Fatigue Life Design for Wind Turbine Components

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Content

- Overview of todays standard methods for life cycle – fatigue calculation until crack

- Fatigue life calculation based on Superposition and Scaling including contact problems
  - Example: Transmission casing of a wind turbine

- Fatigue life calculation based on transient and nonlinear Analysis using MBS/FEA
  - Example: total windturbine

- Summary

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Fatigue Life Design for Wind Turbine Components

State of the art technology for fatigue life calculation

•Nominal stress method – succesful applicable for simple geometrical parts like shafts

•Elastic stress methode (based on FEA (mostly elastic) results and S N curves fatigue life prediction is done)

•Structural stress methode (used for seam weldings: stresses in reference points parallel to the welding enable an extrapolation to the welding toe)

•Local strain approach (stress and strain in combination with cylcic material properties are used)

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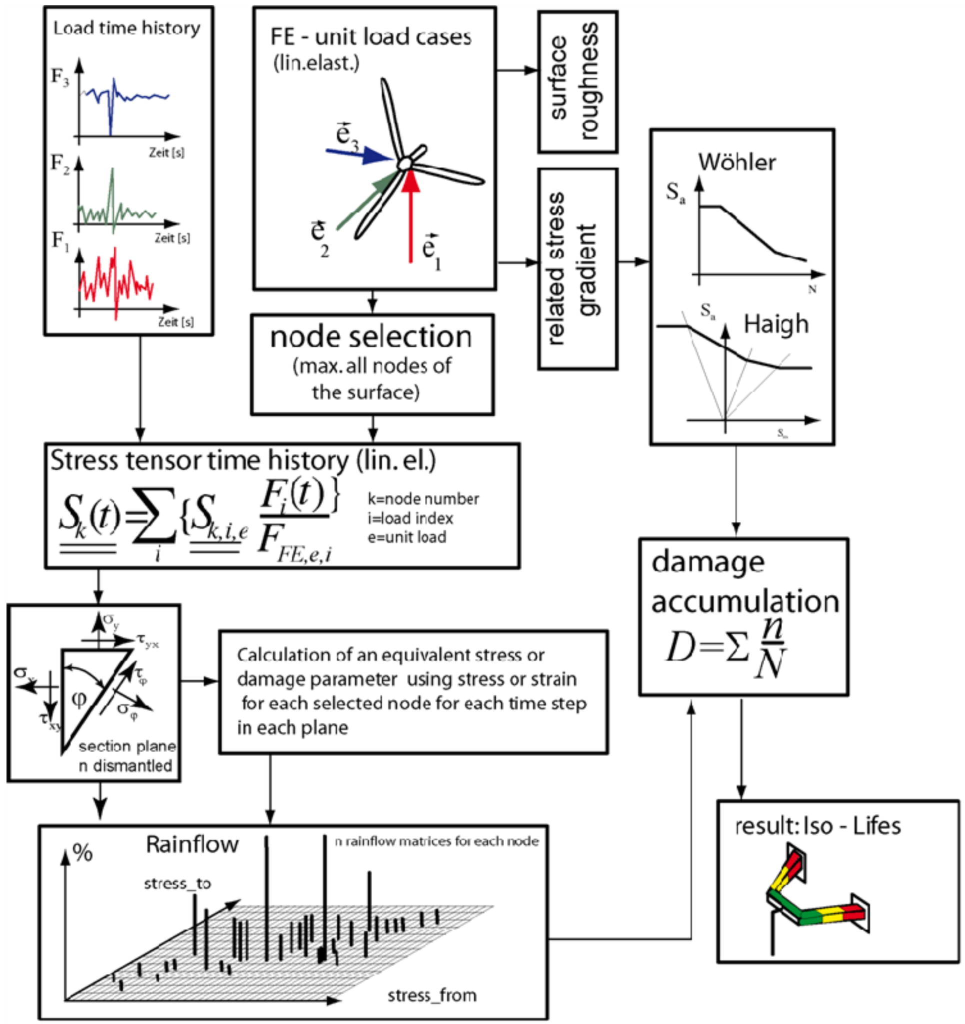
Fatigue life calculation based on Superposition and Scaling



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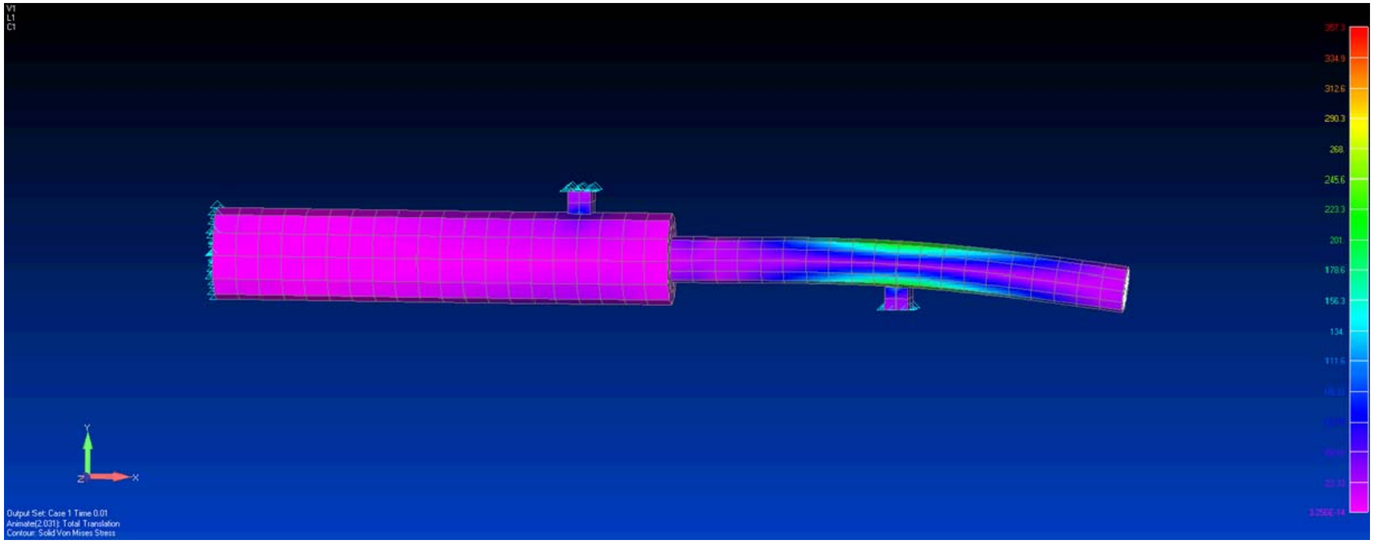
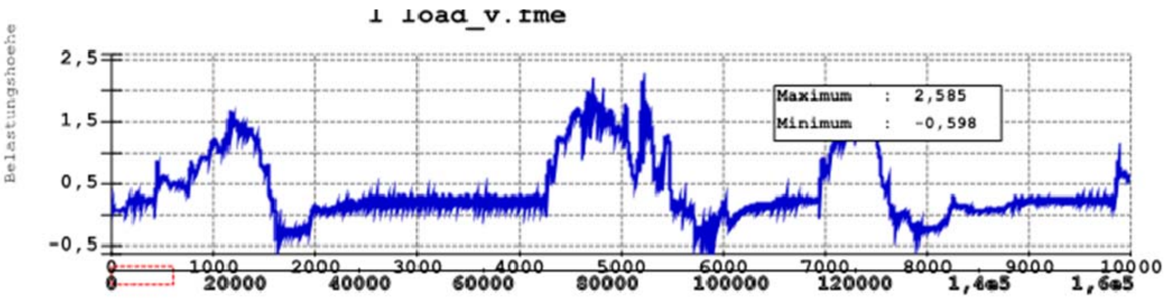
Fatigue life calculation based on Superposition and Scaling
Special problem: contact





Fatigue life calculation based on Superposition and Scaling

Special problem: contact

Contact applications can be calculated using separation in the appropriate unit load cases (positive, negative) and compatible segmentation of load/time function

Stress tensor time history (lin. el.)

$$\underline{\underline{S_k}}(t) = \sum_i \left\{ \underline{\underline{S_{k,i,e}}} \frac{F_i(t)}{F_{FE,e,i}} \right\}$$

k=node number
i=load index
e=unit load

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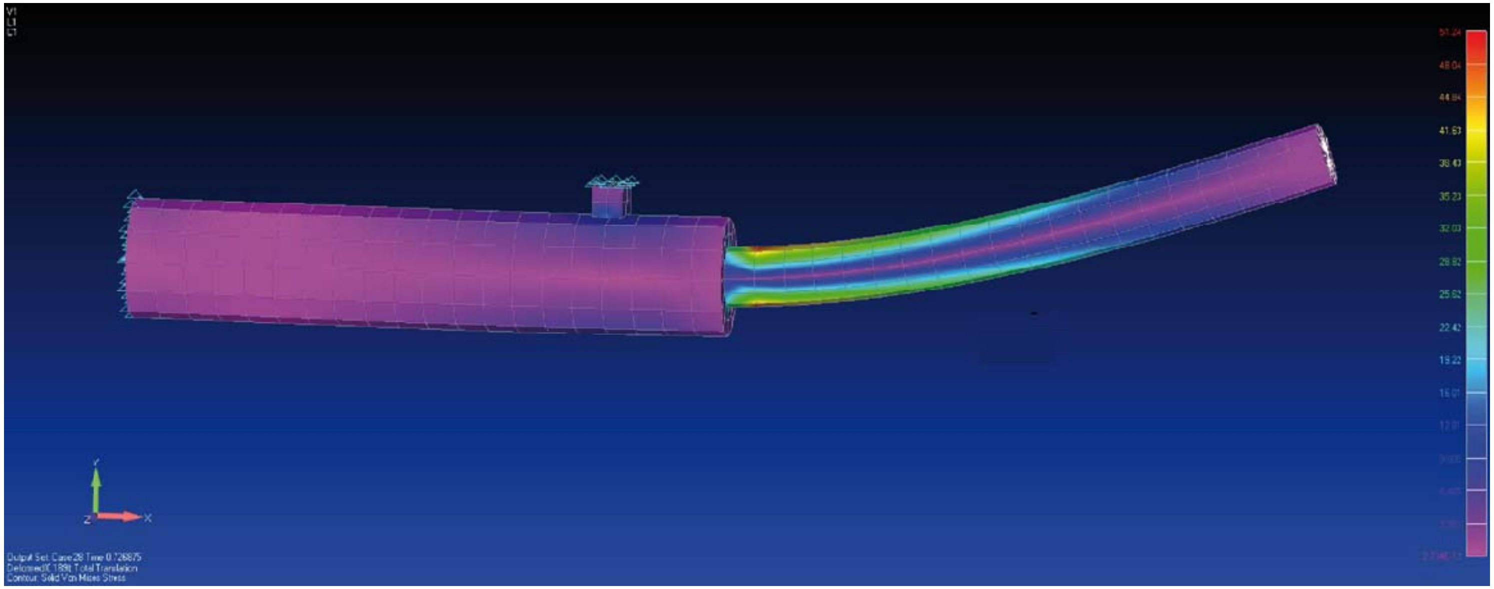
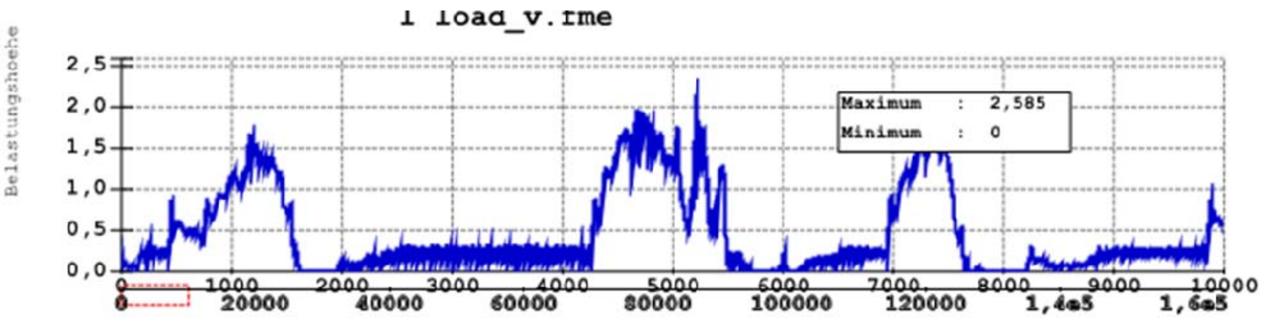
Fatigue life calculation based on Superposition and Scaling

Special problem: contact





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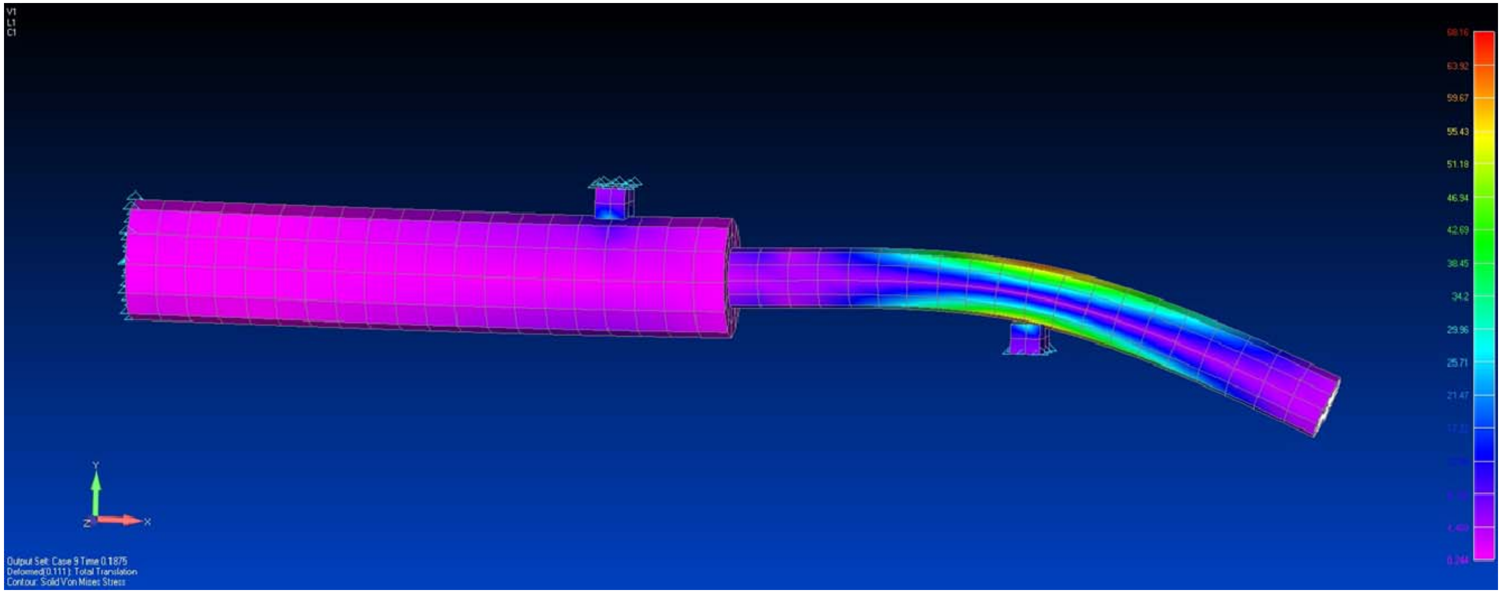
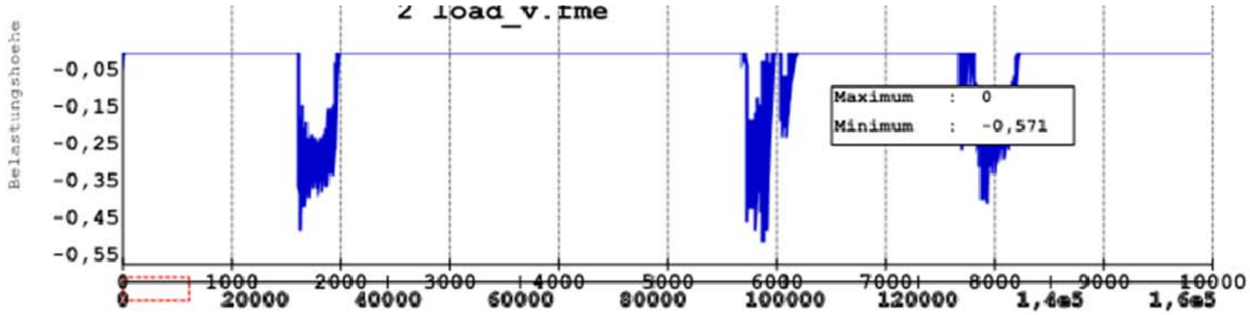
Fatigue life calculation based on Superposition and Scaling

Special problem: contact





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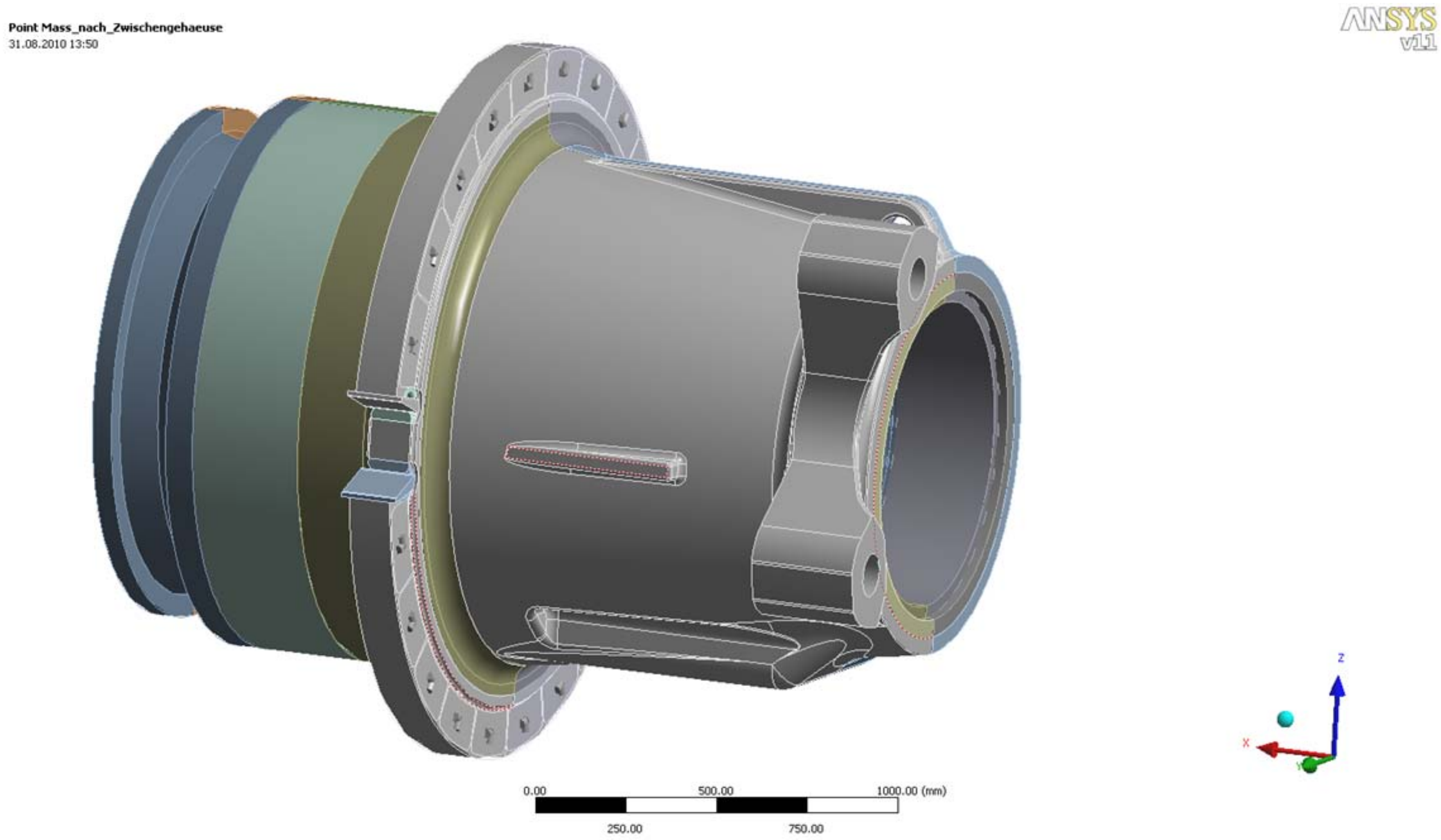
Example: Wind Turbine - Transmission Casing



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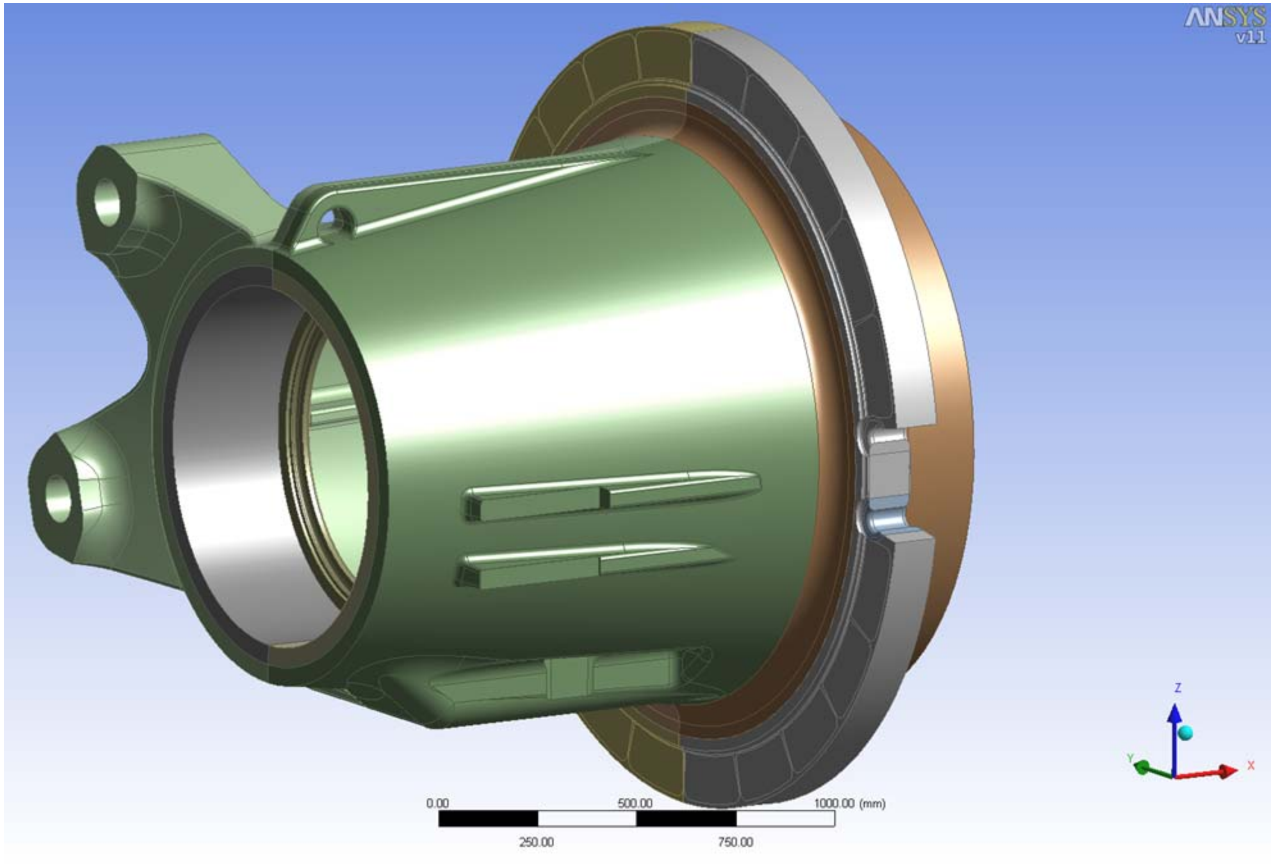
Transmission Casing / CAD Design



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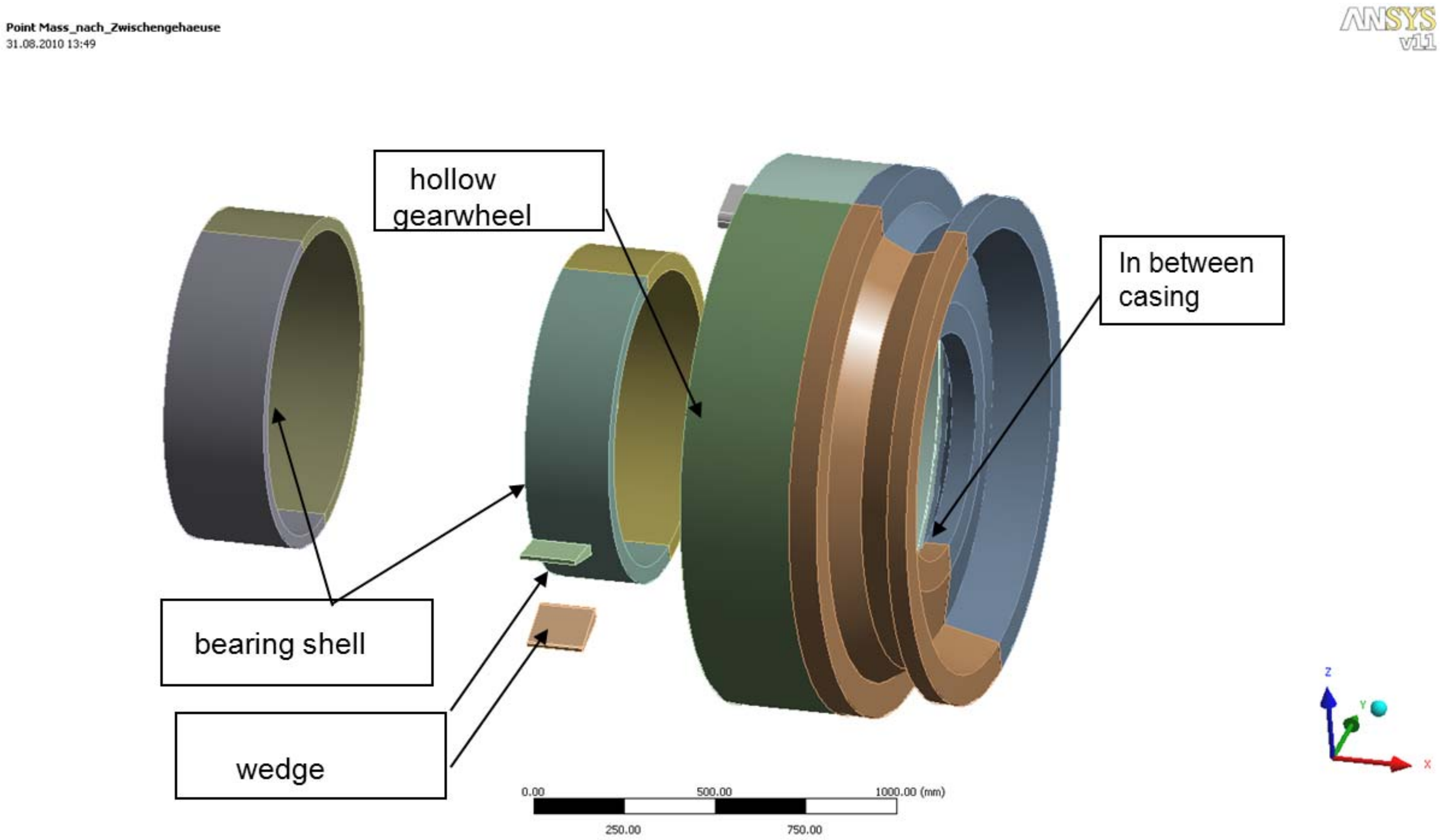
Additional components / Exploded view



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Load conversion for equivalent statical system

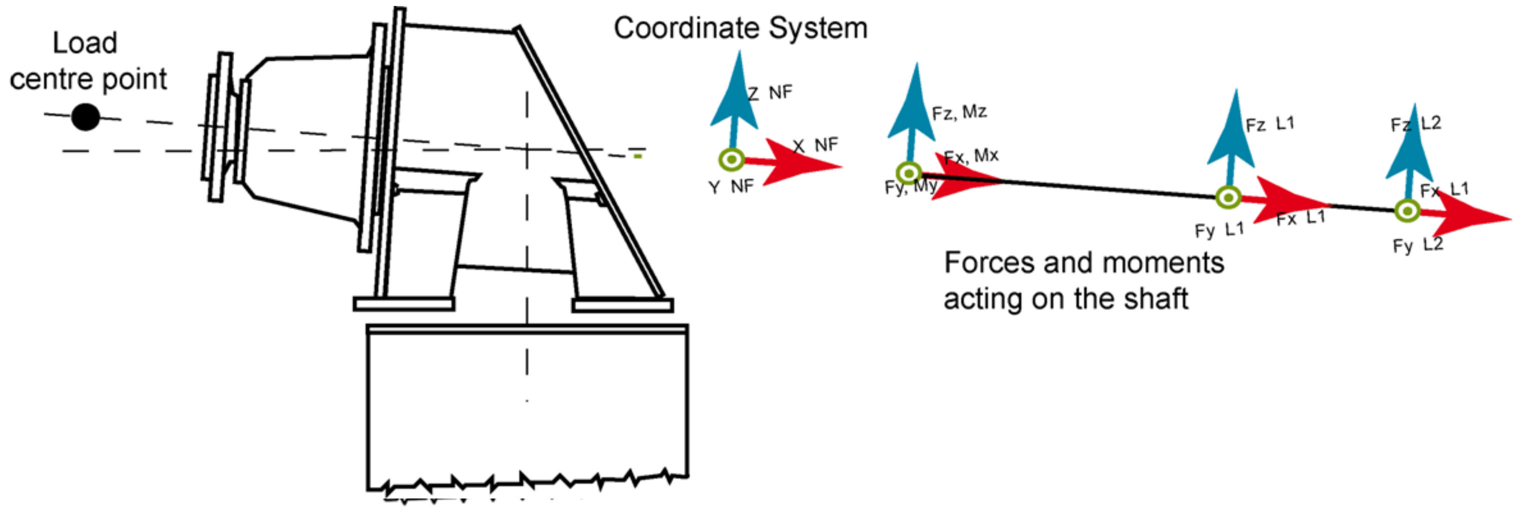

Figure 101-2: hub centre distance

F_{x1}, F_{y1}, F_z	Forces rotor hub
M_{x1}, M_{y1}, M_z	Moments rotor hub
F_{xL1}, F_{yL1}, F_{zL1}	Forces self-aligning roller bearing
F_{xL2}, F_{yL2}, F_{zL2}	Forces cylindrical roller bearing
L_{RL1}	Distance: rotor hub – self-aligning rolling bearing = 1742 mm
L_{L1L2}	Distance: self-aligning rolling bearing – cylindrical roller bearing = 1020 mm

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Calculation of equivalent bearing reaction

The calculation of the single bearing reaction forces according to the following formula:

$$F_{xL1} = F_x$$

$$F_{yL1} = -\frac{M_z - F_y(L_{RL1} + L_{L1L2})}{L_{L1L2}}$$

$$F_{zL1} = -\frac{M_y - F_z(L_{RL1} + L_{L1L2})}{L_{L1L2}}$$

$$F_{xL2} = 0$$

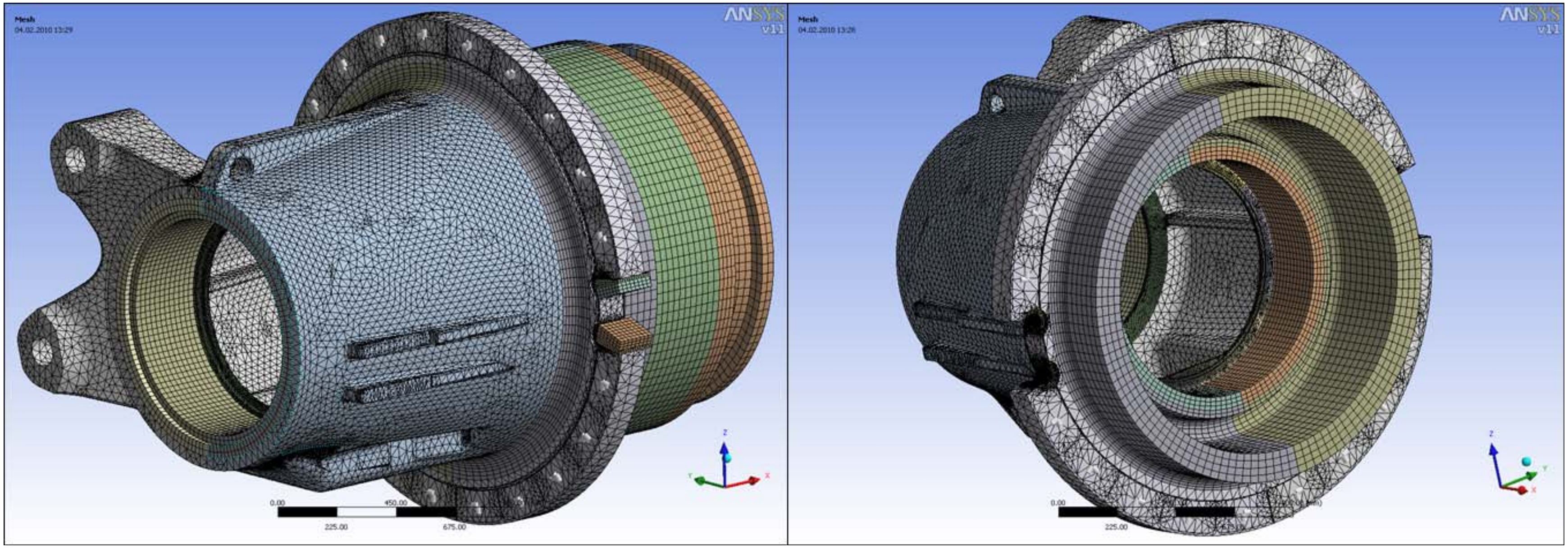
$$F_{yL2} = F_y - F_{yL1}$$

$$F_{zL2} = F_z - F_{zL1}$$

The torsional moment is supported over the ring gear

Fatigue Life Design for Wind Turbine Components

FE Mesh of the transmission system



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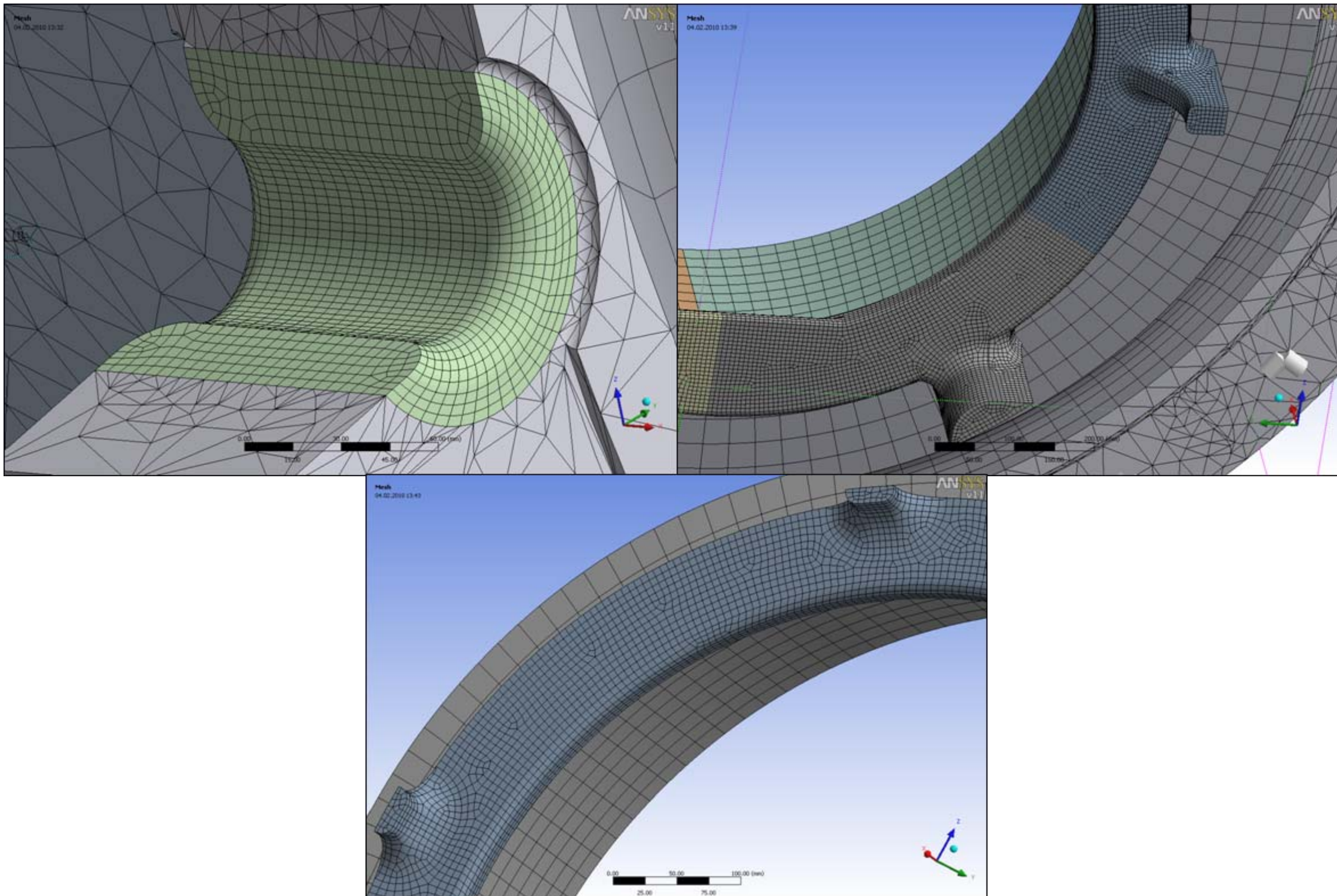
FE Mesh / More details



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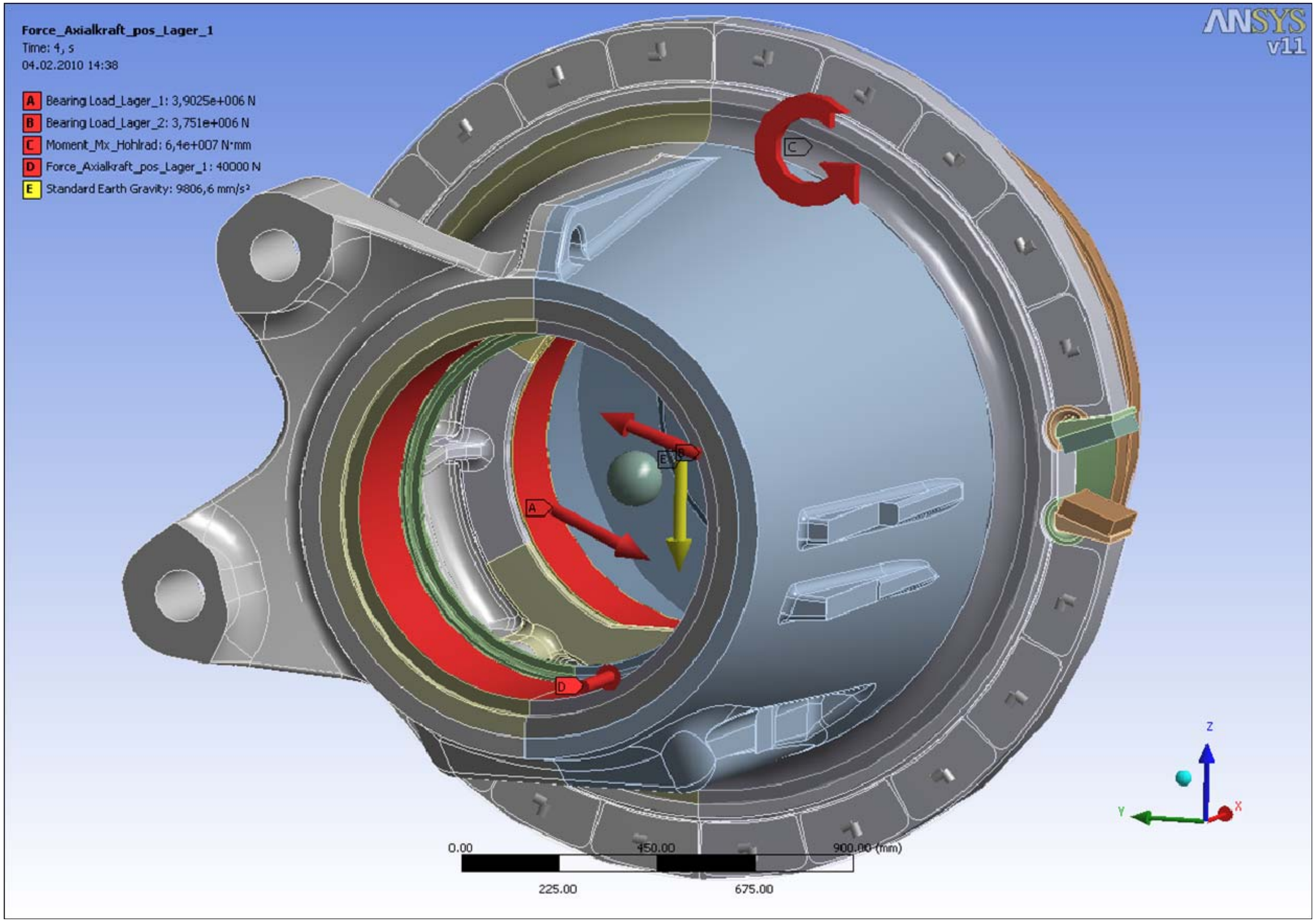
Forces, Moments and Body Loads



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Unit Load Cases

Mx+, Mx-, Fx+, Fx-

- Bearing 1:

  Fy+, Fy, Fz+, Fz-

- Bearing 2:

  Fy+, Fy-, Fz+, Fz-

- Gravity Load

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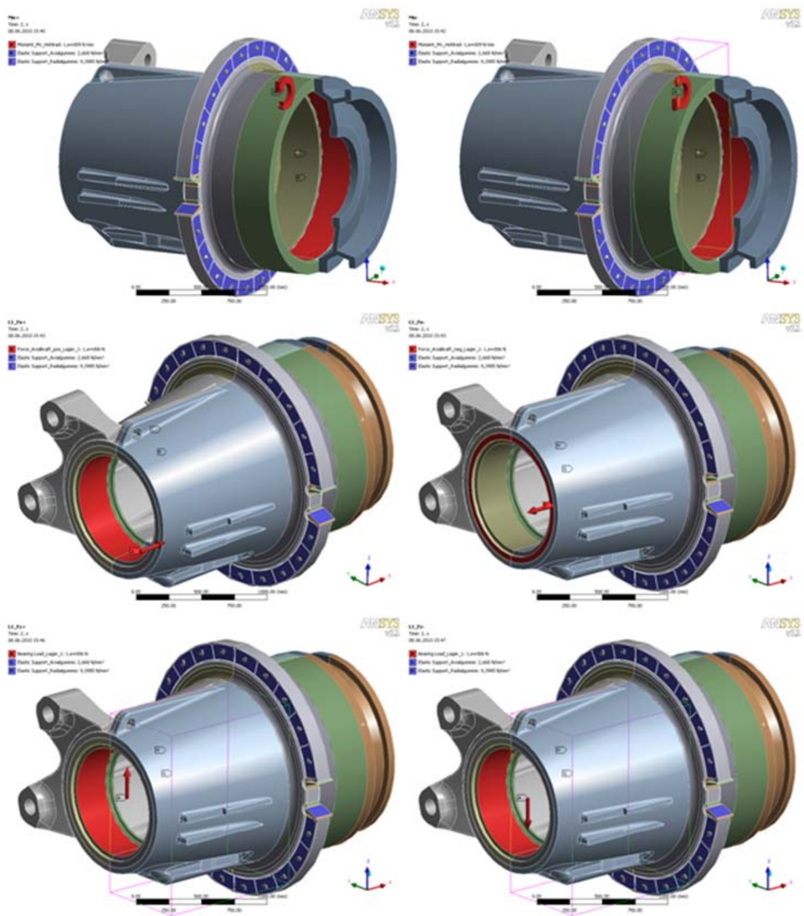
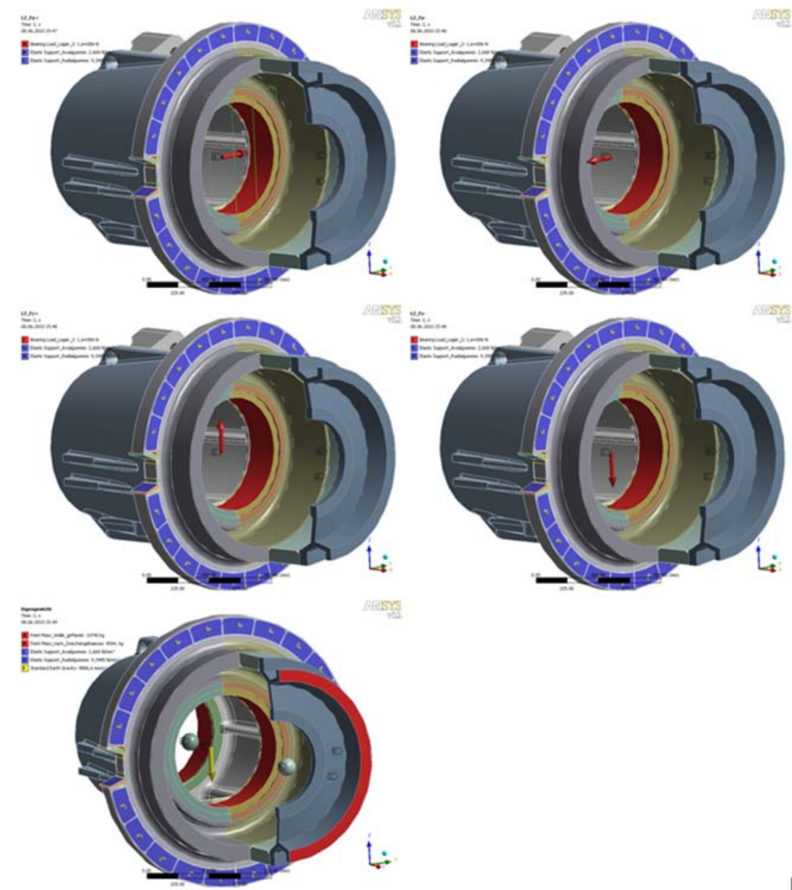
Unit Load Cases





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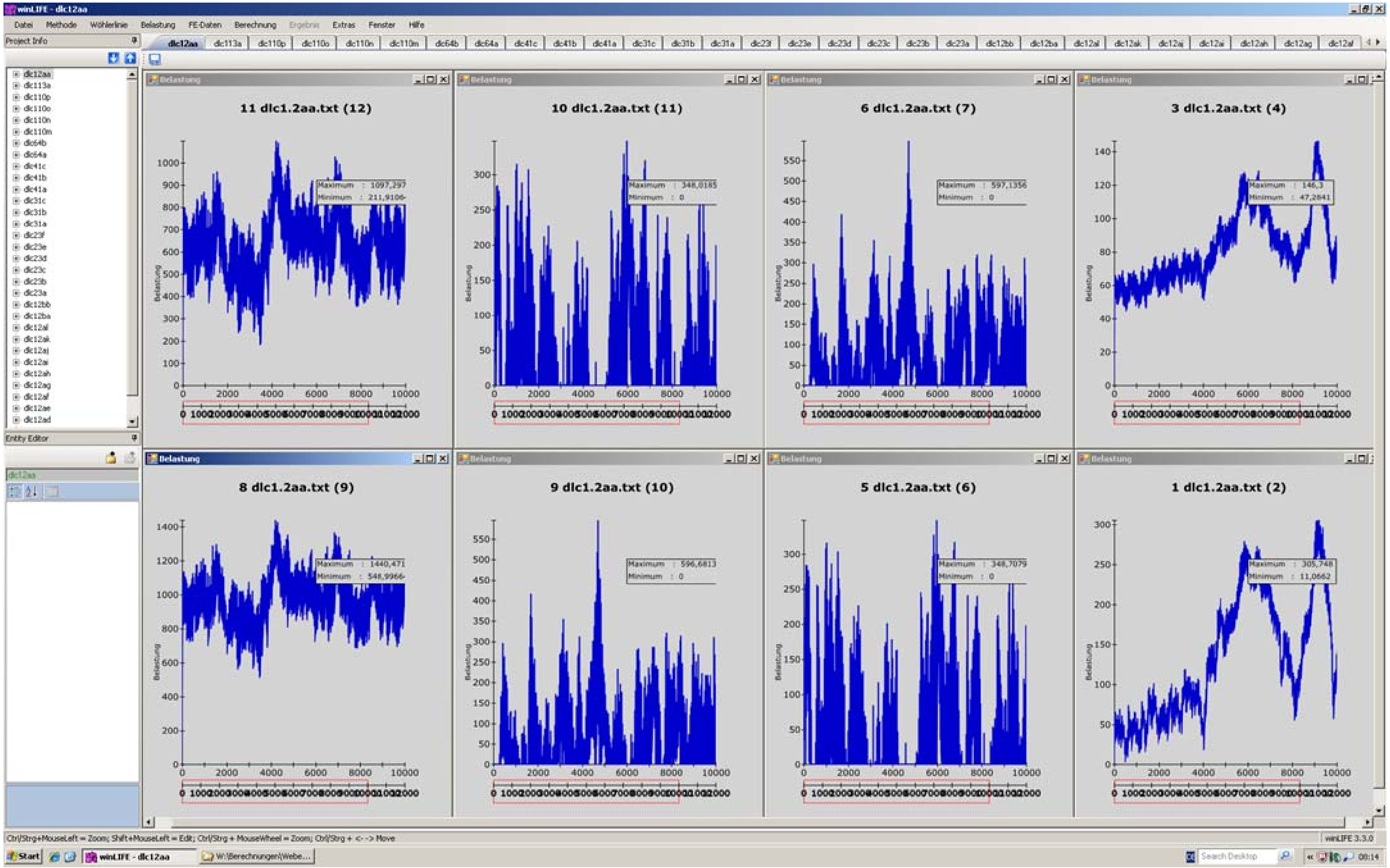
Unit Load Cases



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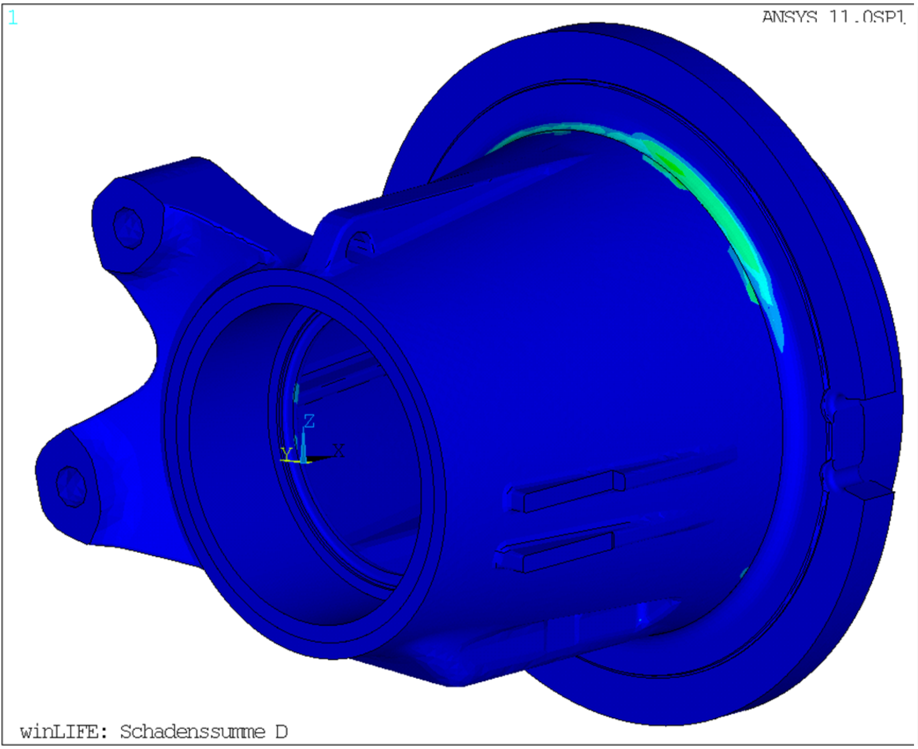
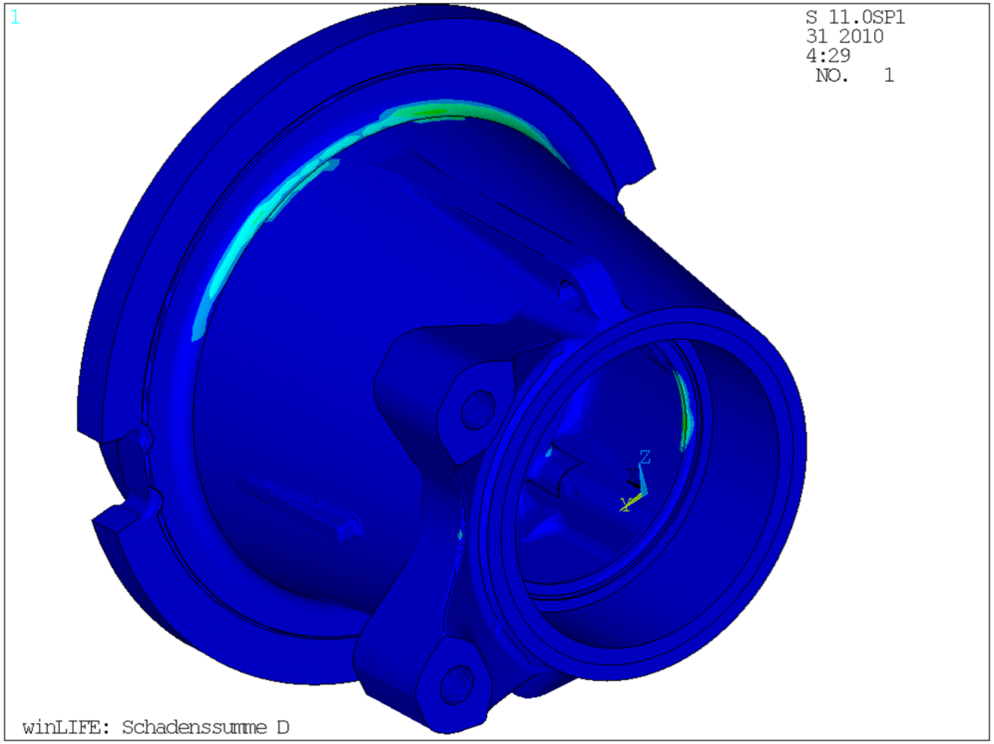
Results / Damage





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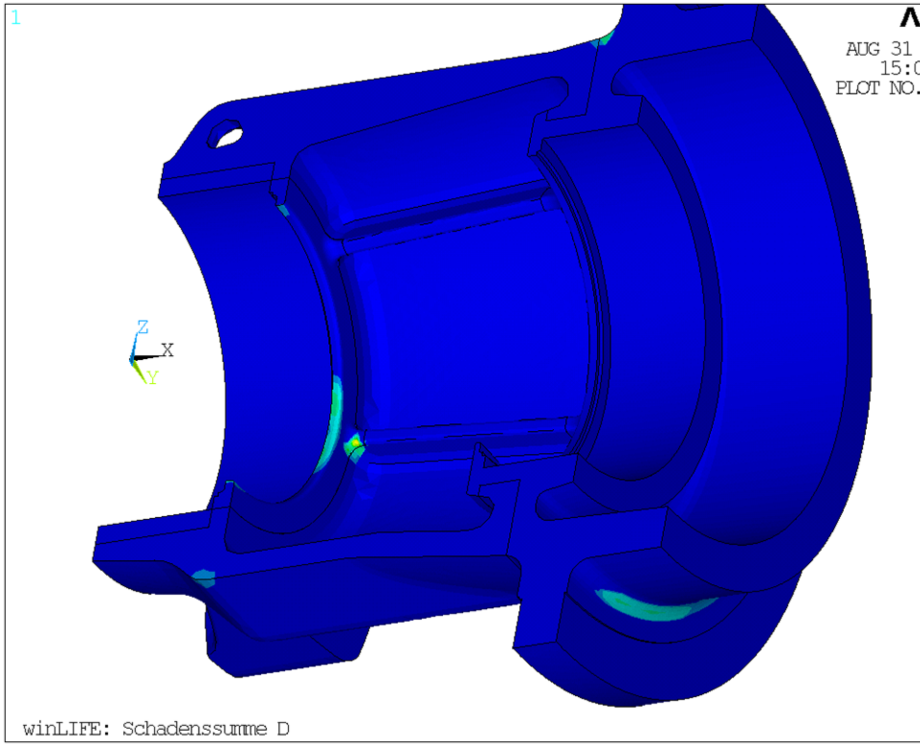

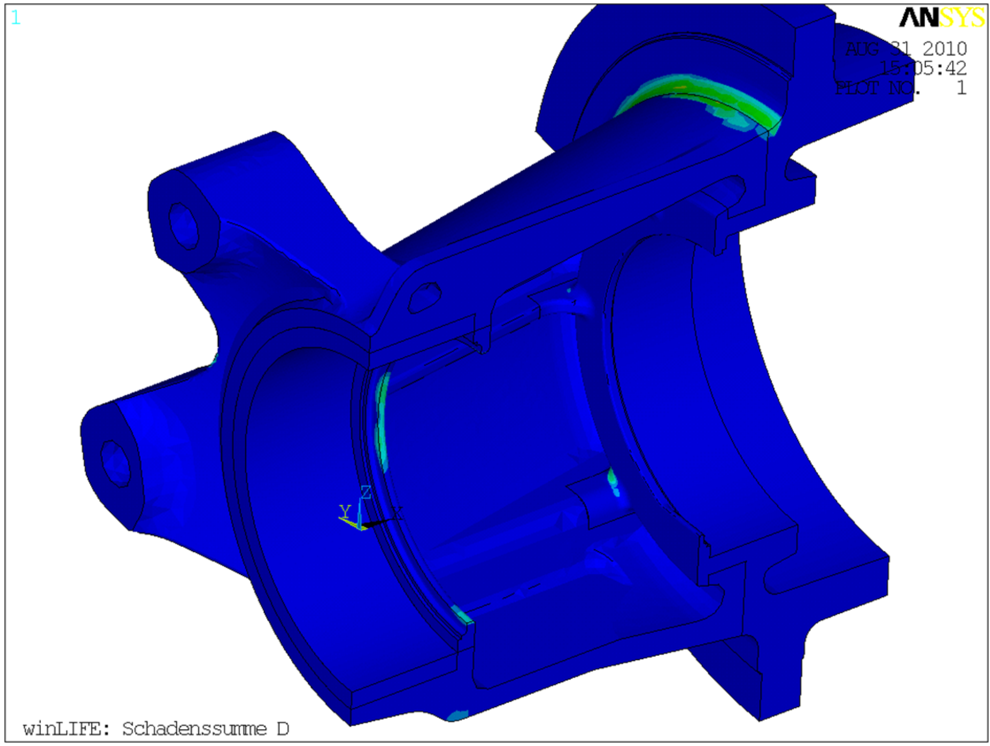

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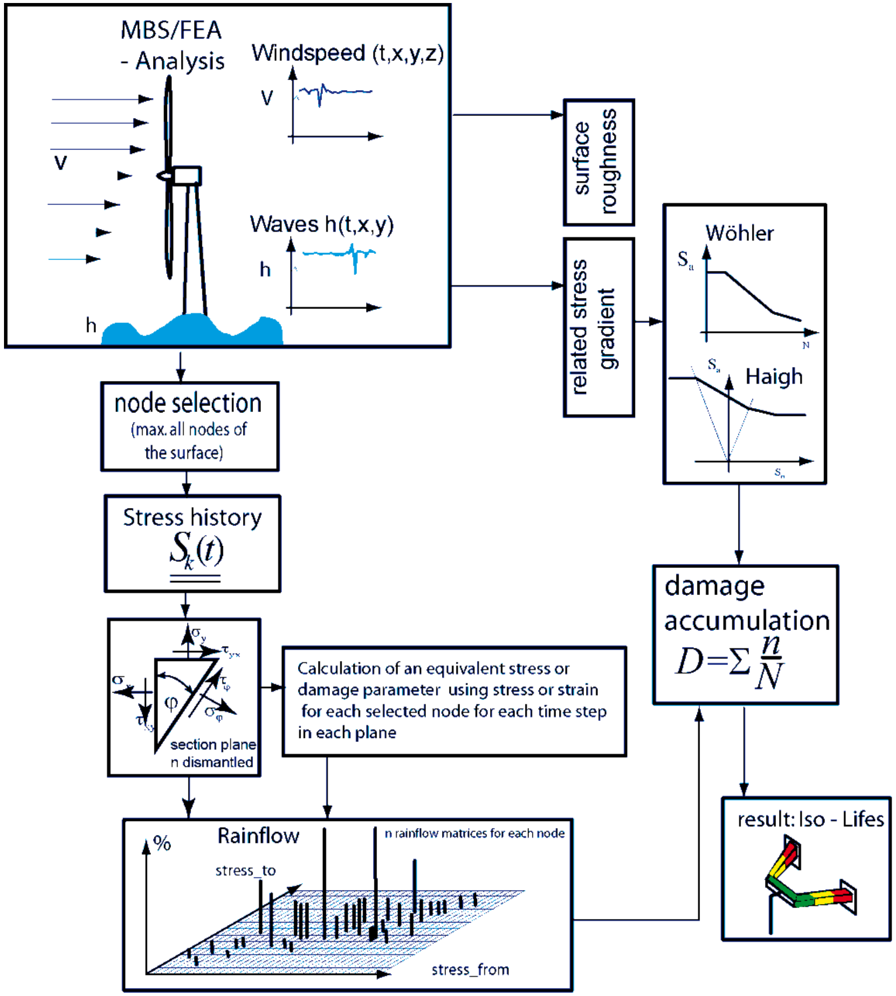
Fatigue Life Calculation based on MBS/FEA



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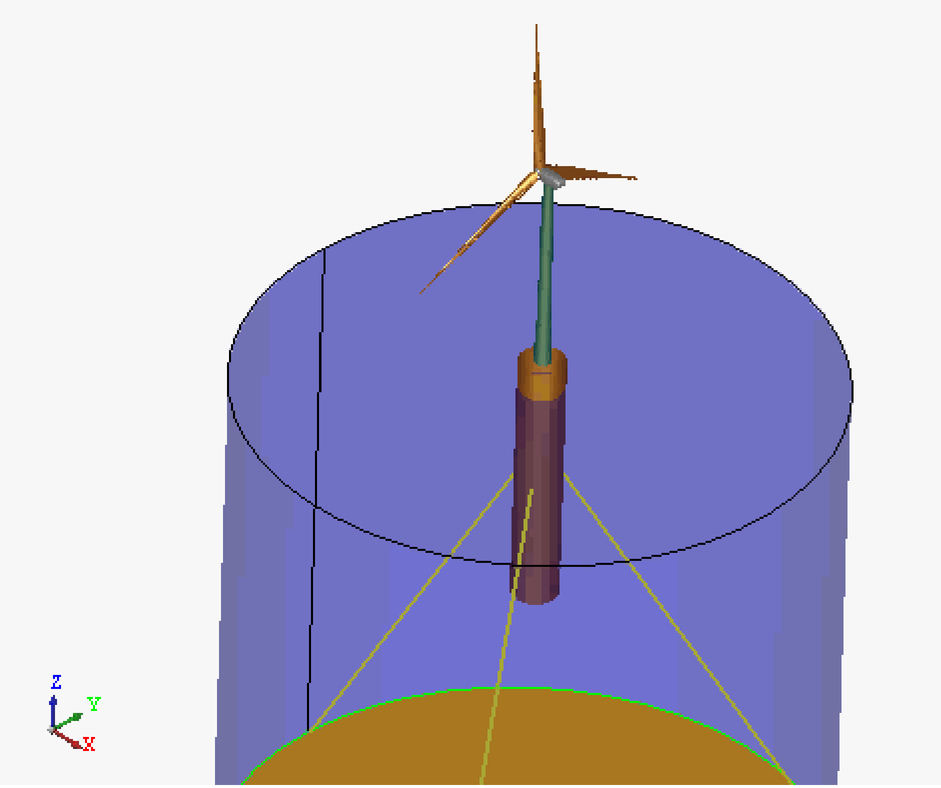
Fatigue Life Calculation based on MBS/FEA
Example: Off-Shore-Wind Generator



- The use of static superpositioning and scaling of unit load cases is limited to non-complex movements and non-high dynamic applications.
- The displayed WEA was done with S4WT (Samcef for Windturbines).
- The stress tensors were exported to winLIFE for calculating the fatigue life.

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Fatigue Life Calculation based on MBS/FEA

- The stress tensors as a function of time necessary for fatigue life calculations can be determined from a combination of MBS and FEM.

- All nonlinearities like contacts will be solved in MBS and FEM

- Challenge: Computing time

- winLIFE supports this process with a direct interface to SAMCEF

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Summary

- The principle of statical superposition can solve complex applications with contact and rotation very efficient with relatively high calculation speed
- As shown in the example the user has to define an appropriate equivalent system for unit load cases
- Measurement data from real windturbines are needed
- Transient Analsis using MBS/FEA like S4WT needs only windspeed and wave information as input data. All dynamic and nonlinear effects are taken into account in the computer model. The calculation speed is comparable slow so that procedure is only aplicable for a limited time history
- As a result a combination of both procedures are helpful in the design phase of a windturbine
- You can carry out both procedures using winLIFE