Efficient Modelling of the Drive Train Dynamics in Wind Turbines

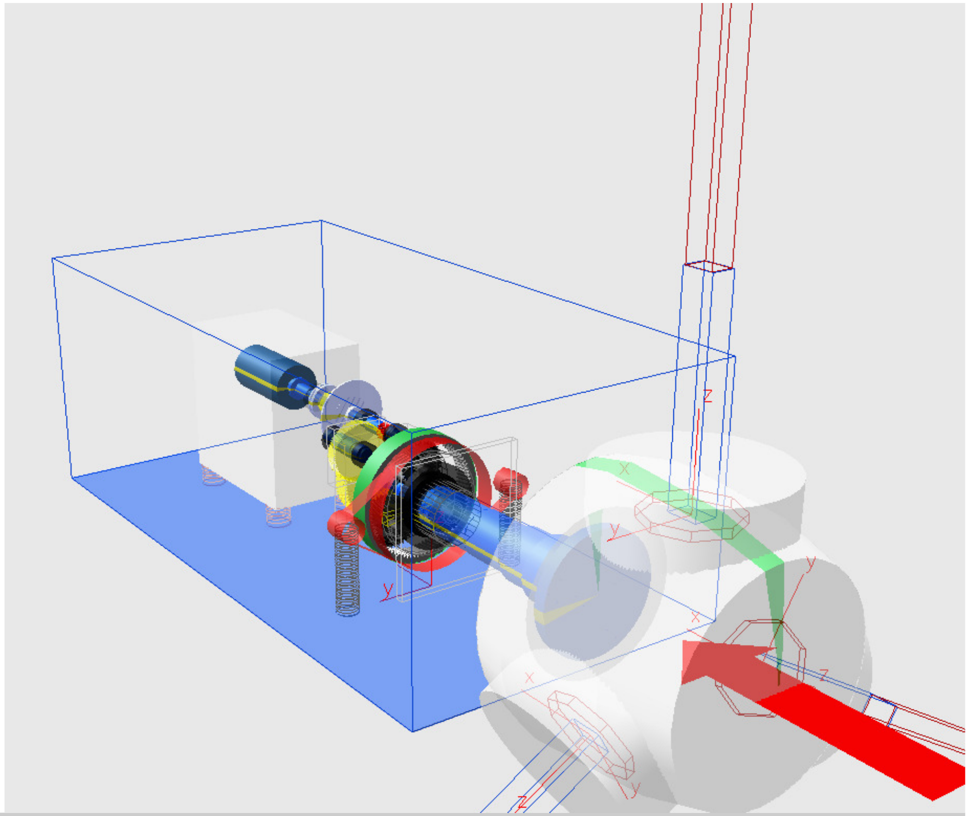
Markus Kochmann
Milan Ristow
www.gl-group.com/glwind

16.12.2008

Germanischer Lloyd

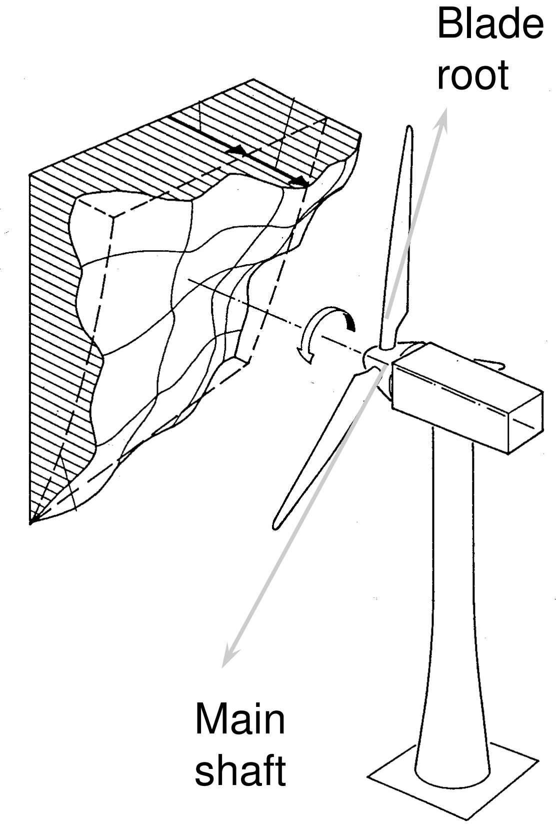
Content

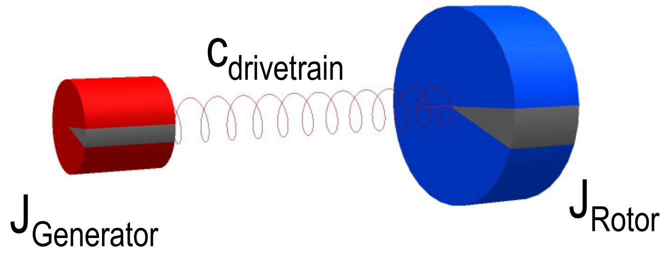
- Importance of drive train analysis
- Current Modelling Requirements
- Modelling Details
  - Main Shaft
  - Gear Model
  - Generator Coupling
- Conclusion



Importance of Drive Train Analysis

- **Load assumptions for the design of drive train components are based on simulations of global model**
- **Dynamic properties and internal loads are neglected**
- **Verification of design loads**
- **Validation of assumptions for global load simulation (e.g. stiffness, mass)**





Certification Requirements

- **GL Guideline for the Certification of Wind Turbines (Edition 2003 with Supplement 2004)**
- **GL Wind Technical Note 068: *"Requirements and recommendations for implementation and documentation of resonance analysis"***

Aim of analysis:

- **Analysis of the dynamic behaviour of the drive train using a detailed simulation model**
- **Verification of model parameter assumptions representing the drive train in global model**

Certification Requirements, Modelling Detail

Major drive train components	**Minimum requirements for modelling structure of comp.**	**Minimum requirements for modelling DOF of components**
Rotor blades	rigid body	edge wise and flap wise
Hub	rigid body	torsional
Main shaft	rigid body; elastic recommended	torsional
Low speed shaft coupling	rigid body	torsional
Gear box housing	rigid body	torsional
Planet carrier	rigid body	torsional
Gear box shafts	rigid bodies; elastic recommended	torsional; axial recommended
Gear box gears	rigid bodies	torsional; axial recommended
Elastic gear box support	rigid body	torsional
Brake disc	rigid body	torsional
Generator coupling	rigid body	torsional
Generator	rigid body	torsional
Elastic generator support	rigid body	torsional

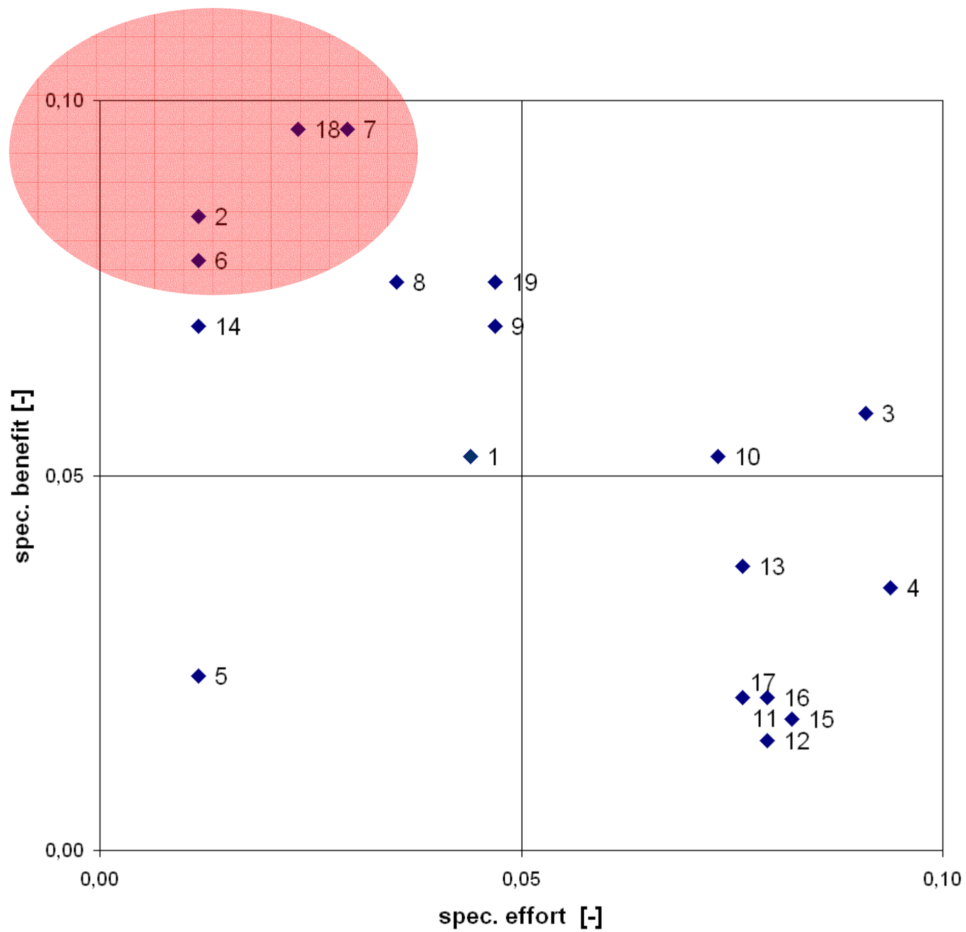
Modelling Detail

- improve model quality
- limit modelling effort
- identify the required level of complexity for components in the drive train model

Modelling Detail

ID	Component / Model Approach
1	3 Point Suspension
2	Gearbox Output Shaft
3	Damping
4	Housing, Stiffness
5	Gearbox, 2^{nd} Stage Shaft
6	Main Shaft
7	Coupling
8	Main Shaft Bearing
9	Bearing Characteristics
10	Gearbox, Floating Sun
11	Main Frame
12	Hub, Super Element
13	Planet Carrier, rot. Stiffness
14	Sun Wheel
15	ANOVA, Shaft Diameter (c, m, J)
16	ANOVA, Shaft Unbalance
17	Tower, Super Element
18	Gear Model, Constraint vs. Detailed Geometry Based
19	Gear Model, Tip Relief

Modelling Detail

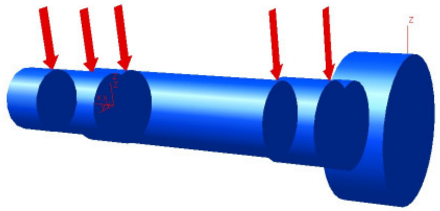


Modelling Detail, Identified Areas

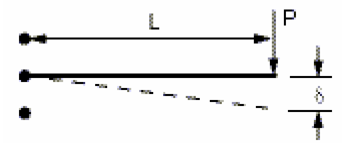
- **Main Shaft**
- **Gear Model**
- **High Speed Shaft / Generator Coupling**

Main Shaft

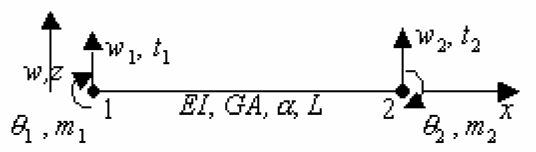
1. Shafts represented by rigid bodies connected by spring damper elements



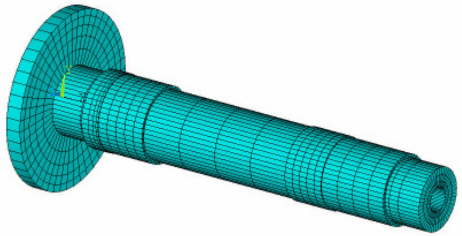
2. Elastic beam elements (Bernoulli)



3. Timoshenko beam elements



4. Structural solid elements



Main Shaft – Model Comparison

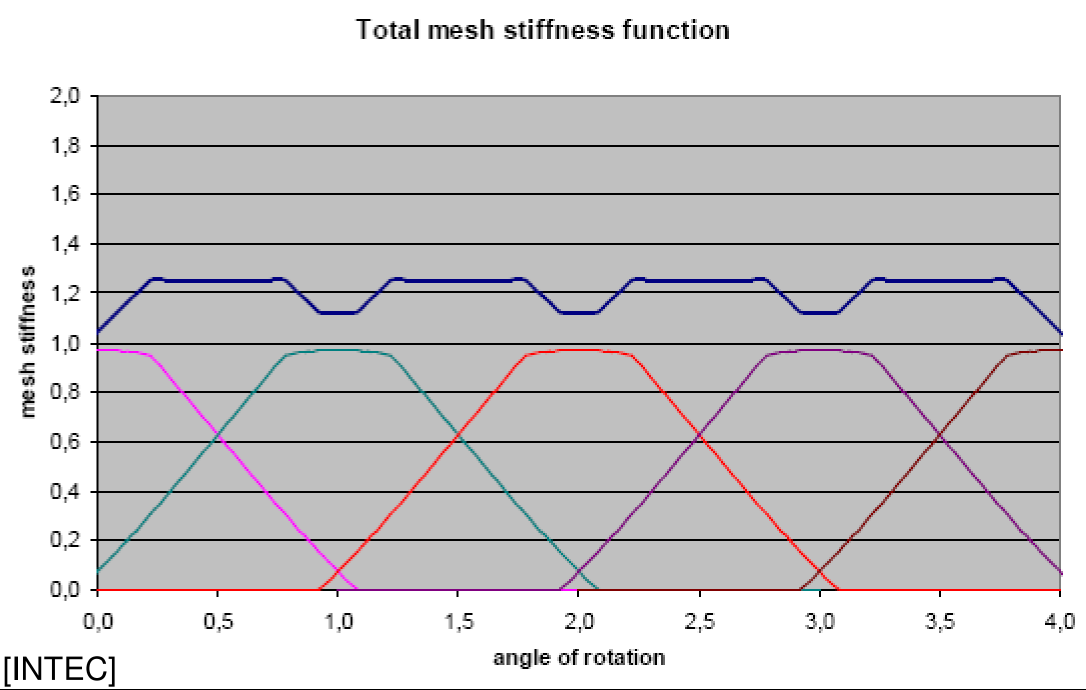
	Bernoulli beam	Timoshenko beam	Structural solid
1st bending	41.6 Hz	40.8 Hz	38.7 Hz
2nd bending	243.2 Hz	219.4 Hz	213.2 Hz
1st torsion	309 Hz	309 Hz	300 Hz
1st elongation	402 Hz	402 Hz	393 Hz
3rd bending	653 Hz	532 Hz	526 Hz
2nd torsion	776 Hz	776 Hz	740 Hz

Main Shaft – Conclusion

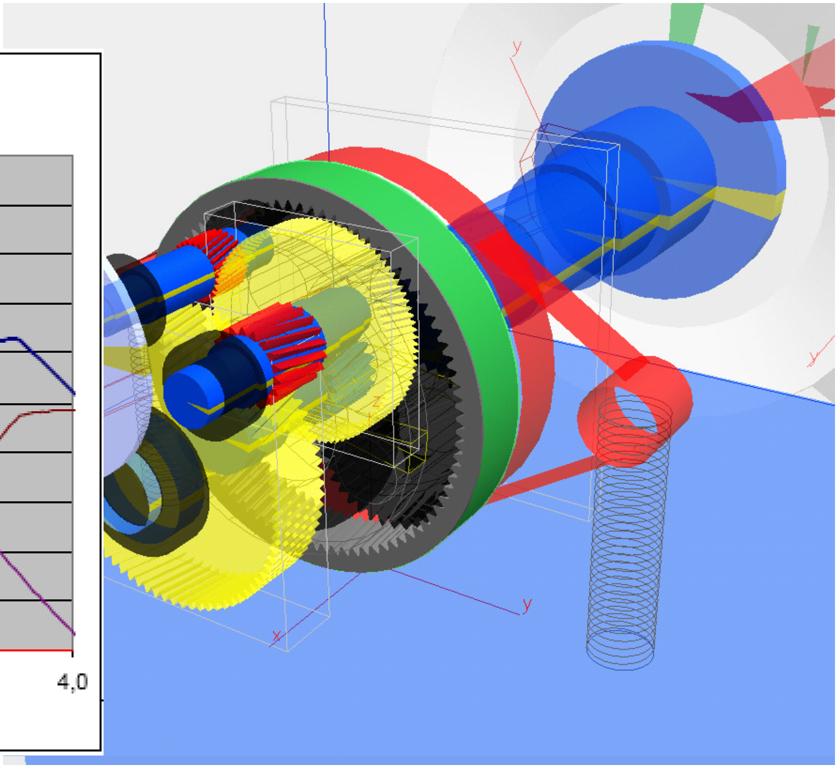
- Analysis of torsional modes: rigid bodies and spring/damping elements
- No notch effects of beam elements with respect to stiffness
- Shear deformation effects have an impact on bending modes
- Inclusion of axial modes: Bernoulli beam.
- Consideration of shear effects and bending modes: Timoshenko beam elements should be the first choice
- The use of solid elements is very complex and not common practice for multi body simulation.

Gear Model

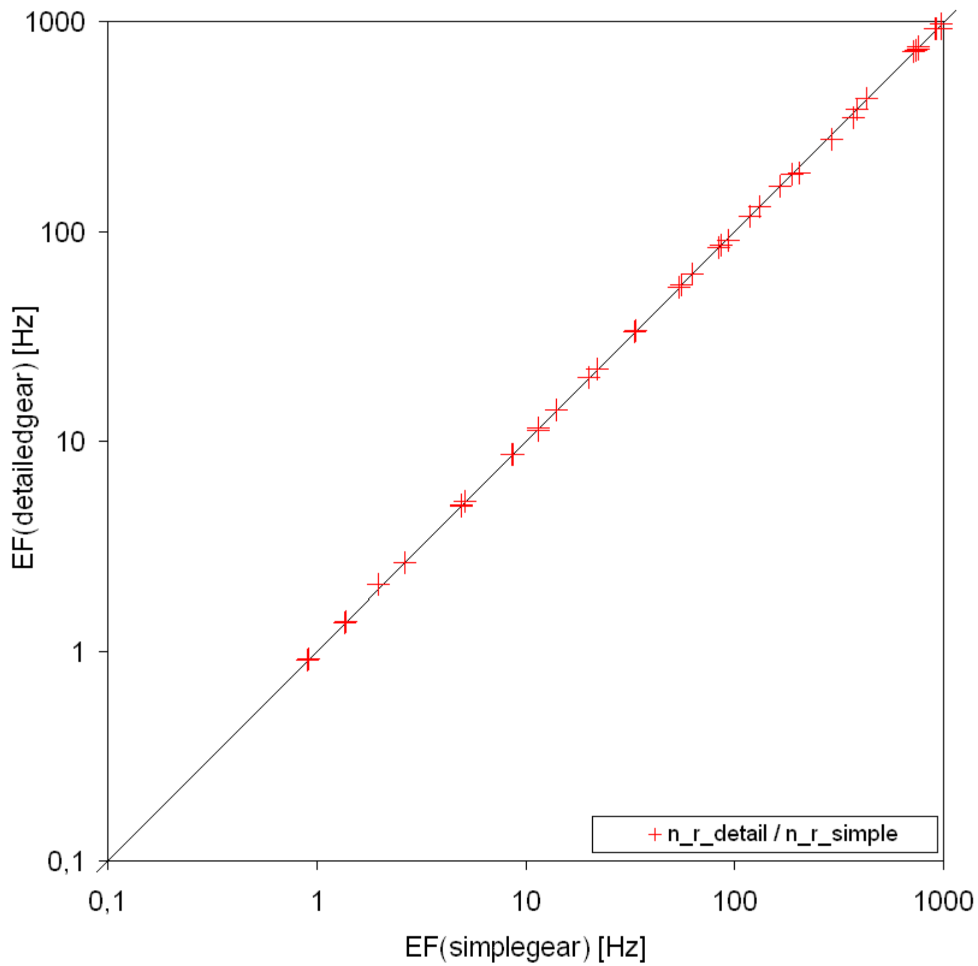
- **Rigid body, constant stiffness at contact point (meshing of gears)**
- **Purpose-built force element**



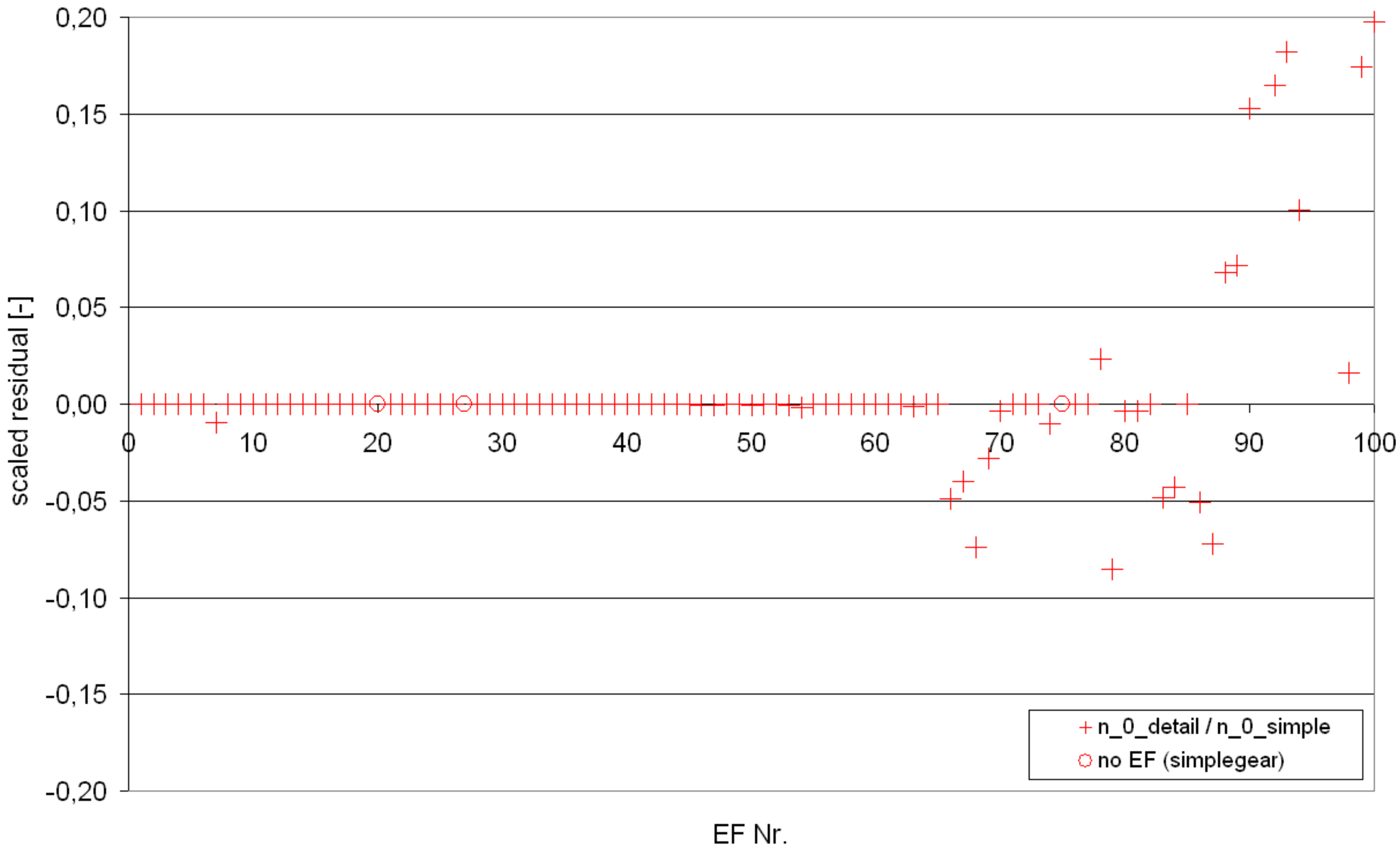
[INTEC]



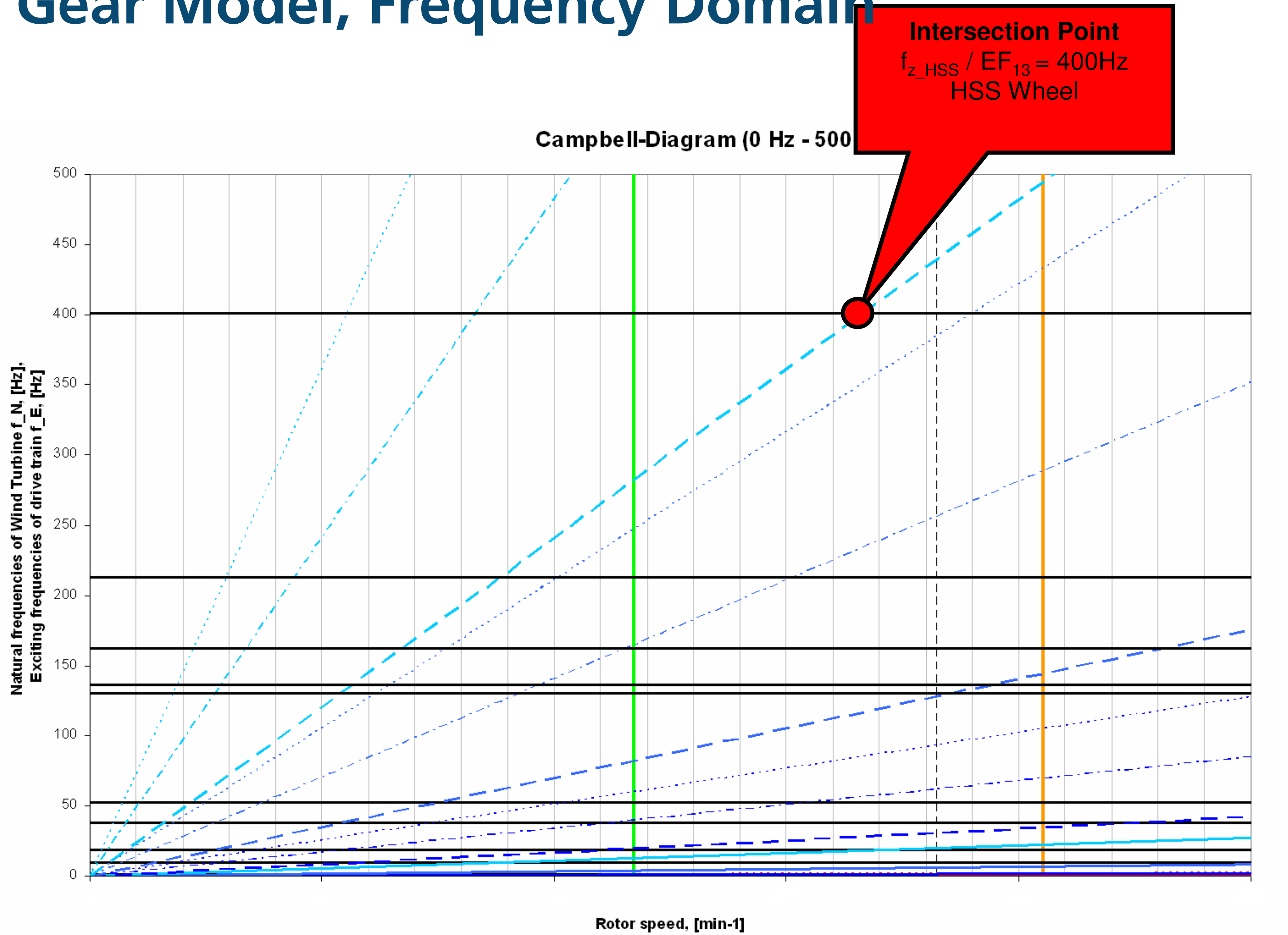
Gear Model, Frequency Domain



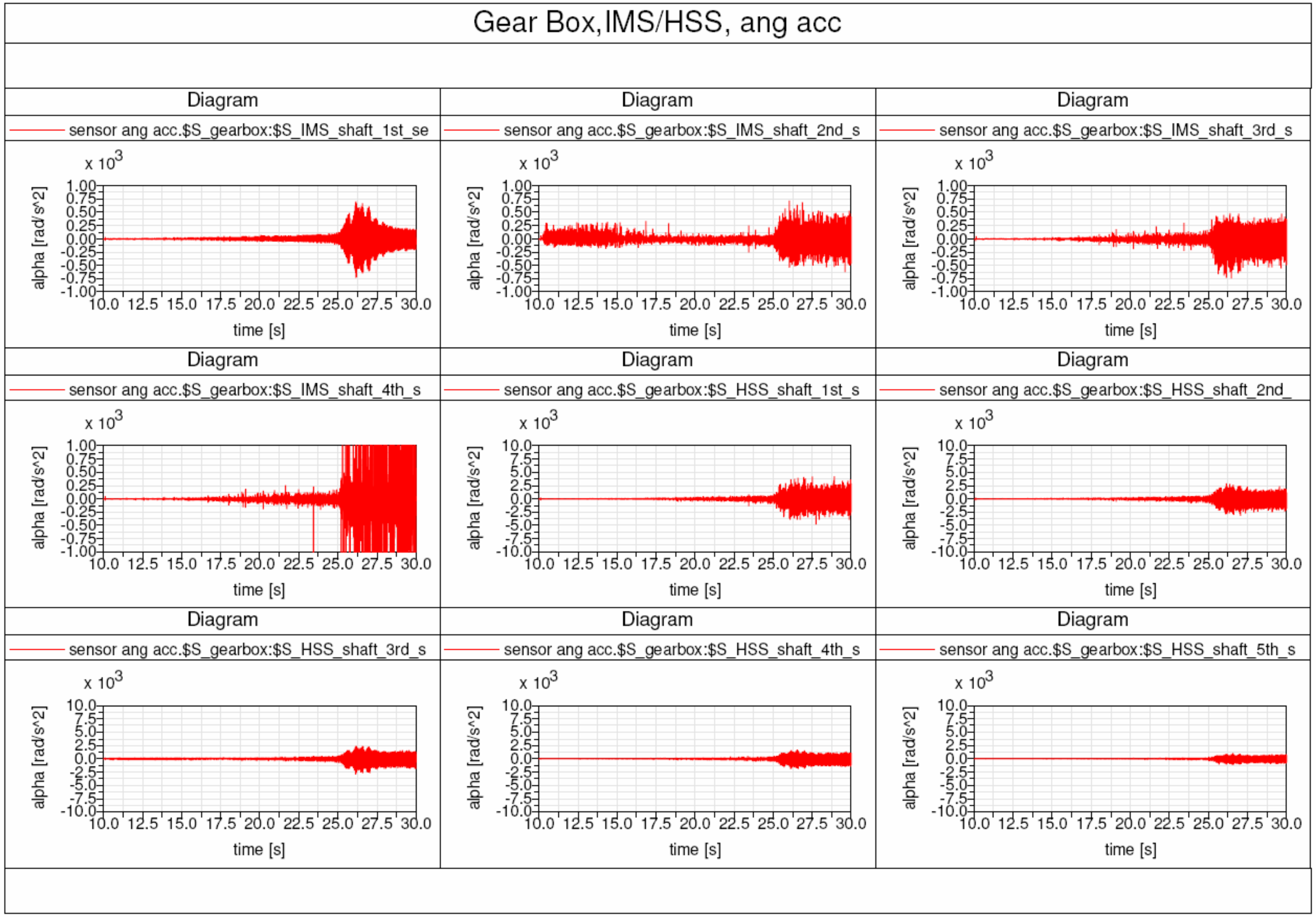
Gear Model, Frequency Domain



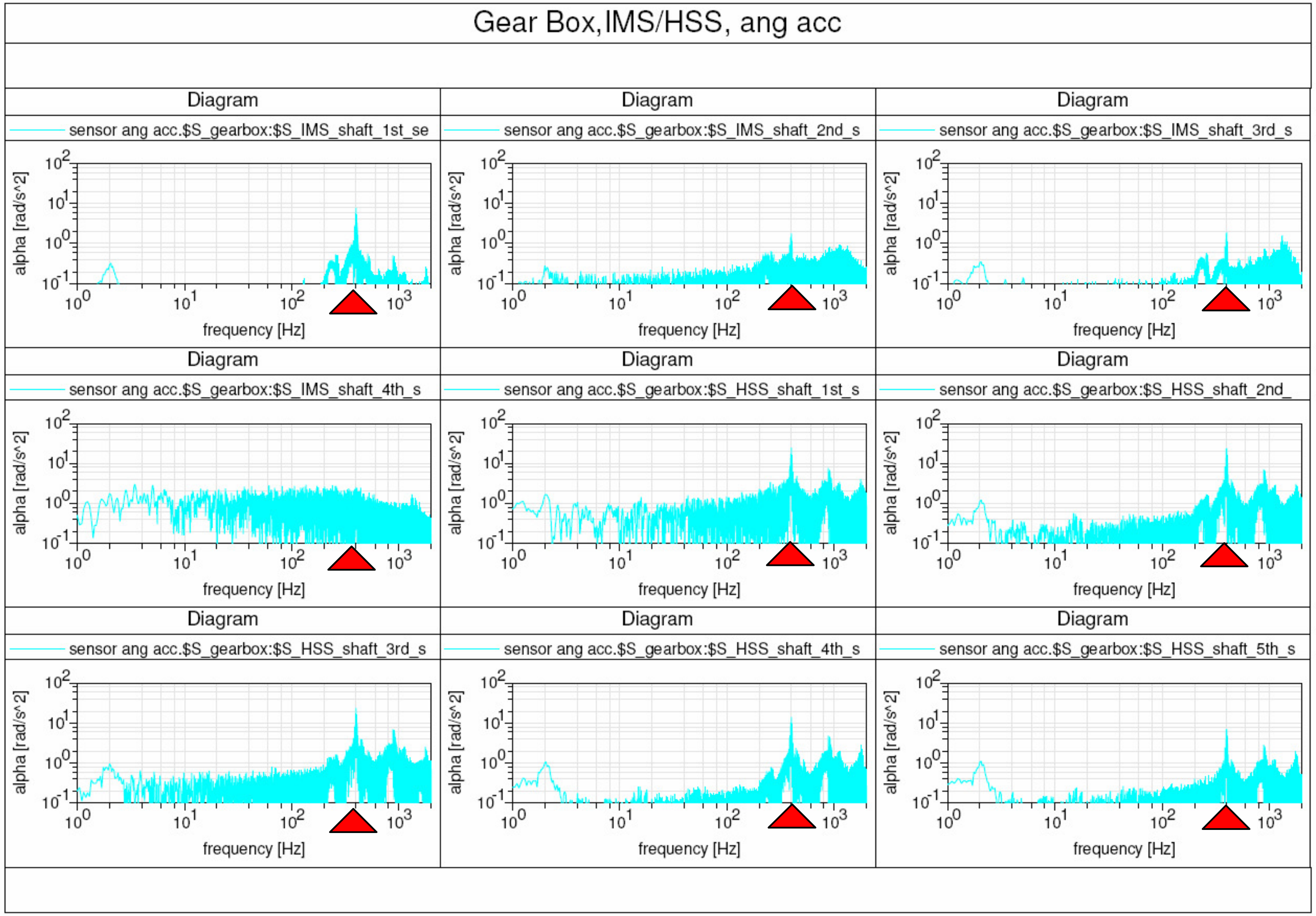
Gear Model, Frequency Domain



Gear Model, Time Domain, Start-Up



Gear Model, Time Domain, Start-Up

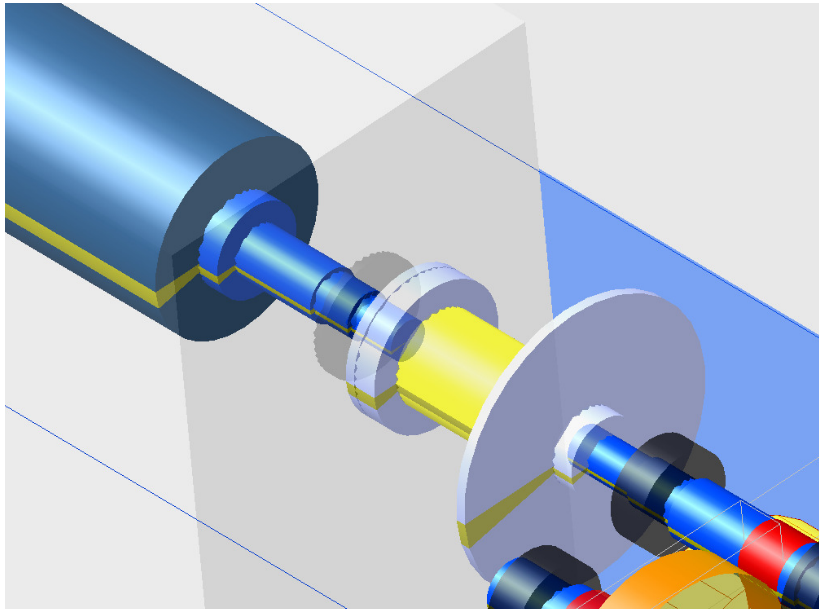


Gear Model - Conclusion

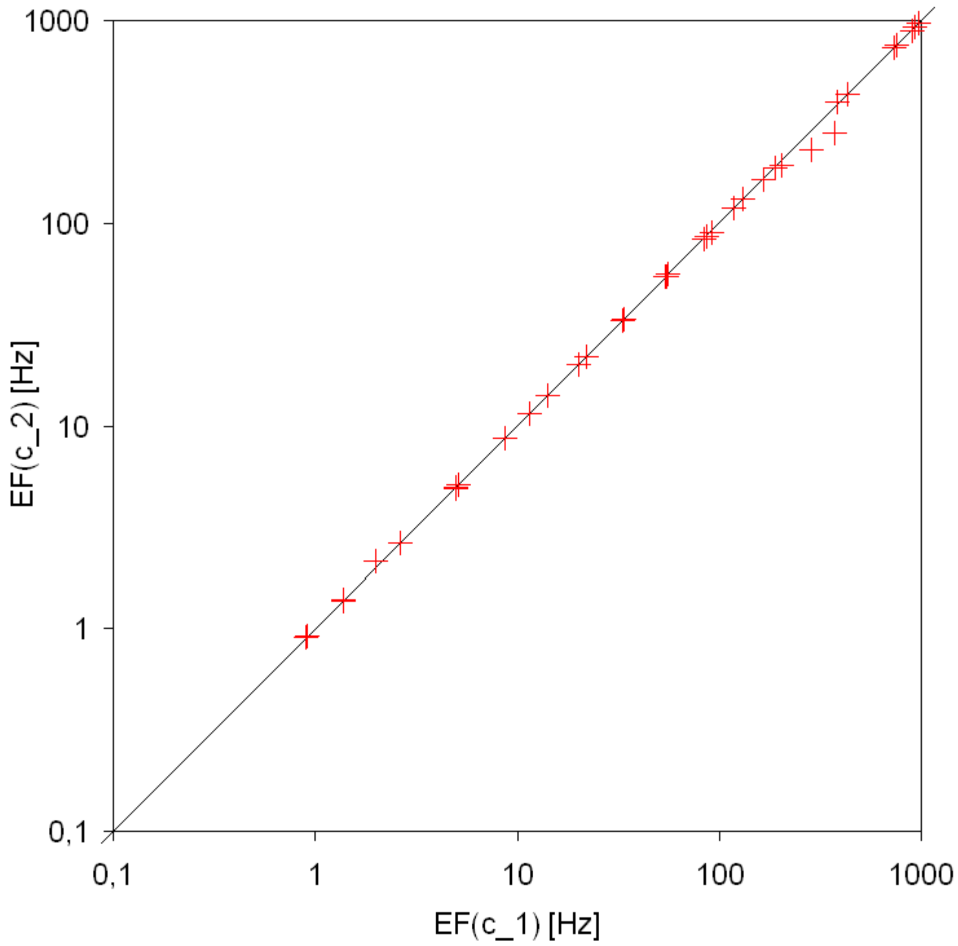
- Similar result quality in frequency domain for both approaches
- Variation of meshing stiffness leads to excitation in time domain for detailed model
- detailed model covers the effects of additional DoF on meshing gears

High Speed Shaft / Generator Coupling

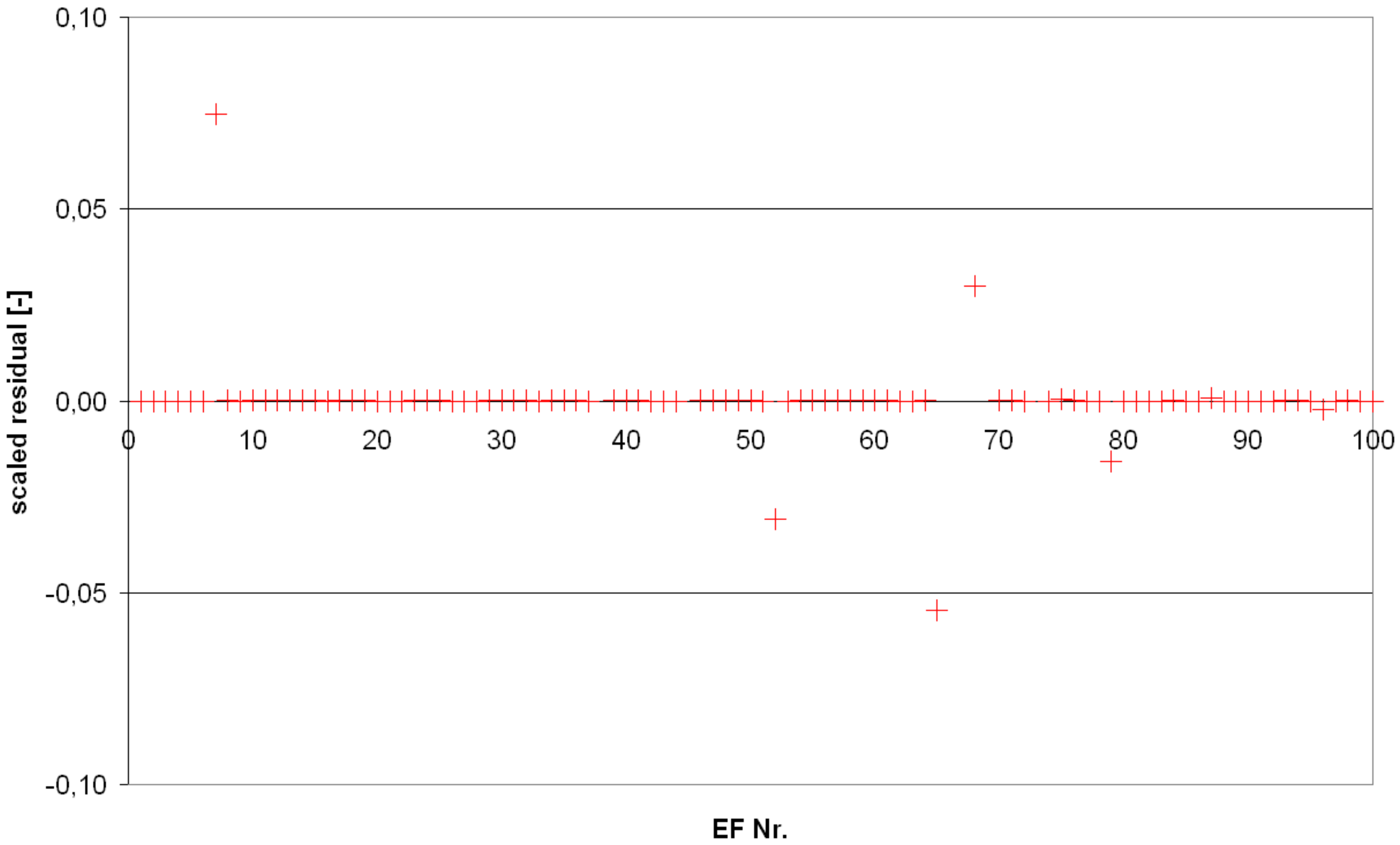
- Influence of couplings torsional stiffness on eigenfrequency of the drive train
- Parameter Variation



High Speed Shaft / Generator Coupling



High Speed Shaft / Generator Coupling



HSS / Generator Coupling - Conclusion

- Eigenfrequencies of HSS and coupling are shifted according to coupling stiffness
- Coupling stiffness has strong effect on first torsional frequency of drive train
- Influence on global loads

Conclusion

- **Main Shaft: Use of rigid bodies and spring/damping elements for analysis of torsional modes**
- **Gear Model: Similar result quality in frequency domain for both approaches**
- **Generator Coupling: Stiffness has strong effect on first torsional frequency of drive train**

Thank you very much for your attention!