Trailing Edge Flaps on Multi-MW Turbine Blades

European Bladed User Conference

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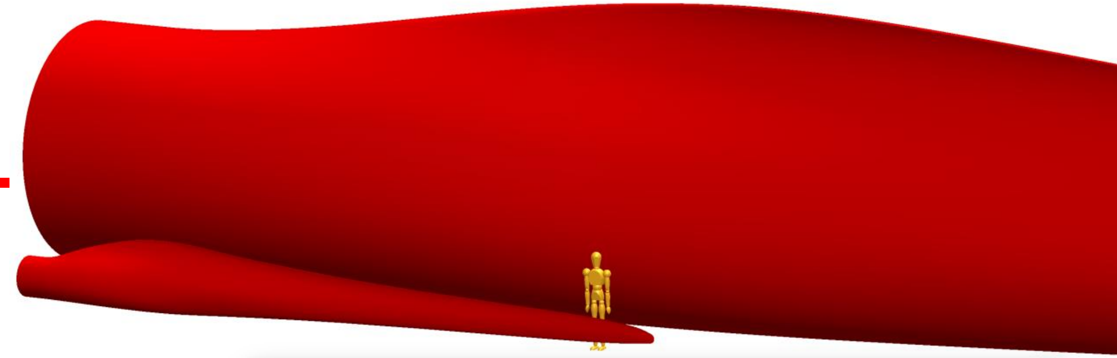
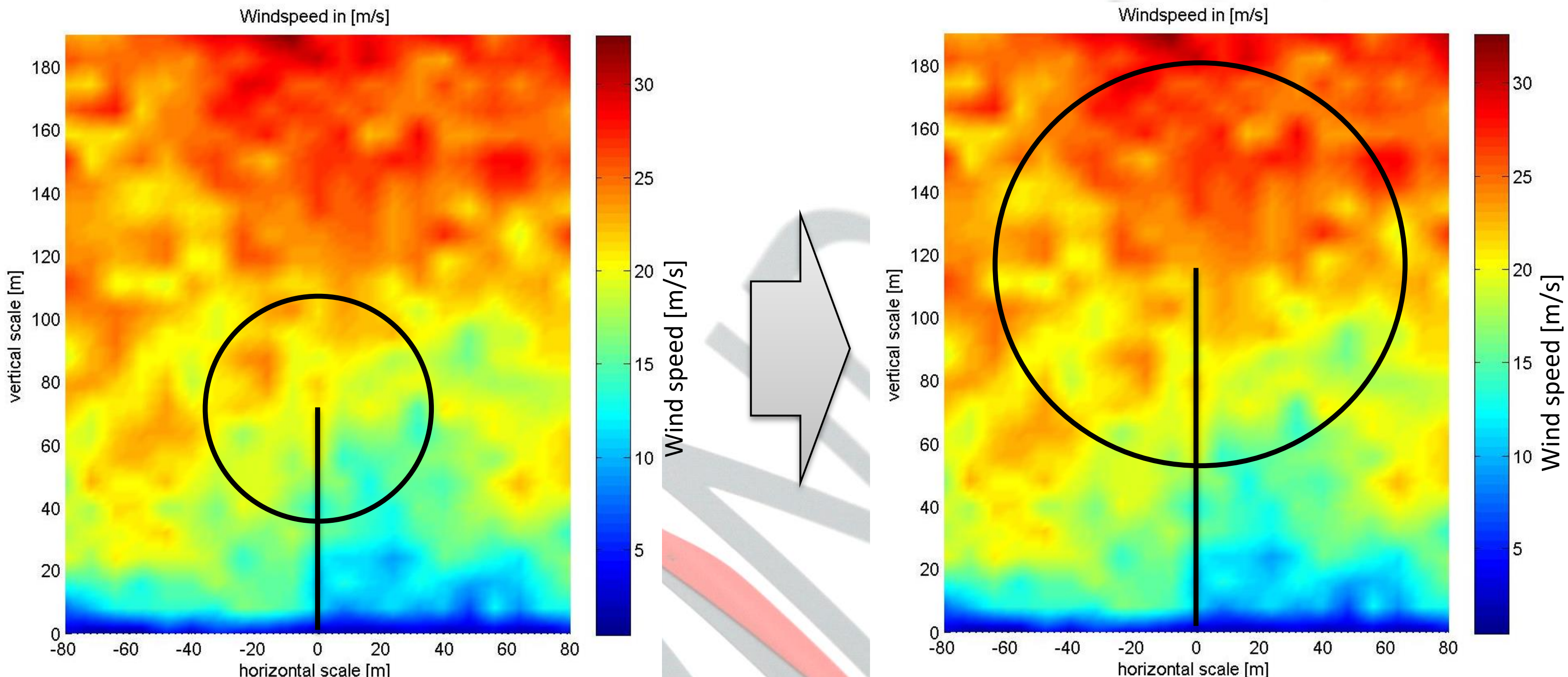
Contents

The Company



- Established in Berlin, Germany in 2007
- International team of 27 full time engineers from 6 different countries
- More than 280 projects (100 individual rotor blade designs)
- TechTrans for rotor blade manufacture (India, Korea, China, Canada, USA)
- Wind turbine component design and consulting works

Why Trailing Edge Flaps?



- Larger blades:
  - Larger spatial turbulence variation / wind shear
  - Slower pitch system
- Flaps: Fast and localized actuation => Limit deflection => Load reduction

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WIntFlap Project

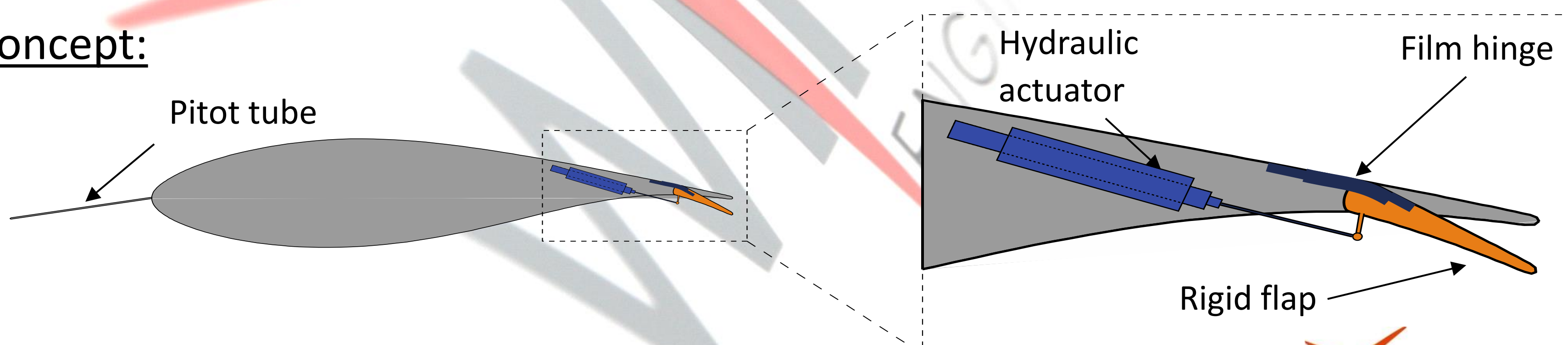
- Development of an active trailing edge flap
  - Robust
  - Easy maintenance

- Funded by the German Federal Ministry of Economic Affairs and Energy

Partners:

WINDnovation Engineering Solutions GmbH · Fluidtechnik TU Dresden · cp.max Rotortechnik

Concept:



WIntFlap Project - Tasks

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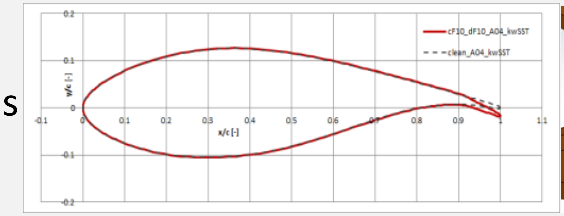
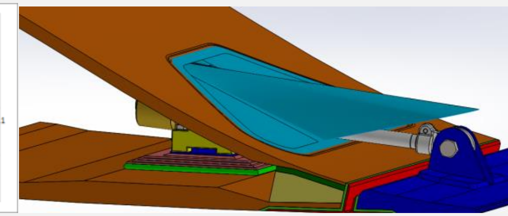
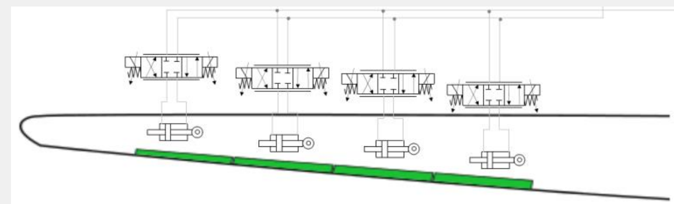
- Aerodynamics
- Controller/Loads
- Blade structure



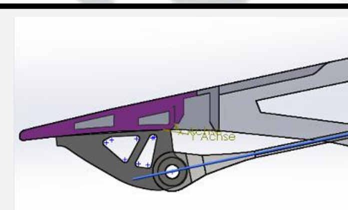


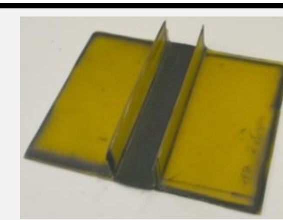
Fluidtechnik TU Dresden

- Actuation
- Lightning protection



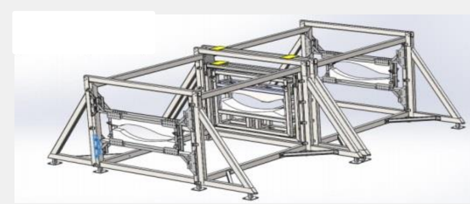
- Film hinge
- FI-element





cp.max ROTORTECHNIK

- Flap structure
- Test bench



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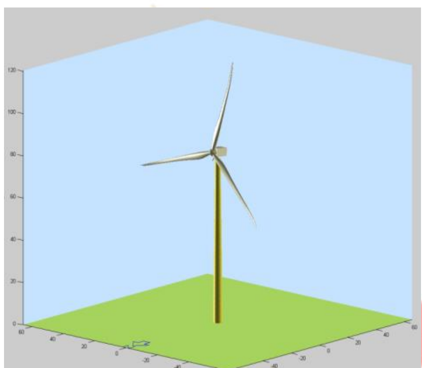
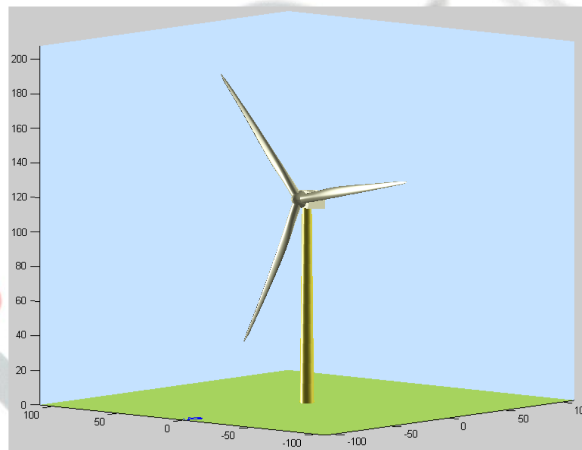
Study Flap Effects: Model Choice

- WIntFlap: Physical design and test of flap for a 1.5 MW rotor blade
- Target blades are in the multi-MW class wind turbines



Results from 1.5MW flap design



Translate into 10MW turbine model

DTU 10 MW RWT	
Wind class	IEC 1A
Rated power	10 MW
Cut in, Cut out wind speed	4 m/s, 25 m/s
Rated wind speed	11.4 m/s
Rated rotor speed	9.6 rpm
Rotor diameter	178.3 m
Hub height	119 m

Adapt turbine to include flaps:

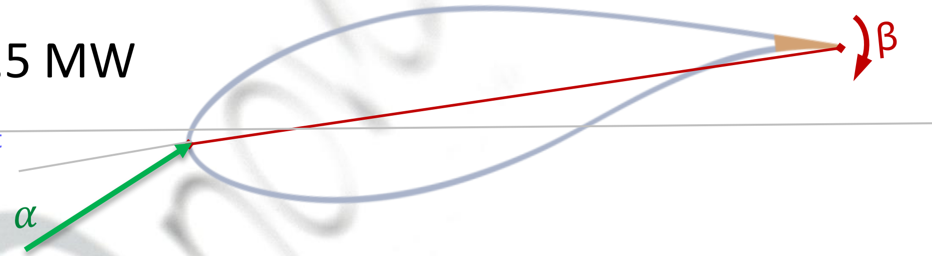
Aerodynamics

Blade structure

Controller

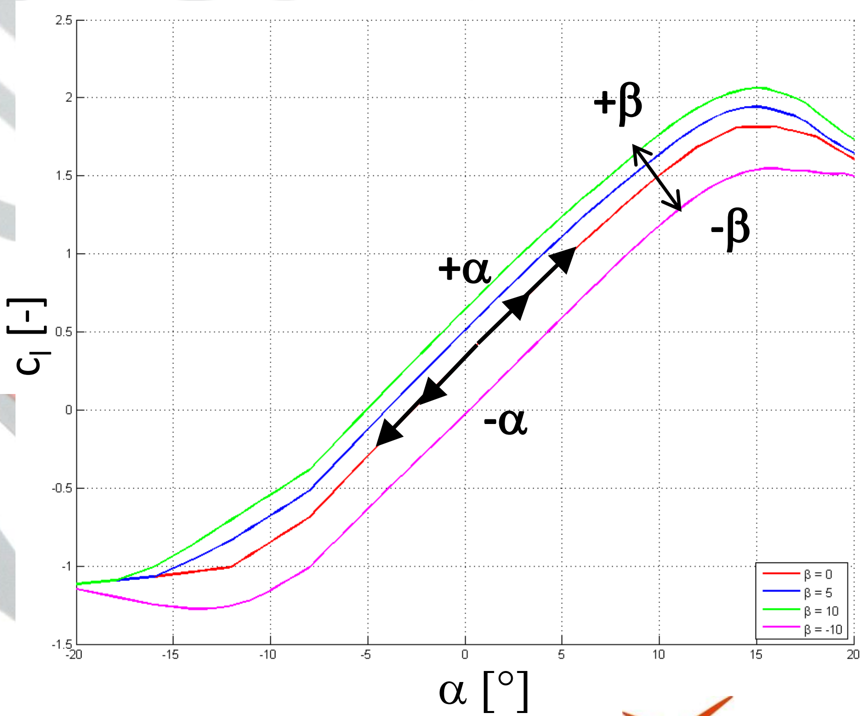
1. Aerodynamics

- Same local flap configuration as with 1.5 MW blade
  - Flap chord-wise extension: 10%
  - Flap deflection limit: ±10°



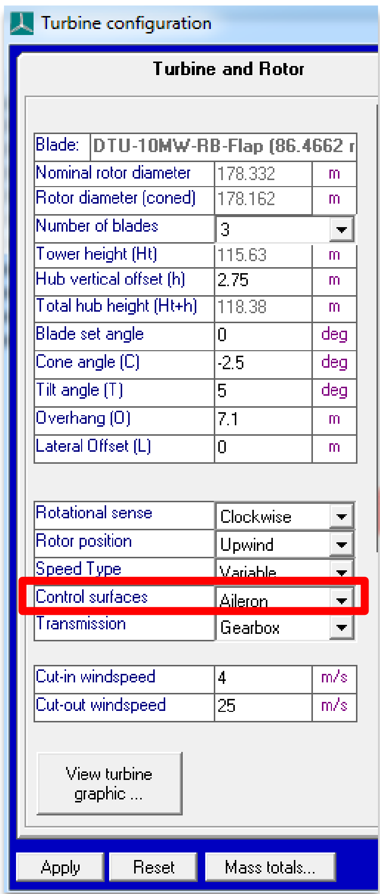
- Airfoil: FFA-W3-241

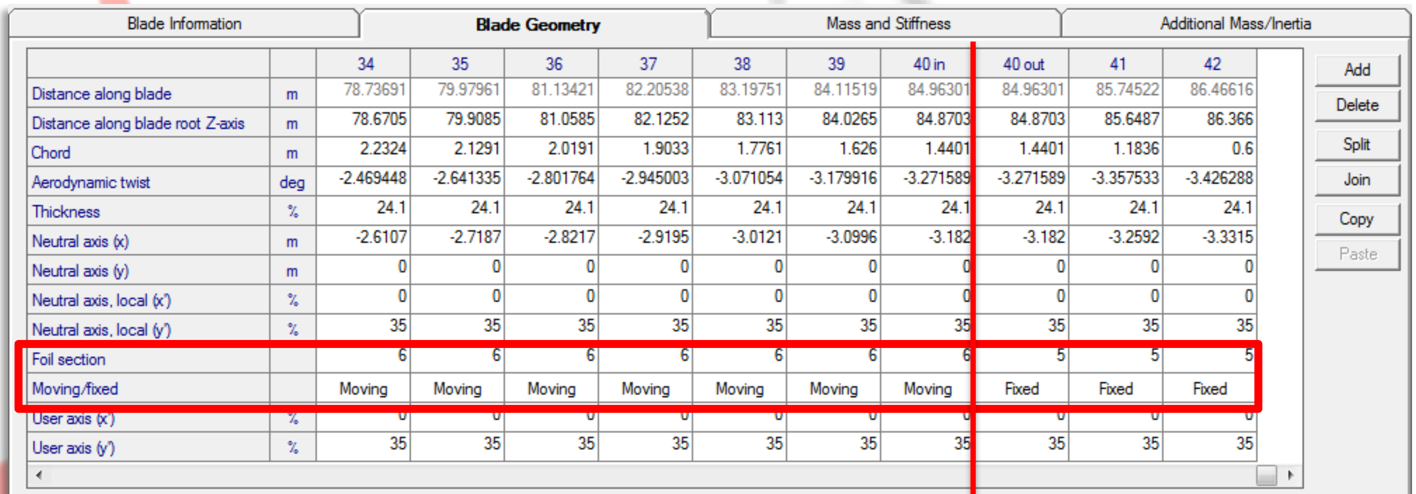
- Effect of flap deflection on airfoil characteristics via 2D-CFD calculations



1. Aerodynamics

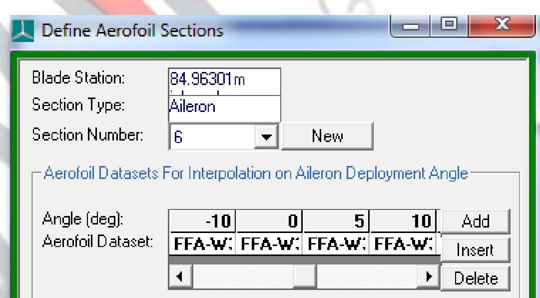
- Bladed: flaps modelled as ailerons (set of polars per deployment angle)





		34	35	36	37	38	39	40 in	40 out	41	42
Distance along blade	m	78.73691	79.97961	81.13421	82.20538	83.19751	84.11519	84.96301	84.96301	85.74522	86.46616
Distance along blade root Z-axis	m	78.6705	79.9085	81.0585	82.1252	83.113	84.0265	84.8703	84.8703	85.6487	86.366
Chord	m	2.2324	2.1291	2.0191	1.9033	1.7761	1.626	1.4401	1.4401	1.1836	0.6
Aerodynamic twist	deg	-2.469448	-2.641335	-2.801764	-2.945003	-3.071054	-3.179916	-3.271589	-3.271589	-3.357533	-3.426288
Thickness	%	24.1	24.1	24.1	24.1	24.1	24.1	24.1	24.1	24.1	24.1
Neutral axis (x)	m	-2.6107	-2.7187	-2.8217	-2.9195	-3.0121	-3.0996	-3.182	-3.182	-3.2592	-3.3315
Neutral axis (y)	m	0	0	0	0	0	0	0	0	0	0
Neutral axis, local (x')	%	0	0	0	0	0	0	0	0	0	0
Neutral axis, local (y')	%	35	35	35	35	35	35	35	35	35	35
Foil section		6	6	6	6	6	6	6	5	5	5
Moving/fixed		Moving	Moving	Moving	Moving	Moving	Moving	Moving	Fixed	Fixed	Fixed
User axis (x')	%	0	0	0	0	0	0	0	0	0	0
User axis (y')	%	35	35	35	35	35	35	35	35	35	35

Split station



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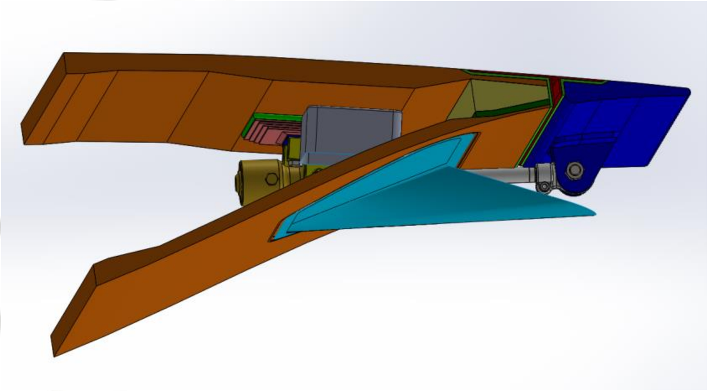
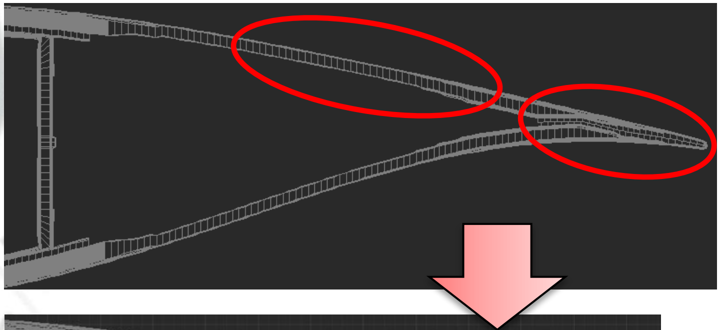
2. Blade Structure

- 1.5 MW actuation device requires rearrangement of trailing edge structure
  - Trailing edge spar cap has to be modified
- Compensation measure:
  - Reinforcement of main spar cap
  - Reinforcement of trailing edge shell
- Consequence:
  - Mechanical equivalent model affected significantly
  - Higher mass due to reinforced spar cap
- Changes in 1.5 MW equivalent model scaled up for 10 MW model

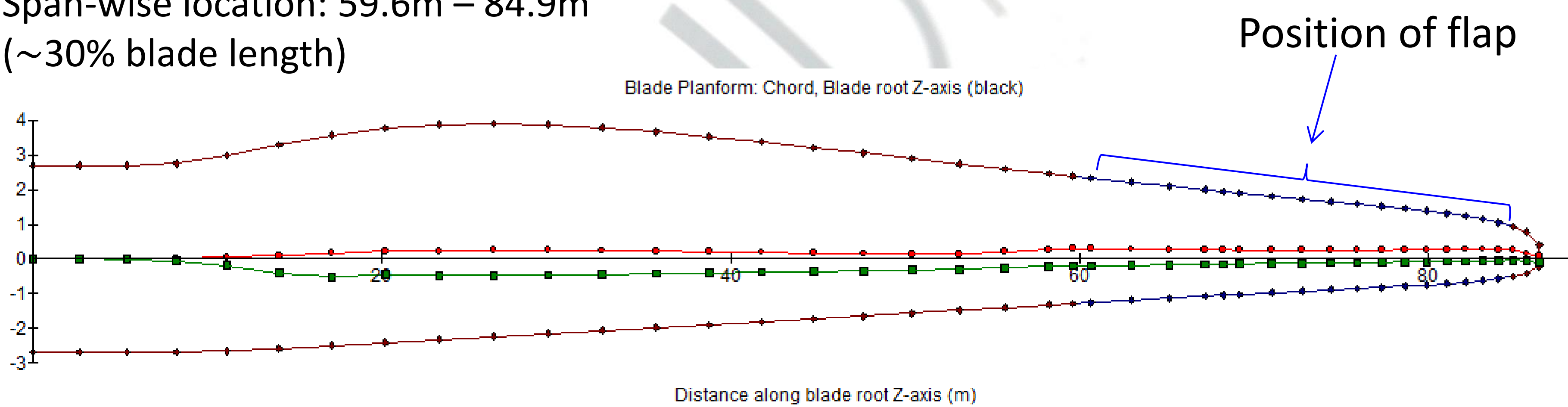




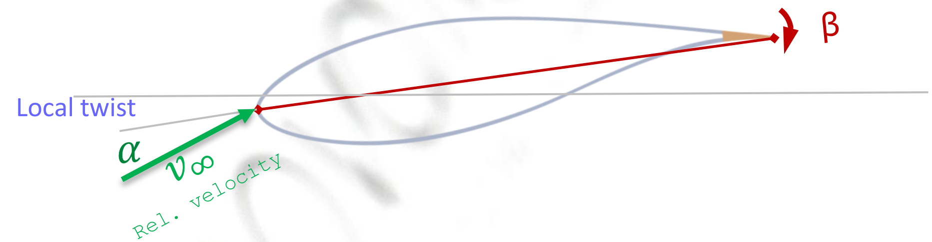
2. Blade Structure

Flap position

Flap
Span-wise location: 59.6m – 84.9m
(~30% blade length)



3. Controller



- Flap controller independent of pitch/torque controller

- Decentralized concept
  - Act on local aerodynamic changes
  - Taken from Madsen2013[1]
  - Simple feed forward control

- Limit influence on energy capture:
  - Only active at rated power

- Idea: Use flap to keep lift constant
  - Limit blade deflection / turbine loads

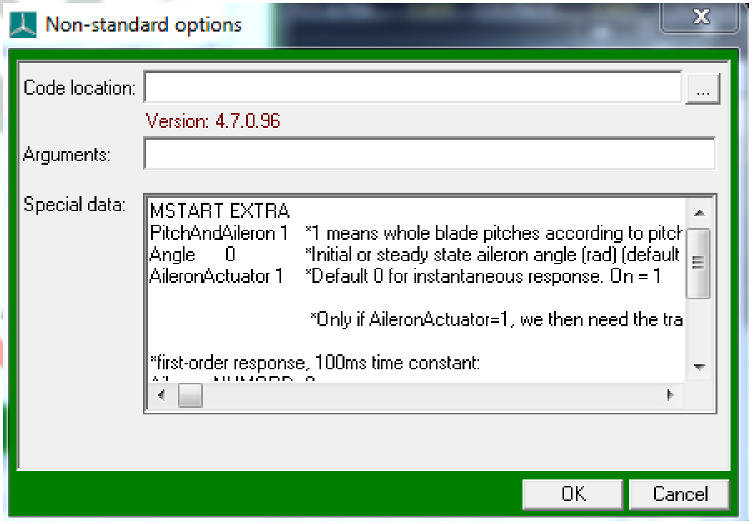
- Sensor:
  - Pitot tube: measures α and v_∞ in outer blade (ideal sensor in Bladed)

1:- Madsen2013 – Helge Aa. Madsen, *Transfer of flap technology form laboratory to industrial application,* Presentation at IQPC – Advances in Rotor Blades for Wind Turbines in Bremen, Germany 2013

3. Controller

- In Bladed:
  - Control of pitch and flap via external controller (using API interface)

- Required non-standard options (Project Info):
  - **<u>PitchAndAileron</u>** (To control pitch and flap)
  - (Aileron initial) **<u>Angle</u>**
  - **<u>AileronActuator</u>** (transfer function)
    - Coefficients



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Load Cases and Variants

- According to GL Guideline for the Certification of Wind Turbines 2010
  - 1.1 Power production with NTM
  - 6.4 Idling with NTM

- Considered fatigue loads (lifetime DEL):

Blade root M_{XR} (Edgewise)
Blade root M_{YR} (Flapwise)

S/N slope: m = 10

Non-rotating hub M_{YN} (Tilt)
Non-rotating hub M_{ZN} (Yaw)

Tower base M_{XT} (Side - Side)
Tower base M_{YT} (Fore - Aft)

S/N slope: m = 4

- Considered variants:

Original

- 10 MW w. original blade structure
- No flap
- Reference

Flap

- 10 MW w. modified structure incl. flap
- Active flap

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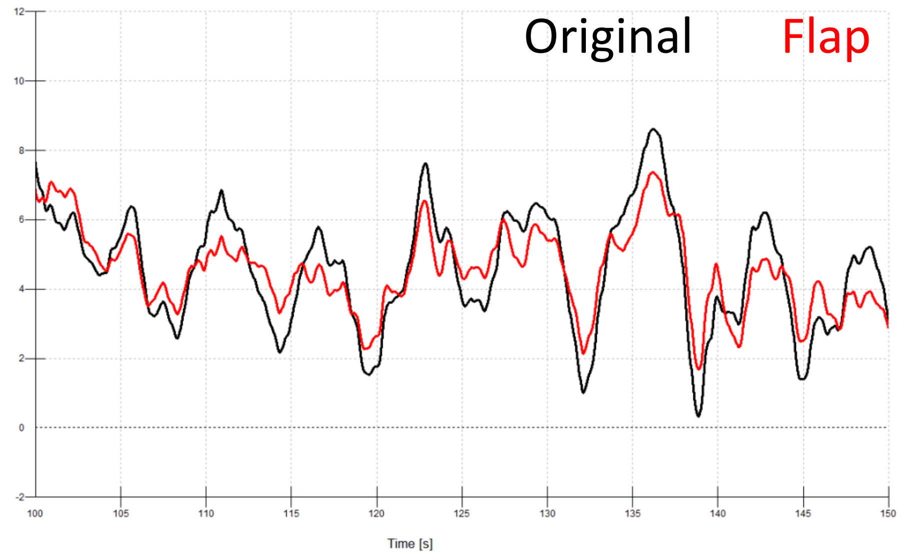
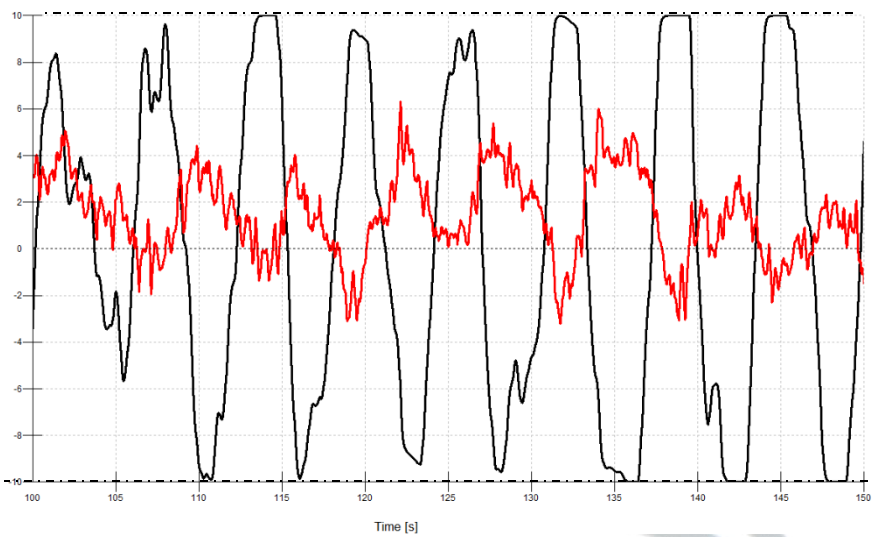
Time Series

Power production with 15 m/s mean wind speed



Blade tip out-of-plane deflection [m]

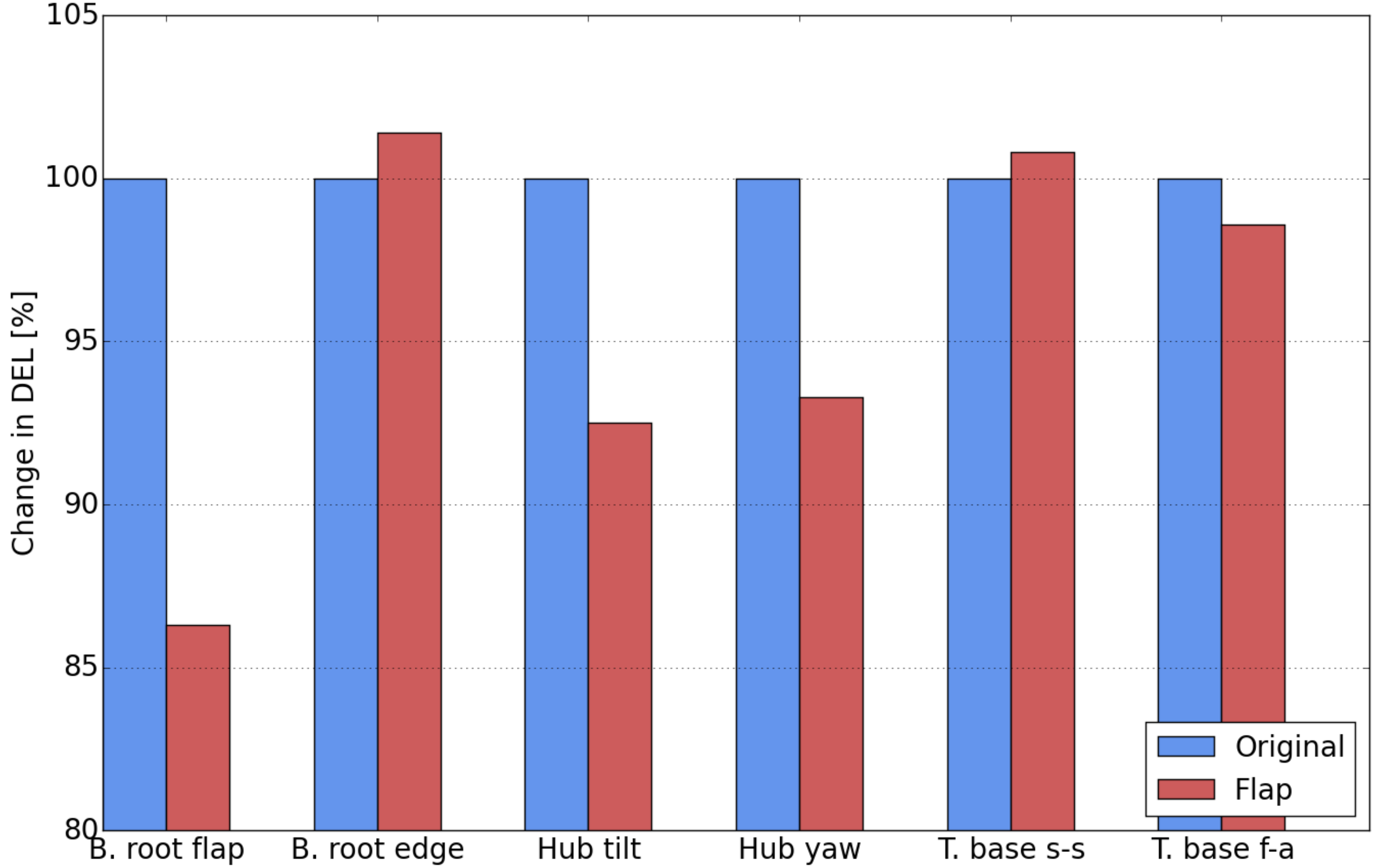
Behavior flap control



Flap angle [deg] AoA [deg]

Effect on Fatigue Loads

Comparison of lifetime DELs (GL2010 DLC 1.1 and 6.4)



Conclusion

- \+ Promising fatigue load reduction potential of flaps:
  - Blade root flapwise bending moment
  - Hub tilt/yaw bending moment

- \- Blade structural modification increases blade mass / static moment
  - Negative effect on blade root edgewise bending moment
  - Limiting factor on flap size

- Impact on blade design loads?
  - Include extreme loads

Next steps

- Study effect of other flap control strategies / conventional sensors (i.e. strain gauges)
  - Include extreme loads

- Analyze flap effects on blade design
  - Detailed redesign of existing multi-MW blade to include flaps
  - Complete load calculation (extreme and fatigue loads)
  - Adapt blade structure to new load set

Thank you for your attention

Source: cp.max

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