Investigation of the validity of BEM for simulation of complex load cases

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Contents

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Motivation

- BEM still workhorse of the industry
- BEM needs correction models
  - Dynamic stall
  - 3D effects
  - Yaw correction
  - Rotor tower interaction

- Larger turbines → accuracy of simplified design models?
  - Comparison to CFD and experiments

Methods of validation

- Comparison to CFD and experiments
- Yawed flow
  - NREL VI experimental turbine
  - 20m Smart Blade turbine
  - INNWIND turbine
- Rotor Tower interaction
  - NREL VI experimental turbine
- Standstill
  - NREL 5MW

Yawed flow models

- 5 years measurements in the ECN Test Site show:
  - average yaw misalignment varies between 2 and 10 degrees
  - Power decrease
  - Azimuthal variation of the loads →fatigue blade loads

Yawed flow models-Video

Yawed flow models

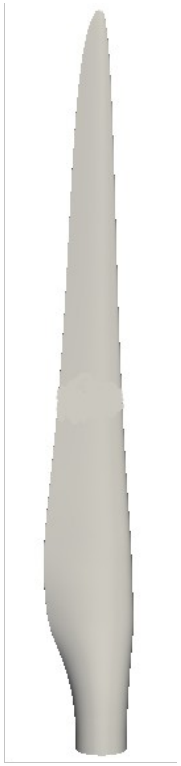
- Large deviation in load prediction
- Clear effect on the results due to improved capture of the skewed wake effect

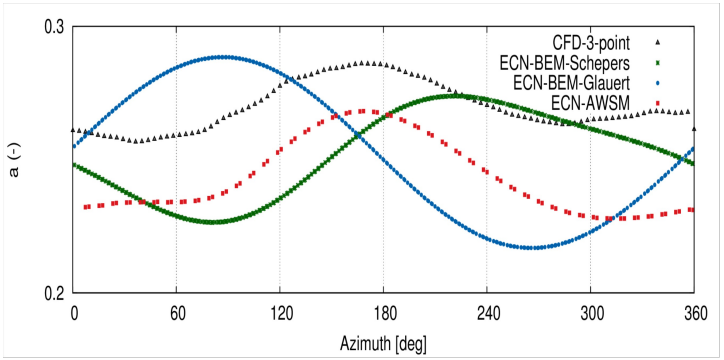
Methods	Power output	Thrust force
CFD	494 kW	89 kN
BEM - Schepers	525 kW (+6%)	95 kN (+6%)
BEM - P&P	576 kW (+16%)	99 kN (+11%)
BEM - GDW	680 kW (+37%)	107 kN (+20%)

Smart Balde: Development and Design of Intelligent Rotor Blades

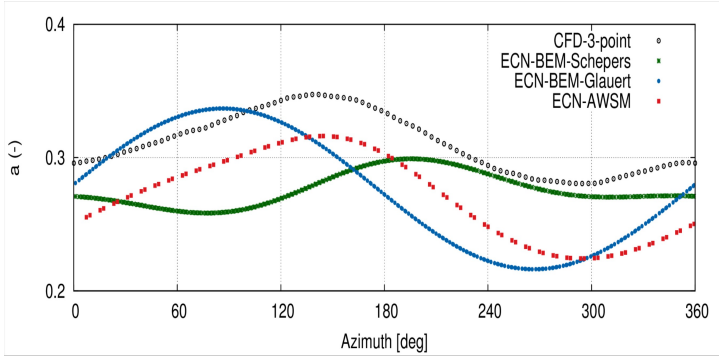
Yawed flow models

- Large deviation in axial induction factor prediction
- CFD can improve the engineering models





r/R=30%



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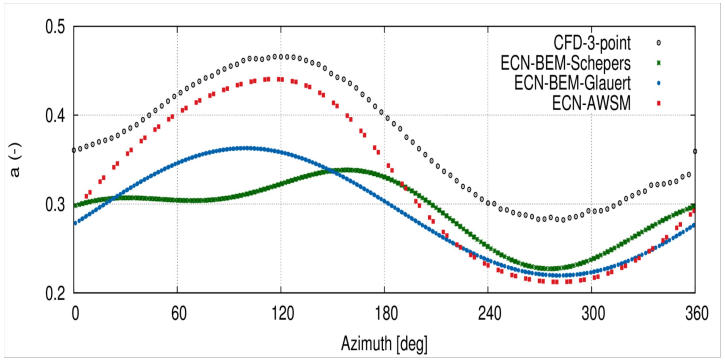
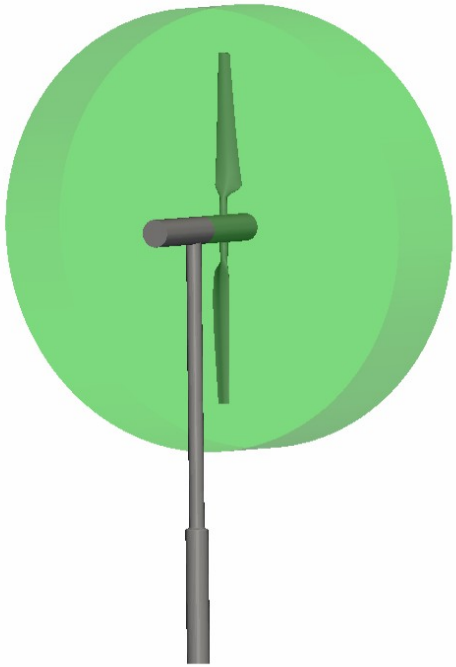


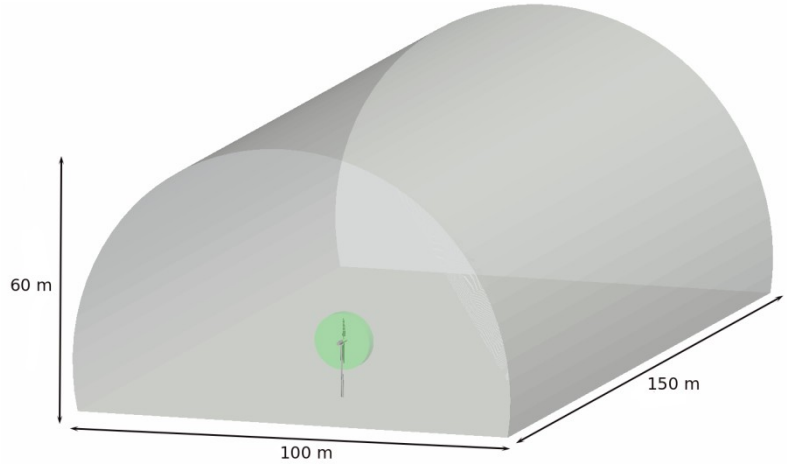
r/R=90%

Rotor tower interaction models -Video

Rotor tower interaction models

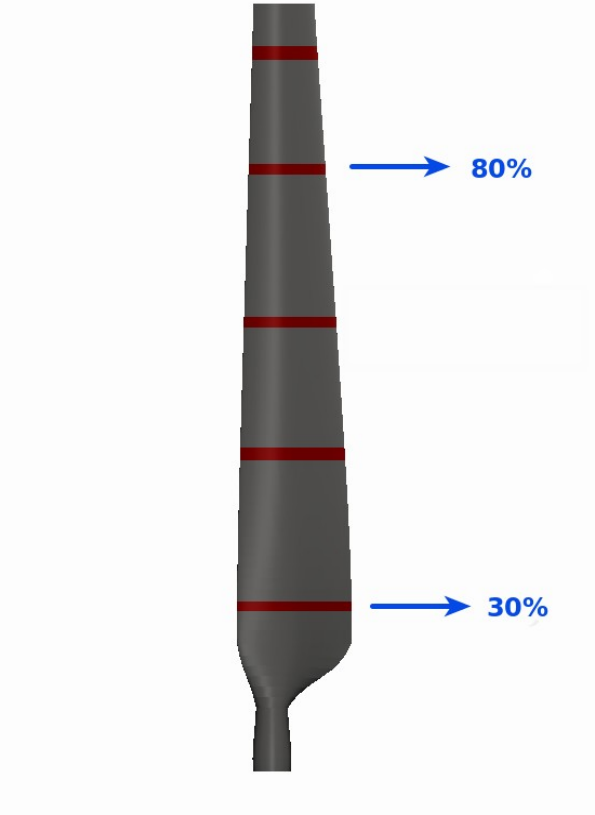
- Mesh is created by BladeBlockMesher tool of ForWind-IWES
- ca. 10 Million cells
- ca. 29.000 cells on blade surface
- Rotor meshed in separate cylinder

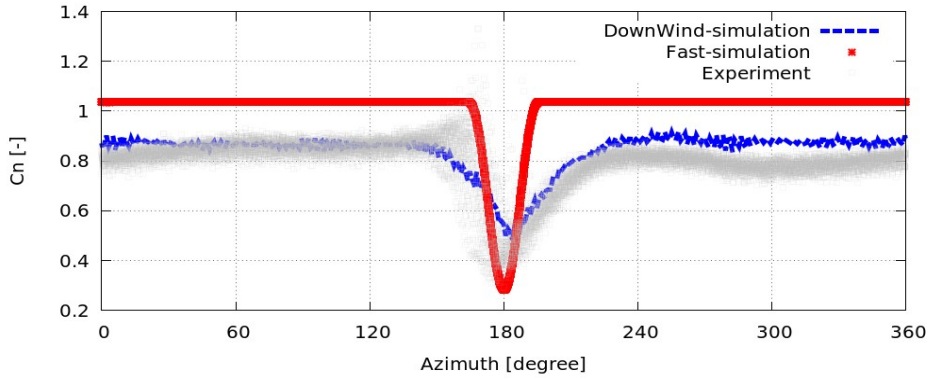


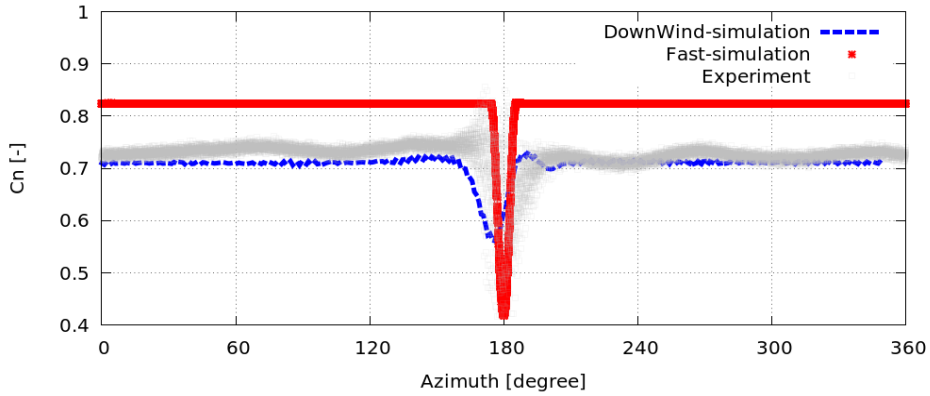


Rotor tower interaction models

- Accurate CFD simulations
- Deviation between FAST and CFD is presented







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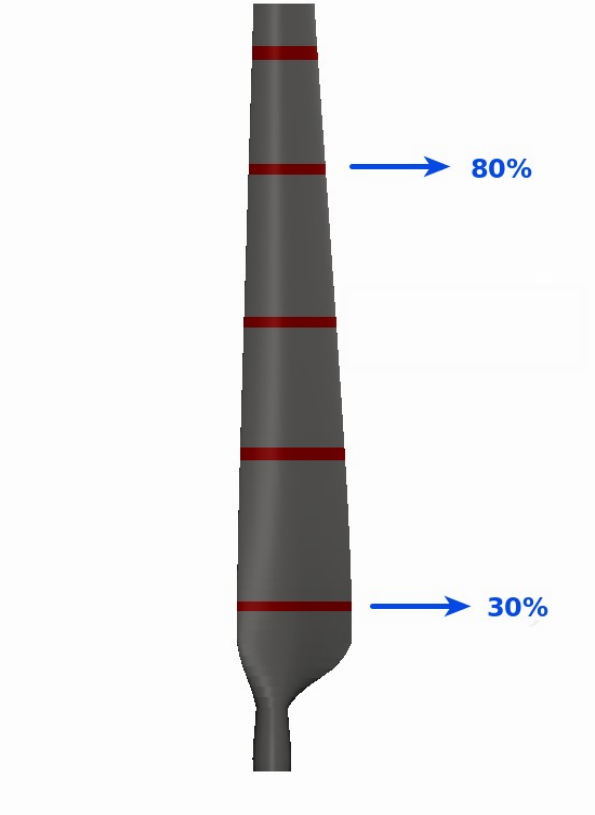

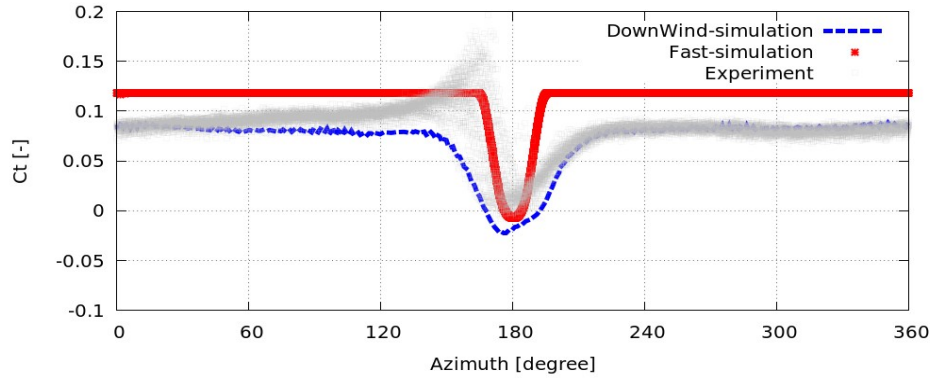

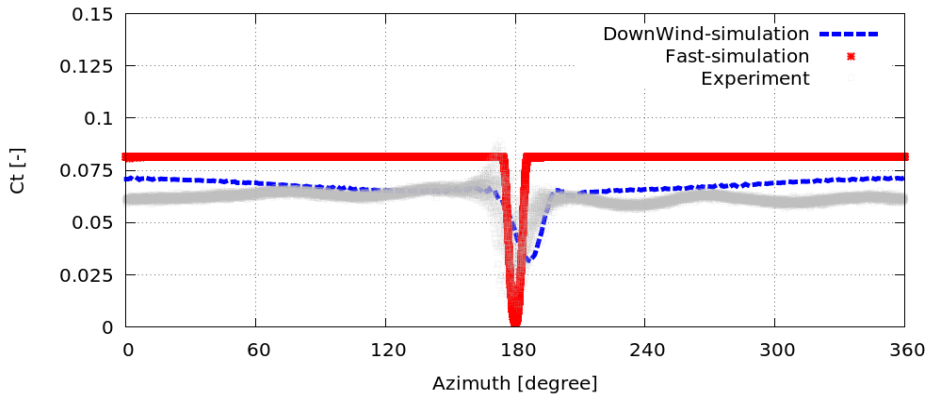

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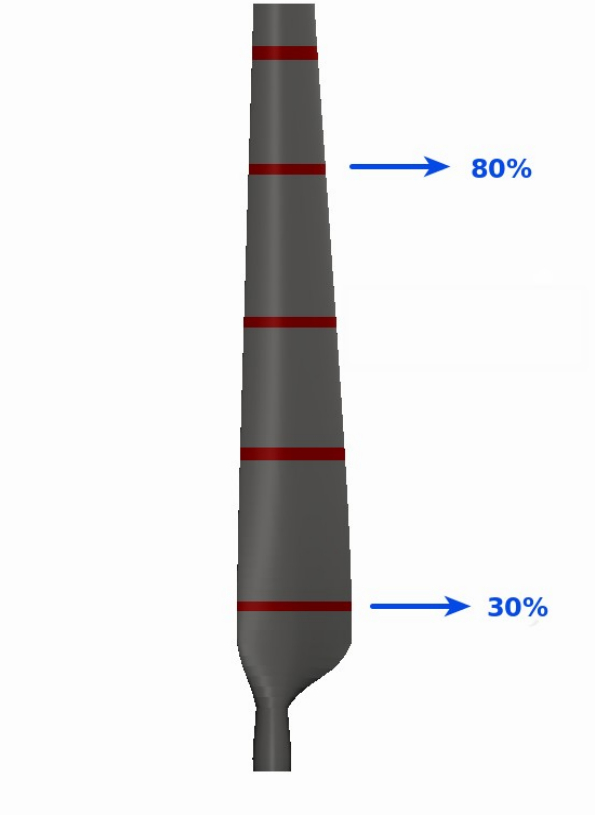
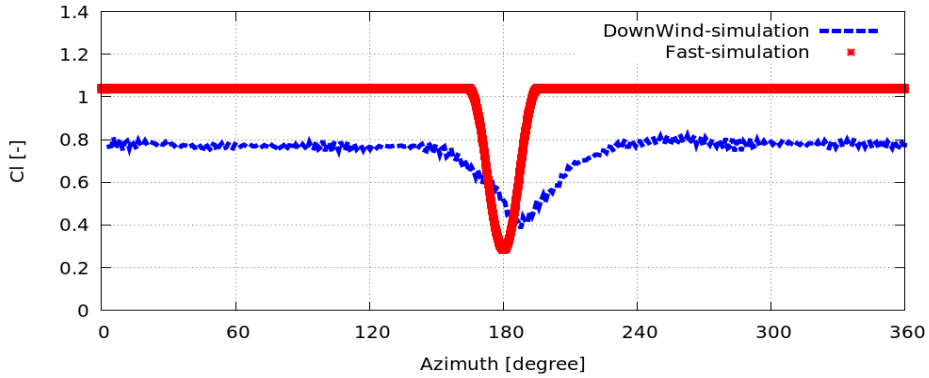
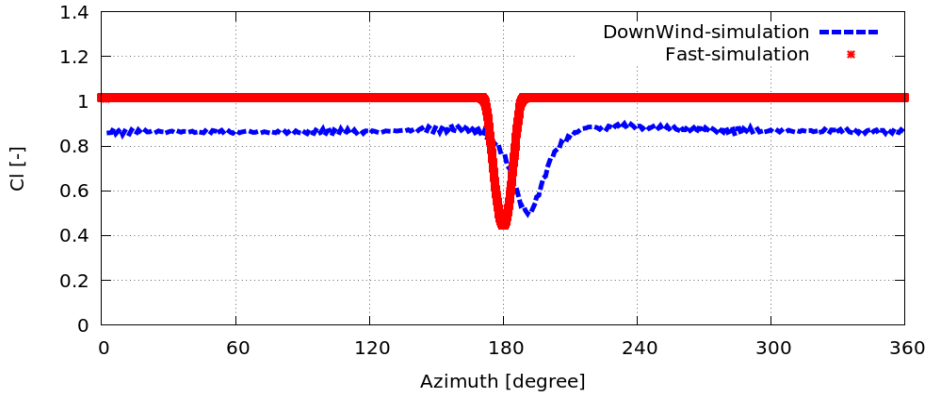
Rotor tower interaction models

- Accurate CFD simulations

Deviation between FAST and CFD is presented







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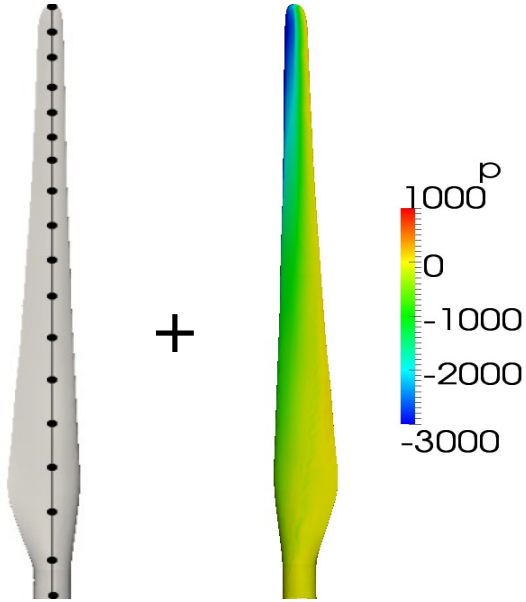
Fluid-structure coupling

High fidelity for complex flow situations

- Simulations of large, flexible rotor blades complex
- Accurate predictions require multiphysics solution
- Fluid-structure coupling necessary
- Coupling of OpenFOAM and inhouse beam solver
- Based on Geometrically Exact Beam Theory (GEBT)
- Large deformations and cross sectional couplings supported

- Geometrically resolved, fully coupled simulations possible
- Runtime post-processing fully integrated

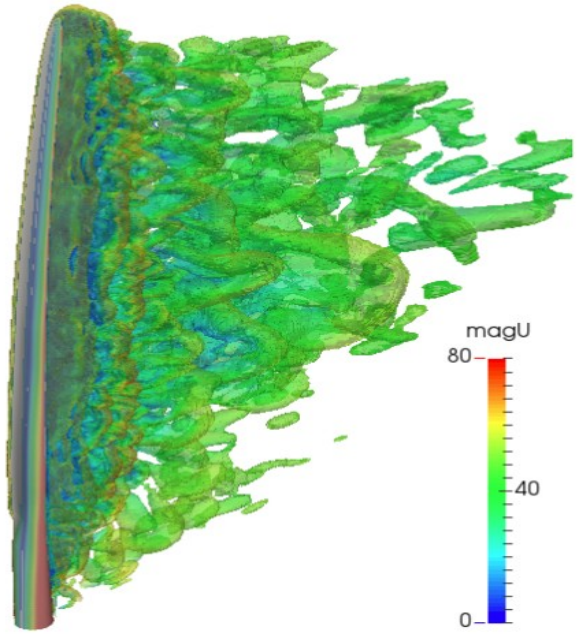


Wind turbines at standstill

High fidelity for complex flow situations

- Standstill case required by IEC 61400-1
- High angles of attack + strong interaction between fluid and structure
- Numerical complex simulation
- Validity of low fidelity models?

- Simulations performed on NREL 5MW
  - FAST
  - Fluid-structure coupled 3D CFD (DDES)
  - 45 m/s, Inflow angle 90°
  - 24 million cells, fully structured



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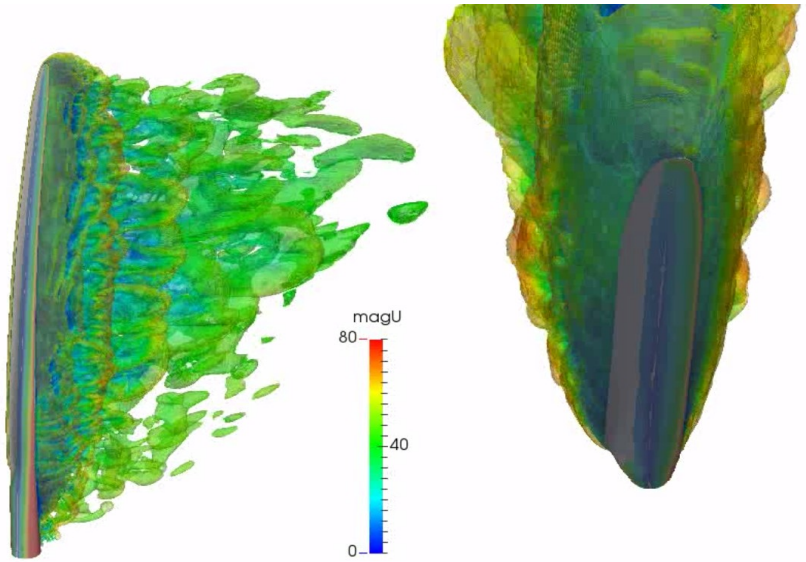
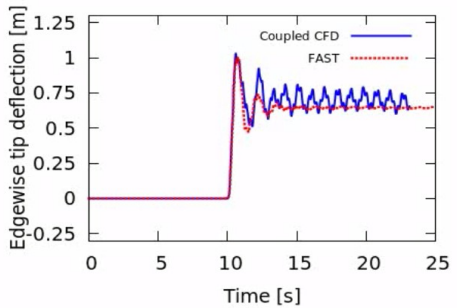
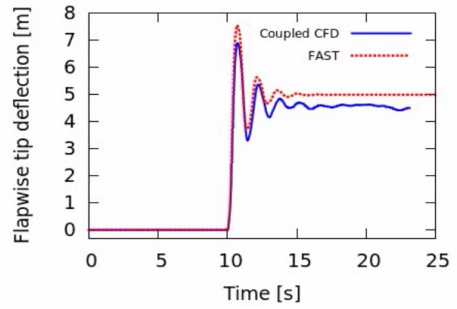
Fluid-structure coupling

High fidelity for complex flow situations

- Mean deflections show reasonable agreement
- Significant differences in edgewise blade dynamics
- Edgewise vibrations not predicted by FAST
- Vortex shedding not captured in BEM
- Standstill simulations with BEM should be treated with care







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Conclusion and Outlook

- An investigation of BEM in complex flow situations was presented
- Three complex scenarios were analyzed
  - Yawed inflow
  - Tower shadow
  - Standstill
- A comparison with CFD simulations and experiments showed:
  - The yaw correction models show clear deviations
  - Tower model is not accurate
  - Results from BEM for standstill should be treated with care

- CFD results can be used to improve the BEM correction models

Thank You For Your Attention
Any questions?

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