

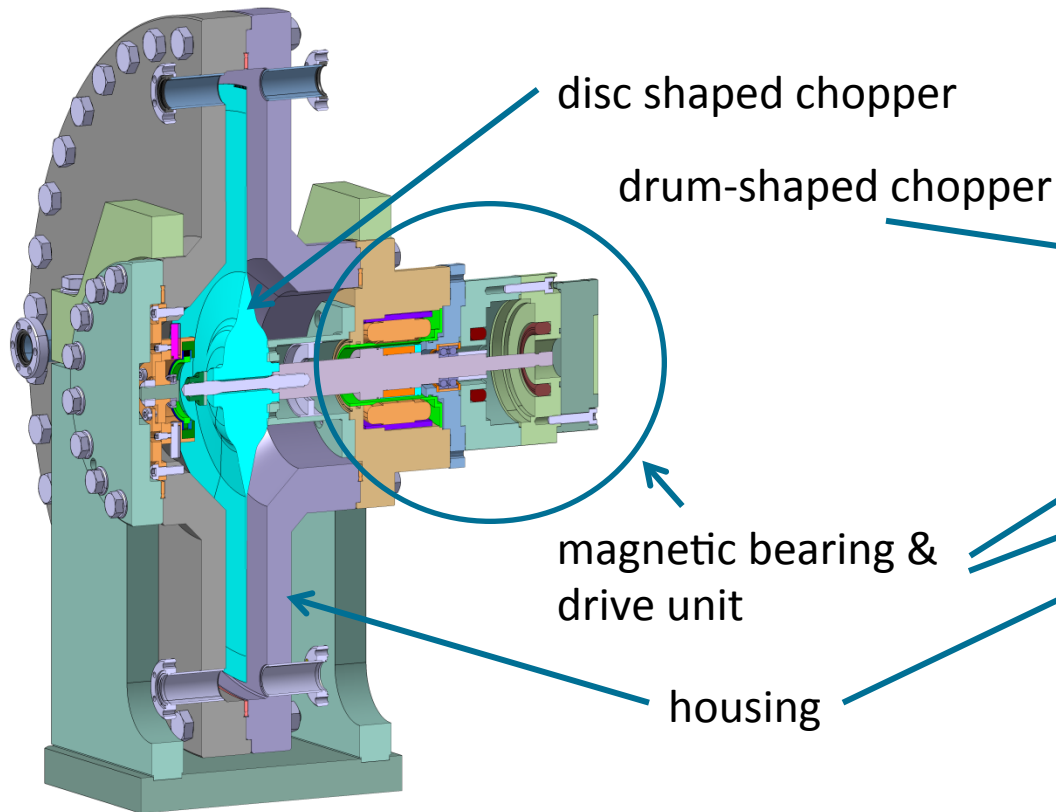
Chopper Design Process at ZEA-1

19 September 2014 | Stephan Schönen, ZEA-1

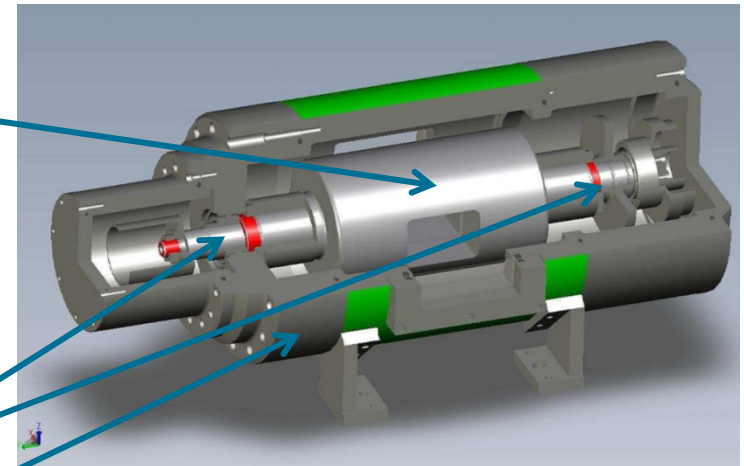
Motivation

- increasing requirements on chopper systems compared to former devices
- strong dependencies between different aspects of chopper design
- well adapted process in the design phase needed to fulfil requirements

Typical Designs

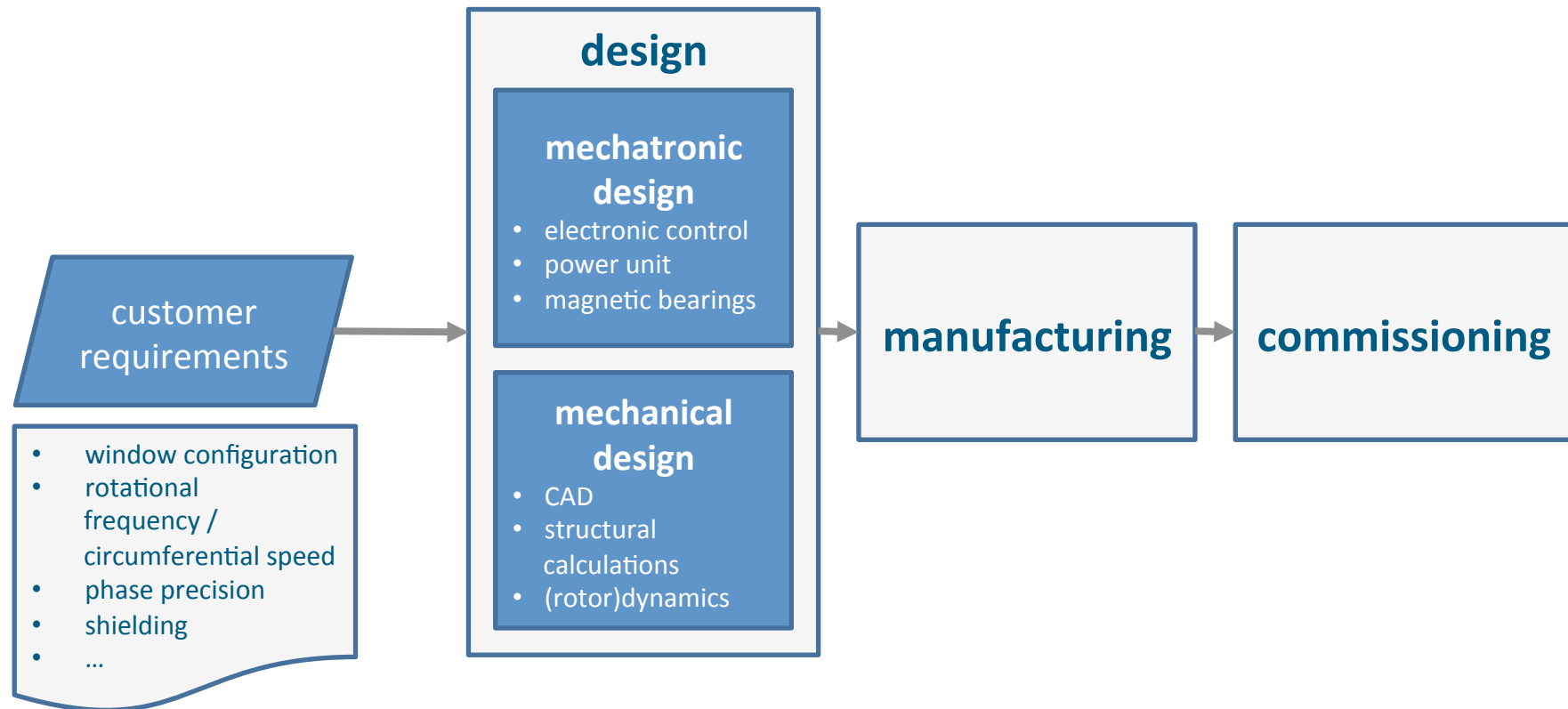


disc chopper

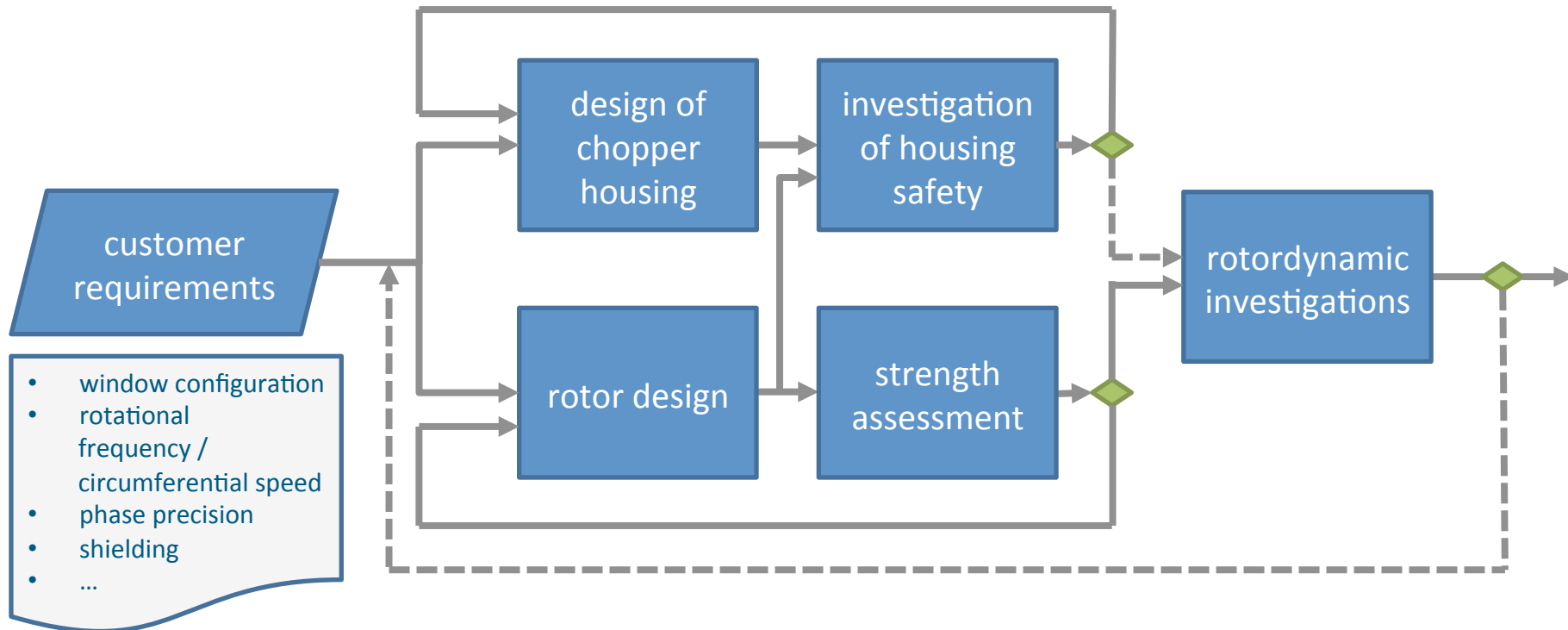


Fermi chopper

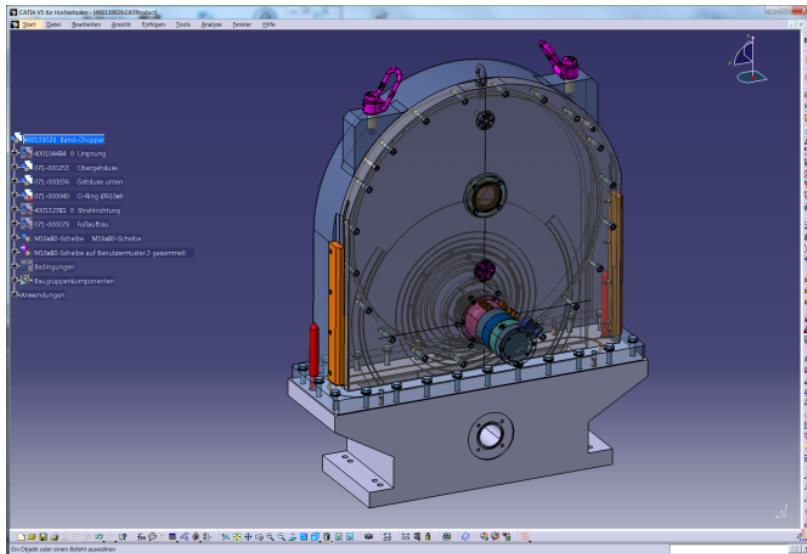
Workflow



Mechanical Design



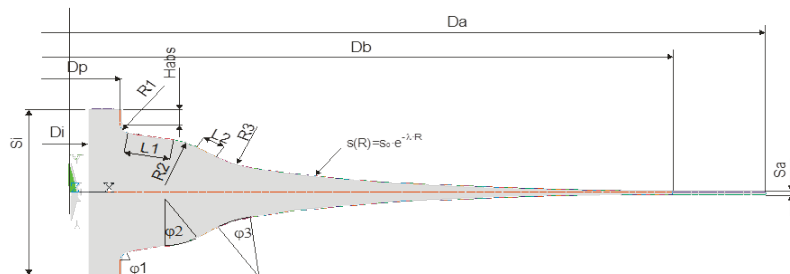
Design of Rotor and Housing



first draft:

- CAD (CATIA V5)
- parametric FEA-models for optimisation

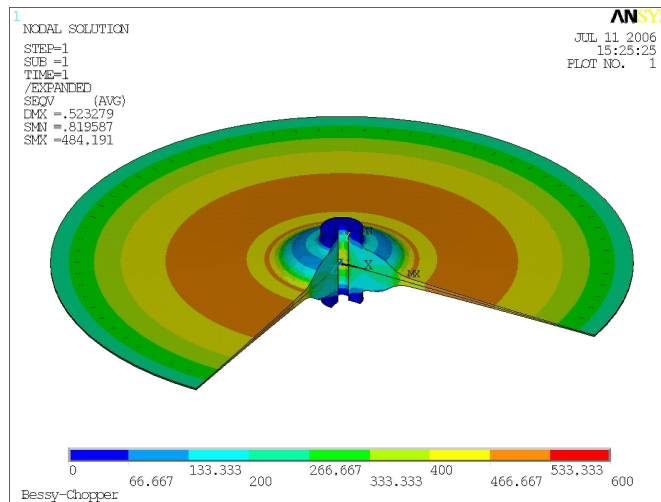
CAD-model of a chopper assembly



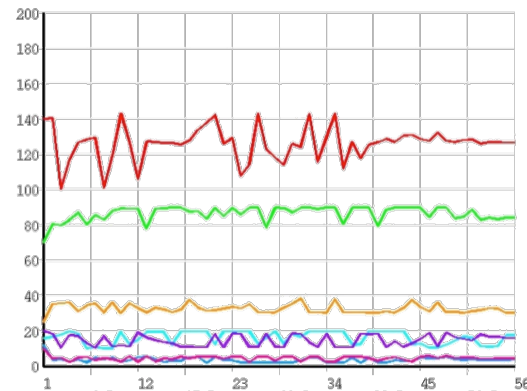
parametric model of a chopper disc

Disk Design

Example: Shape optimisation of a chopper disc

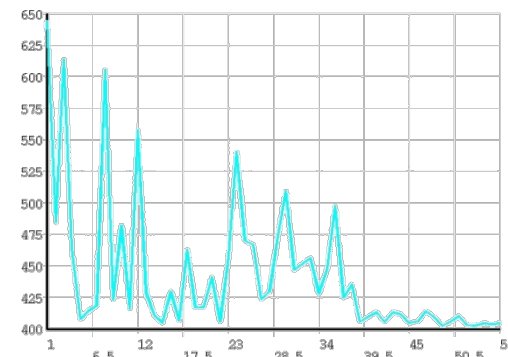


- parametric model
- application of optimisation algorithms
- 56 iterations
- stress reduction: 650 MPa → 400 MPa



parameters

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max. equivalent stress in MPa

7

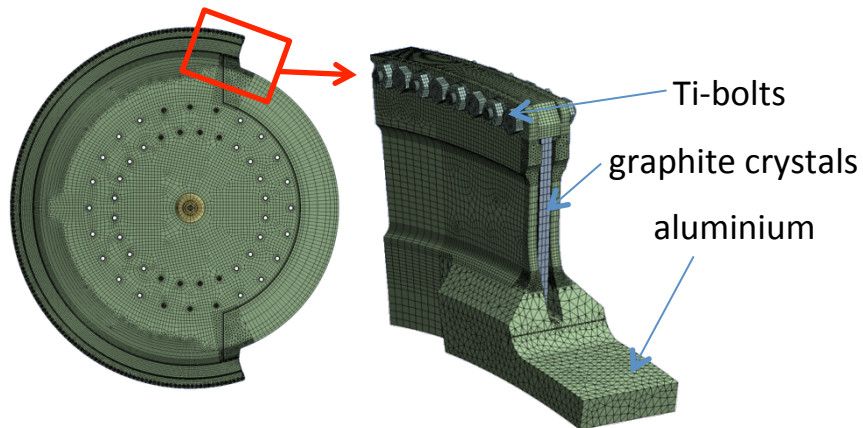
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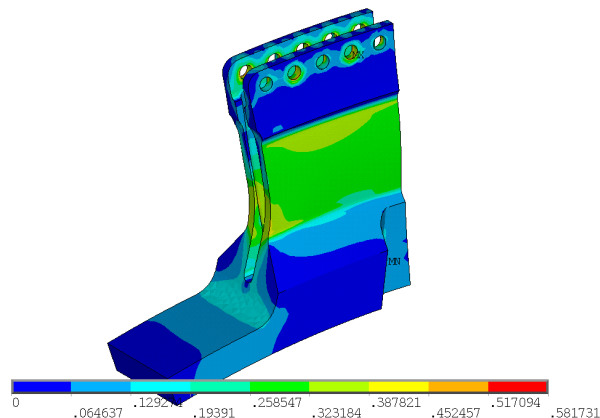
Strength Assessment of Rotor

Example: Strength assessment of new PST-chopper



total model

sub model

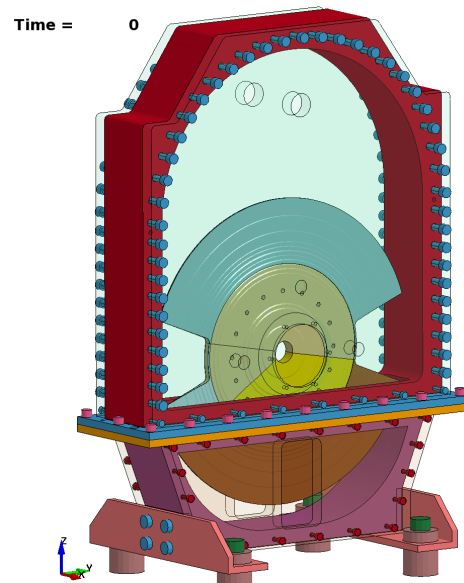


degree of utilisation according to FKM-guideline

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- operation frequencies of up to 1000 Hz
 - additional centrifugal load due to neutron-absorbing coatings
 - beam windows
-
- high stresses
 - lightweight and beam compatible materials (high strength aluminium, titanium,...)
 - state of the art design rules (FKM-guideline,...)

Chopper Housing Safety



initial state of chopper disc broken into two pieces

Aspects:

- very low probability of chopper disc failure
- scenarios:
 - bearing system failure
 - chopper disc failure

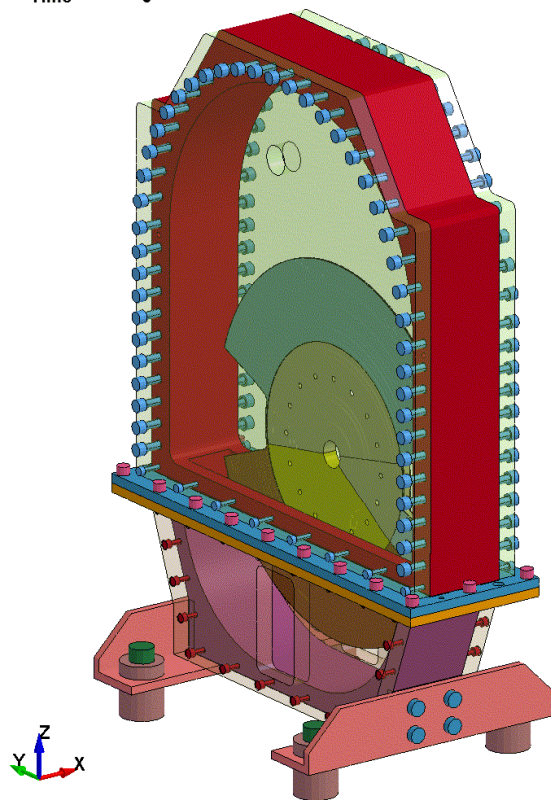
Procedure:

- explicit finite-element-analysis
- Identification and elimination of weak spots.

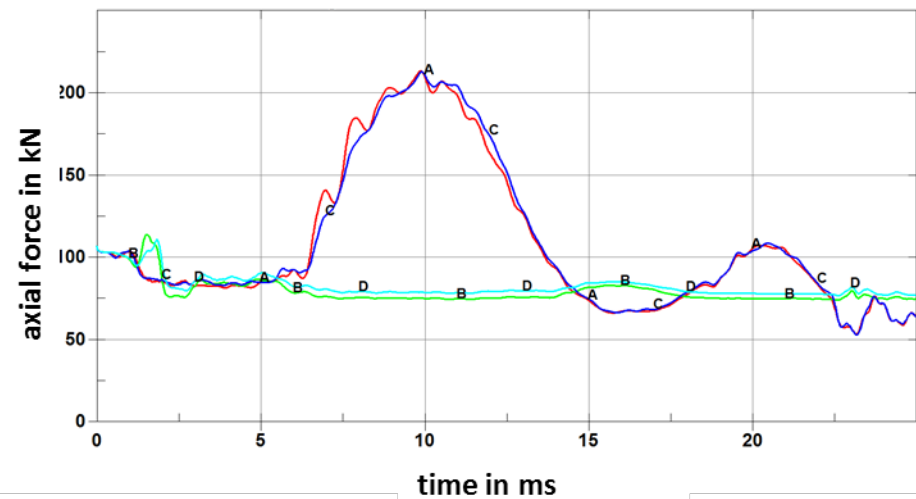
Chopper Housing Safety

Example: Simulation of chopper disc failure

Time = 0



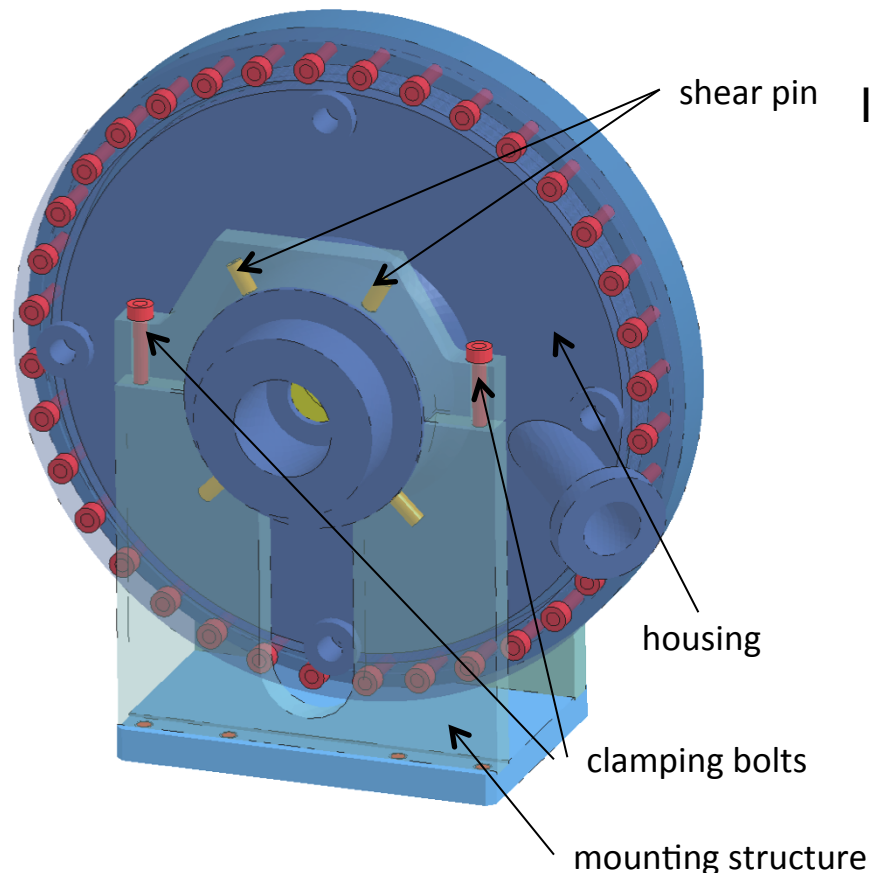
broken chopper disc in housing



axial force of anchor bolts during the crash

Chopper Housing Safety

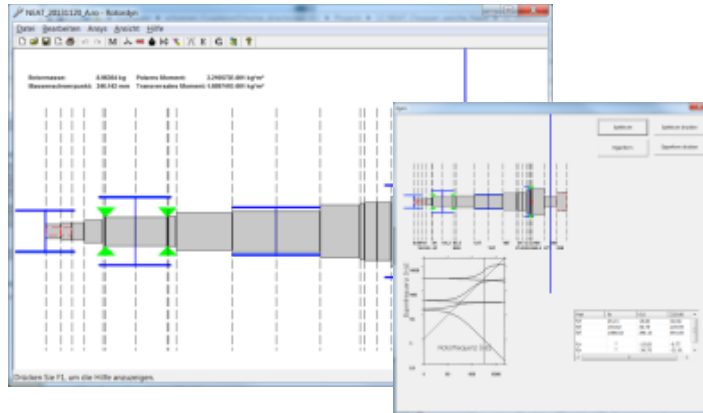
Example: Safety concept of a chopper housing



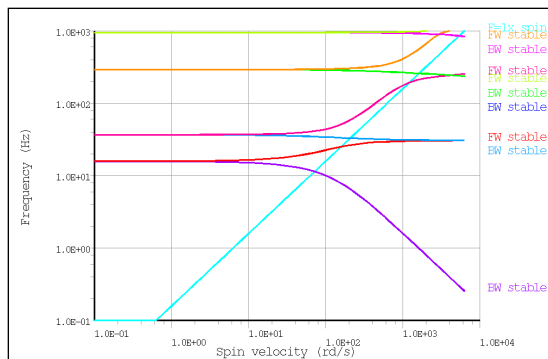
In the case of disc failure...

- ... shear pins fail.
- ... housing can rotate in mounting structure.
- ... openings to neutron guides are closed.
- ... dynamic loads of anchorage are reduced.

Rotordynamic Analyses



In house developed software „Rotordyn“



Campbell diagram

Aspects:

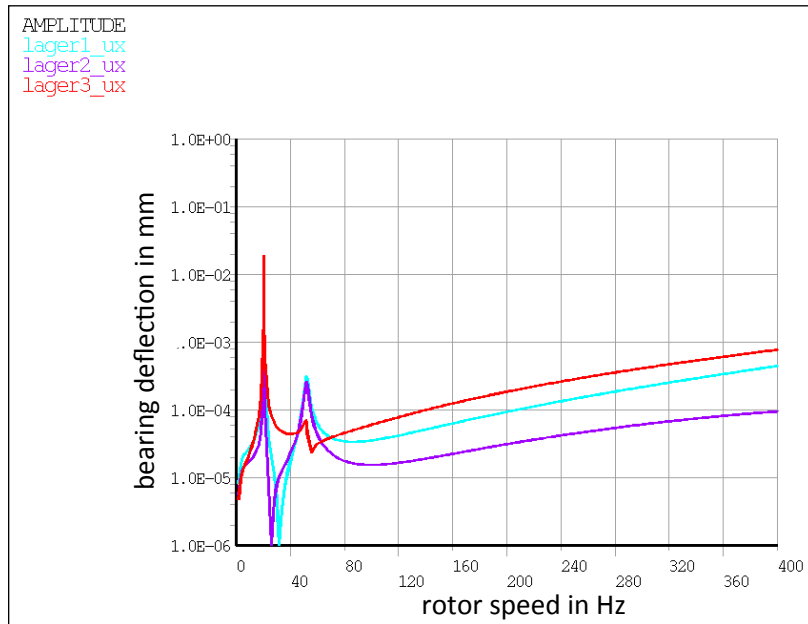
- Operation near critical frequencies excitable by unbalances should be avoided.
- They depend on the system consisting of bearing, shaft and rotor (disc).

Procedure:

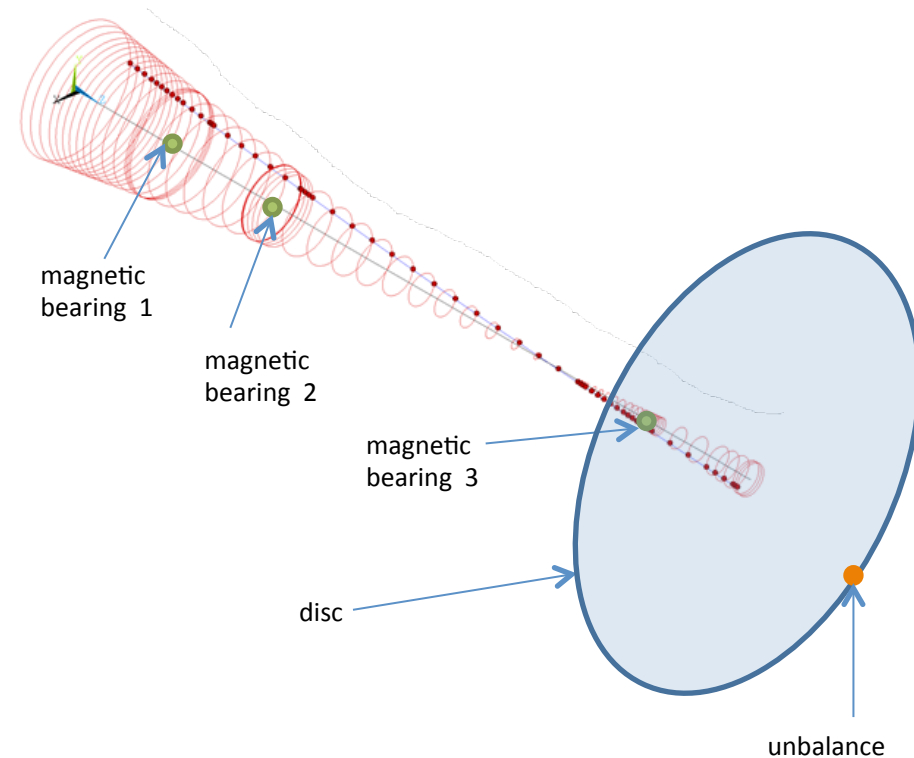
- determination of critical frequencies including gyroscopic effects
- approximations of responses to assumed unbalances of the rotor
- investigations on possibilities to shift critical frequencies

Rotordynamic Analyses

Example: Simulation of unbalance response of a rotor in magnetic bearings



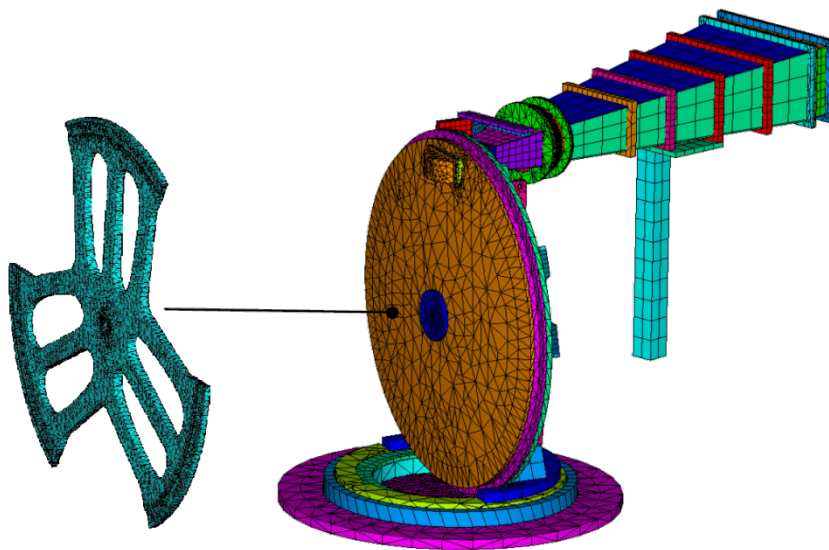
bearing deflection as function of operation frequency



orbit plot of the shaft

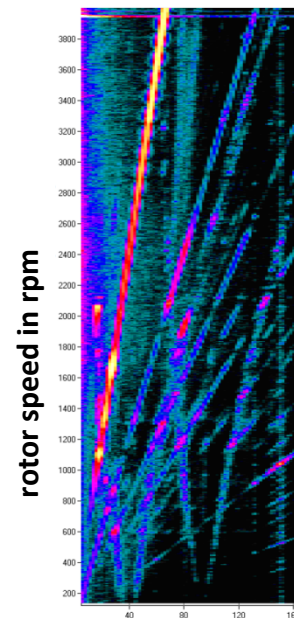
Rotordynamic Analyses

Example: Measurement and simulation of natural frequencies depending on rotor speed



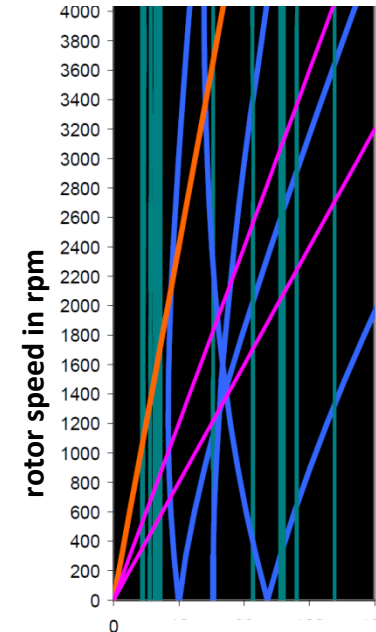
FEA-model

measurement



frequency in Hz

simulation



frequency in Hz

results

Conclusion

- Chopper design is a complex process with strong interaction between the different design aspects.
- Close collaboration between all participants of the development process is essential for the success.

Thank you for your attention.