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A procedure to redesign a comparable blade structure of a two-bladed turbine based on a three-bladed reference

Marcel Schütt[1], Fabian Anstock[1] and Vera Schorbach[1]

[1]Hamburg University of Applied Sciences (HAW Hamburg)

EERA DeepWind Conference 2021

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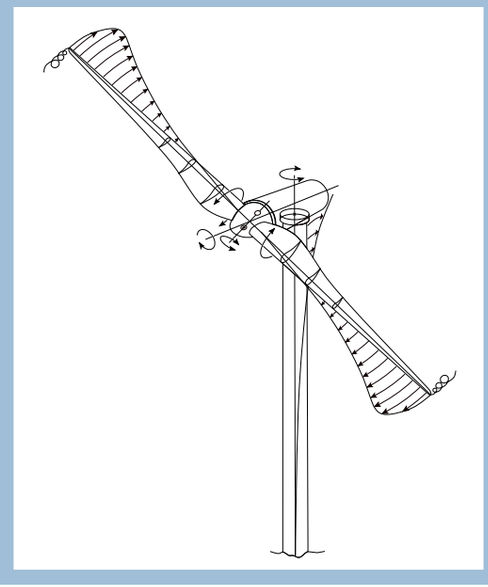
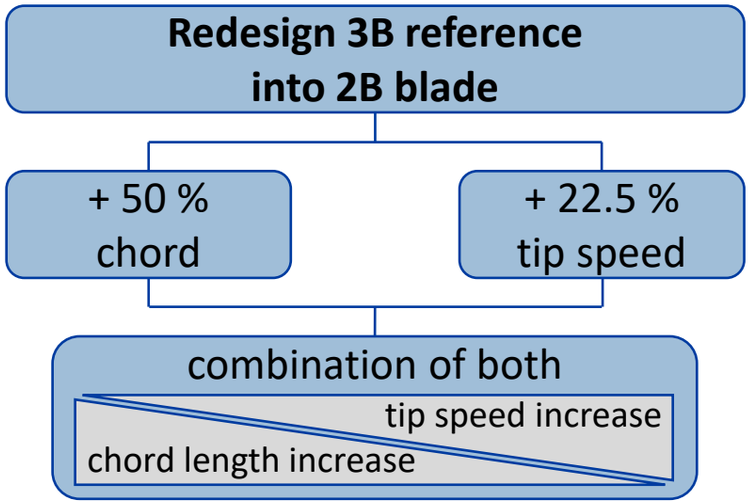


The challenge of comparing the blade structure of 2- and 3-bladed turbines

The simplified aerodynamic redesign philosophies:



The relative blade structure does not change during the redesign!

The impact of the chosen philosophy on the structural characteristics:

- Increased chord: More beneficial for the blade structure due to improvements in blade stiffness (higher second moment of area)
  - Overproport. thinner material thickn. → Higher rotor mass savings → Lower buckling resistance
- Increased tip speed: Less beneficial for the blade structure (but offers other cost benefits, e.g. in the drive train)
  - Not such reduced material thickn. → Higher buckling resistance → Lower rotor mass savings

Conflict of interest between prevent buckling and saving rotor mass!

Approach to overcome the challenge: One tip speed should results in the same buckling stability as the 3B reference → **"BREAK-EVEN-POINT"**

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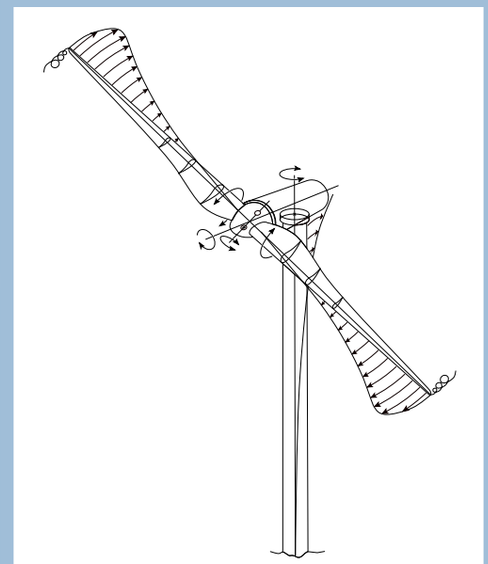


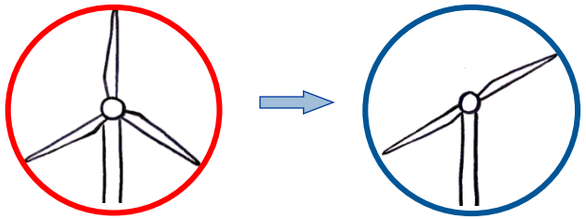
The procedure to detect the “break-even-point”

1. Choose tip speed

- Initial tip speed of the two-bladed turbine’s blade (e.g. 100 m/s)

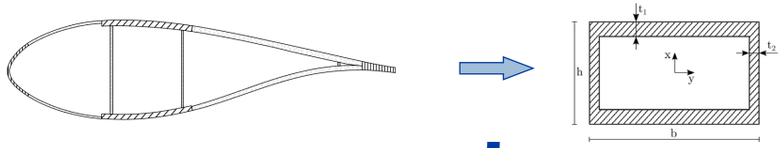
2. Aerodynamic redesign

- Convert a 3B reference blade into a 2B one by using the approach of fair comparablility[1]



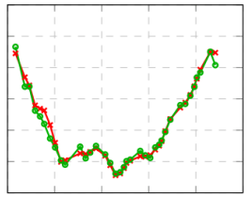
3. Structural redesign

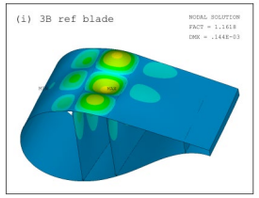
- Adapt the material thicknesses of the blade parts according to the method of progressive structural scaling[2]



4. Evaluation of the structural characteristics

- Analyze the stress distributions, the buckling load factor, and the blade weight by use of FEAs





5. Repeat procedure

- Use the procedure as iterative process

Compared on the next slides:

2B 20 MW blades with tip speeds

- 90 m/s,
- 95 m/s,
- 100 m/s,
- 105 m/s, and
- 110 m/s

➡ 3B reference: INNWIND 20 MW

[1] Anstock F., Schütt M., and Schorbach V. A new approach for comparability of two- and three-bladed 20 MW offshore wind turbines. *Journal of Physics: Conference Series*, 2019.
[2] Schütt M., Anstock F., and Schorbach V. Progressive structural scaling of a 20 MW two-bladed offshore wind turbine rotor blade examined by finite element analyses. *Journal of Physics: Conference Series*, 2020.

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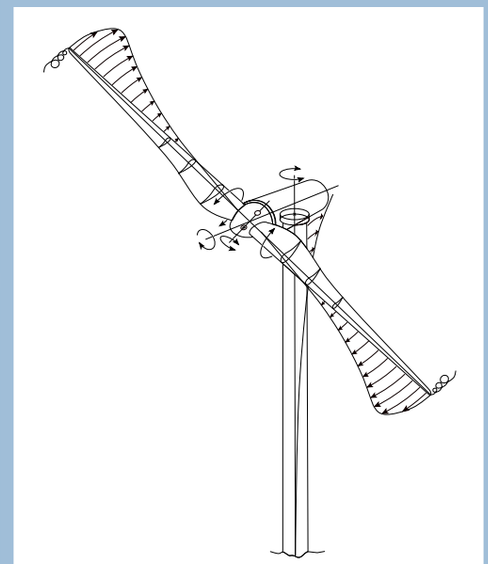
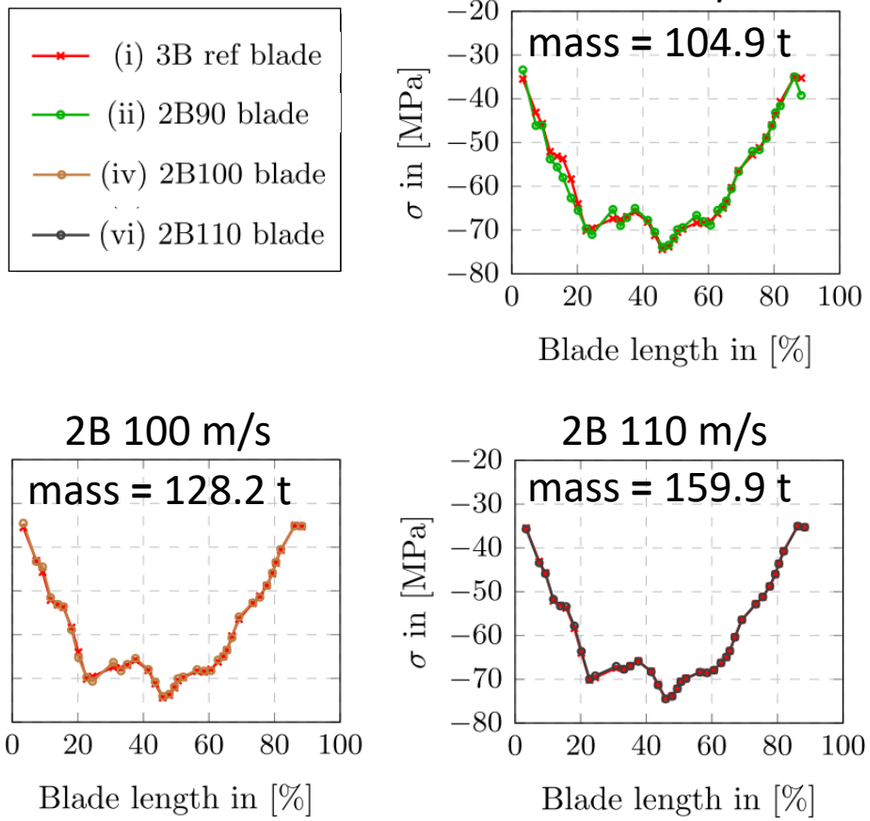
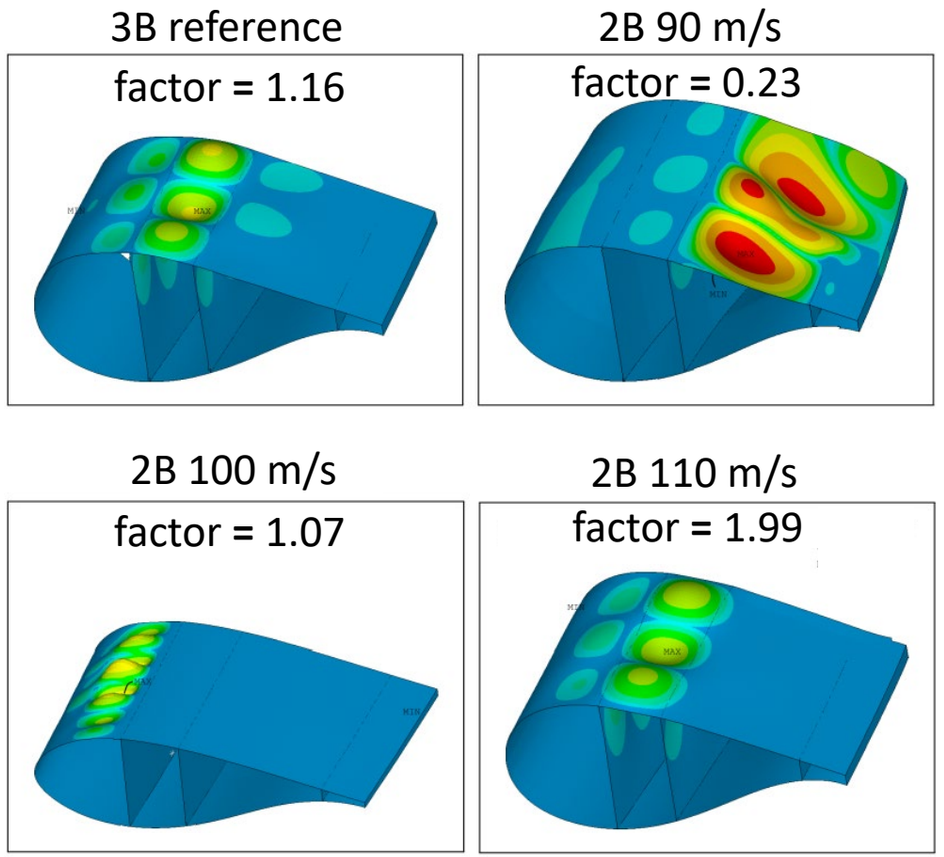


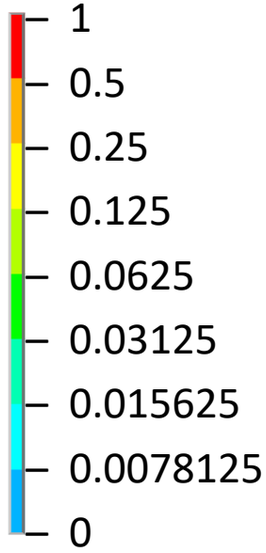
Appr. equal stresses (e.g. at spar caps)



But different buckling load factors



Deflection in [mm]



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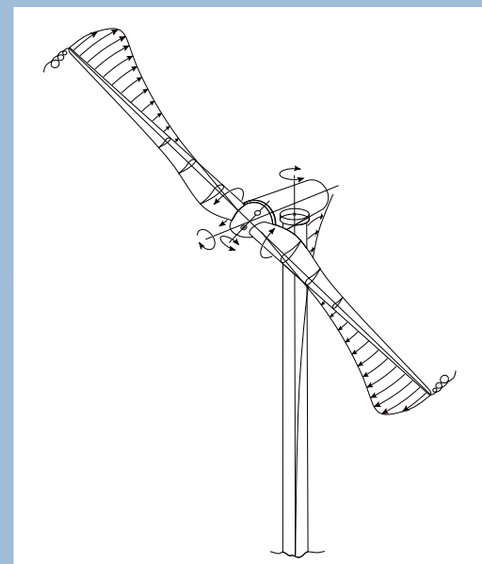
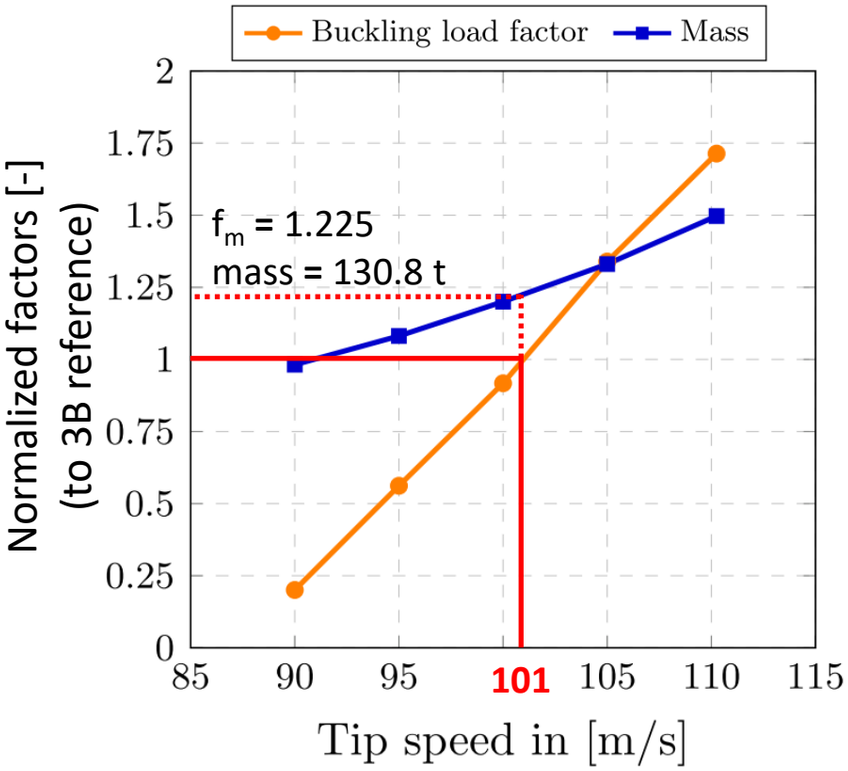


The “break-even-point”

Comparison of all buckling load factors and masses in one diagram:



Conclusion

- ✓ The “break-even-point” blade provides appr. the same stress distribution and appr. the same buckling resistance
- ✓ The redesigned “break-even-point” 2B turbine’s blade enables a fair comparison with the 3B reference, concerning
  - ✓ the blades’ aerodynamics,
  - ✓ the blades’ loads, and finally
  - ✓ the blades’ structures.
- ✓ The procedure can be easily repeated for any other turbine and blade size, for which a fair comparison of 2B and 3B turbine blades should be investigated.
- ✓ The “break-even-point” procedure detected the most beneficial combination of preventing buckling and saving rotor mass.
- ✓ This compromise outperforms both extremes of increased chord or tip speed in contrast to most descriptions in literature.

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