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Benchmarking aerodynamic prediction of unsteady rotor aerodynamics of active flaps on wind turbine blades using ranging fidelity tools

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Abstract

Simulations of a stiff rotor configuration of the DTU 10MW Reference Wind Turbine are performed in order to assess the impact of prescribed flap motion on the aerodynamic loads on a blade sectional and rotor integral level. Results of the engineering models used by DTU (HAWC2), TUDelft (Bladed) and NTUA (hGAST) are compared to the CFD predictions of USTUTT-IAG (FLOWer). Results show fairly good comparison in terms of axial loading, while alignment of tangential and drag-related forces across the numerical codes needs to be improved, together with unsteady corrections associated with rotor wake dynamics. The use of a new wake model in HAWC2 shows considerable accuracy improvements.

Objectives

The load alleviation potential of using active flaps on wind turbine rotors has been investigated in the past decade using various models, controllers, configurations and load cases [1, 2]. In this work, the unsteady aerodynamic simulations utilizing various codes of ranging fidelity, present a first approach for documenting such an evaluation on an overall realistic setup.

Main objectives:

- investigation of the purely aerodynamic effect of trailing edge flaps on the resulting blade loads and power of the wind turbine
- current numerical tools validation at representative operating conditions against CFD

Methods

- Codes
  - FLOWer (USTUTT-IAG)
  - HAWC2 (DTU) - Including near wake model [3]
  - hGAST (NTUA)
  - Bladed (TUDelft)
- Wind turbine model
  - DTU 10MW Reference Wind Turbine [4]
  - An active flap covering 10% of blade length with CRTEF characteristics [2]
  - CFD: Fully turbulent boundary layer, BEM: transitional data
- Cases
  - Prescribed sinusoidal flap signal (±10º) at 3p and 6p frequencies at 11.4m/s and 19m/s

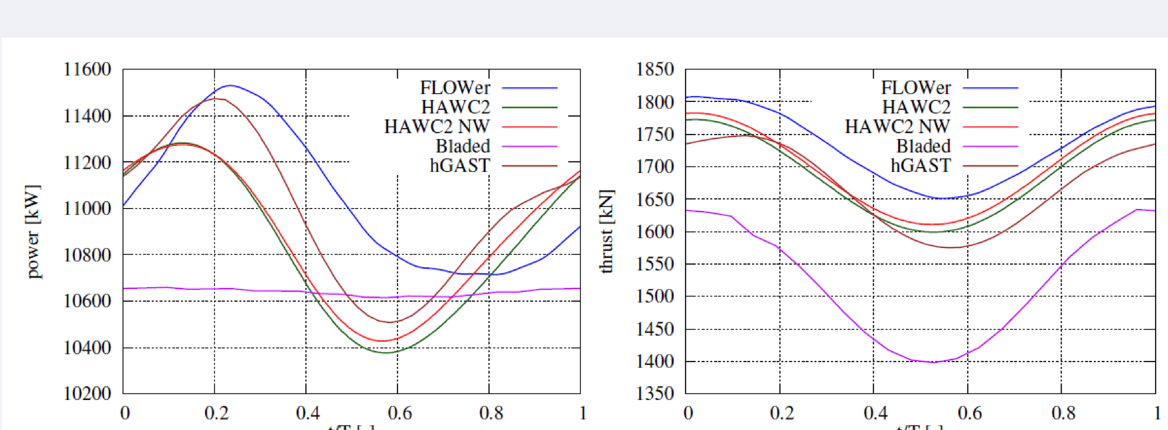
Flap configuration	
Chordwise extension	10%
Deflection angle limits	±10deg
Spanwise length	8.9m (10% of blade length)
Spanwise location	71.32m-62.40m (from rotor center)
Airfoil	FFA-W3-241
Max ΔC_L	±0.4

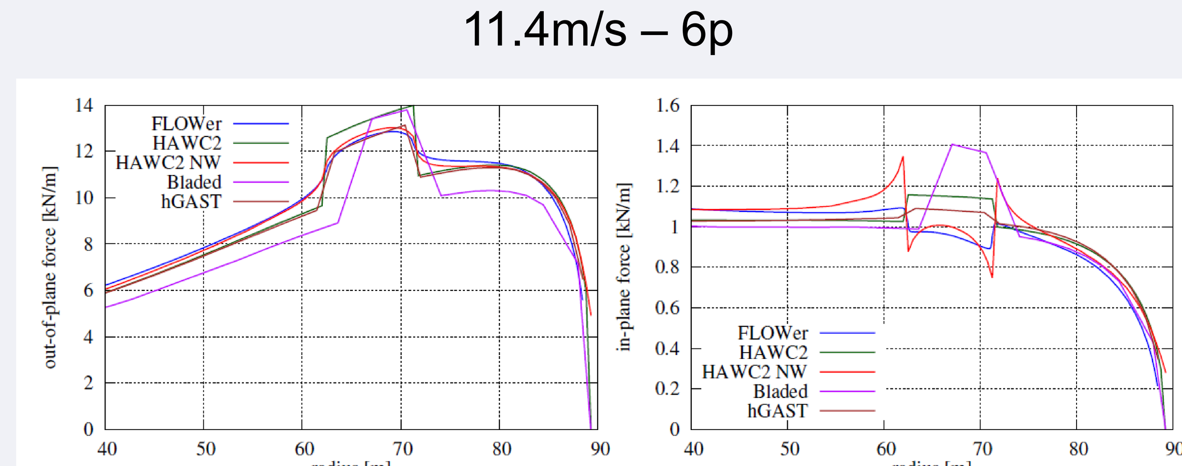
Case	11.4m/s - $1p_{sine}$	11.4m/s - $3p_{sine}$	11.4m/s - $6p_{sine}$	19.0m/s - $6p_{sine}$
wind speed [m/s]	11.4	11.4	11.4	11.4
rotor speed [rpm]	9.6	9.6	9.6	9.6
pitch angle [deg]	0	0	0	16.432
flap [deg]	$\pm 10 \cdot sin(1 \cdot p \cdot t)$	$\pm 10 \cdot sin(3 \cdot p \cdot t)$	$\pm 10 \cdot sin(6 \cdot p \cdot t)$	$\pm 10 \cdot sin(6 \cdot p \cdot t)$

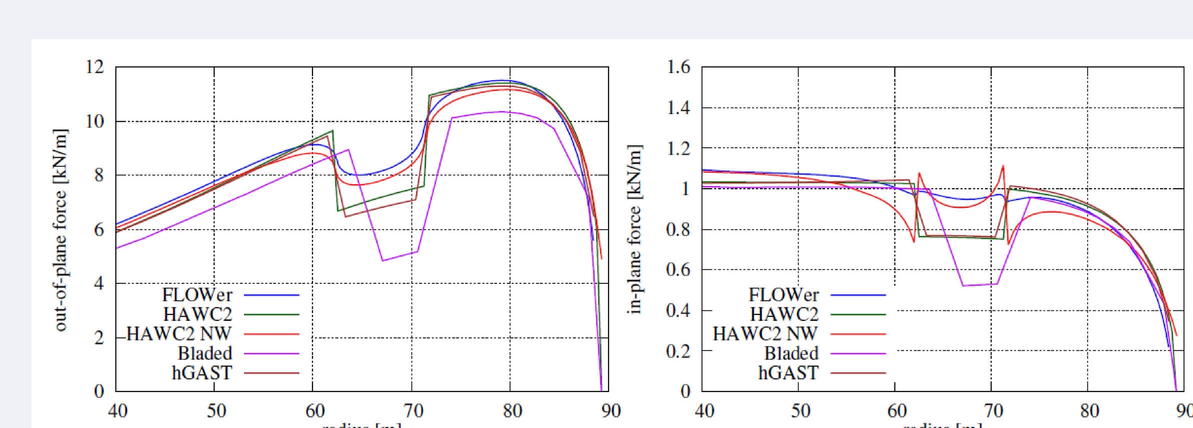
Results

- Rotor loads
  - Aerodynamic power and thrust
- Radial distribution of loads
  - Normal and tangential force distribution at extreme flap positions

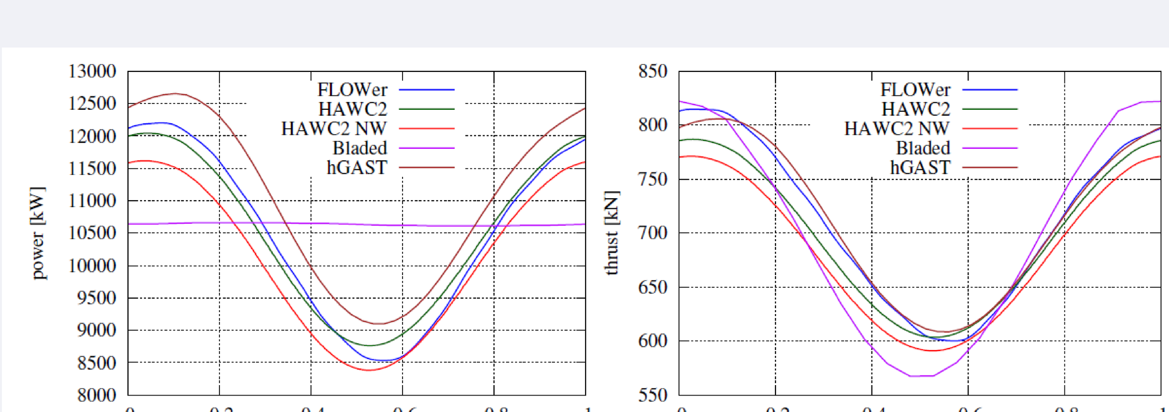
11.4m/s – 6p

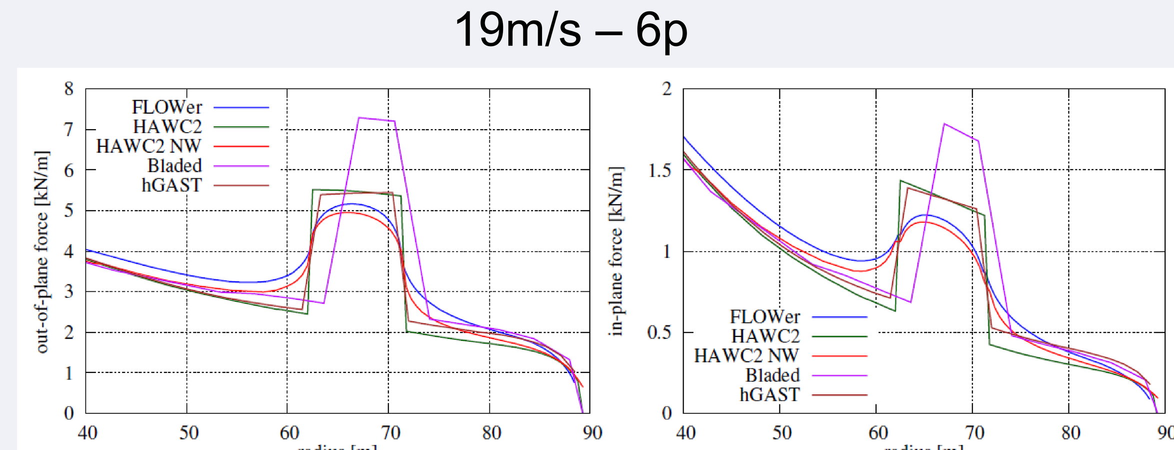


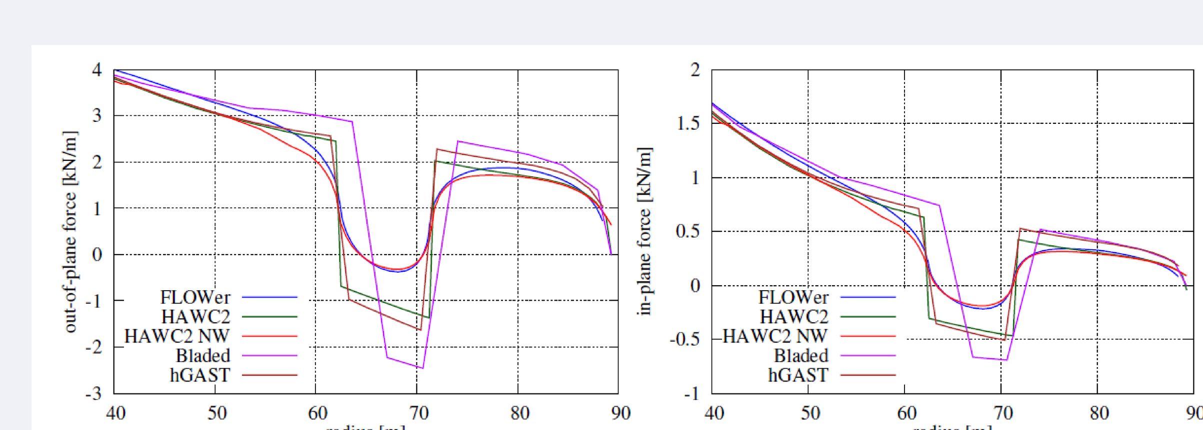




19m/s – 6p







Conclusions

- Fairly good prediction of BEM-based codes compared to CFD
- Discrepancy in predicting the correct shape and amplitude of the tangential force response, resulting in underestimation of thrust and power variations
- Significant improvement using the near wake model in HAWC2

References

1. Barlas, T. K. and van Kuik, G. A. M., Review of state of the art in smart rotor control research for wind turbines, Progress in Aerospace Sciences — 2010, Volume 46, Issue 1, pp. 1-27, 2010.
2. Madsen, H. A. et al., Towards an industrial manufactured morphing trailing edge flap system for wind turbines, Proceedings of EWEA 2014, Barcelona, Spain, 2014.
3. Pirrung G. R. Madsen H. A. Kim T. and Heinz J. A coupled near and far wake model for wind turbine aerodynamics, Wind Energy DOI:10.1002/we.1969, 2016
4. Bak C. et al, Description of the DTU 10 MW Reference Wind Turbine, Technical report, DTU Vindenergi-I-0092, 2013.

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