Aerostructural Design Study for a 100 kW Rotor

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Background

- DTU Wind Energy has throughout many years developed software dedicated to analysis of wind turbines at many levels of fidelity.
- Many of these tools are now well consolidated, validated, and used in industry.
- Development of multidisciplinary design tools began in the late 1990s and resulted in the HAWTOpt framework.

This talk

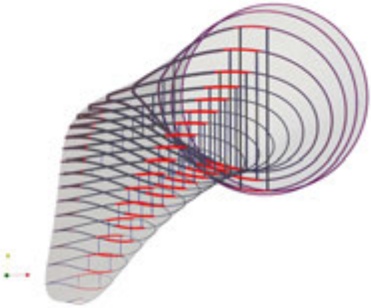
- Overview of the aerostructural design tool HAWTOpt2: the choices made for that tool.
- Show an example application of this tool: Aerostructural design of a 100 kW rotor.

Choices

- A central decision for the development of the HAWTOpt2 framework was to use the existing tools available.
- The existing aeroelastic tools provide us with a powerful basis for developing advanced aerostructural designs.
- We wanted the the underlying optimization framework to be open and possible to modify and extend.
- We chose to program it in Python and to use OpenMDAO to define workflows and interface to optimizers.

HawtOpt2: Tool for Aero-servo-elastic Optimization of Wind Turbines

- Geometric parameterisation using splines,
- HAWCStab2/HAWC2 interface:
  - AEP,
  - Frequency placement,
  - Fatigue in frequency domain,
  - Reduced DLB in time domain,
- BECAS interface:
  - Calculation of structural properties,
  - Calculation of material stresses and fatigue.



Multidisciplinary Design Framework
Aerostructural Optimization Workflow Diagram

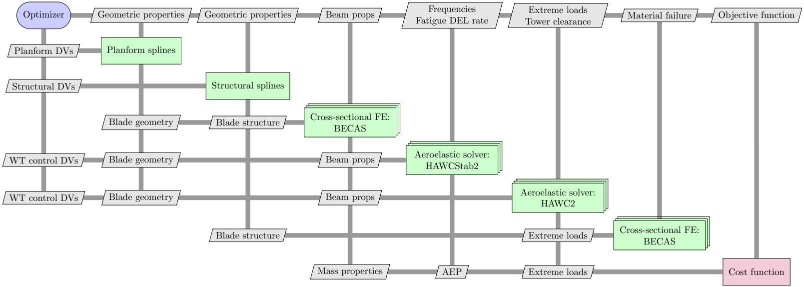


Figure: Extended Design Structure Matrix diagram of the workflow of HawtOpt2.

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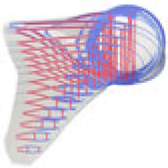
100 kW Rotor Design Study

Objective

- Exploration of aerostructurally tailored blade designs applied to a 100 kW sized turbine.
- Design of a new rotor for an existing platform that maximized energy production.
- Design variables include blade planform and detailed internal structural layup,
- Constraints on loads based on original rotor and platform.

Three Design Tracks

- Straight blade - no torsion
- Blade with sweep,
- Blade with material couplings.



100 kW Rotor Design Study
Design Summary

Quantity	KB1	KB2	Diff.	KB3	Diff.
AEP [kWh] (C=7, k=2)	405.1	412.5	1.018	408.9	1.009
Blade length [m]	11.064	11.35	1.026	11.231	1.015
Blade mass [kg]	256.87	257.14	0.999	256.85	0.999
TSR [-]	10.084	10.625	1.054	9.779	0.970

Table: Summary of overall properties of the three blade designs.

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100 kW Rotor Design Study
Blade planform

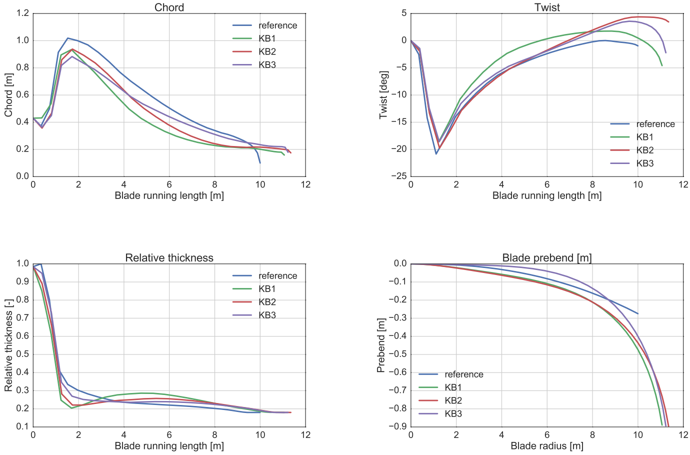


Figure: Blade planform for the three designs.

100 kW Rotor Design Study
Blade planform

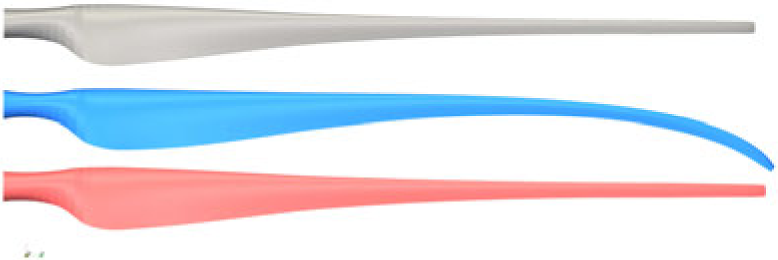


Figure: Blade planforms of KB1, KB2 and KB3.

100 kW Rotor Design Study
Design Performances

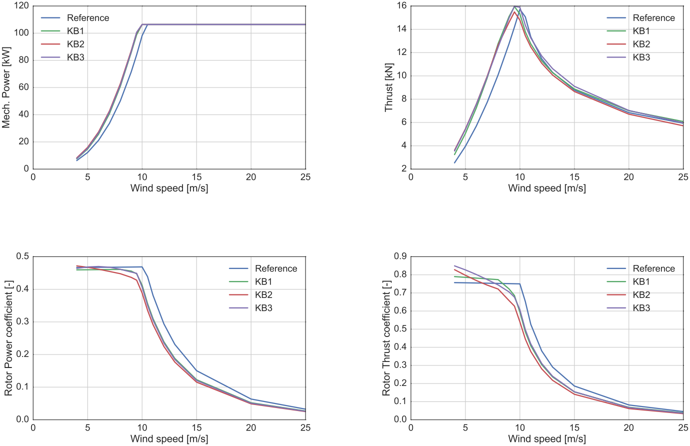
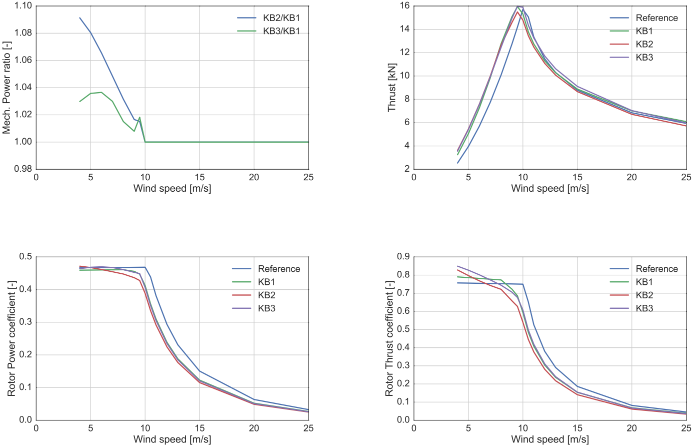


Figure: Mechanical power and thrust as function of wind speed.

100 kW Rotor Design Study
Design Performances



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Design Performances

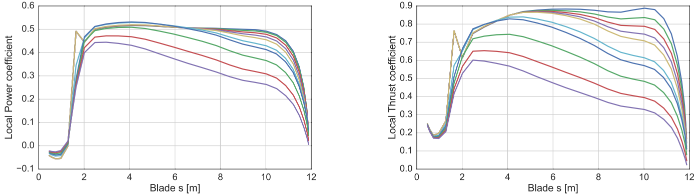

Figure: Blade spanwise load coefficients for the swept blade KB2.

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Summary

- Aerostructural wind turbine design tool HAWTOpt2 used to explore the design a 100 kW rotor,
- Systematic exploration of two passive load alleviation design directions,
- Including passive load alleviation features results in up to 2% AEP increase for this rotor.