

Blade model comparison based on static and modal test scenarios

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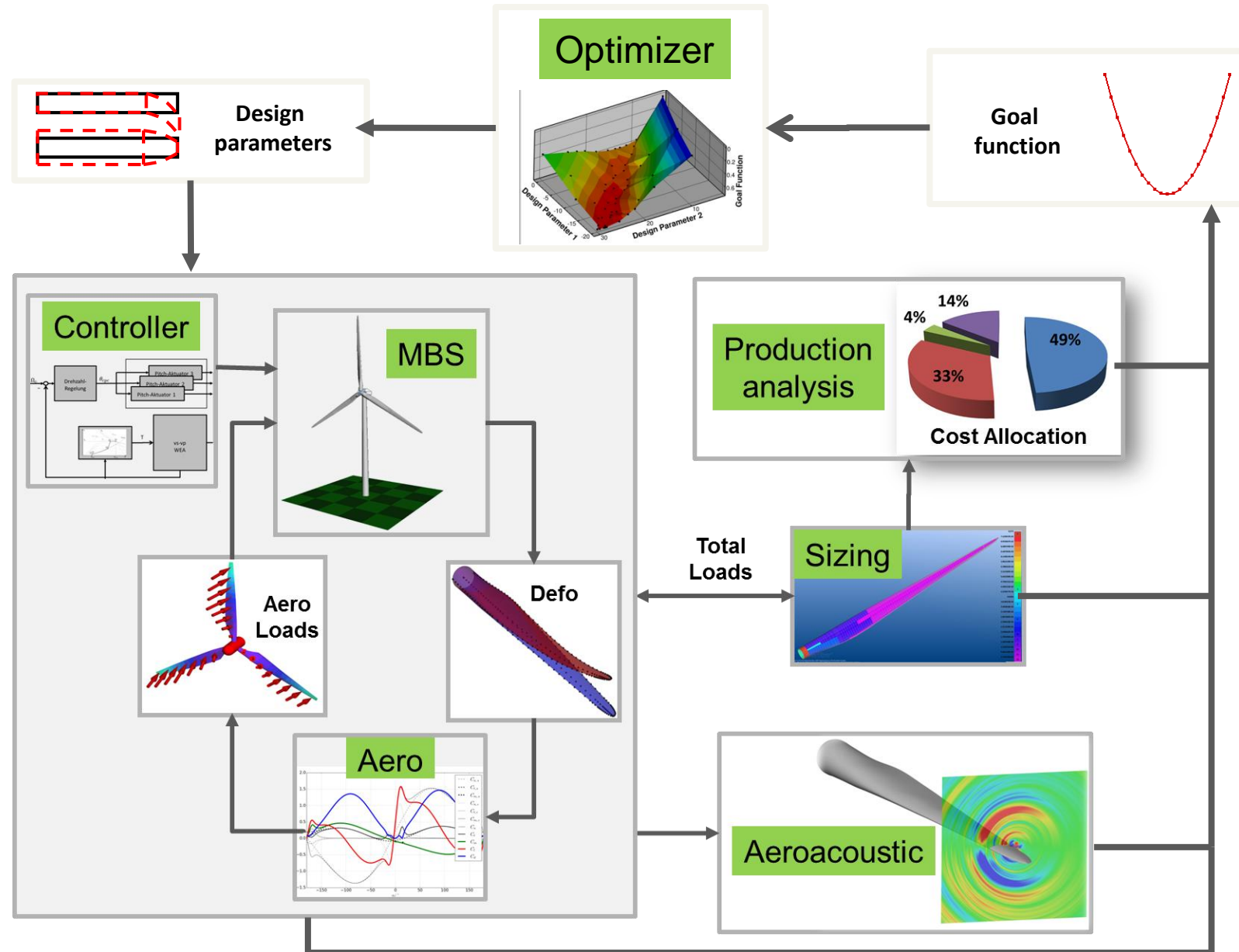
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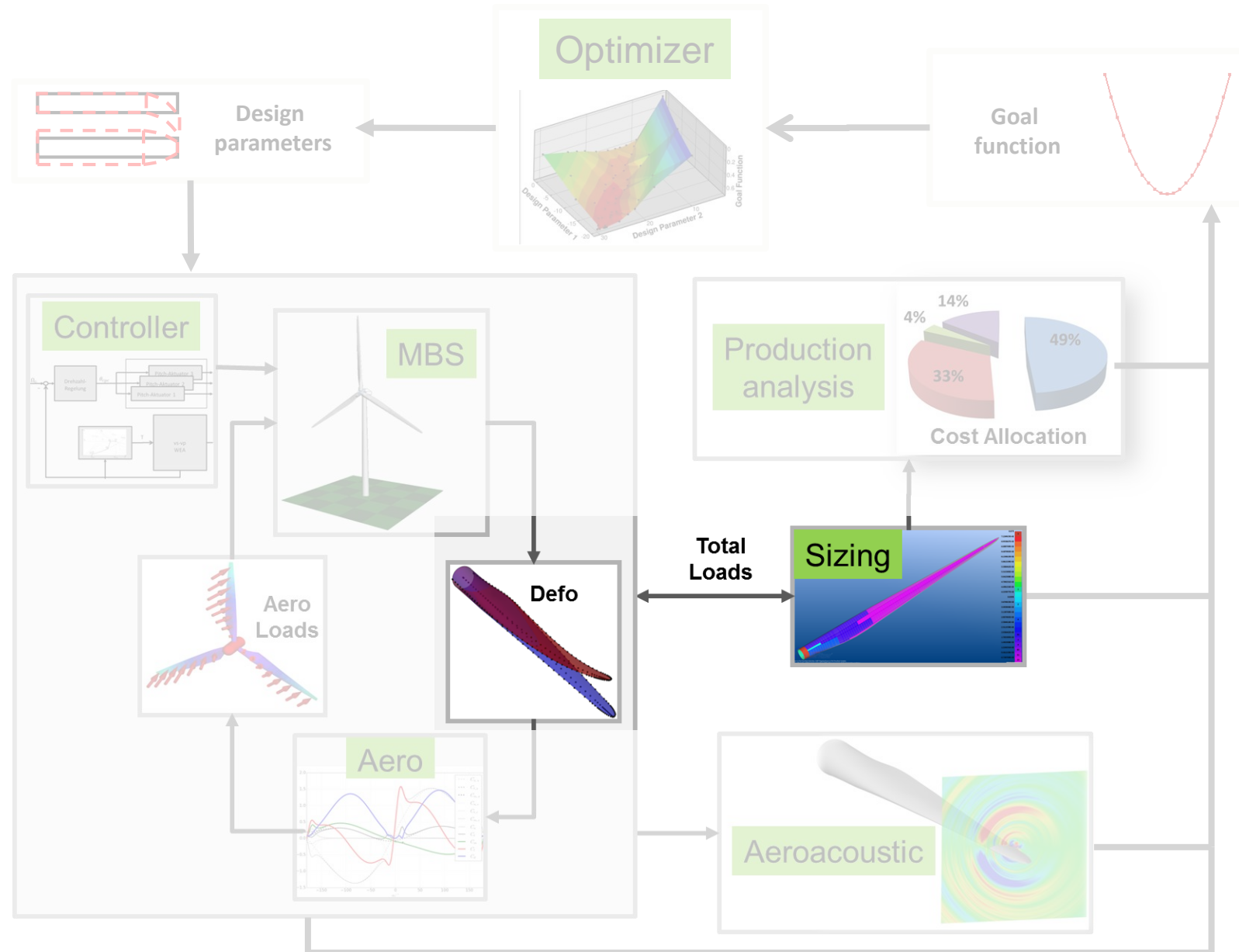
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Design Process

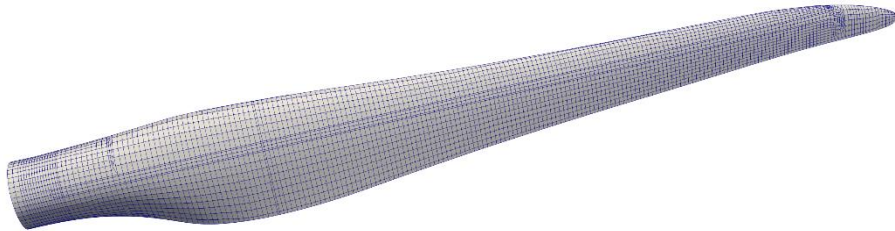


Design Process



Reference rotorblade

- Size: 20m
- Modelled with quadratic finite shell and solid elements
- Validated against an experimental data set

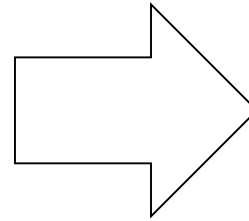


Reference model: <http://doi.org/10.5281/zenodo.3628356>



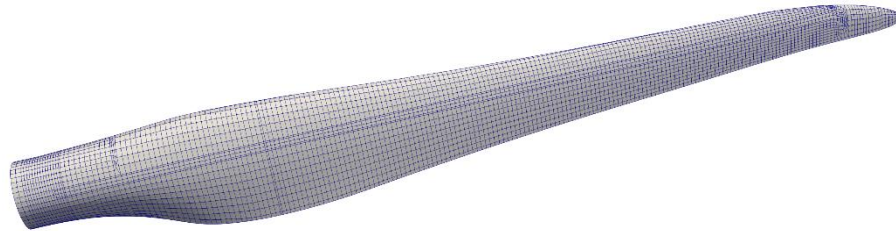
Reference rotorblade

- Size: 20m
- Modelled with quadratic finite shell and solid elements
- Validated against an experimental data set



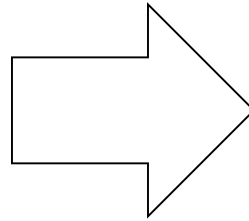
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CPACS - xml schema



Reference rotorblade

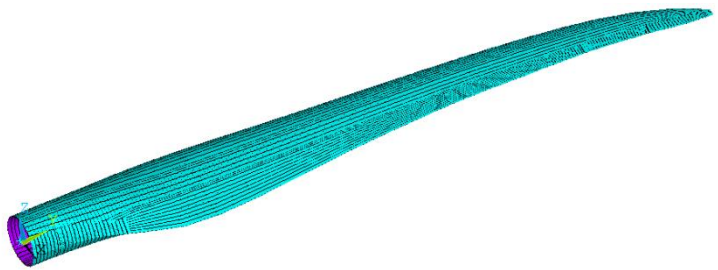
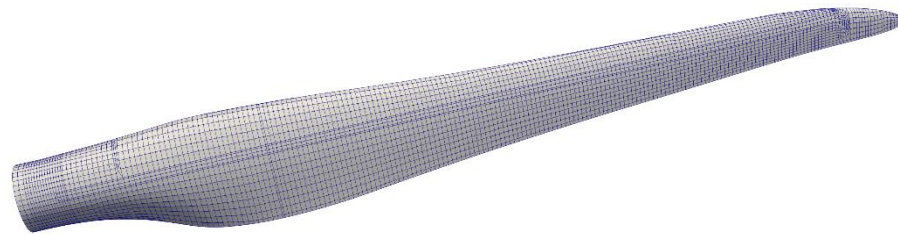
- Size: 20m
- Modelled with quadratic finite shell and solid elements
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CPACS - xml schema

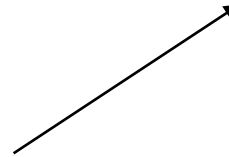
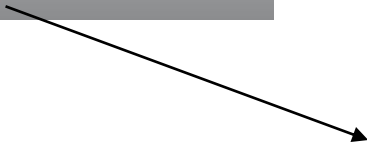
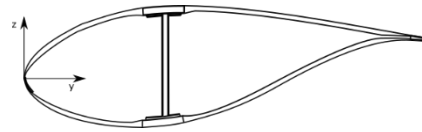
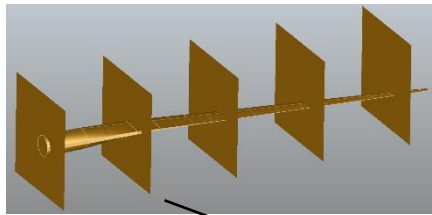


DELiS model based on CPACS

Reference model: <http://doi.org/10.5281/zenodo.3628356>



Beam model



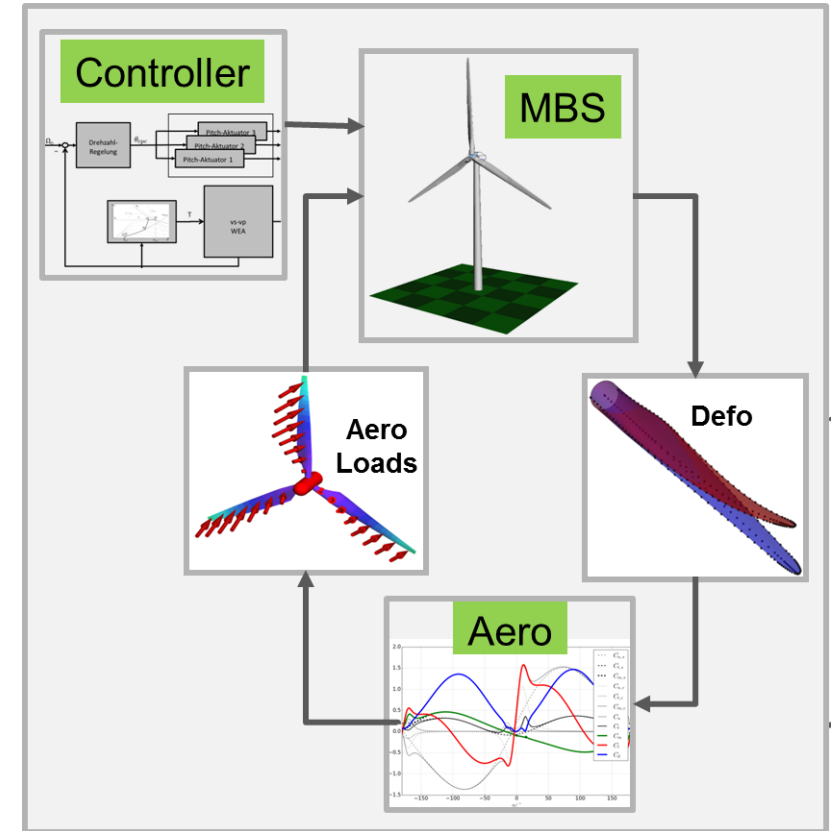
Beam model

Ansys

$$\begin{bmatrix} m & 0 & 0 & 0 & mG_z & -mG_y \\ 0 & m & 0 & -mG_z & 0 & mG_x \\ 0 & 0 & m & mG_y & -mG_x & 0 \\ 0 & -mG_z & mG_y & J_{Oxx} & J_{Oxy} & J_{Oxz} \\ mG_z & 0 & -mG_x & J_{Oxy} & J_{Oyy} & J_{Oyz} \\ -mG_y & mG_x & 0 & J_{Oxz} & J_{Oyz} & J_{Ozz} \end{bmatrix}$$

ABD beam

$$\begin{bmatrix} EA & -z_c EA & y_c EA & 0 & 0 & 0 \\ -z_c EA & EI_{yy} + z_c^2 EA & -EI_{yz} - y_c z_c EA & 0 & 0 & 0 \\ y_c EA & -EI_{yz} - y_c z_c EA & EI_{zz} + y_c^2 EA & 0 & 0 & 0 \\ 0 & 0 & 0 & GJ + y_s^2 GAsc_z + z_s^2 GAsc_y & 0 & 0 \\ 0 & 0 & 0 & 0 & GAsc_z & 0 \\ 0 & 0 & 0 & 0 & 0 & GAsc_y \end{bmatrix}$$



<https://docs.abdbeam.org/en/latest/>



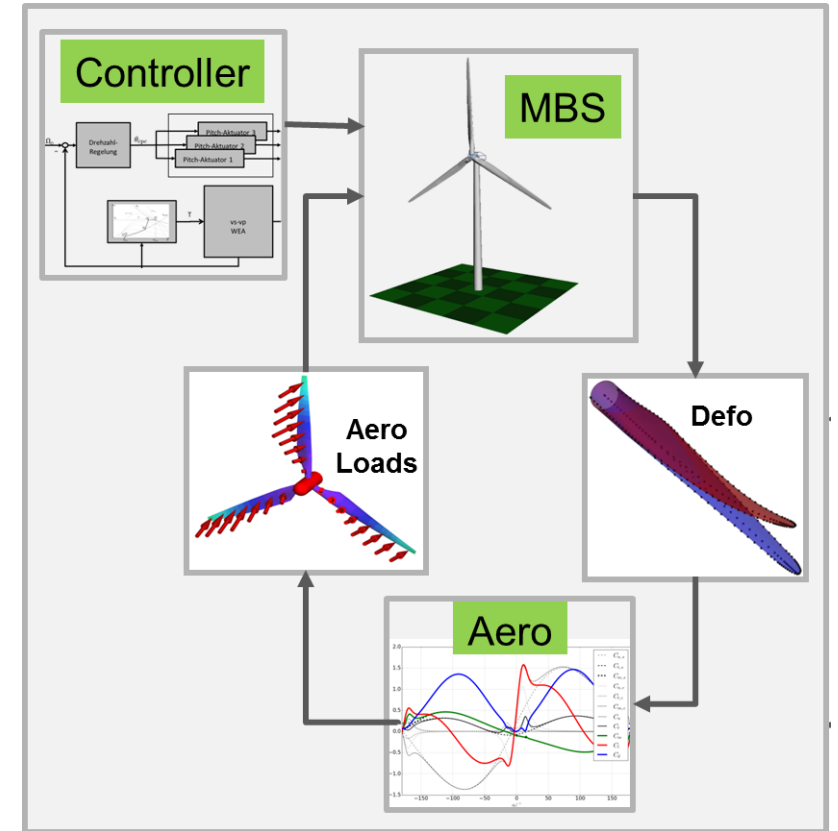
Beam model

Ansys

$$\begin{bmatrix} m & 0 & 0 & 0 & mG_z & -mG_y \\ 0 & m & 0 & -mG_z & 0 & mG_x \\ 0 & 0 & m & mG_y & -mG_x & 0 \\ 0 & -mG_z & mG_y & J_{oxx} & J_{oxy} & J_{oxz} \\ mG_z & 0 & -mG_x & J_{oxy} & J_{oyy} & J_{oyz} \\ -mG_y & mG_x & 0 & J_{oxz} & J_{oyz} & J_{ozz} \end{bmatrix}$$

ABD beam

$$\begin{bmatrix} EA & -z_c EA & y_c EA & 0 & 0 & 0 \\ -z_c EA & EI_{yy} + z_c^2 EA & -EI_{yz} - y_c z_c EA & 0 & 0 & 0 \\ y_c EA & -EI_{yz} - y_c z_c EA & EI_{zz} + y_c^2 EA & 0 & 0 & 0 \\ 0 & 0 & 0 & GJ + \cancel{y_s^2 GAsc_z} + \cancel{z_s^2 GAsc_y} & 0 & 0 \\ \hline 0 & 0 & 0 & 0 & \cancel{GAsc_z} & 0 \\ 0 & 0 & 0 & 0 & 0 & \cancel{GAsc_y} \end{bmatrix}$$



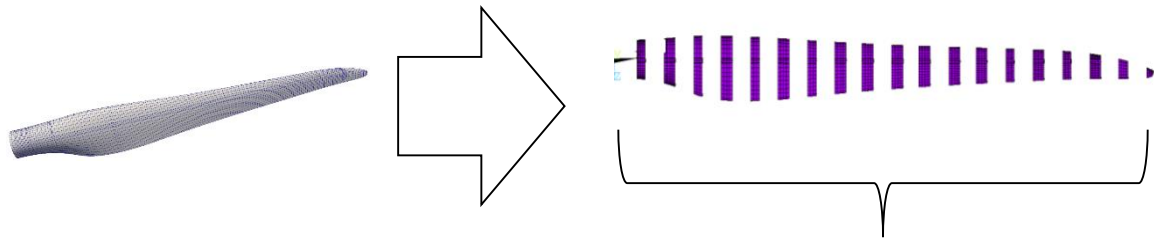
<https://docs.abdbeam.org/en/latest/>



Modal reduction



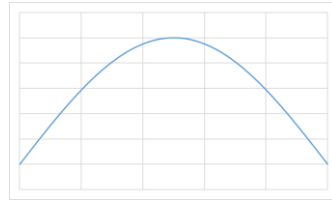
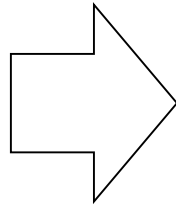
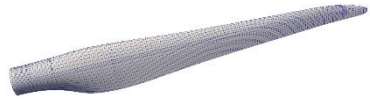
Modal reduction



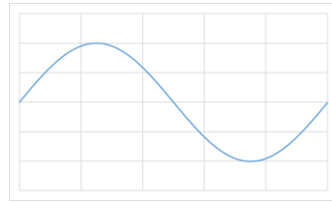
- Condensation onto 20 nodes at aerodynamic centers
- Inclusion of 10 Component-Mode-Synthesis (CMS) Modes



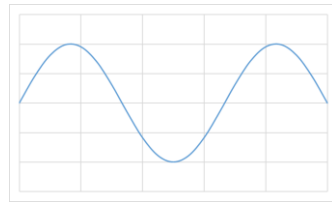
Modal reduction



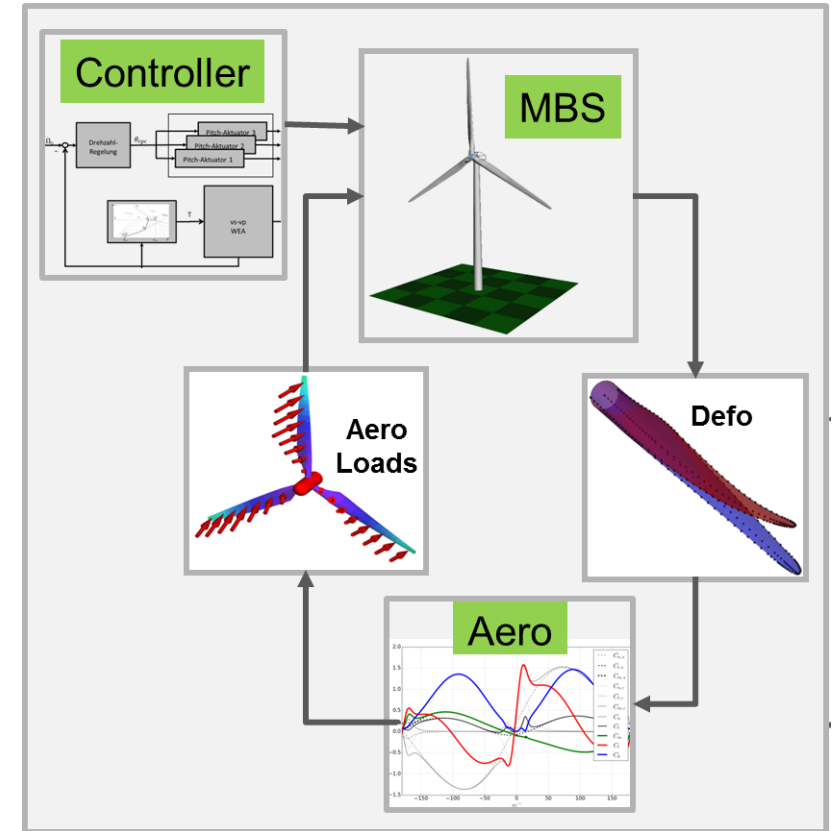
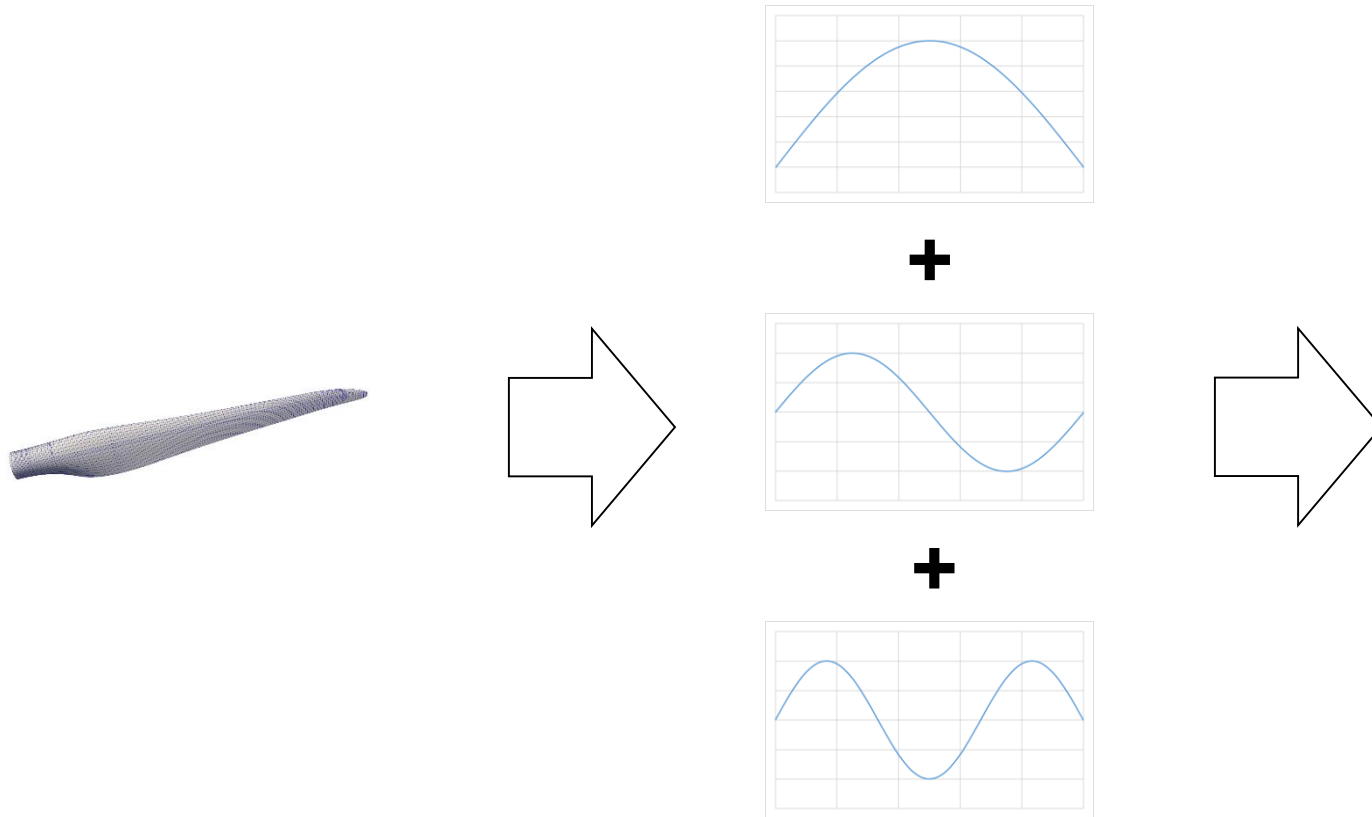
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Modal reduction



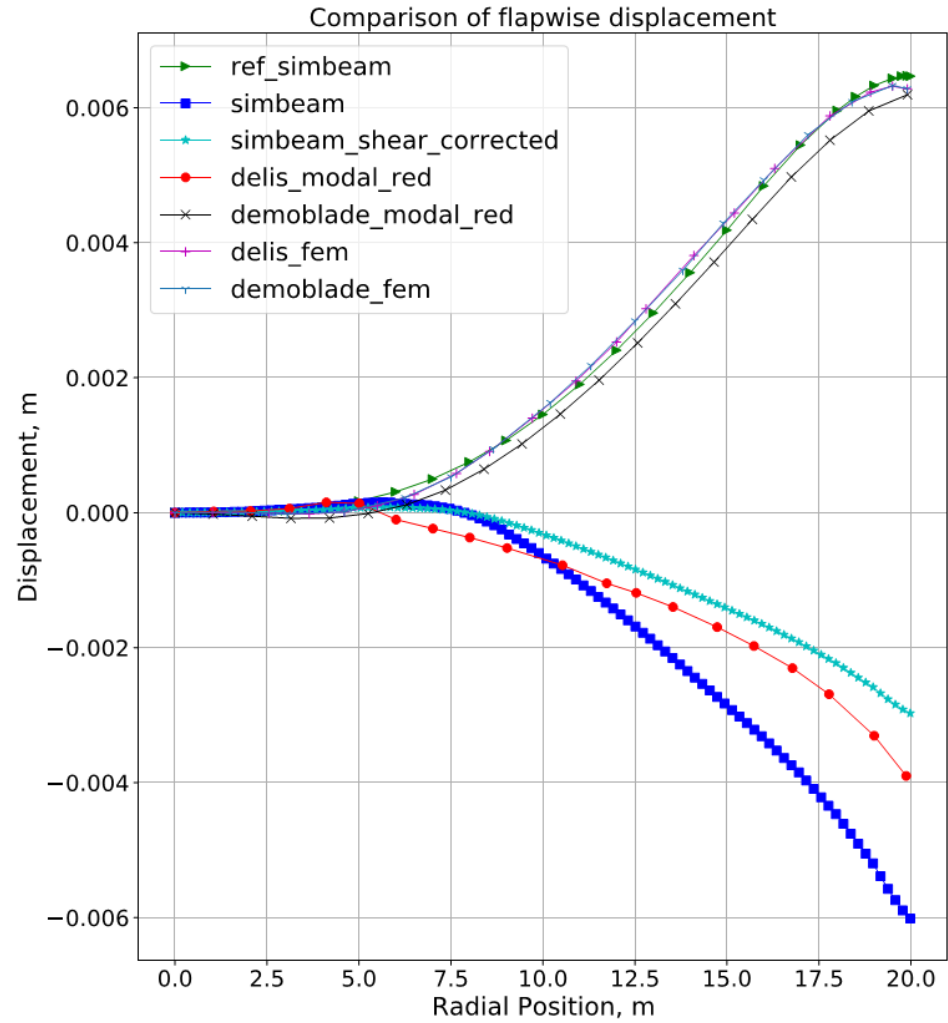
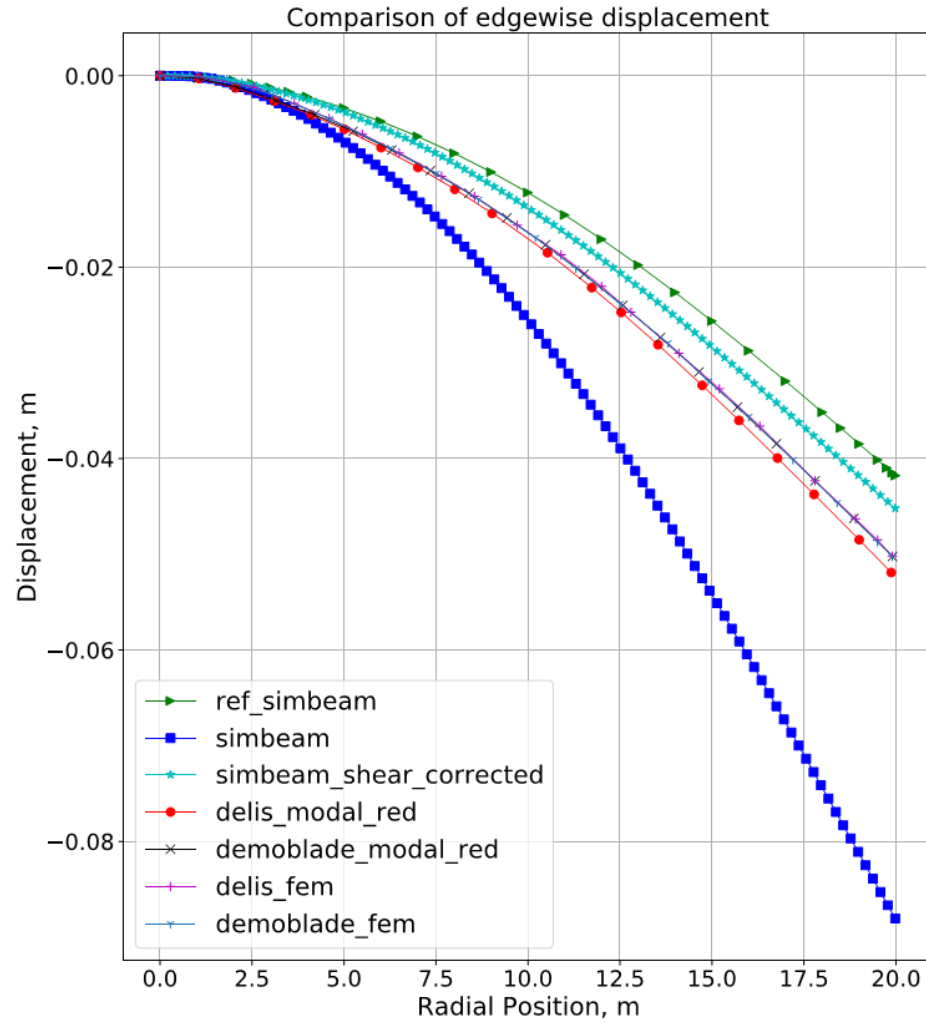
Models

Name in Plots	Model	Method
Ref_simbeam	Reference loads model	MBS beam
Simbeam	DELiS model as beam model	MBS beam
Simbeam_shear_corrected	DELiS model as beam model + shear correction from ref_simbeam	MBS beam
Delis_modal_red	DELiS model	MBS modal reduction
Demoblade_modal_red	Reference model	MBS modal reduction
Delis_fem	DELiS model	FEM
Demoblade_fem	Reference model	FEM



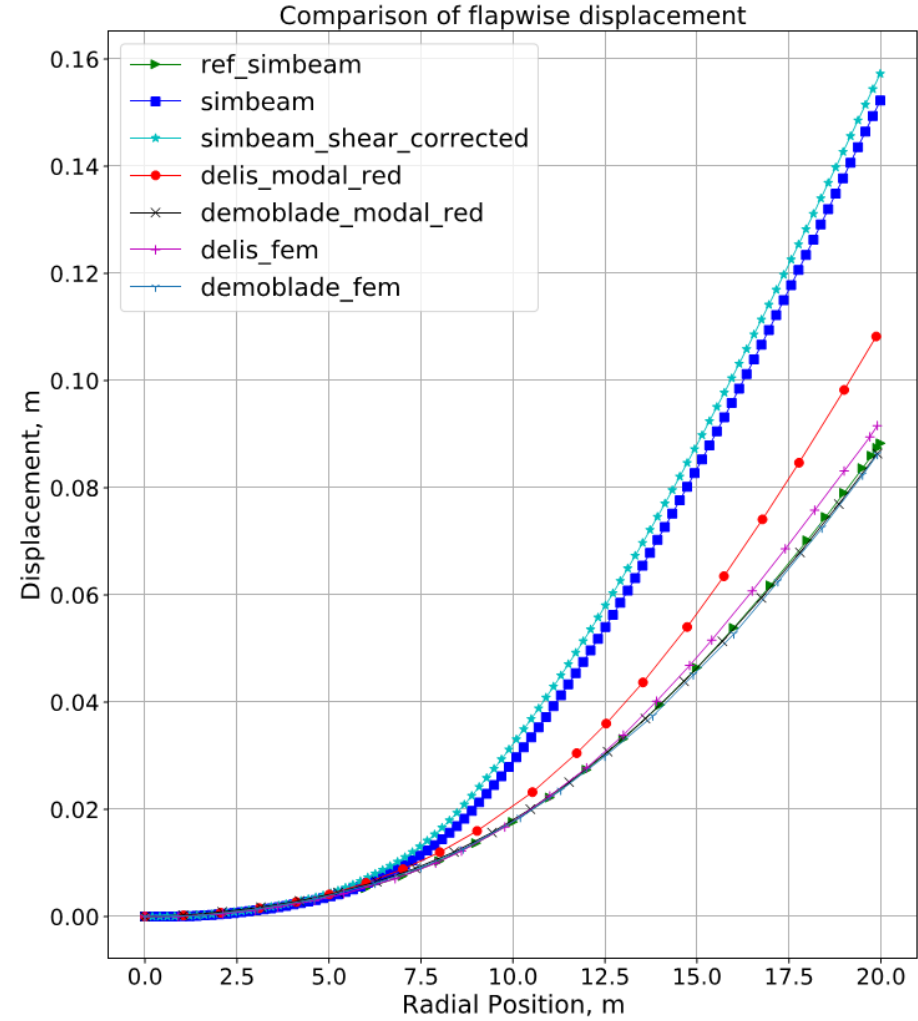
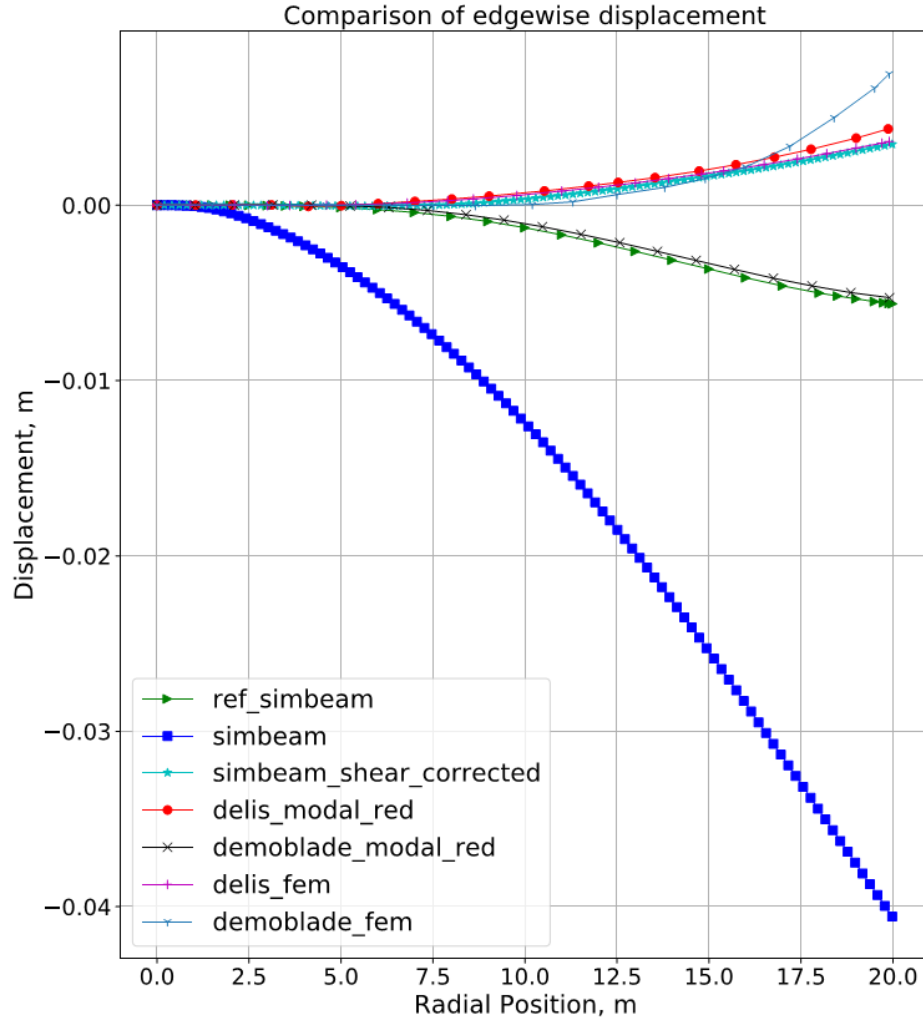
Edgewise 1g

Edgewise 1g load, 0° pitch, 90° azimuth

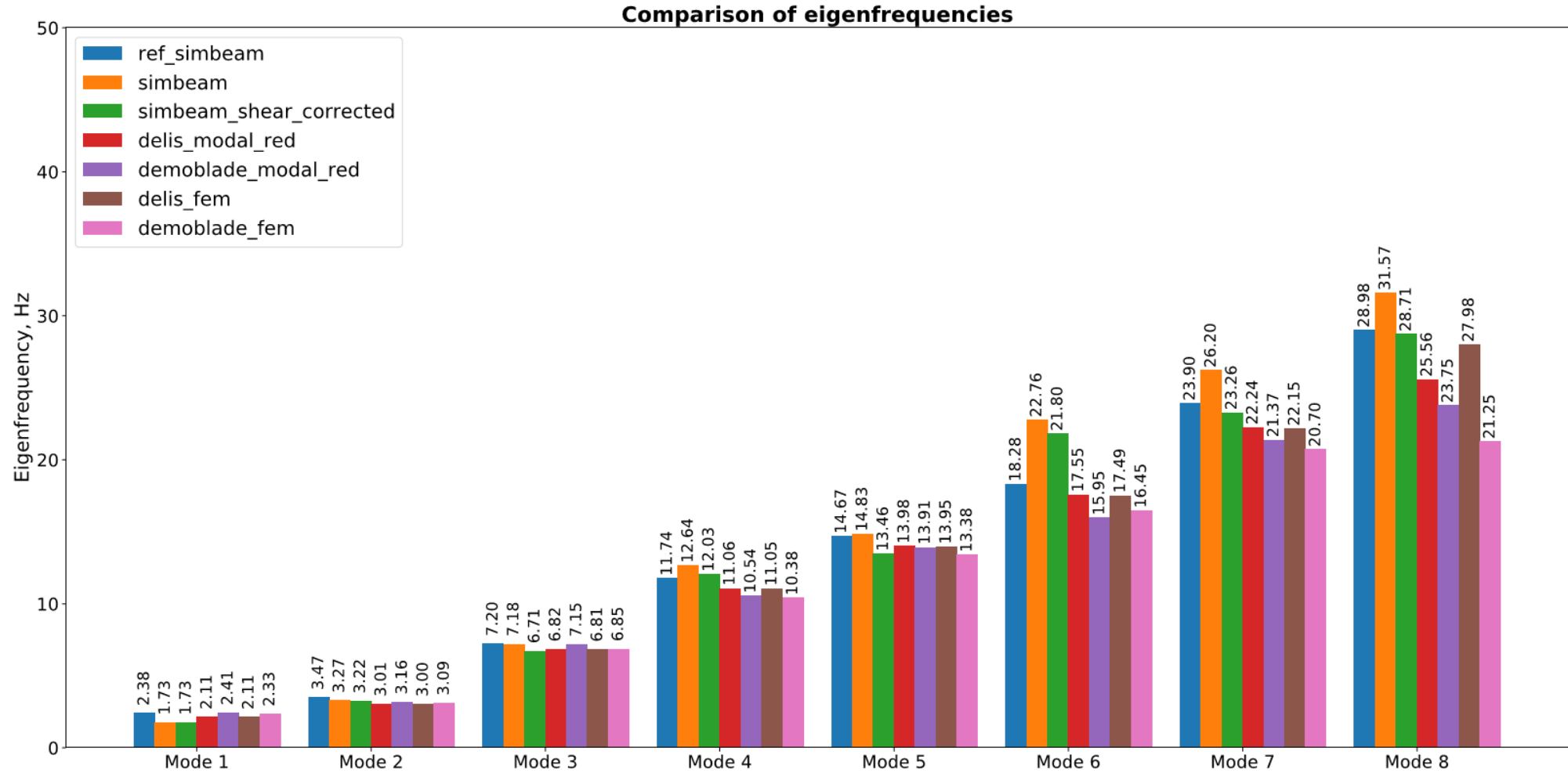


Flapwise 1g

Flapwise 1g load, 90° pitch, 90° azimuth



Eigenfrequencies



Conclusion

- Modal reduction is a good way of modelling and allows to obtain accurate beam models
- It circumvents the struggle of finding appropriate shear correction factors
- ABD python package needs more tests for wind turbine blades

- Determine shear correction factors and beam parameters with optimization or fitting



Thank you!

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Reference model can be found here

Christian Willberg. (2021). Smartblades 2 finite element
reference wind turbine blade model

<http://doi.org/10.5281/zenodo.3628356>



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