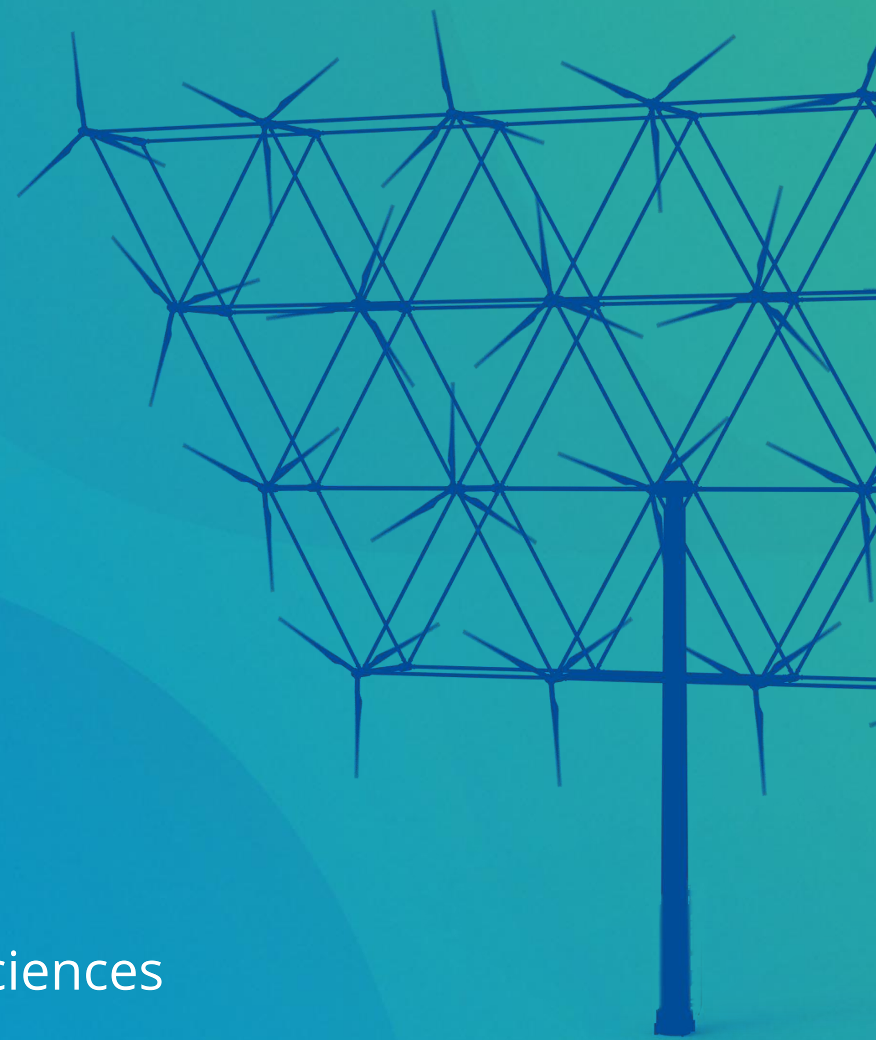


MRS space frame loads and rotor interactions

Multi-Rotor Seminar 2025, Hamburg University of Applied Sciences

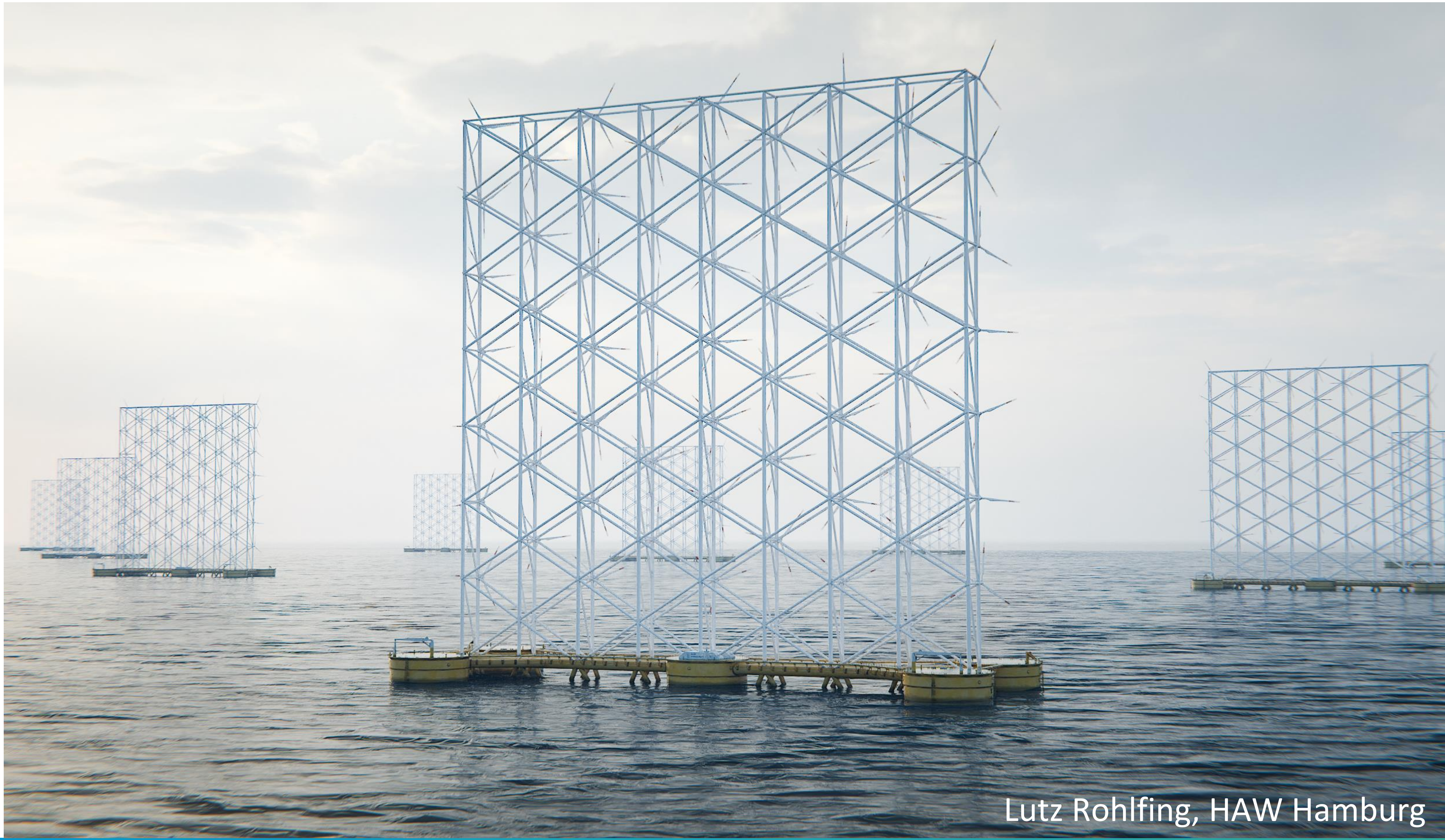
Sven Störtenbecker, Peter Dalhoff

Sponsored by:

MRS space frame loads and rotor interactions

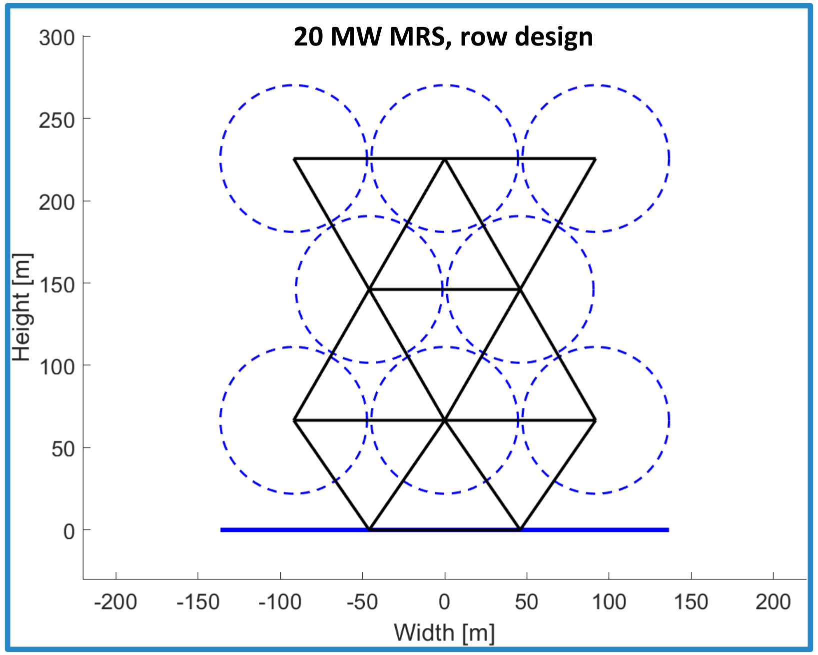
- **MRS floater space frame loads and masses**

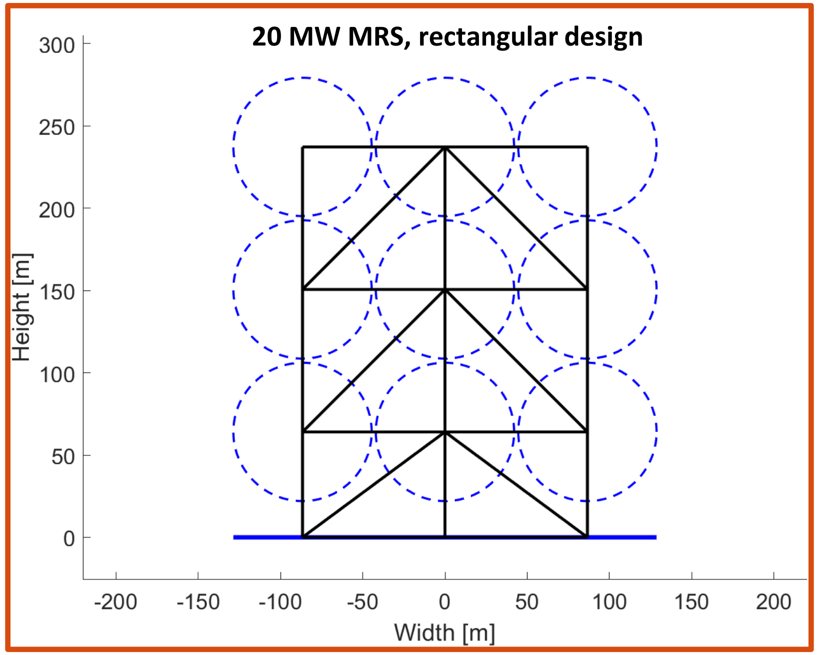
- MRS rotor interactions:
  - Rotor-structure
  - Rotor-rotor

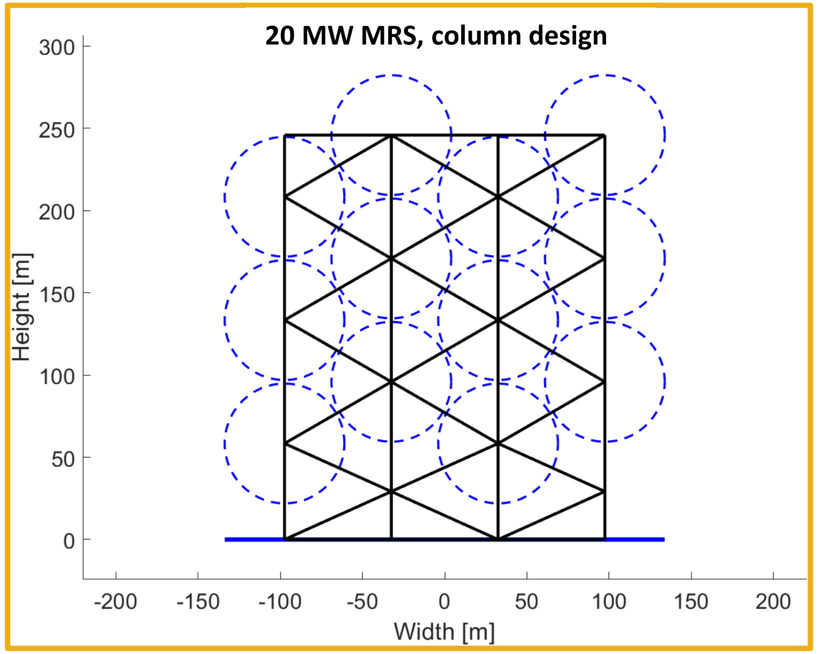


MRS space frame loads

20 MW designs





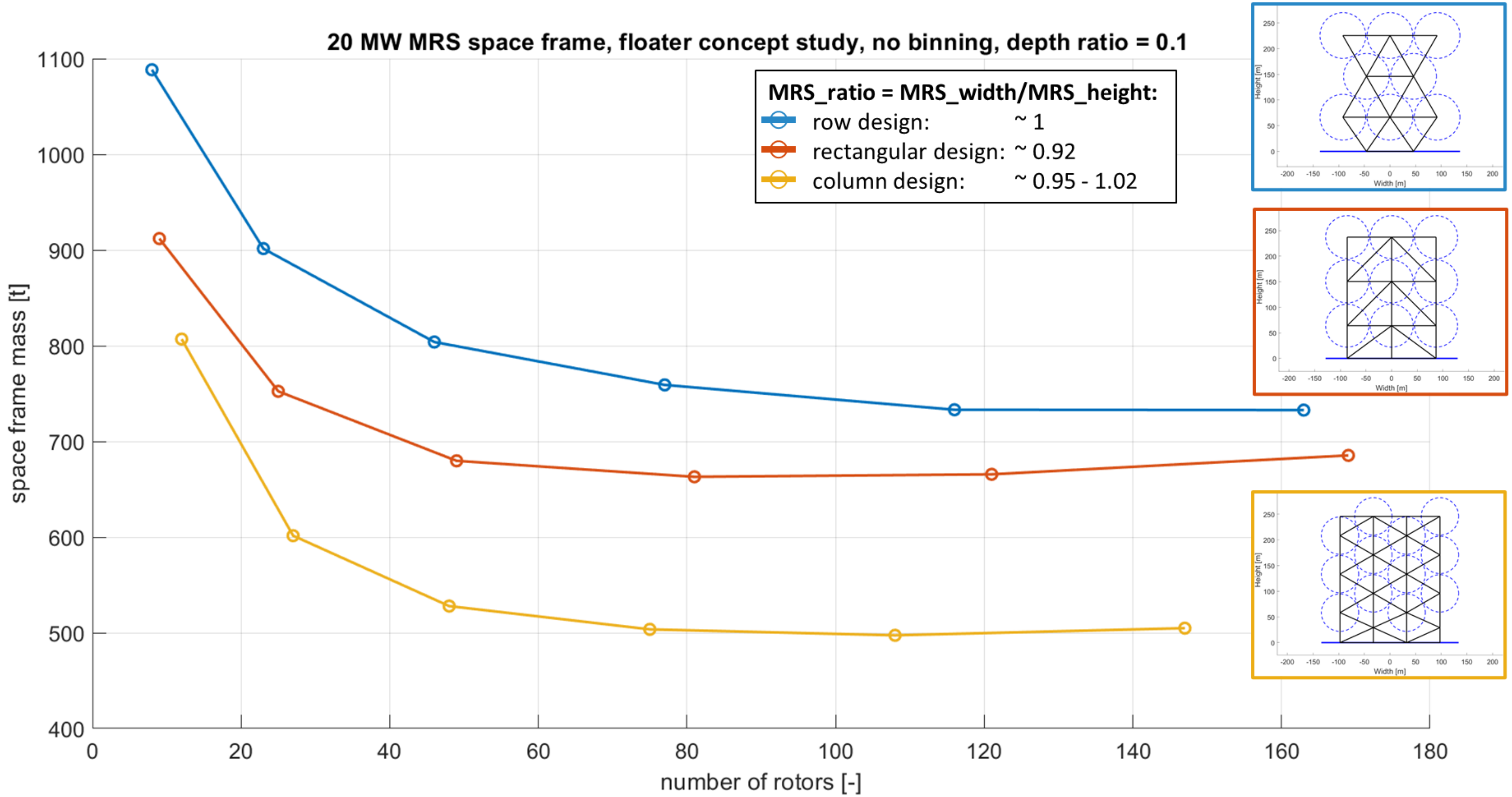


- 20 MW overall capacity
- Dimensioning of space frame members based on yield strength and buckling
- Maximum thrust and RNA gravitational forces acting on rotor nodes
- No binning of diameters

- Space frame masses shown here just to compare topologies with each other, since fatigue would increase masses (based on number of rotors)
- depth ratio = space frame depth/space frame width set to 0.1

MRS space frame loads

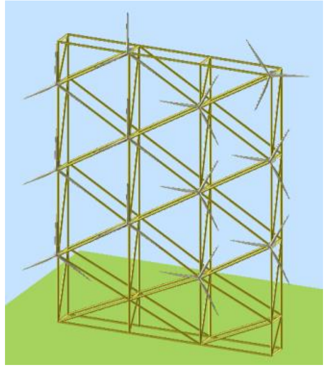
Space frame masses based on yield strength and buckling



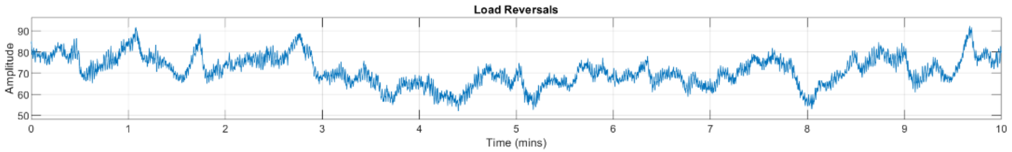
MRS space frame loads

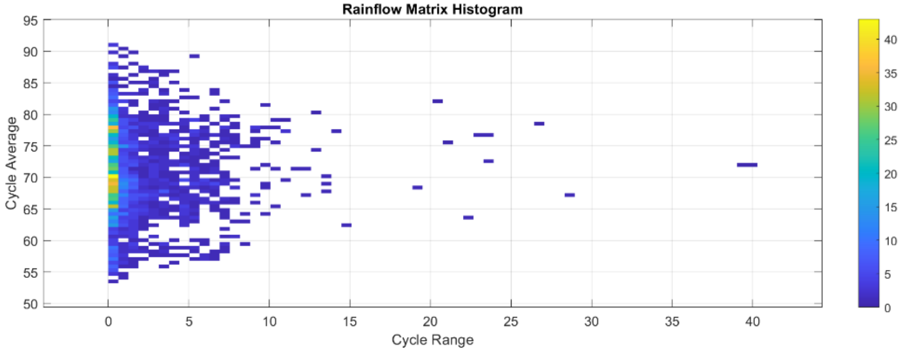
Space frame fatigue dimensioning

Aero(elastic) Load Simulation (DLC 1.2 IEC 61400-1): Rotor loads

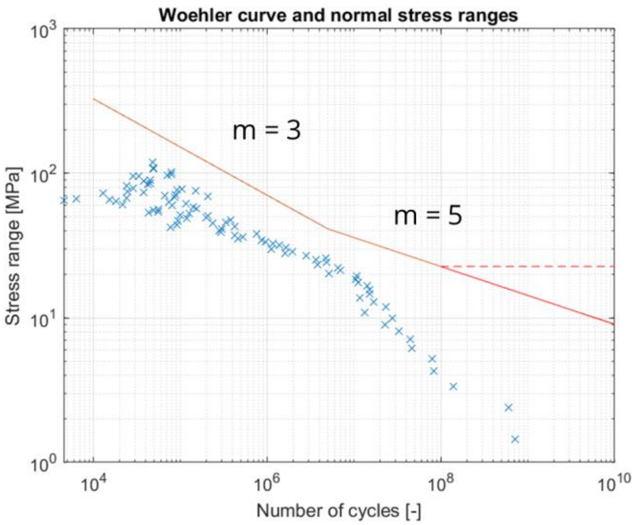


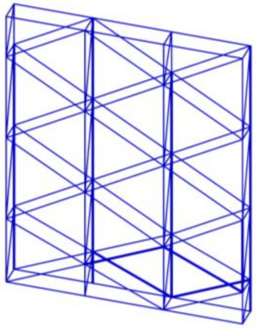
Linear System: Superposition Stress time series





Damage calculation: D





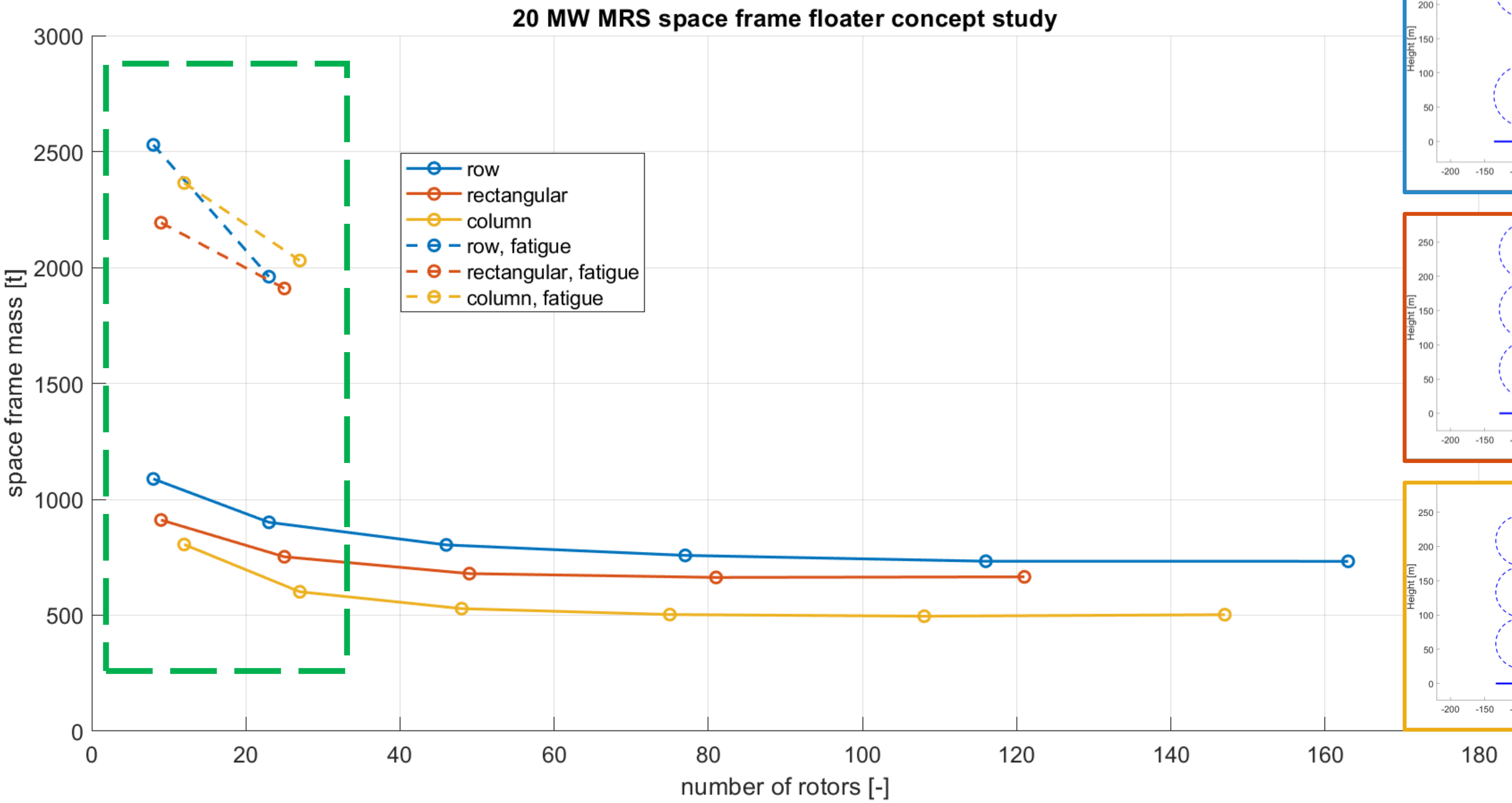
Finite Element Analysis (FEA): Unit stresses

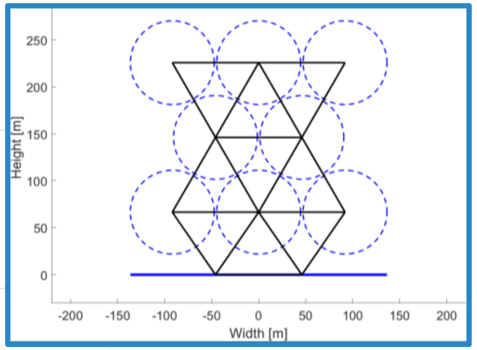
Rainflow count

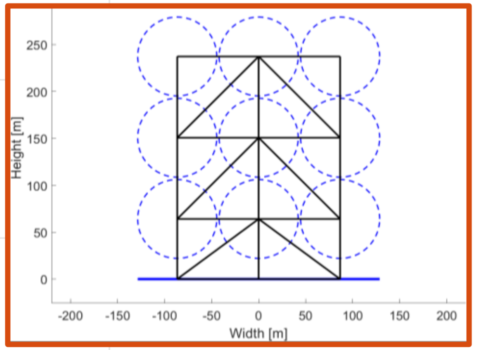
Redimensioning if necessary

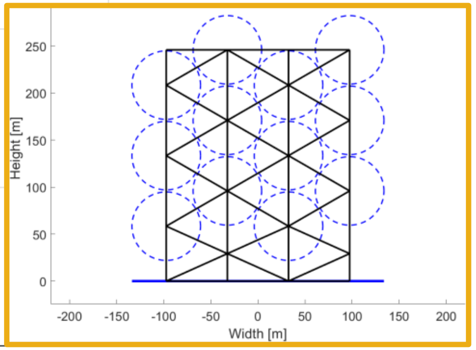
MRS space frame loads

Space frame fatigue results





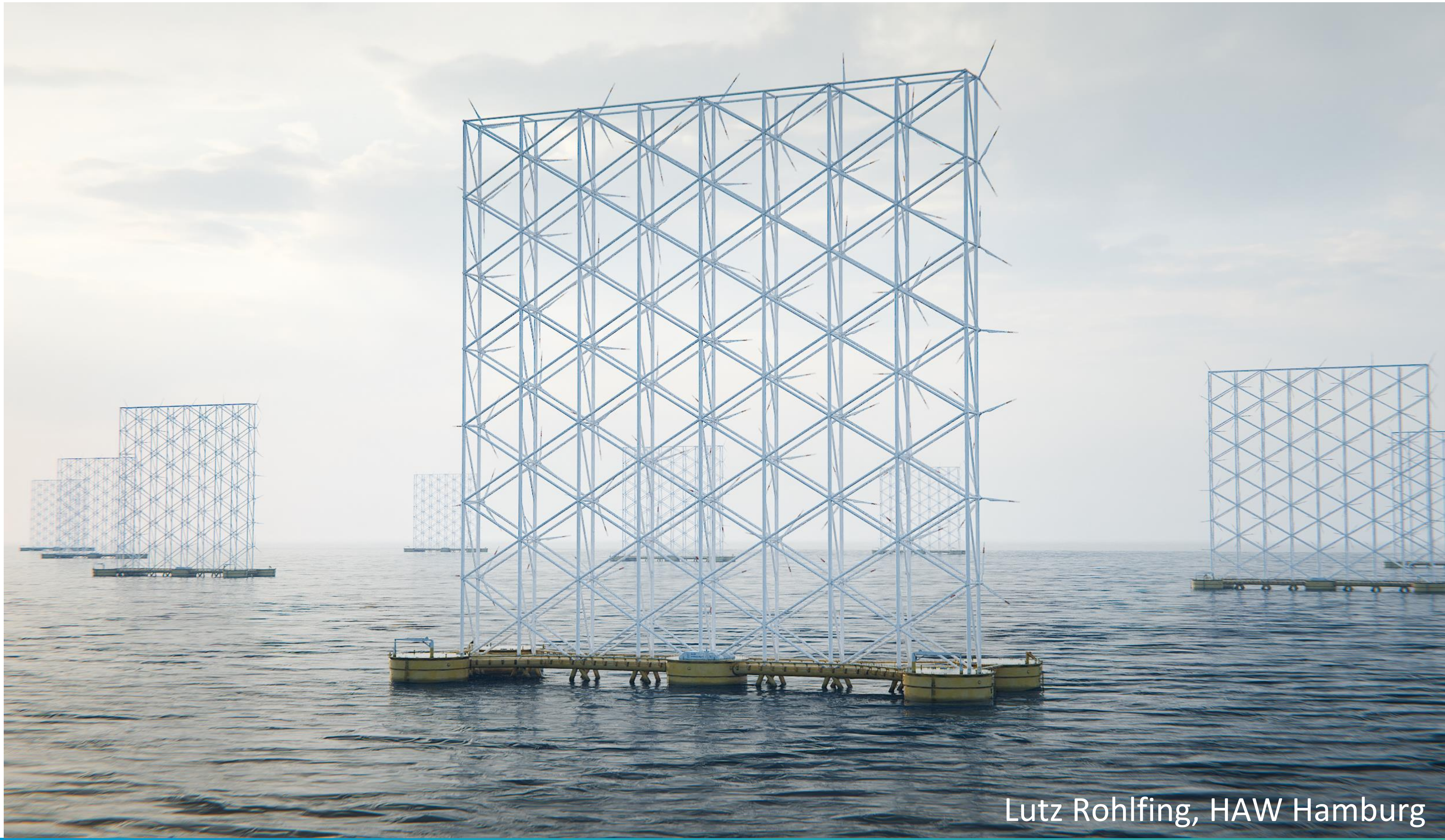




MRS space frame loads and rotor interactions

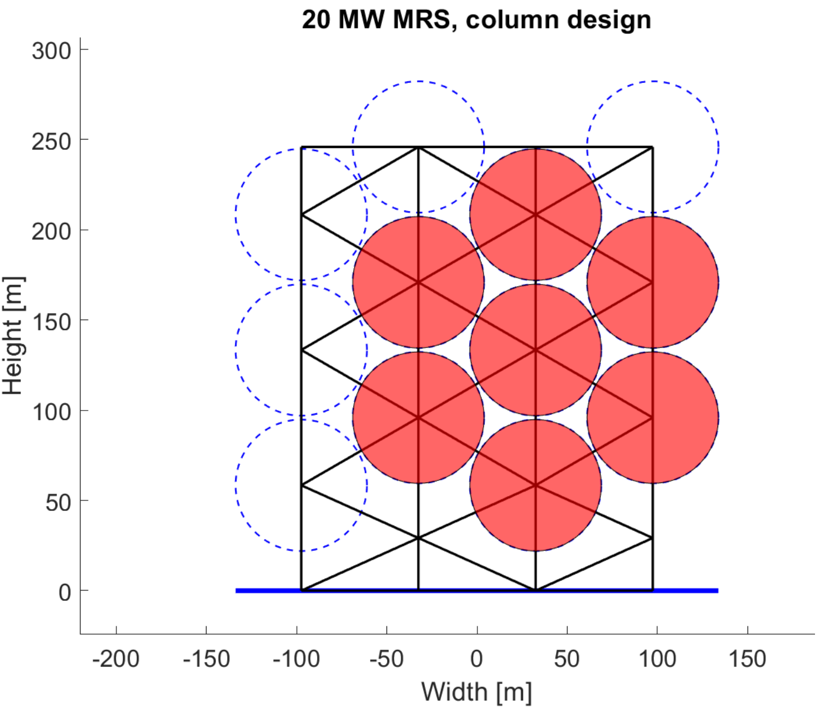
- MRS floater space frame loads and masses

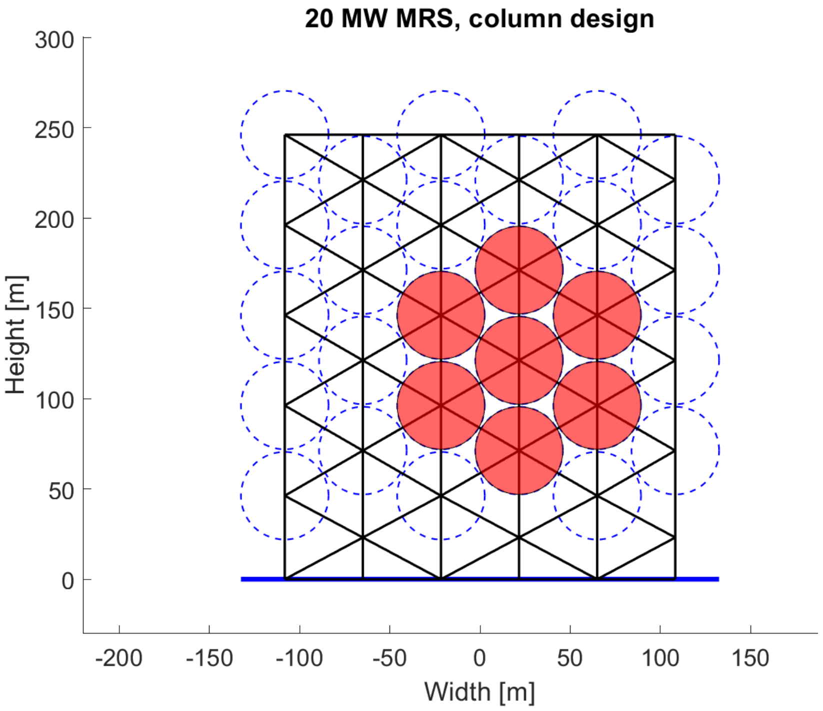
- **MRS rotor interactions:**
  - **Rotor-structure**
  - **Rotor-rotor**

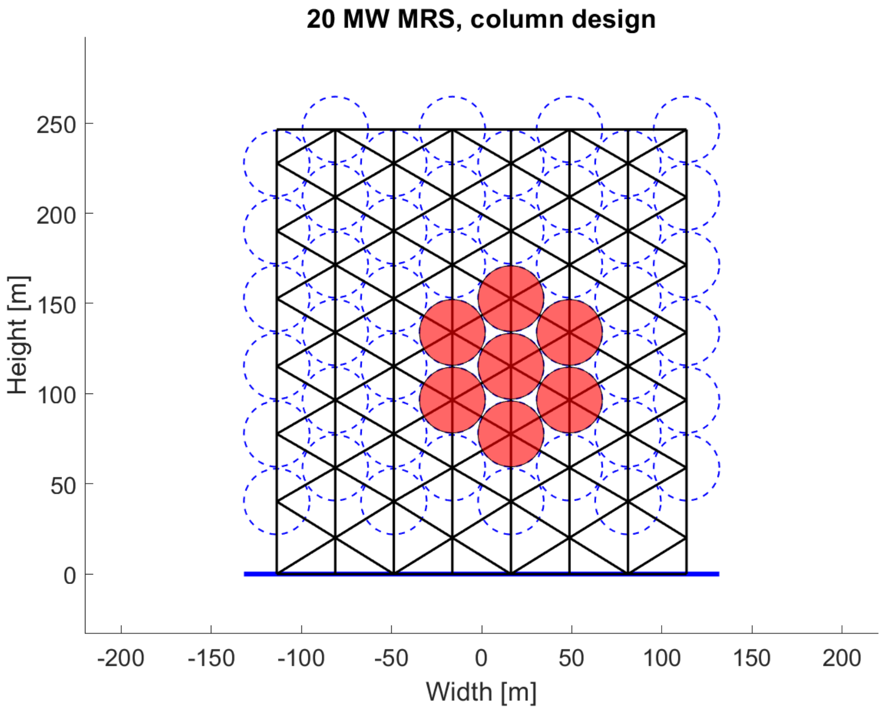


MRS rotor interactions

20 MW MRS column designs







n_{rotor} = 12
P_{rotor} = 1.67 MW
D_{rotor} = 72.8 m

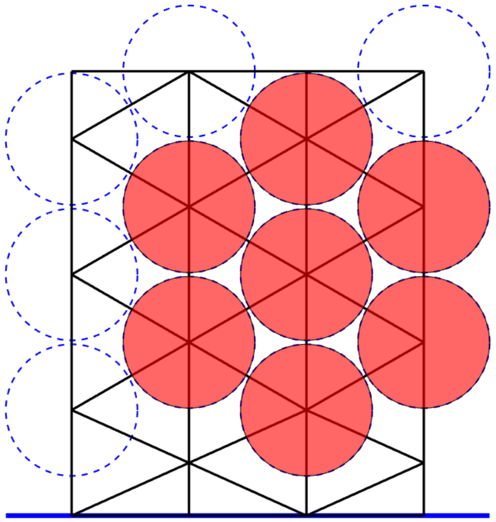
n_{rotor} = 27
P_{rotor} = 741 kW
D_{rotor} = 48.5 m

n_{rotor} = 48
P_{rotor} = 417 kW
D_{rotor} = 36.4 m

MRS rotor interactions

Rotor-structure interactions

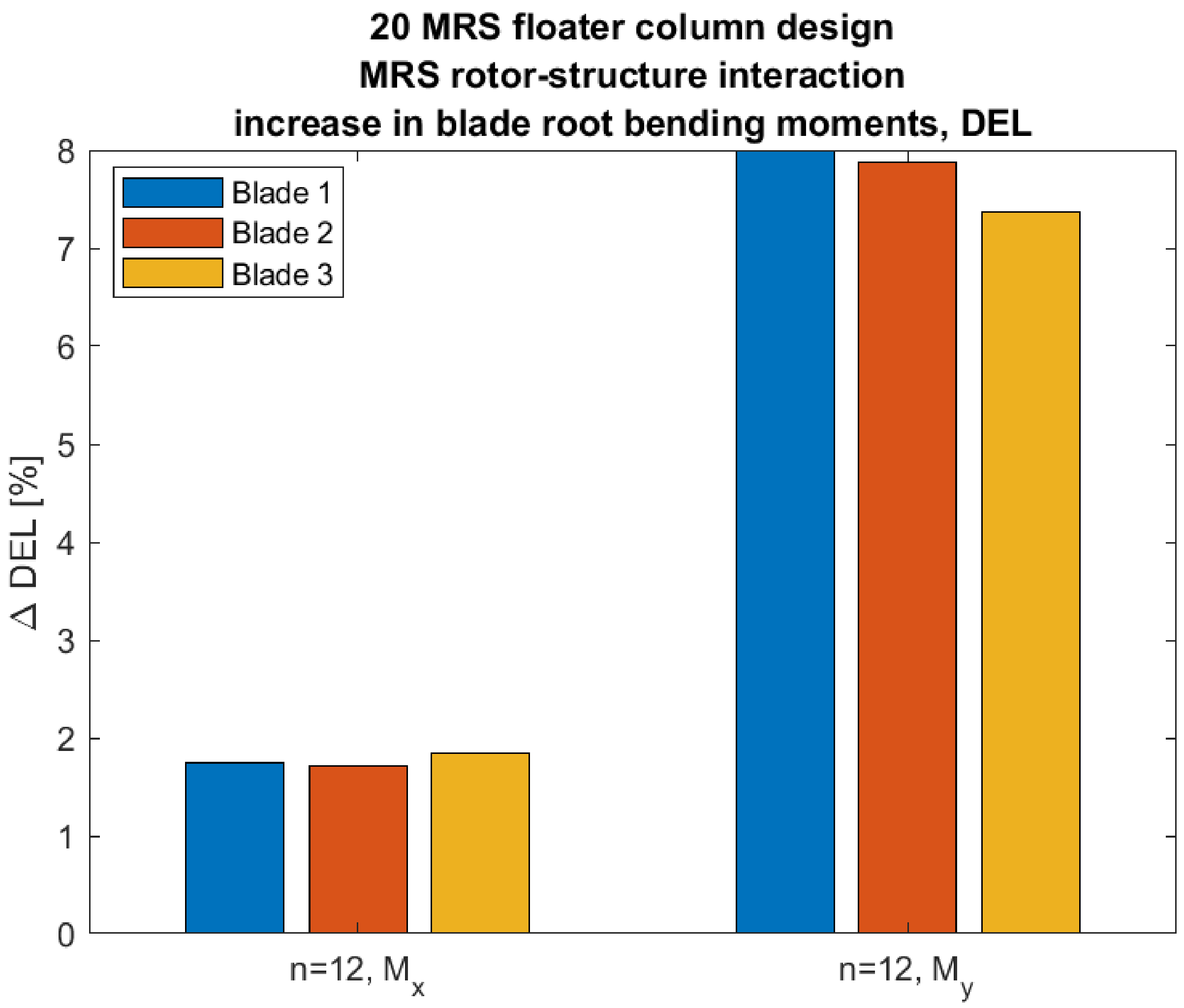
- Aerodynamic interaction between rotor blades and space frame members
- Reduction of wind speed in front of space frame members
- BEM (Blade element momentum theory) based simulation: tower shadow, potential flow theory based on space frame member (tower) diameter
- Up to six neighbouring rotors/connections: 6p excitation per blade
- Blade root bending moments: edgewise M_x, flapwise M_y
- Calculation of damage equivalent load (DEL) with and without tower shadow
- N_{ref} = 5e6 und Wöhler-Exponent k=10 for glass and carbon fibre reinforced plastic blade materials



$$\mathrm{DEL} = \Delta M_{\blacksquare} = \left[\frac{\sum_i \left(n_i * \Delta M_{Ai}{}^{k}\right)}{N_{ref}}\right]^{1/k}$$

MRS rotor interactions

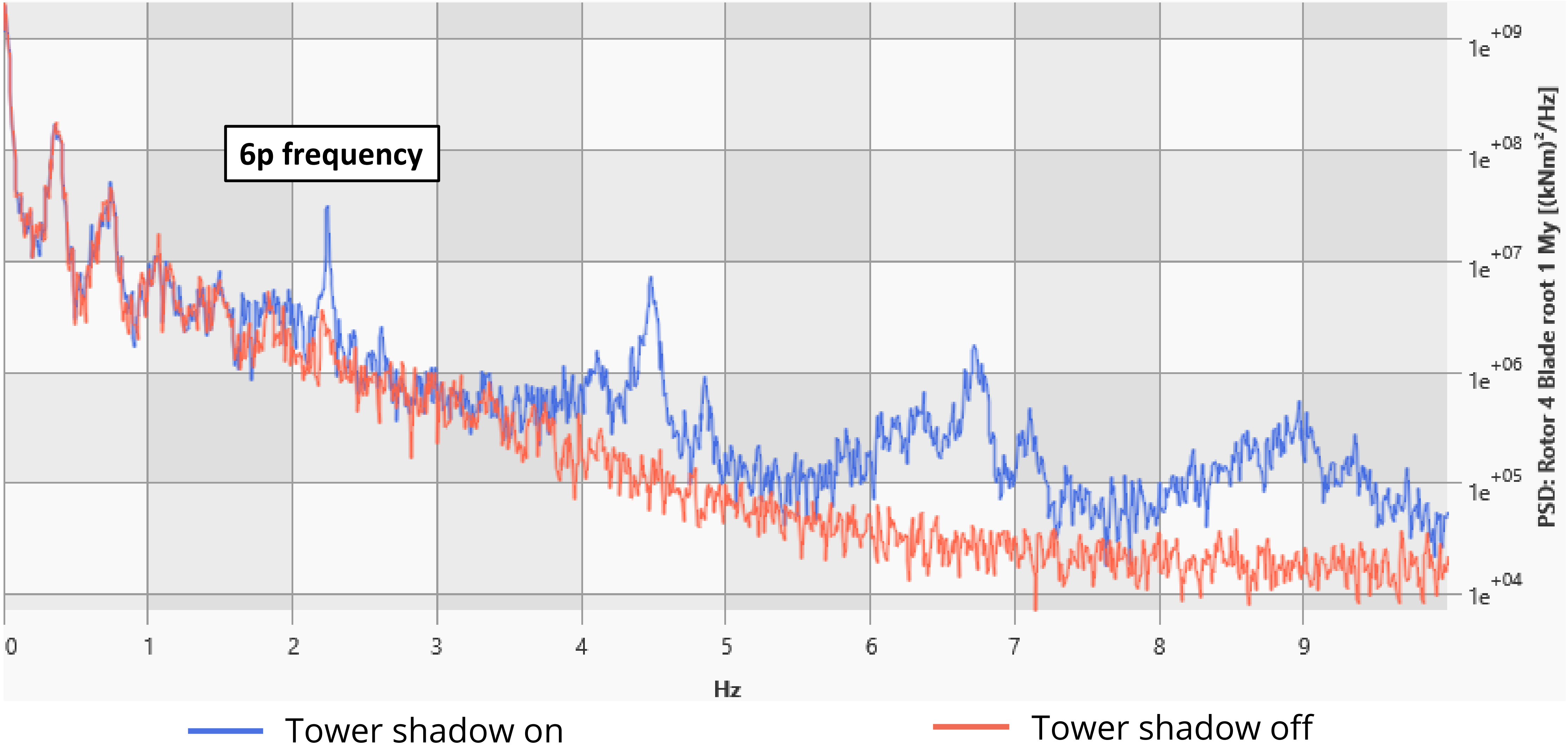
Rotor-structure interactions



- Increase in damage equivalent loads (DEL) for “tower shadow on” compared to “tower shadow off”
- **Initial results (not final)**: aerodynamic simulations were done before space frame dimensioning: only arbitrary space frame diameters were used so far
- Blades would normally have to endure rotor-tower interactions in case of a single-rotor (SR) system. This would also increase blade root DEL compared to “tower shadow off”
- Both, simulation and DEL comparison with fatigue dimensioned space frame diameters as well as DEL comparison with SR (same rotor diameter as the MRS) are coming up

MRS rotor interactions

Power spectral density (PSD), flapwise blade root bending moment 1 $\mathbf{M_y}$



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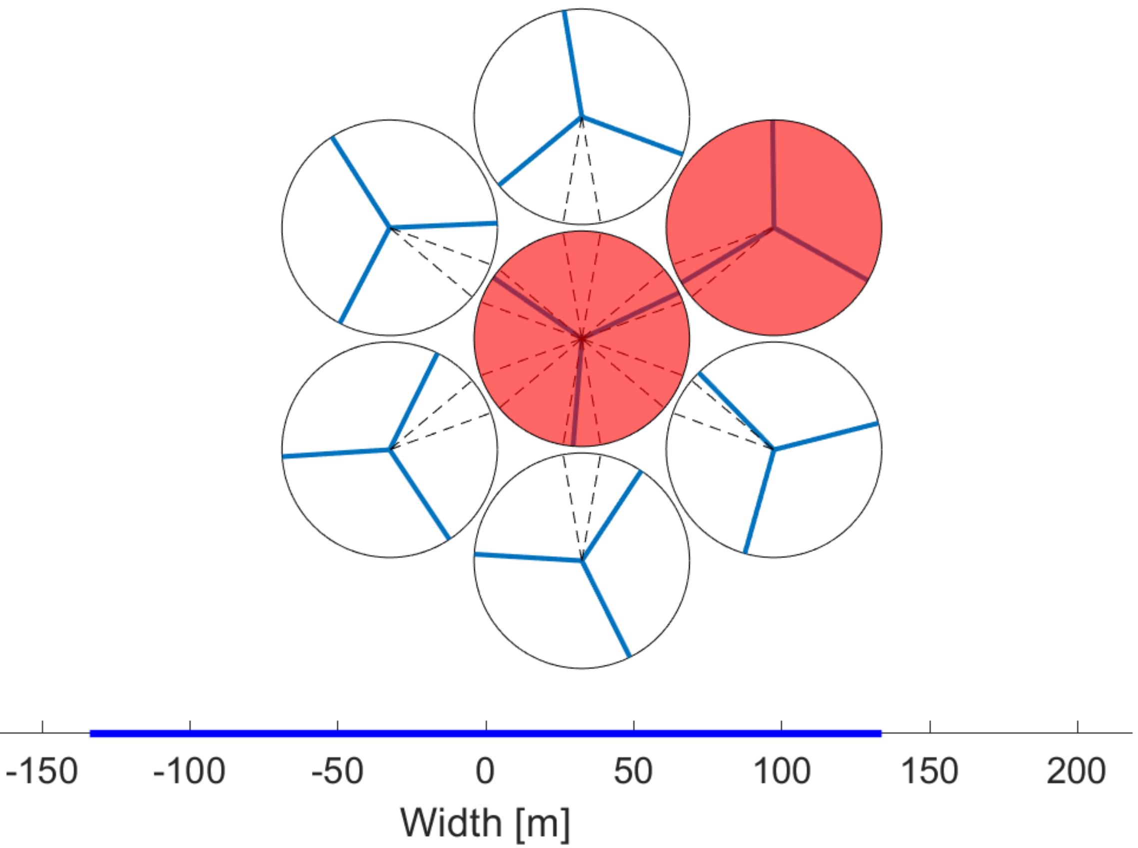
MRS rotor interactions

Rotor-rotor interaction

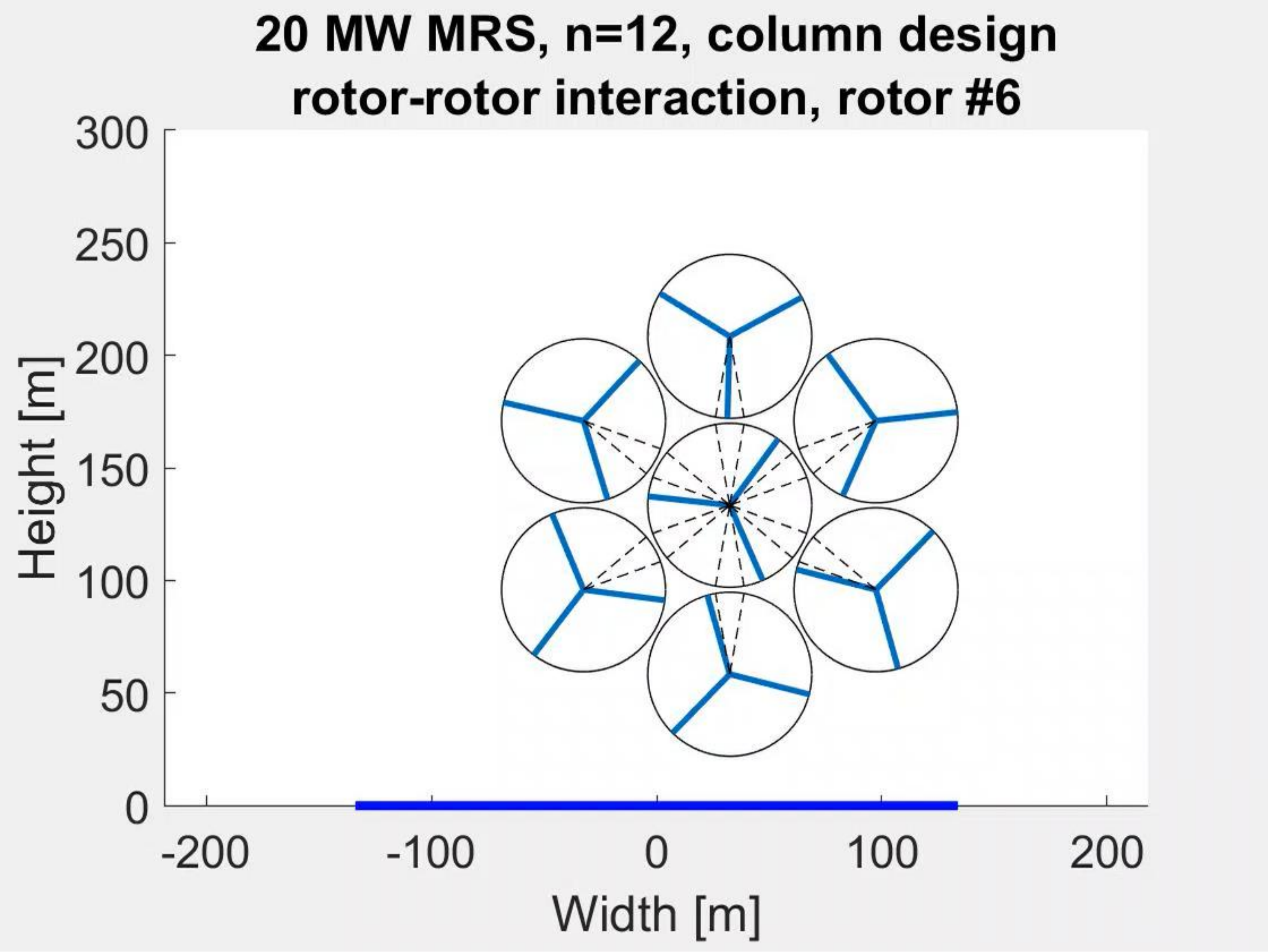
20 MW MRS, n=12, column design
rotor-rotor interaction, rotor #6



- Blade tip passing event
- Rotor positions: BEM based aerodynamic simulations
- Rotor-rotor interaction when both blades are in the area defined by the interaction angle
- Parameter study:
    - Variation of interaction angle: 2:2:20 [°]
    - Rotor-rotor interaction: load increase of blade root bending moments: edgewise $\mathrm{M_x}$ and flapwise $\mathrm{M_y}$ if rotor-rotor interaction occurs
    - Variation of load increase: 1:1:10 [%]
    - Calculation of DEL

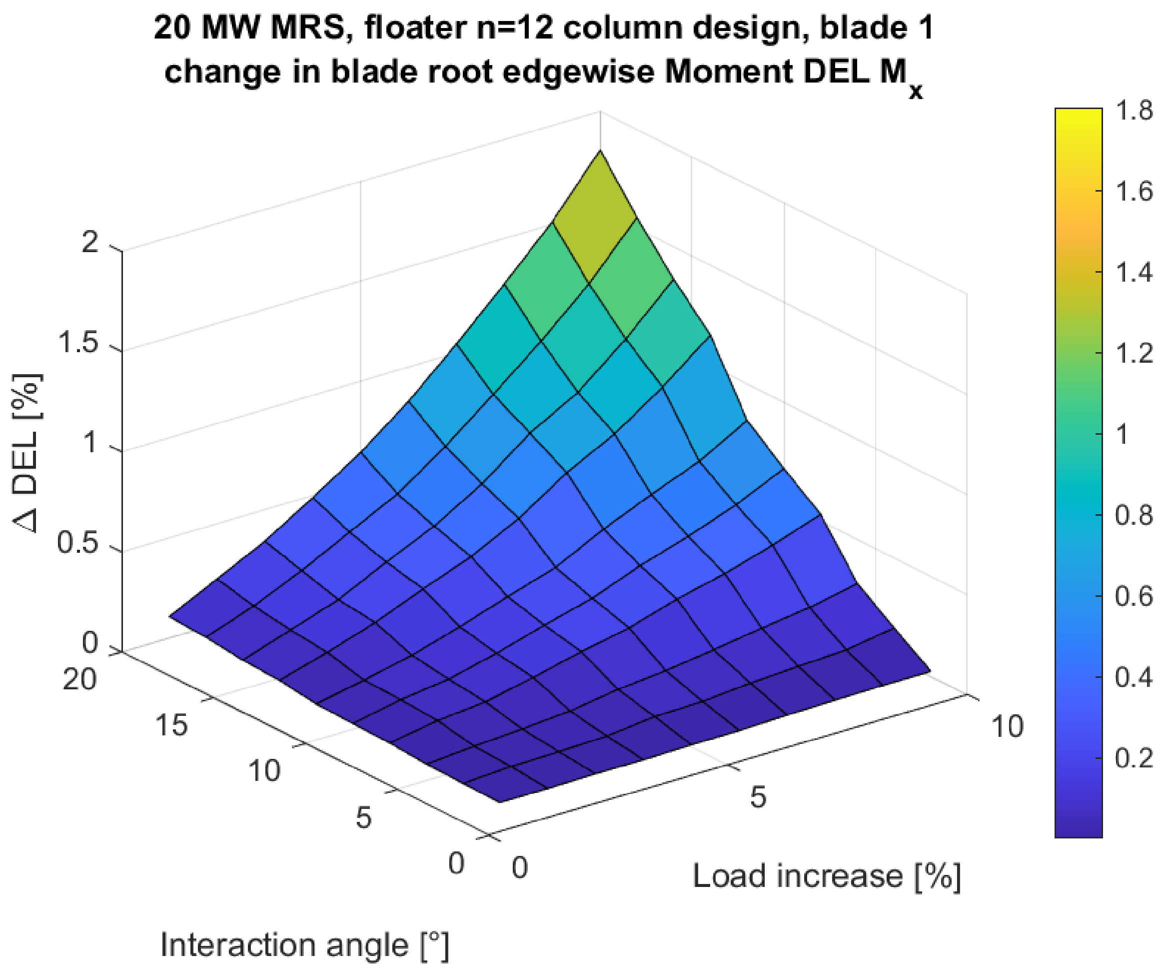
MRS rotor interactions

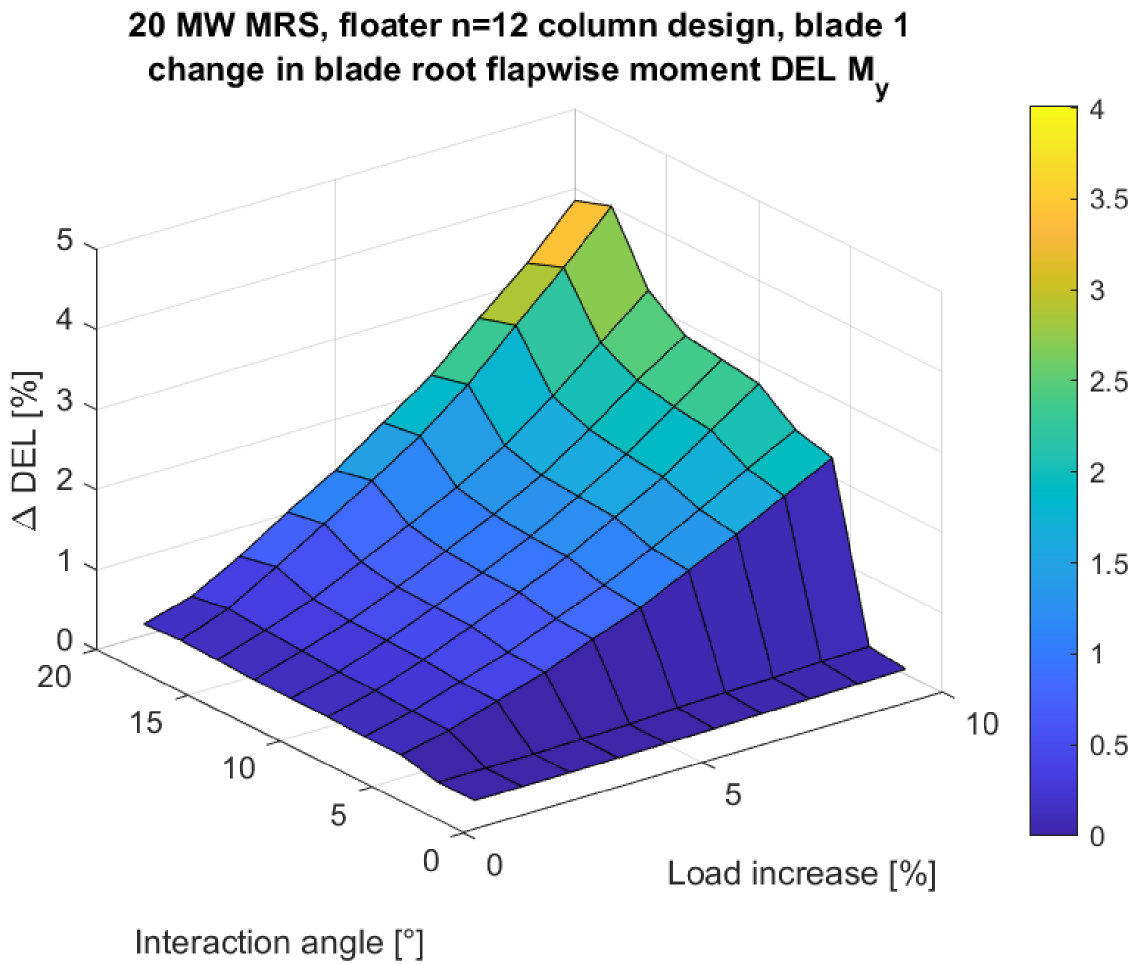
Rotor-rotor interaction, animation (not in real-time) based on BEM simulation



MRS rotor interactions

Rotor-rotor interaction, parameter study





Coming soon

- Next set of fatigue results
- Fatigue results of refined space frame concepts
- Proper investigation of rotor-structure interaction with fatigue dimensioned space frame members (only arbitrary diameters so far)
- Fine-tuning of rotor-rotor interaction (increase of loads) based on external, published CFD (Computational fluid dynamics) simulations

Thank you.

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