals

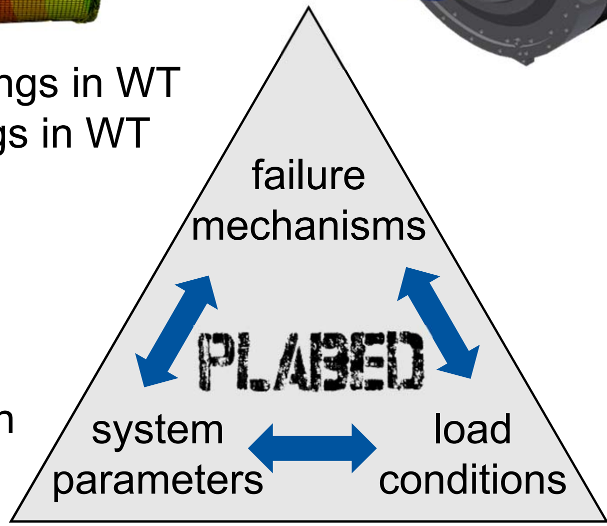
- Extend and validate current calculation methods for planetary bearings in WT
- Formulate an extended guideline for the design of planetary bearings in WT

➡ Increase economic efficiency of WT

Approach

- Test bench for planetary bearings
- Simulation of system deformations and transformation on test bench
- Reproduction of load conditions, evocation of failure mechanisms

➡ Profound system understanding

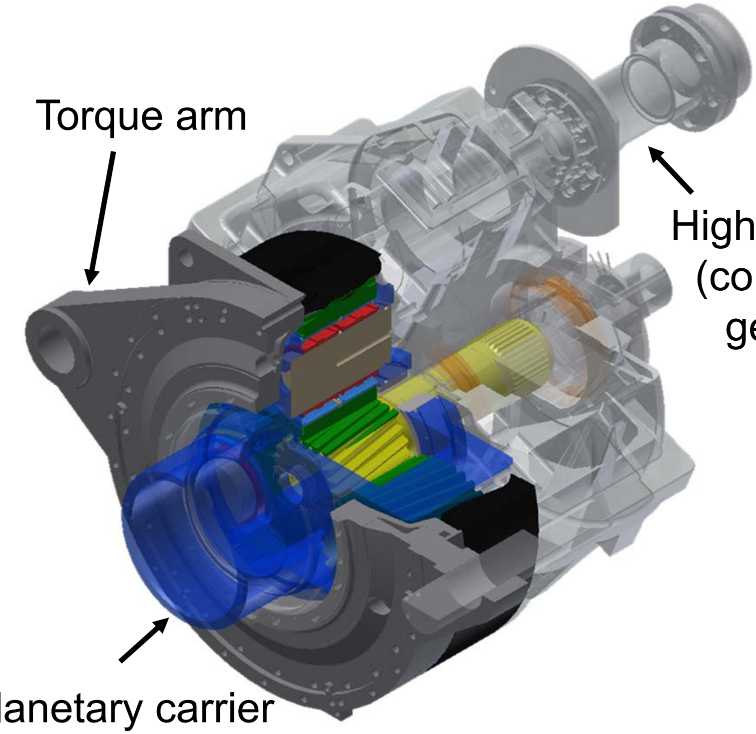


More information: https://www.cwd.rwth-aachen.de/1/projects/plabed/

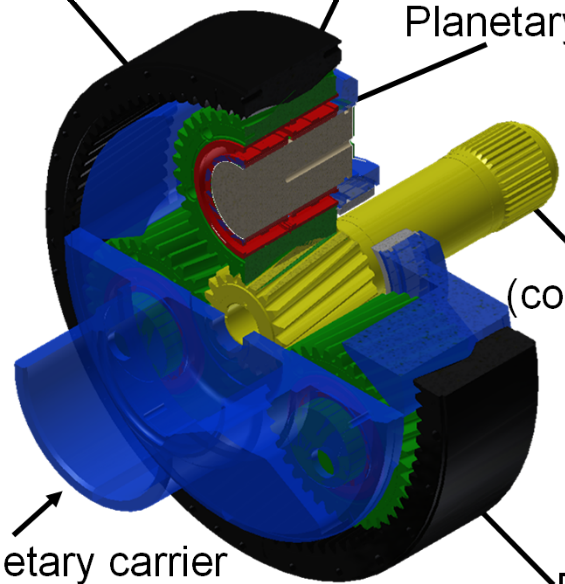
Overview

System overview „gearbox“ and „planetary stage“

Gearbox



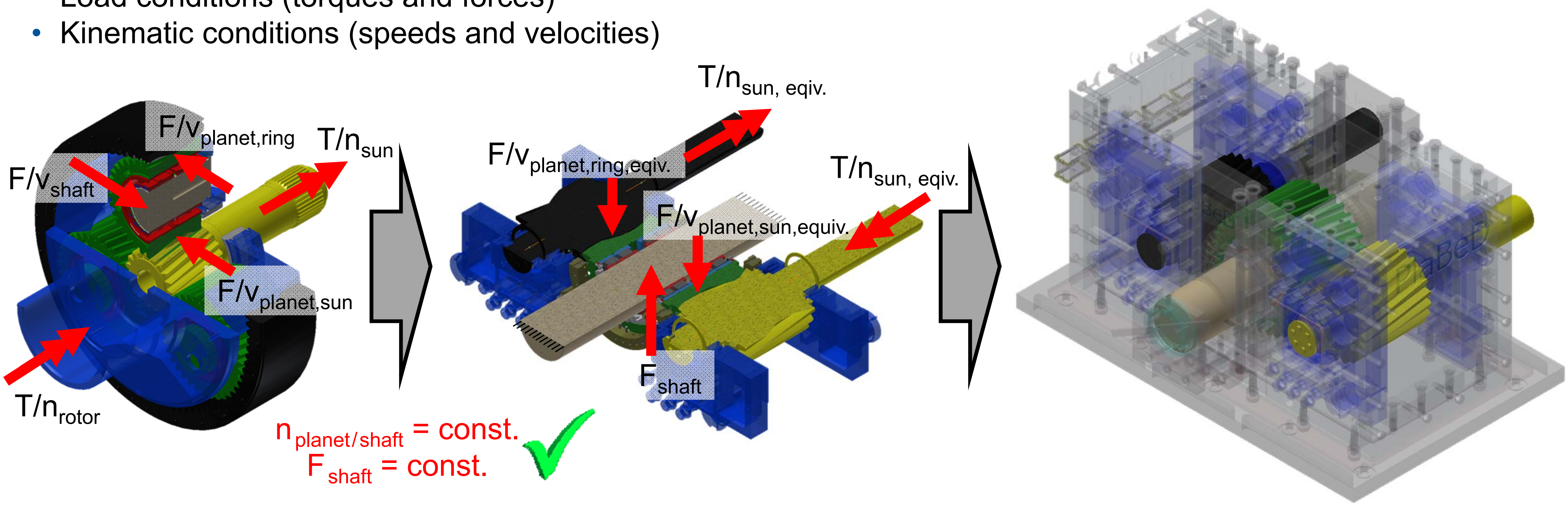
Planetary stage



Equivalent mechanical testing system

Transfer from WT gearbox to test bench

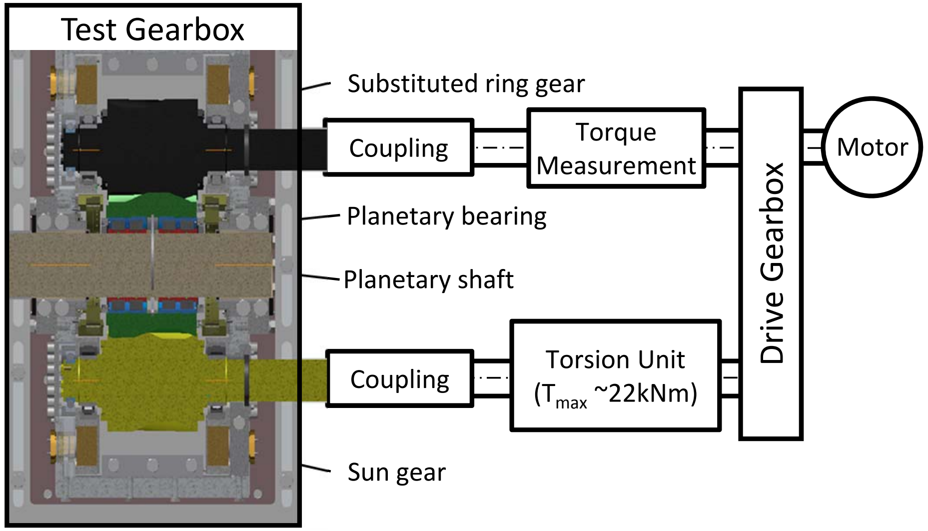
- Load conditions (torques and forces)
- Kinematic conditions (speeds and velocities)

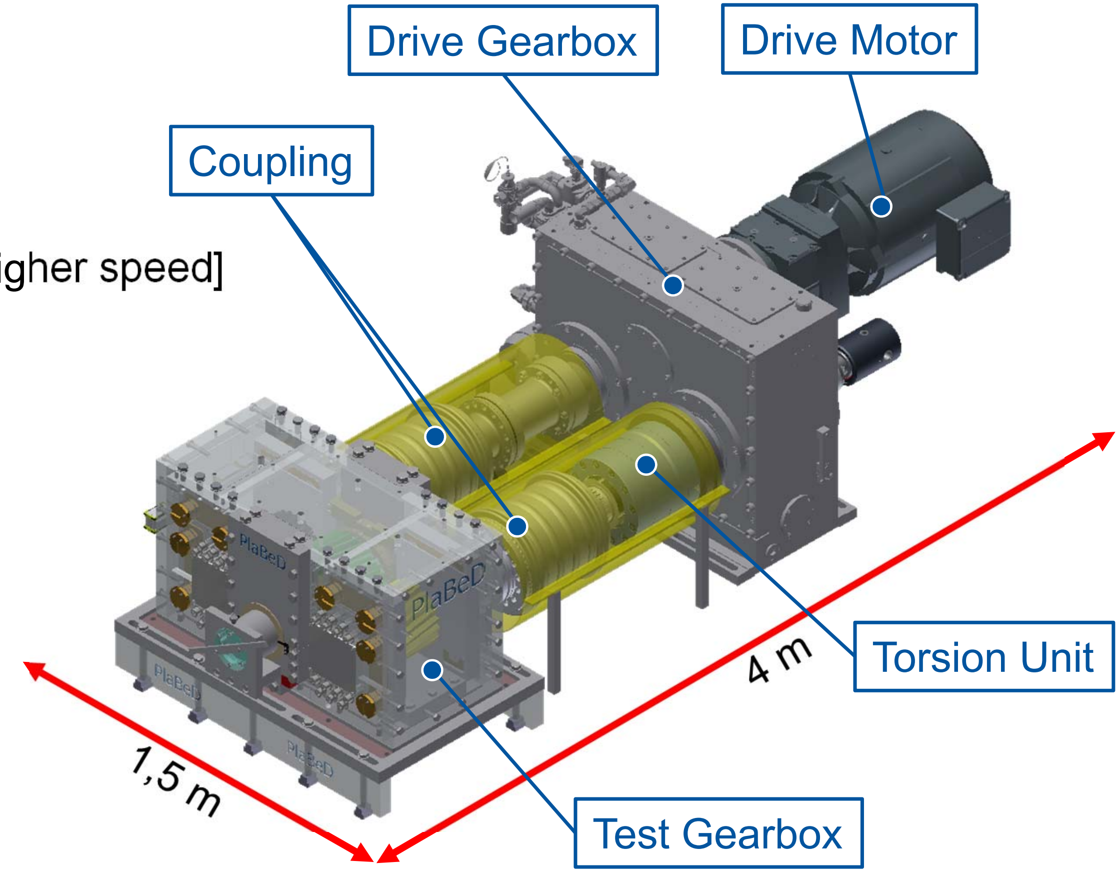


yellow = sun (shaft) **green = planetary gear** **black = (substituted) ring gear** **blue = (substituted) planetary carrier**

Setup as mechanical bracing rig

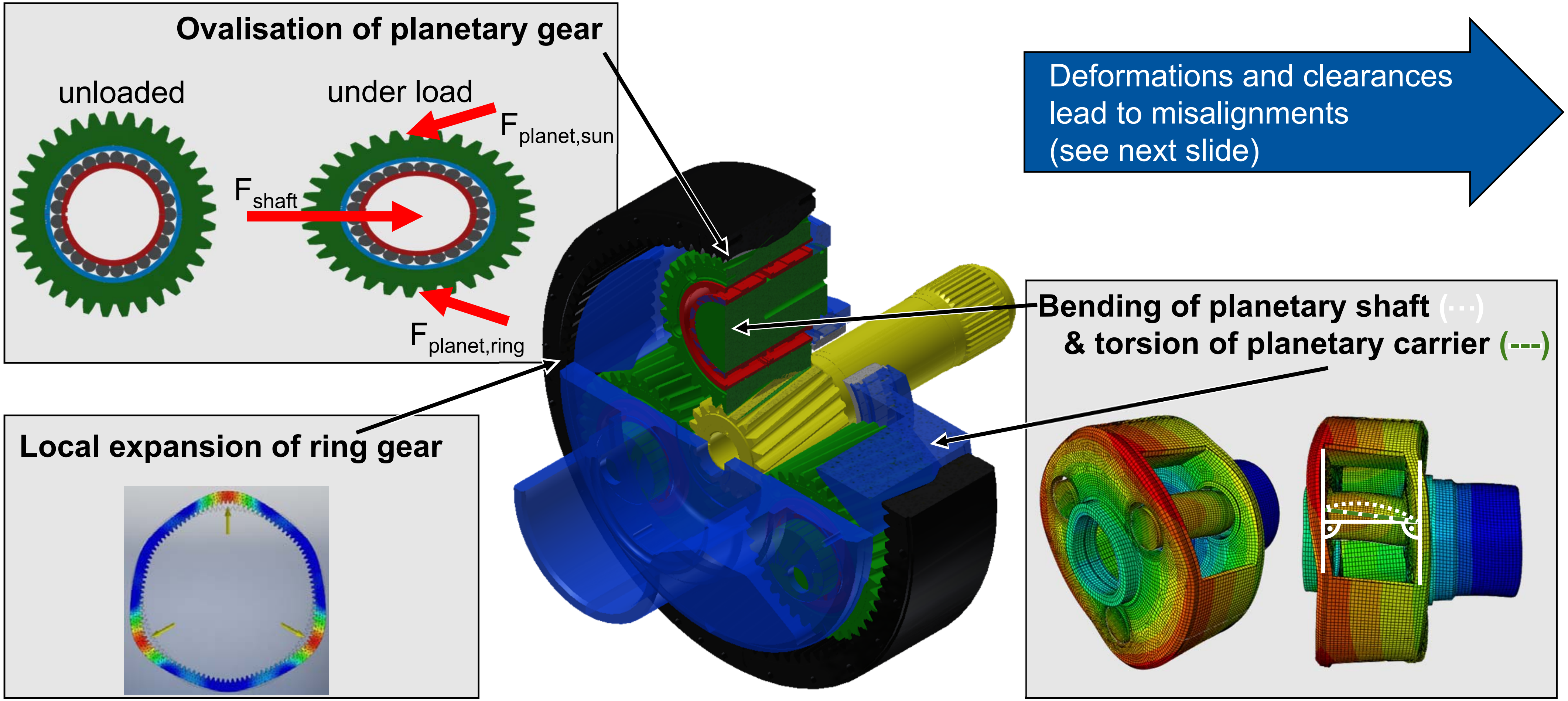
- Max. torque (sun): 22kNm
- Max. speed (planet bearing): 265 1/min
- Motor power: 55 kW
- Equiv. bracing power: 925 kW [~2,75 MW WT at higher speed]





Overview

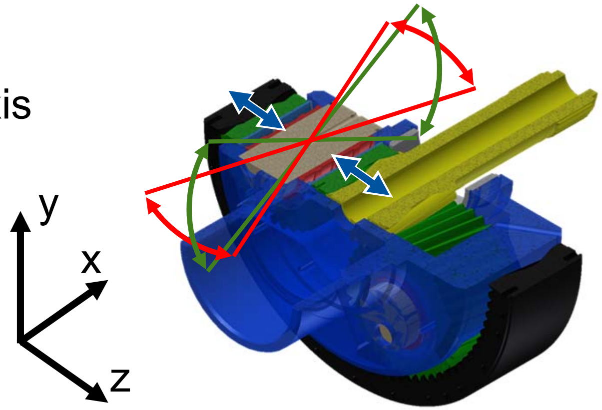
Relevant deformations in the planetary stage

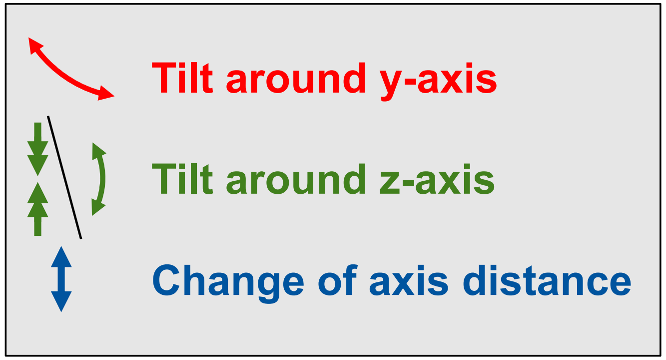


Relevant misalignments in the planerary stage

Misalignments

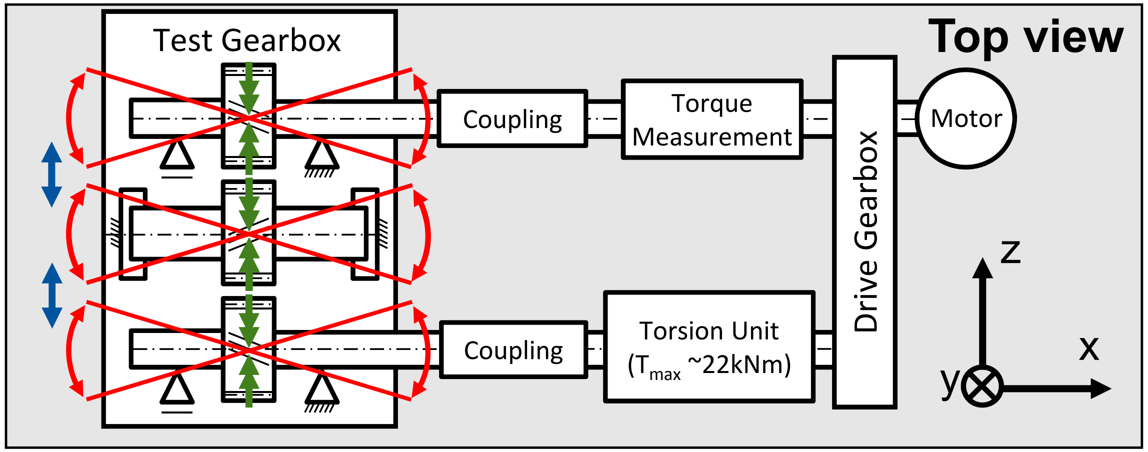
- Tilting of components around y- and z-axis
  - gears (sun, planetary gear, ring gear)
  - planetary carrier
- Change of axis distances
  - sun – planetary gear
  - ring gear – planetary gear





Transfer to test bench

- Indendent active adjustment of all relevant angles and distances on test bench possible
  - axis distances
  - gear alignment angles
- Tilting of planetary gear transfered to sun and ring gear

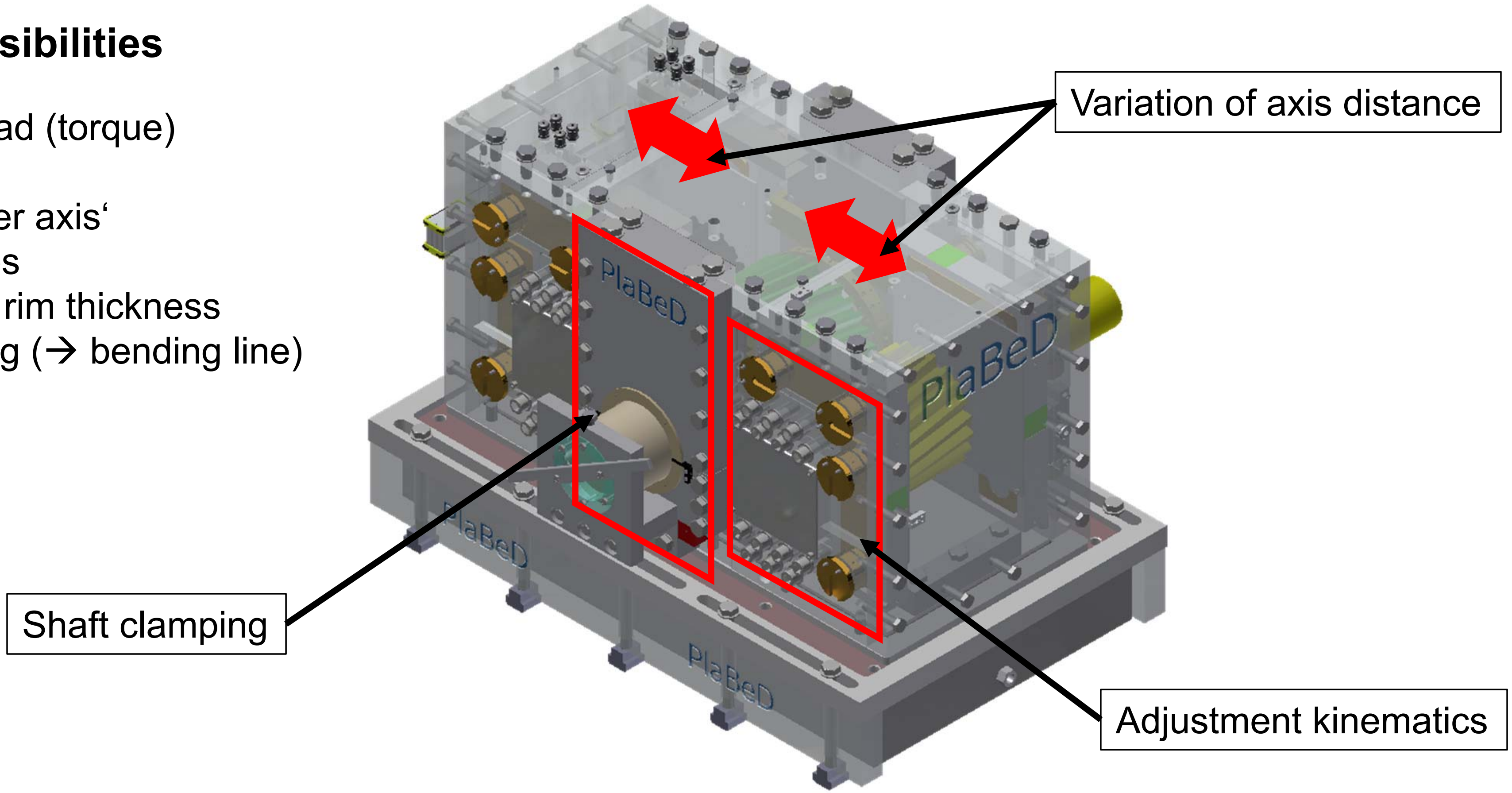


Overview

Detailled functionalities – Overview

Variation possibilities

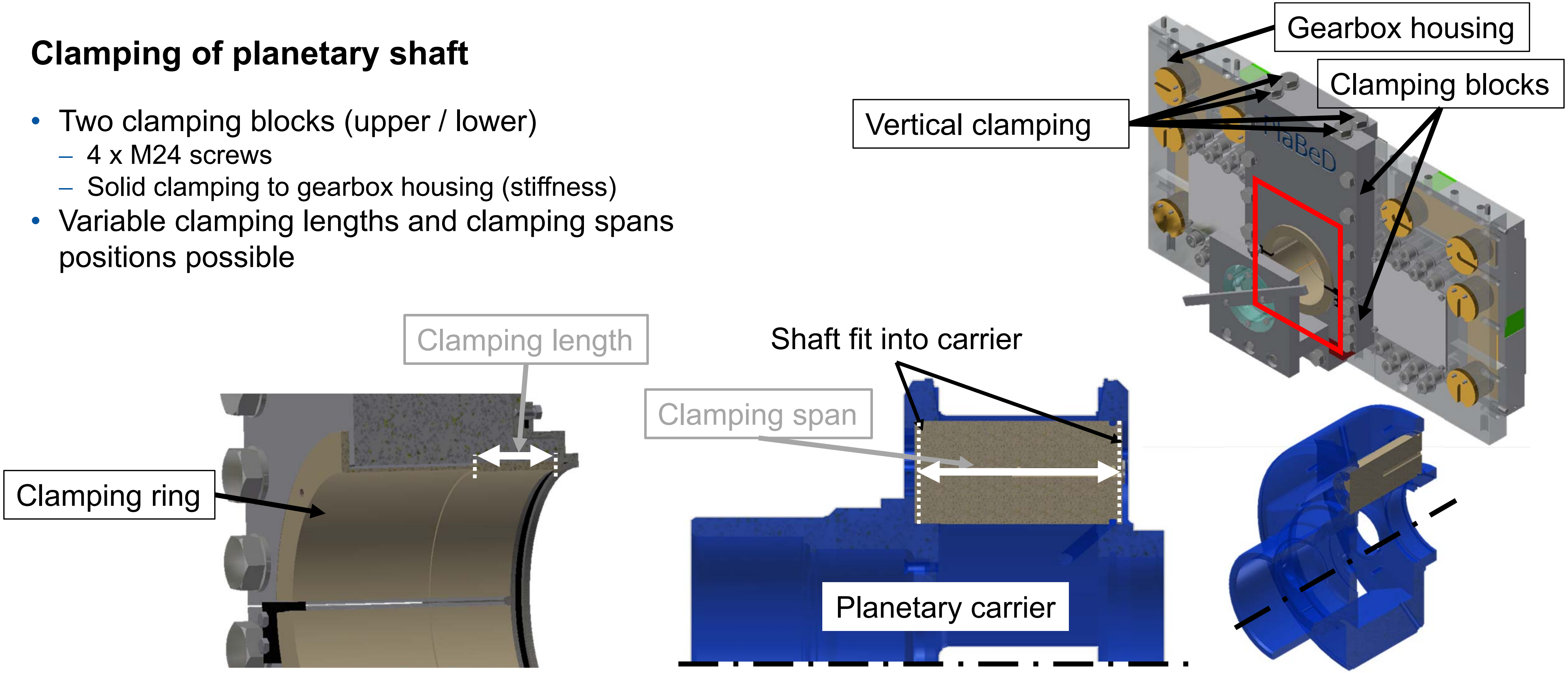
- Speed and load (torque)
- Temperature
- Angles of outer axis‘
- Axis‘ distances
- Relative gear rim thickness
- Shaft clamping (→ bending line)



Detailled functionalities (1)

Clamping of planetary shaft

- Two clamping blocks (upper / lower)
  - 4 x M24 screws
  - Solid clamping to gearbox housing (stiffness)
- Variable clamping lengths and clamping spans positions possible



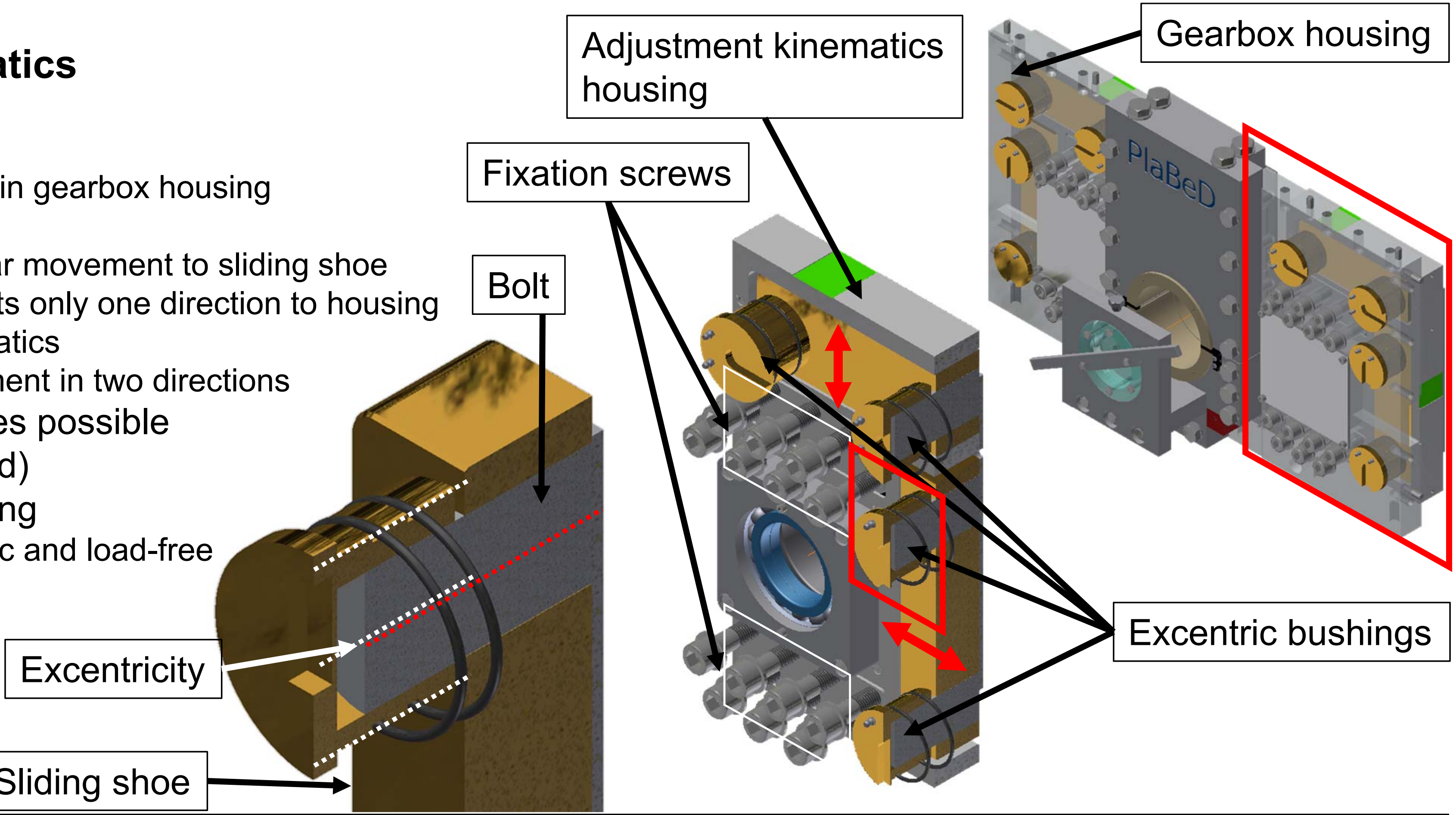
Detailled functionalities (2)

Adjustment kinematics

- Excentric bushings
  - Only rotational DOF in gearbox housing
  - Excentric bore
  - Bolt transmits circular movement to sliding shoe
  - Sliding shoe transmits only one direction to housing of adjustment kinematics

  → Independent movement in two directions
- Different excentricities possible (~25-200 µm planned)
- Fixation before loading

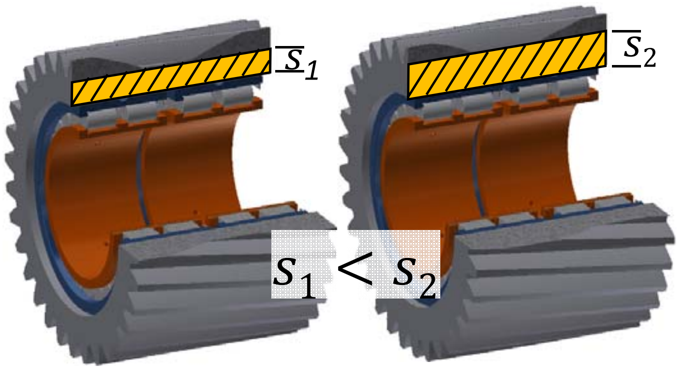
  → Movement only static and load-free



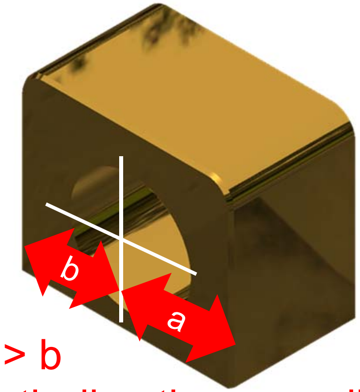
Detailled functionalities (3)

Variation of axis distance

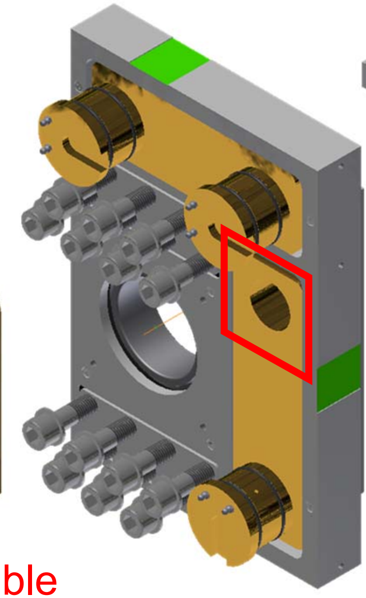
- In range of **µm continuously** to reproduce carrier deformations / local ring gear expansion (adjustment kinematics)
- In range of **mm stepwise** to allow planetary gears with different „ gear rim thickness“
  - Different gear rim elasticity
  - Different influence on planetary bearing (tooth bending, ovalisation of planetary gear)

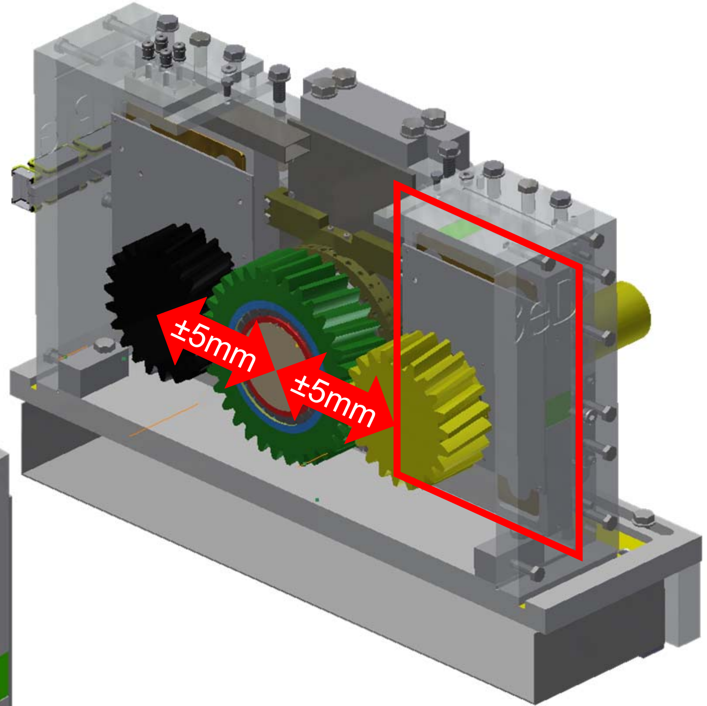


Gears with different rim thickness



a > b
Both directions possible

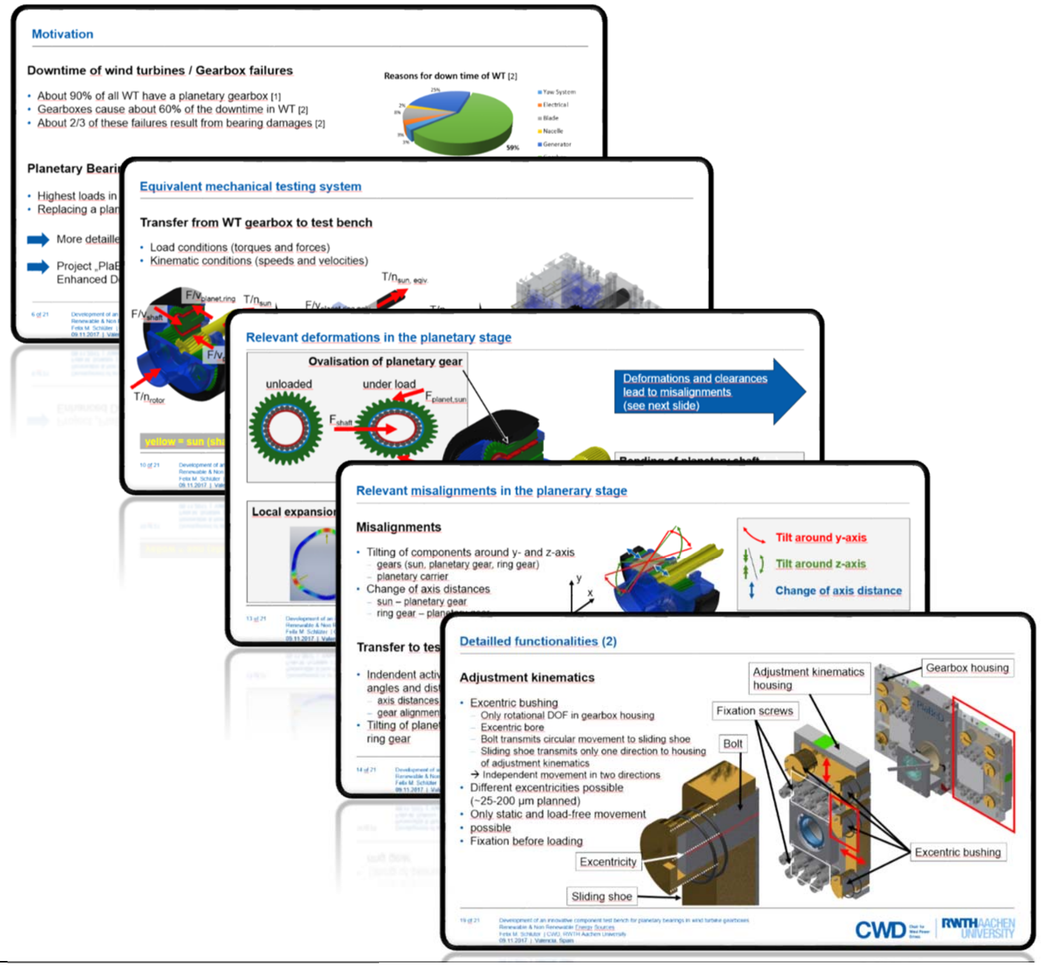




Overview

Summary

- Motivation
  - Premature failures in planetary bearings in WT
  - Detailled investigation of failure mechanisms necessary
- Test Bench Concept
  - Equivalent mechanical testing system
  - One instead of three planets
  - Mechanical bracing rig
  - Testing equivalent of 2,8 MW WT with 55 kW motor
- Deformations and Misalignments
  - Simulation of system deformations
  - Misalignments resulting from deformations
  - Transfer of misalignments on test bench kinemaics
- Detailled functionalities
  - Variation of speed, torque and temperature
  - Variation of outer axis‘ angles and axis‘ distances
  - Manipulation of planetary shaft‘s bending line



Thank you for your attention

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Sources:

- [1]: Crowther, A.: Sources of time-varying contact stress and misalignments in wind turbine planetary sets, 2010
- [2]: Scott, K.G.; Infield, D.: Effects of Extreme and Transient Loads on Wind Turbine Drive Trains, AIAA Technical Conferences, Boston, 2013
- [3]: Thalmann, D.; Duskunovic, F.: Lager für Leistung, K-Magazin, Ausgabe 5/6 2009
- [4]: Bozan, C.; Cugno, S.: Developments and trends in wind turbine rolling bearings, Organi di transmissione, Issue 5, 2010