IEA Task 47

Innovative aerodynamic experiment technologies and simulations on wind turbines in turbulent inflow

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- Introduction: History of aerodynamic IEA Tasks, Achievements
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History of aerodynamic IEA Tasks

Since 1991, IEA has played a very important role in aerodynamic model improvement

- 1991-1997: IEA Task 14 (Field Rotor Aerodynamics)
- 1997-2001: IEA Task 18 (Field Rotor Aerodynamics, enhanced)
- 2001-2007: IEA Task 20: (NREL Phase VI, NASA-Ames wind tunnel measurements
- 2008-2020: IEA Task 29: Phases 1 to 3 ((New) Mexico wind tunnel measurements), Phase IV (DanAero field measurements)

Nowadays there isn't a single designer to find who would dare to design a wind turbine with the aerodynamic modelling from the 1980's [1])

[1)] J.G. Schepers *Engineering models in aerodynamics*, TUDelft *PhD thesis, November 2012*

[2)] Grol van, H.J., Snel, H., Schepers, J.G., *Wind Turbine Benchmark Exercise on Mechanical Loads, A State of the Art Report* ECN-C-91-030/31, 1991,
(a description of state of the art design models at the end of the 1980's)

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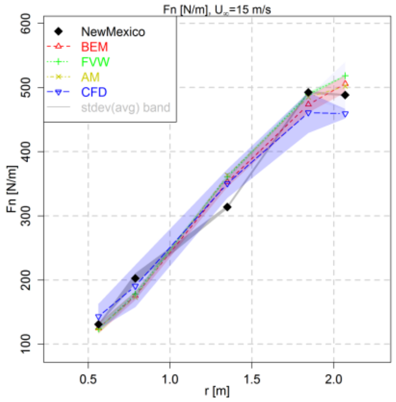
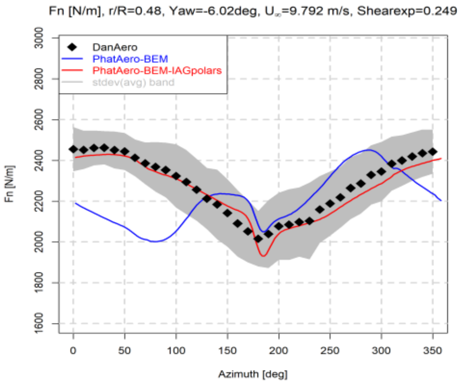
Some results of IEA Task 29

- Often (not always…) a good agreement between calculations and Mexico **wind tunnel** measurements
  - ➢ steady uniform conditions, rigid small scale turbines
- Larger disagreement between calculations and DanAero **field** measurements, with several non-understood phenomena
  - ➢ Atmospheric turbulent inflow, MW turbines



- Added value of CFD in modelling complex 3D aerodynamics clearly demonstrated



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Why Task 47: Because we are now in 2021

Turbine sizes grow to **12 MW+**

Illustrated by press release on Stretch project:

- 4 years project, funded by RvO
- Led by LM, with TNO and GE as partners
- Aim: stretch rotor diameters to 230-240 m
- Unprecedented (aerodynamic) challenges have to be overwon

ONONTGONNEN TERREIN

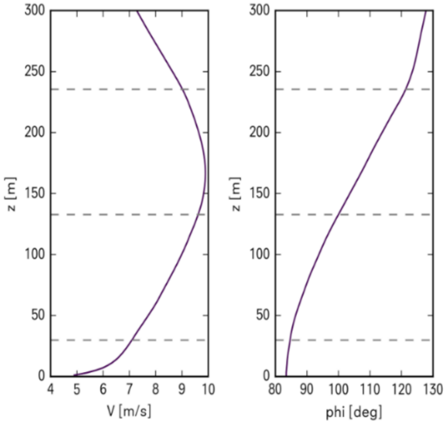
In het vierjarige programma STRETCH, gefinancierd door de rijksoverheid (RVO), werkt TNO nauw samen met General Electric (GE) Renewable Energy, tevens eigenaar van de Haliade-X, en hun dochterbedrijf LM Wind Power dat een uitgebreide testfaciliteit heeft in de Wieringermeer voor experimenten aan windturbinebladen. De partijen werken al langer samen in onderzoeksprojecten voor het doorbreken van aerodynamische barrières om steeds grotere turbines mogelijk te maken. De komende tijd gaat het om het verder opschalen van het rotorblad tot een diameter van zo'n 230-240 meter. Bij de **Haliade-X** is dat nog 220 meter. Dat betekent het betreden van onontgonnen aerodynamisch terrein. Onderzoek moet uitwijzen welke krachten bij die lengtes worden uitgeoefend en welke gevolgen dit heeft voor de belasting van de rotorhub en de daaraan verbonden bladen.

> "Je kunt de bladen niet ongestraft groter maken, ze worden dan te zwaar of te duur"

GRENZEN VERLEGGEN

In STRETCH buigen de experts zich over het verder verlengen van het blad en het testen van de rotorhub, het ophangpunt van de drie bladen. "Het ontwerp van de Haliade-X was al een enorme stap, maar in dit project gaan we de grenzen opnieuw verleggen", zegt Peter Eecen. "Je kunt de turbinebladen niet ongestraft groter maken. Ze worden dan veel te zwaar of te duur en dan is het

Why Task 47: An illustration of the unprecedented modelling challenges



Shear and extreme veer from year 2015 at met-mast IJmuiden
Dashed lines indicate hub height and limits of 10 MW rotor plane
Schepers, J.G.; van Dorp, P; Verzijlbergh, R.; Jonker, H (2020) *Aero-elastic loads on a 10 MW turbine exposed to extreme events selected from a year-long LES over the North Sea* Wind Energy Science, https://doi.org/10.5194/wes-2020-1

- Shear and extreme veer (wind direction as function of height) from year 2015 (only…) at North Sea Met-Mast IJmuiden
- The veer for a 10 MW turbine is almost 40 degrees!!!
- This violates all assumptions in industrial design codes

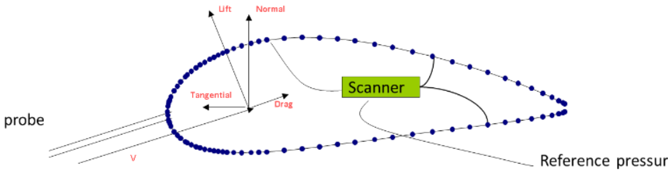
Why Task 47:

Because we are now in 2021 and the IEA 15 MW Reference Wind Turbine has become available as a public ‘testbed’ to investigate the modelling challenges for 15 MW wind turbines

Gaertner, Evan, Jennifer Rinker, Latha Sethuraman, Frederik Zahle, Benjamin Anderson, Garrett Barter, Nikhar Abbas, Fanzhong Meng, Pietro Bortolotti, Witold Skrzypinski, George Scott, Roland Feil, Henrik Bredmose, Katherine Dykes, Matt Shields, Christopher Allen, and Anthony Viselli. 2020. *Definition of the IEA 15-Megawatt Offshore Reference Wind*. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5000-75698. https://www.nrel.gov/docs/fy20osti/75698.pdf

Why Task 47: Because we are in 2021 when many countries (finally…) started up aerodynamic field experiments

- Good aerodynamic field measurement data on MW scale are far too limited
- Aerodynamic field experiments are now initiated at several countries (Denmark, France, Germany, Holland, Italy, Switzerland, USA). Experiments up to 8 MW
  - ✓Very **specialised** experiments *), **cooperation** extremely useful



*) Some specific issues Drilling pressure holes non-intrusive in blades, choosing the right type of pressure transducers and data acquisition with the right measurement range and frequency response taking into account length of tubes, connecting sensors to the data acquisiton system, choosing the right locations for the sensors, powering the sensors, purging pressure tubes, protecting pressure tubes and sensors against rain, vibrations and centrifugal forces, calibration of pressure scanners, account for varying reference pressure, calibration of pitot tubes, definition of angle of attack and dynamic pressure, measurement uncertainties

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Work Plan

- **WP1: Measurements and simulations**
  - Cooperation on the field of specialised aerodynamic experiments
  - Steepening the learning curve by **sharing** experiences and possibly hardware
  - Cross fertilisation of **theory** and **experiment.** Theory improves experiment and vice versa
    - How to compare turbulent calculations and measurements consistently?

- **WP2: Turbulent calculations on 15MW RWT**
  - Mutual comparison of calculational results low versus high fidelity models
  - Calibrate efficient industrial BEM codes with high fidelity but time consuming CFD
    - How to compare results from different calculational methods
  - Recommendations to WP1

- **WP3: Cooperation with other IEA Tasks**
  - Contact persons to other IEA Tasks
  - Common Benchmarks with IEA Task 30 and IEA Task 39

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The common Benchmarks with IEA Task 30 and IEA Task 39

- Benchmark with IEA Task 30: OC6
  - Benchmark on the Unaflow measurements in PoliMi wind tunnel on 'floating' wind turbine

IRPWind

2nd Call for Joint Experiments

ECN › TNO innovation for life

IAG ECN

DTU

POLITECNICO MILANO 1863

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- Benchmark with IEA Task 39, Quiet wind turbine technology, on acoustic models:
  - Aerodynamics is driving for acoustics

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Management information

- Project period: January 1st 2021-December 31st 2024
- Expected number of participants>= Task 29 participants
- IEA Task 29 participants:
  - China (Chinese Wind Energy Association)
  - Denmark(Technical University of Denmark and Siemens Gamesa)
  - France (ONERA, Ecole de Nantes, IFPEN, EDF)
  - Germany(University of Stuttgart (IAG), University of Applied Sciences Kiel/ (UAS Kiel) Forwind, Fraunhofer IWES, Enercon, WINDnovation, Deutsches Zentrum für Luft- und Raumfahrt e.V. DLR, University of Applied Sciences Emden/Leer, University of Kassel)
  - Italy PoliMi, CNR-INSEAN, RSE
  - Netherlands (TNO, University of Delft, (TUDelft), CWI, LM Netherlands, Det Norske Vertitas-Germanische Lloyd
    - TNO is the Operating Agent
  - Sweden (Uppsala University Campus Gotland)
  - Switzerland (OST – Eastern Switzerland University of Applied Sciences)
  - USA (National Renewable Energy Laboratory (NREL and Sandia Lab)).

Questions?