Light Rotor: The 10-MW reference wind turbine

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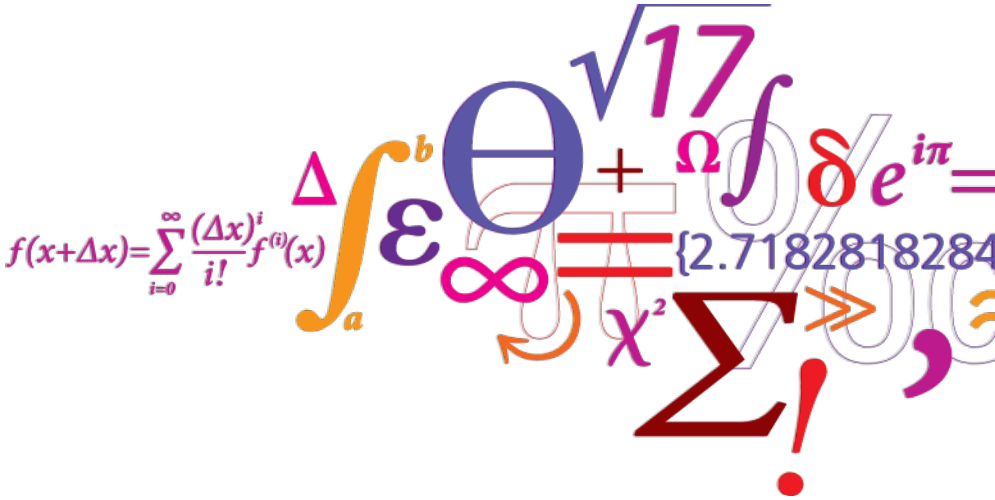

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Background

- Wind turbines and rotors are growing in size
- Several investigations have been carried out to reveal the result of upscaling
- Wind turbine mass will with direct upscaling increase with (rotor radius)^3
- The power will only increase with (rotor radius)^2

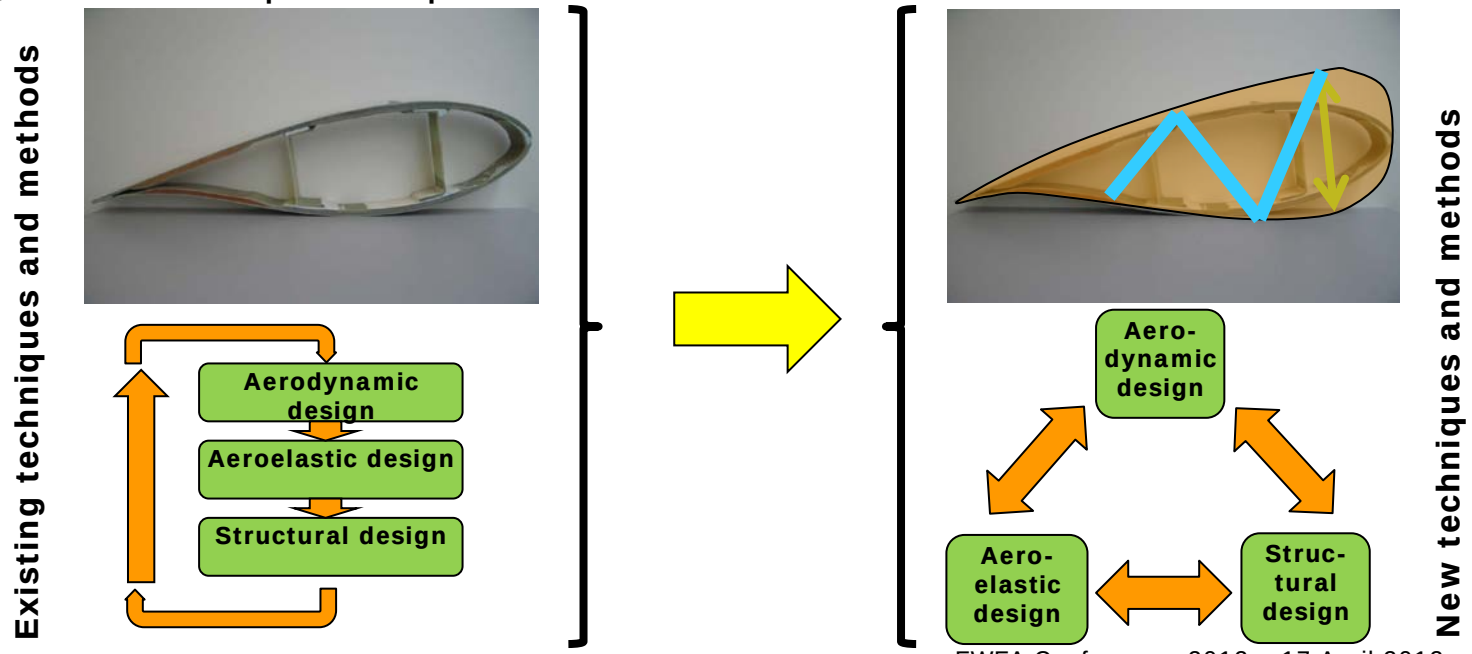
- The gravity will have an increasing impact on the loads

- An obvious question is therefore:
  - How should the ***power of 3*** **for the wind turbine mass** be reduced in the process of upscaling?
  - More specifically: How should the ***power of 3*** **for the blade mass** be reduced?

- That is the reason for establishing a project to investigate this issue.

Background

- The ”Light Rotor” project is a cooperation between DTU Wind Energy and Vestas
- The objective is to develop the basis for design of wind turbine blades for use on 10MW rotors with lower weight, tailored aeroelastic response and optimized aerodynamic efficiency.
- This will be achieved by developing and applying a combination of thick airfoils, blade sweep and optimized structure



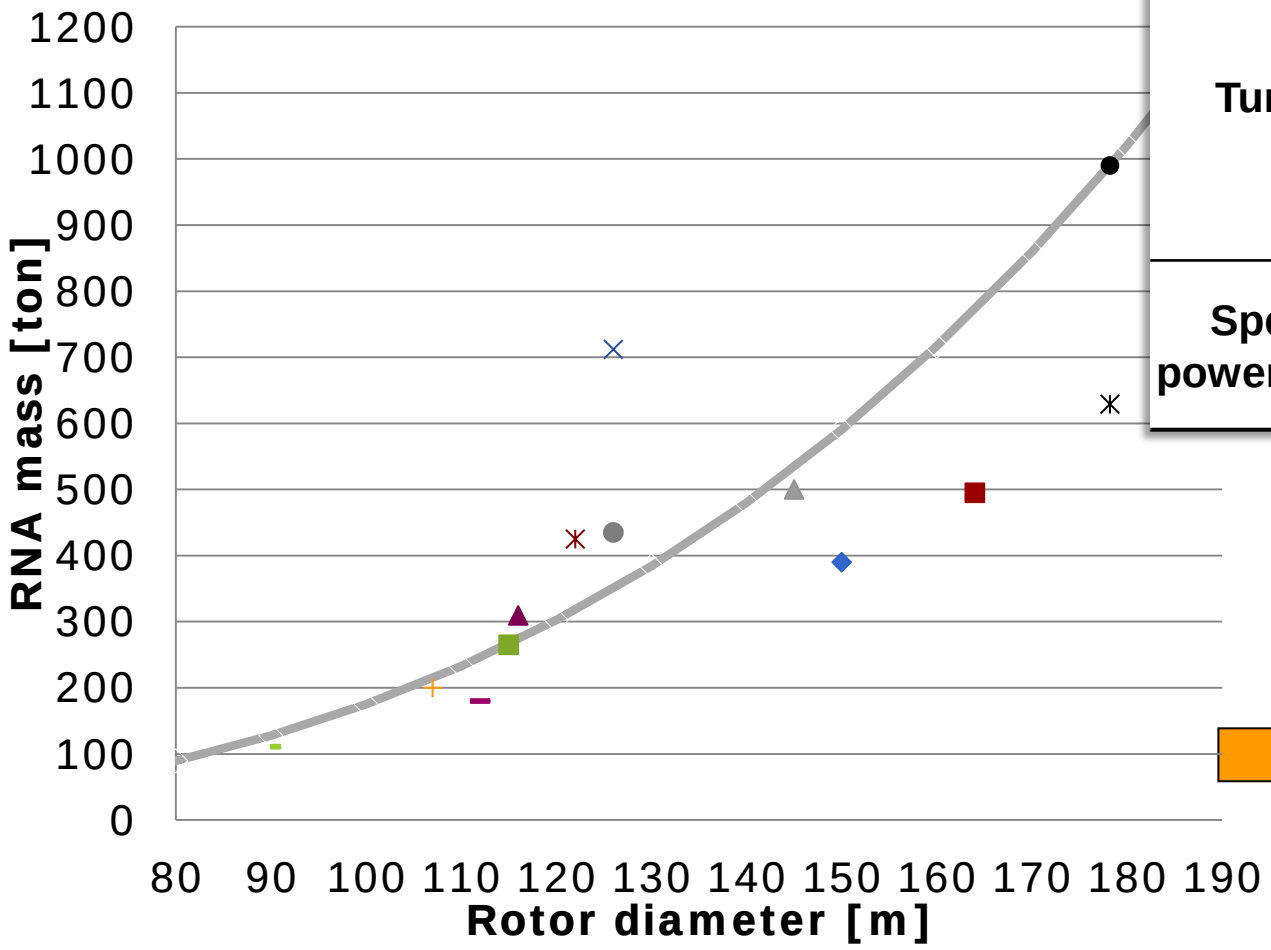
This presentation

- This presentation is about the development of a 10MW reference wind turbine, where future ”light weight” designs can be compared
- This 10MW reference wind turbine is not expected to be an exceptional light weight construction, but rather a fair upscaling of an existing wind turbine
- The presented turbine is iteration #2 in the design process and not the final design

Outline

- Basic considerations
- The method
- Results from the LR10-MW turbine
  - Aerodynamic design
  - Structural design
  - Aeroelastic stability
  - Loads
- Conclusions

Basic considerations

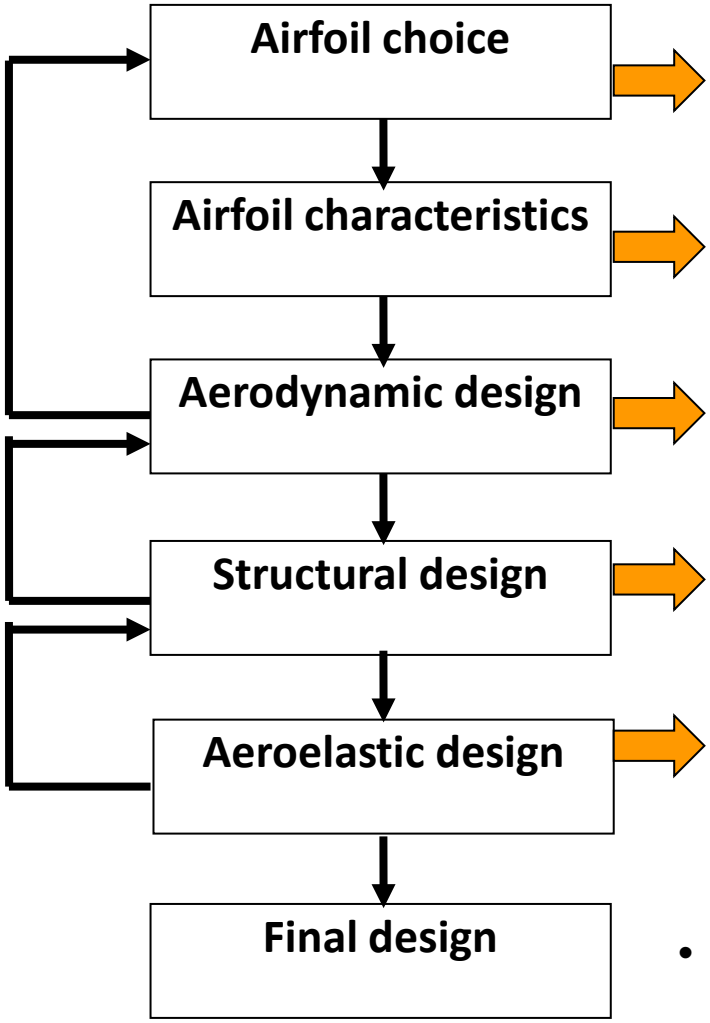


Turbine	V90-3.0MW	V112-3.0MW	V164-7.0MW	Artificial 5MW reference
Specific power [W/m^2]	472	305	331	407

$R = 89.17\,m$

$RNA\ mass = 629\,tons$

The method



FFA-W3-xxx airfoils. 24.1% to 36.0% relative thickness, 60% airfoil scaled from FFA-W3-360 and cylinder.

XFOIL computations at *Re* 9×10^6 to 13×10^6 3D corrected

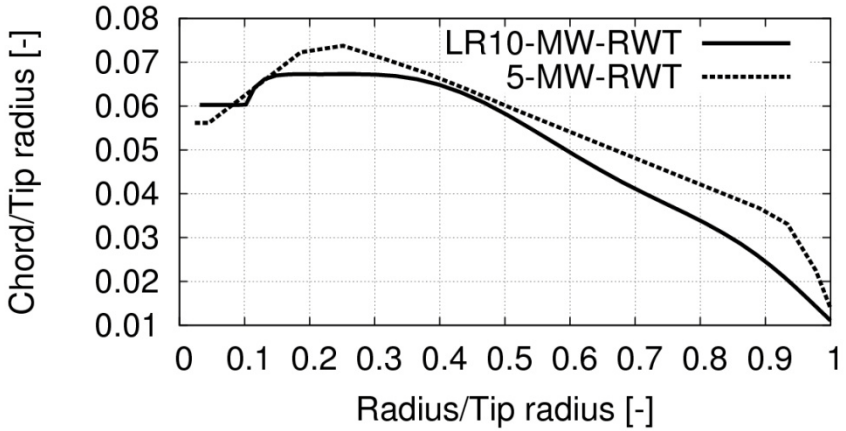
HAWTOPT numerical optimizations. Max tip speed = 80m/s, λ=8.06, min relative airfoil thickness = 24.1%

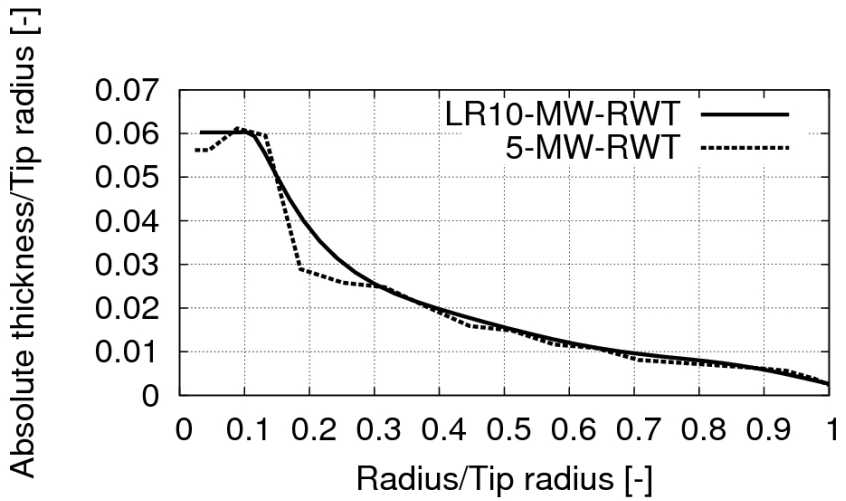
ABAQUS (6.11) FEM computations. Uniaxial, biaxial and triaxial laminates were used together with PVC foam as sandwich core material

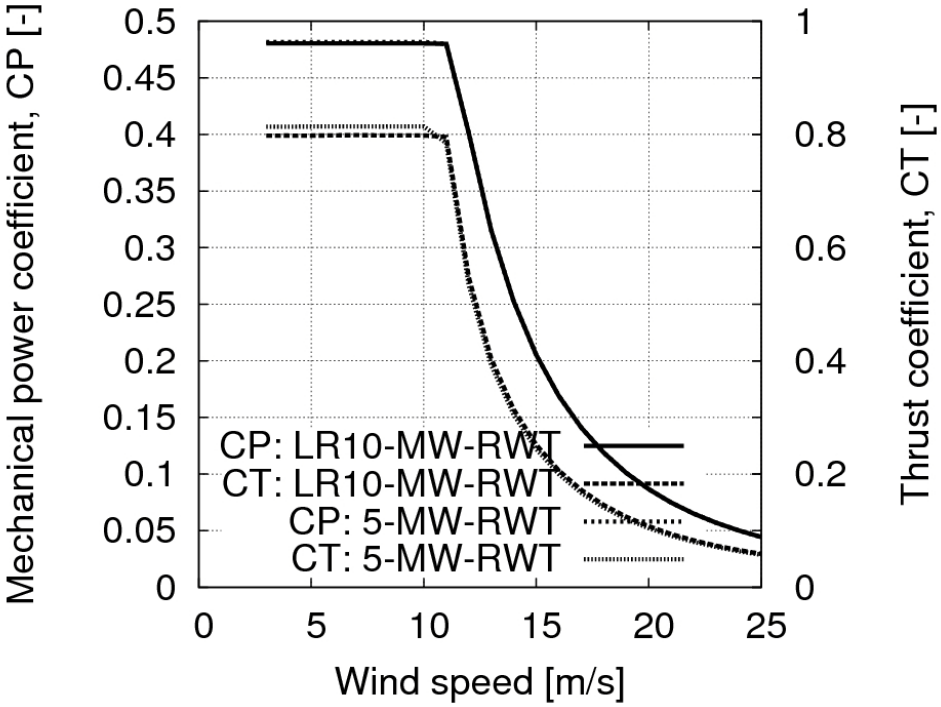
HAWCSTAB2 (aero-servo-elastic stability tool) and HAWC2 (aeroelastic code) computations. Class IA according to IEC-61400-1 standard for offshore application

- **Iteration #2 is presented**

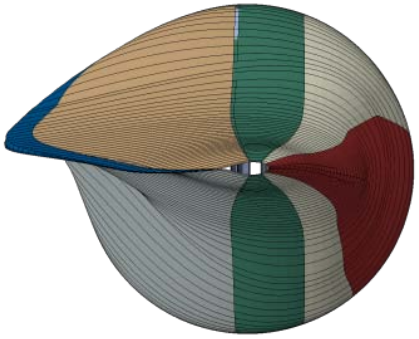
The LR10-MW turbine: Aerodynamic design HAWTOPT



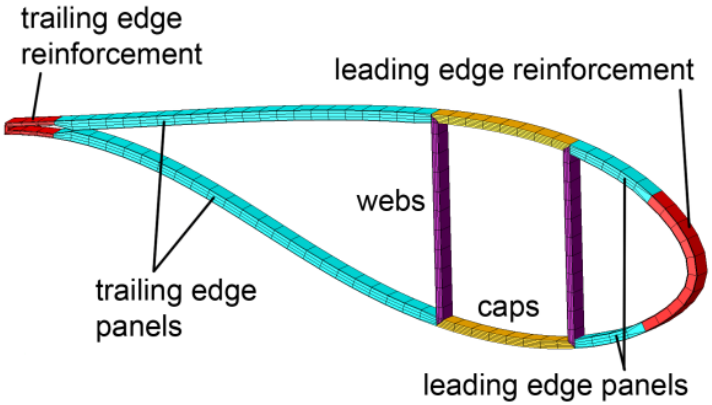


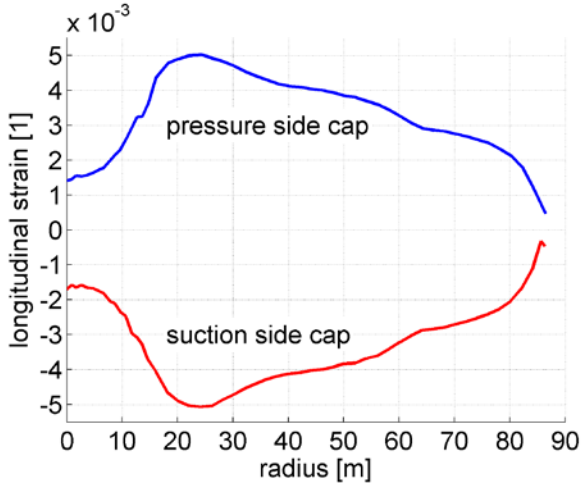


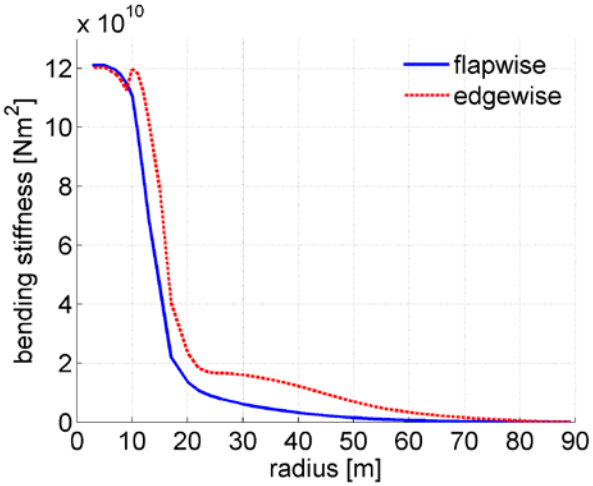
The LR10-MW turbine: Structural blade design ABAQUS



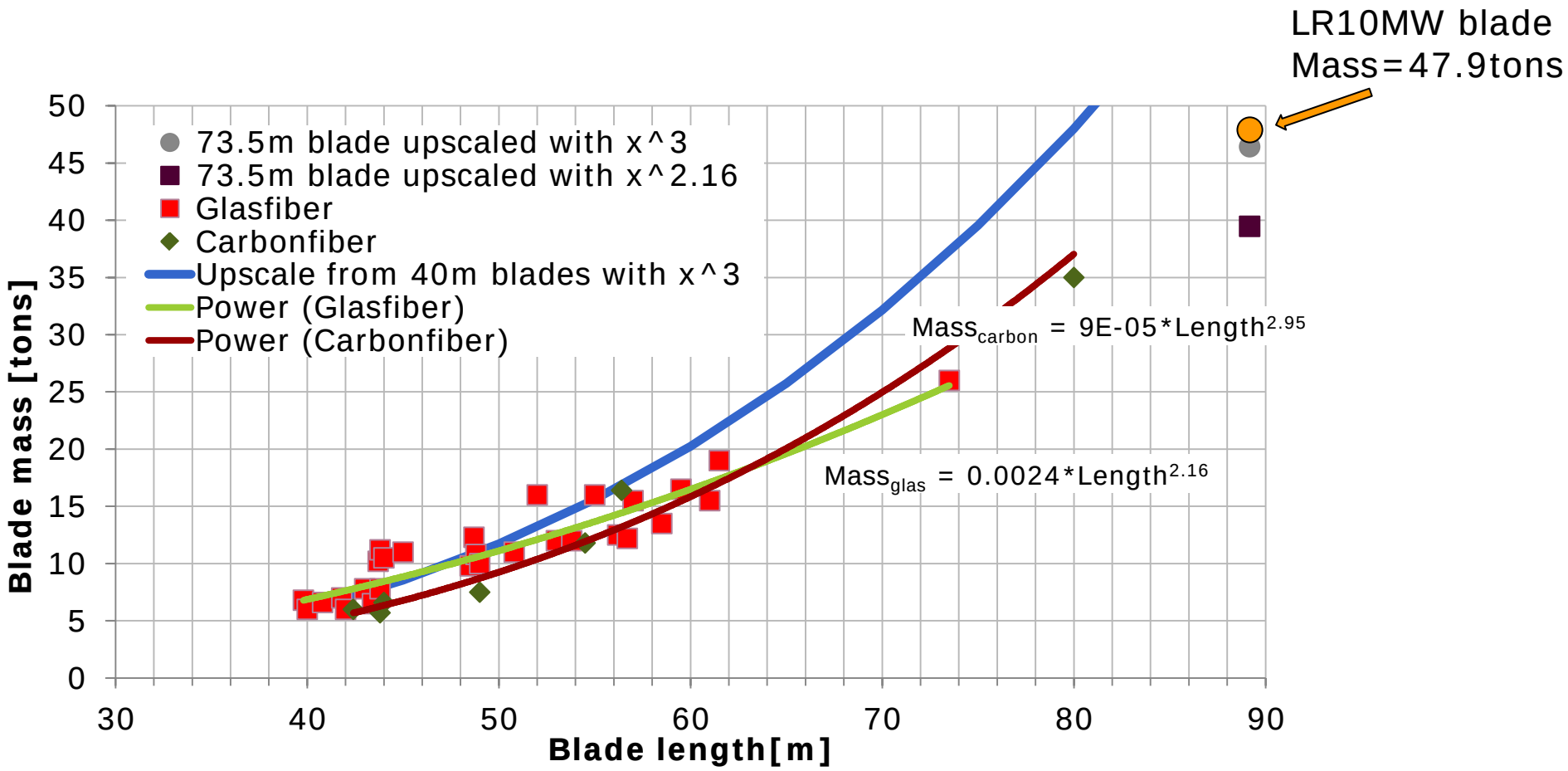
Mode Number	*Frequency [Hz]*	*Remark*
1	0.5210	First flapwise
2	0.8820	First edgewise
3	1.6142	Second flapw.
4	2.8173	Second edgew.
5	3.4027	Third flapwise
6	5.0342	First torsional



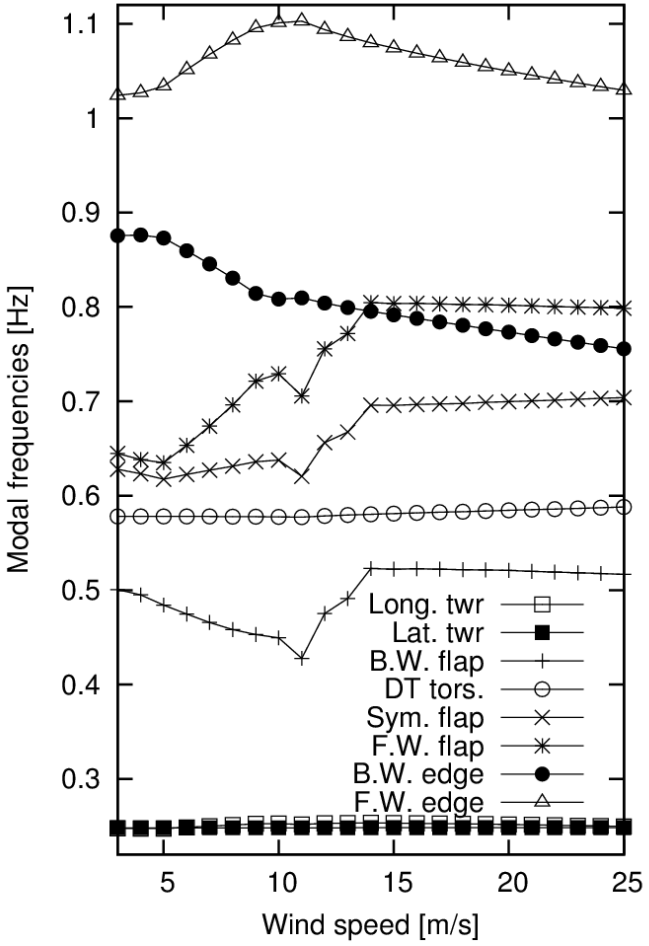


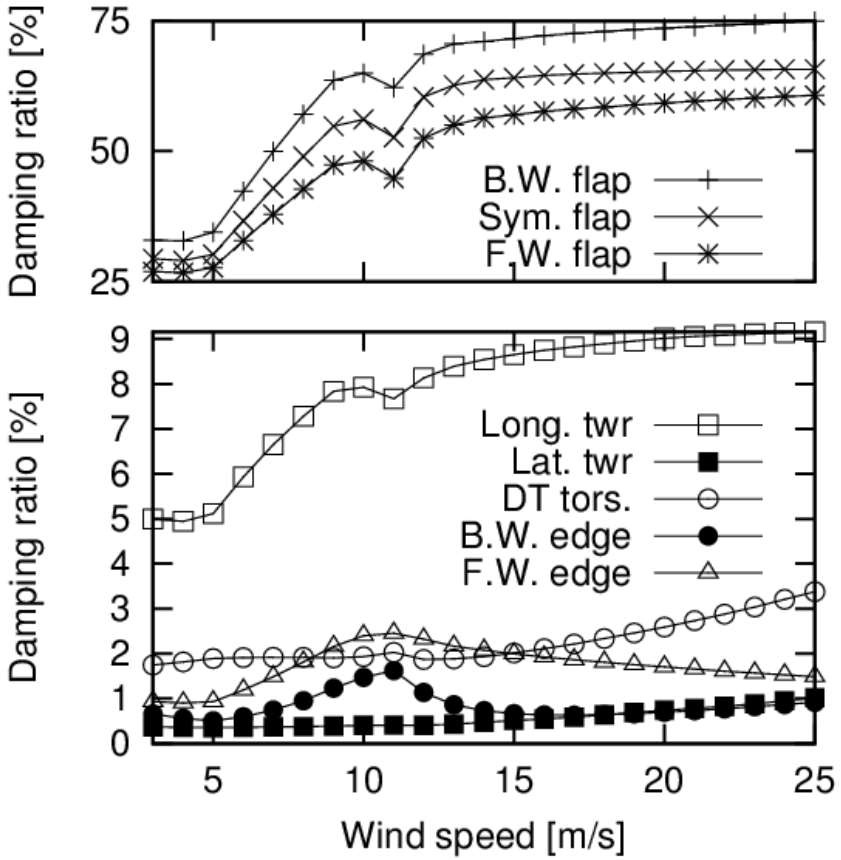


The LR10-MW turbine: Blade mass

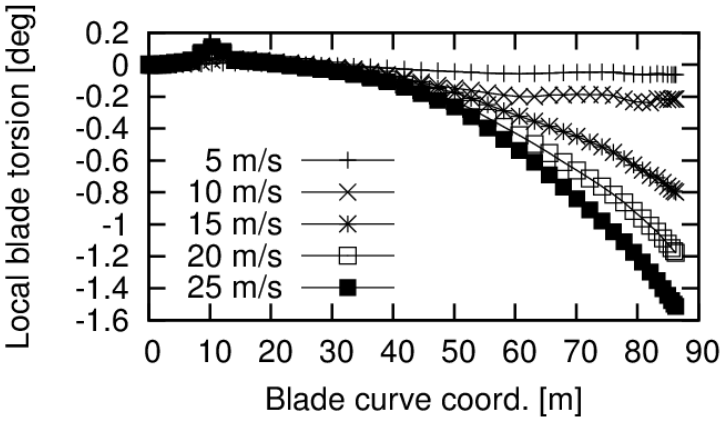


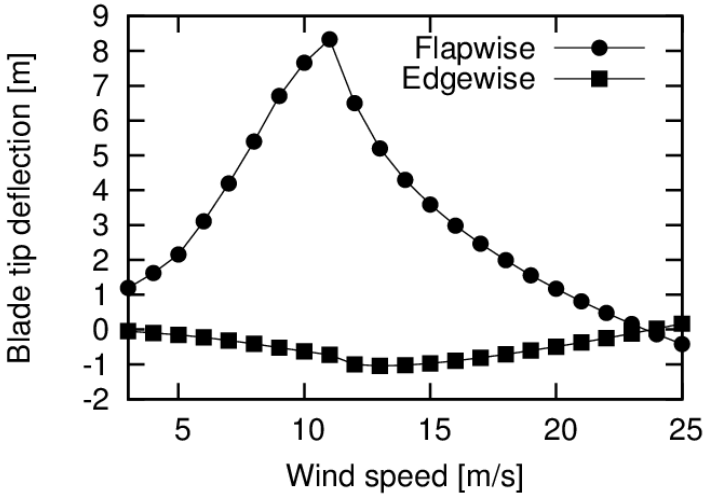
The LR10-MW turbine: Aeroelastic stability HAWCSTAB2

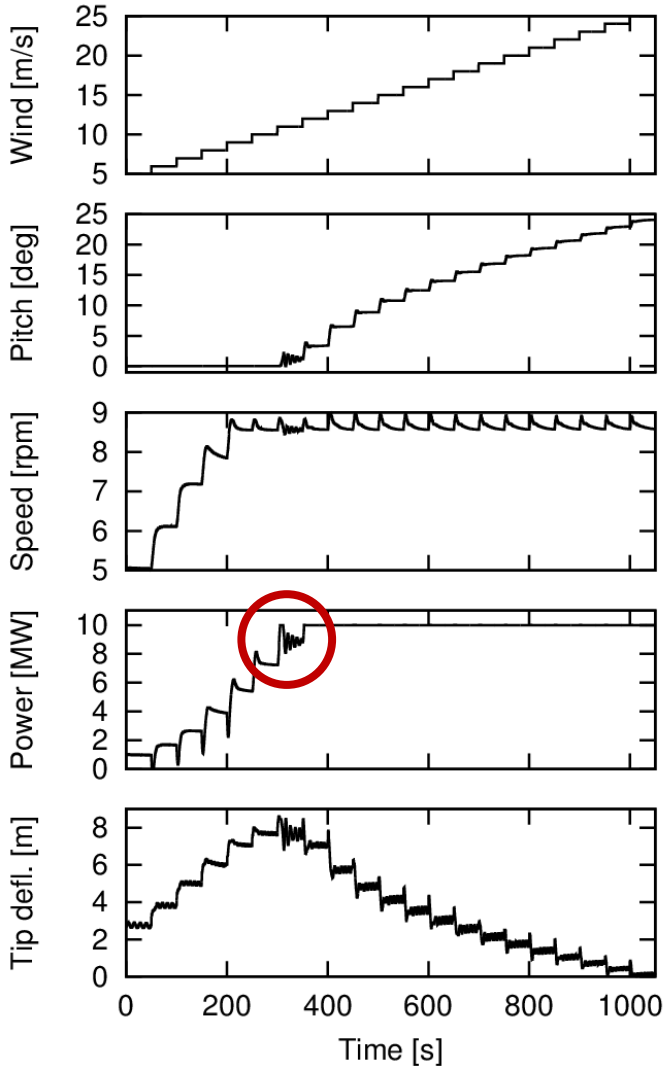




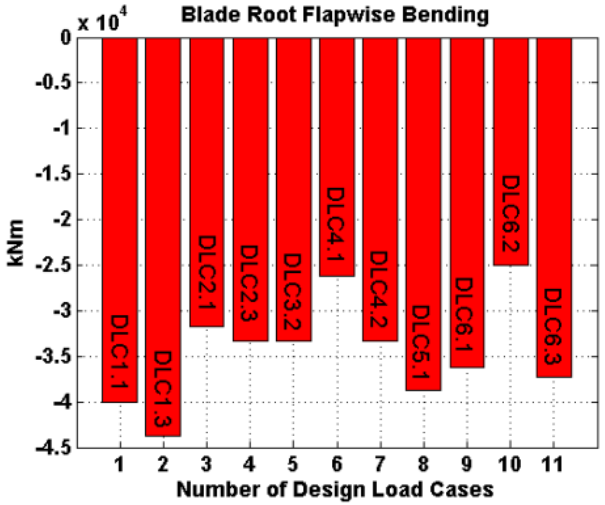
The LR10-MW turbine: Aeroelastic stability HAWCSTAB2

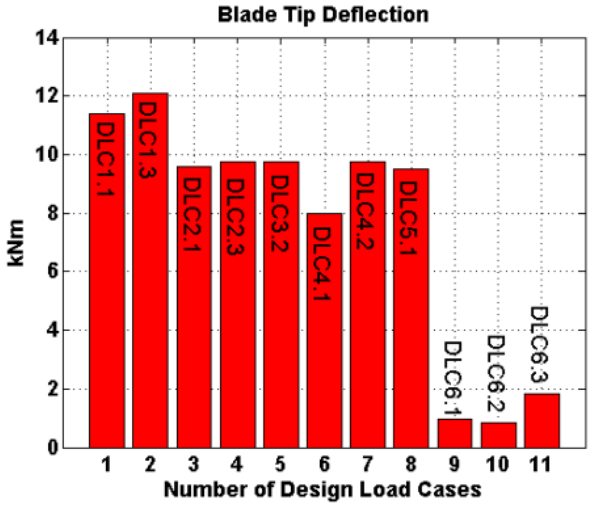


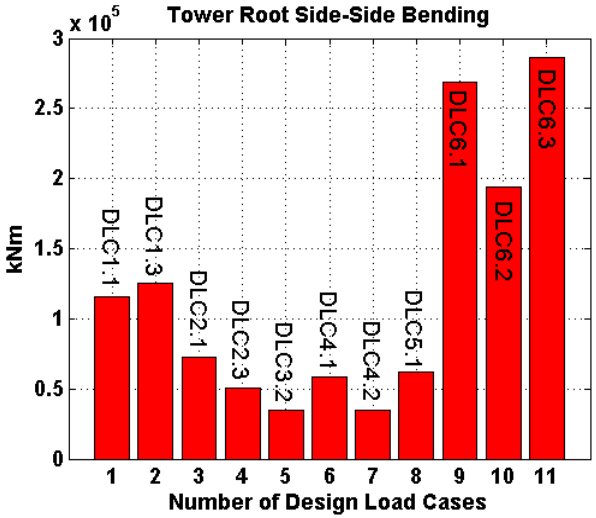


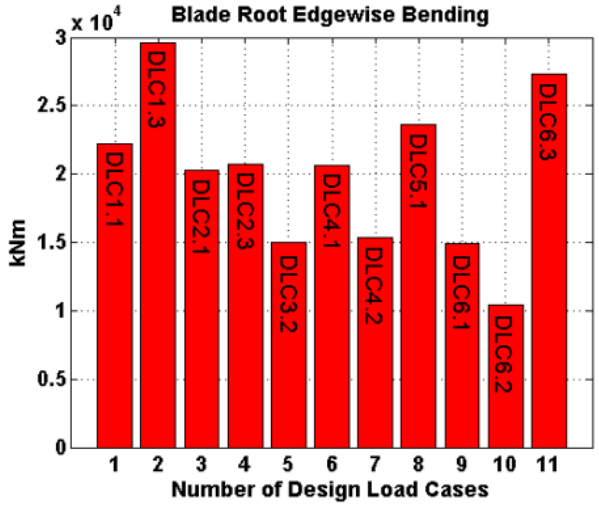


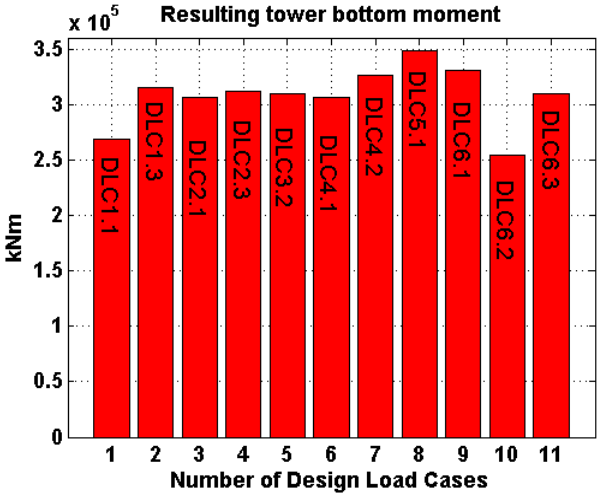
The LR10-MW turbine: Loads HAWC2

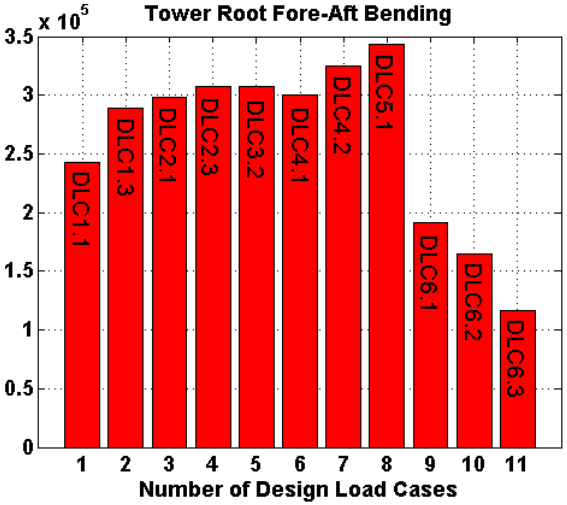












Conclusions

- A rotor and a wind turbine for a 10-MW wind turbine are designed with the shown results for Iteration #2 in the design process.
- The design process will need more iterations between aerodynamic, structural and aeroelastic design.
- It is of primary importance to design the rotor together with the entire system: Foundation, tower, drivetrain and rotor.
- Several issues were highlighted:
  - Selecting the specific power is not trivial. For this rotor it was chosen to maintain the specific power of the artificial 5-MW wind turbine.
  - The mass of the *LR10-MW blade* seems to be somewhat too high compared to a blade directly upscaled from e.g. LM73.5P.
  - Estimating the drive train mass is not trivial
  - The mass of the turbine is highly depending on concepts/technology

- In the further work, the challenges in the control needs to be solved.
- Also, the balance between power performance, loads and structural layout will be investigated further resulting in changes in the present design.

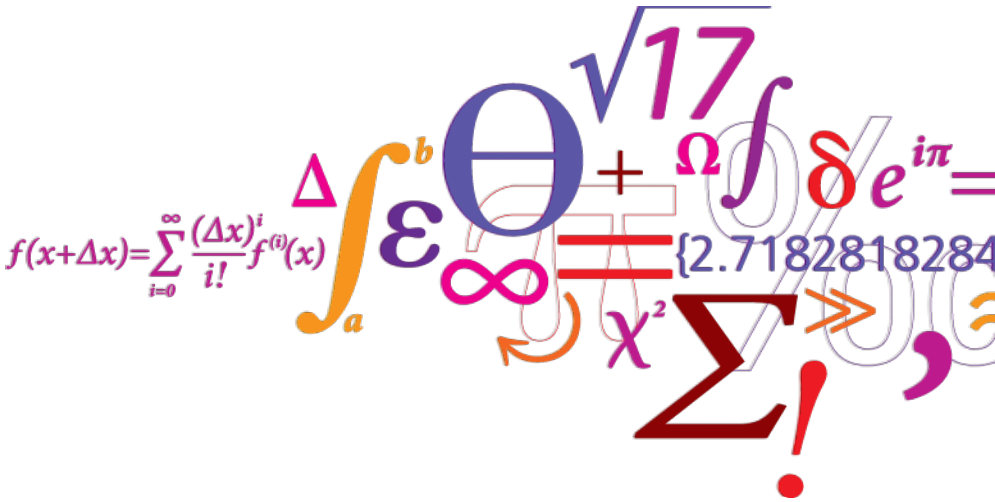
Availability

- The final design incl. aeroelastic model and blade layout will be available on:
  - **www.vindenergi.dtu.dk**
  - under the menu *Research*
  - from **July 1, 2012**

Acknowledgements

- Thanks to the ***Danish Energy Agency*** for partly funding the **EUDP 2010-1 Light Rotor project**

Thank you for the attention!



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