Rotor/ABL Aerodynamics, TASK-1

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RISØ-DTU, 03-02-2011

Outline

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2. Available Experiments
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4. Ph.D. and Post Doc.
5. Status of work
6. Technical Results
   - Mexico Yaw Results
   - Nrel Standstill Pitch
   - Dan-Aero Results

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Objective

Task-1: Rotor/ABL Aerodynamics

Investigate the effect of Atmospheric Boundary Layer characteristics on rotor aerodynamics, using Computational Fluid Dynamics (CFD)

- Wind Shear and yaw
- Unsteady inflow, inflow turbulence
- Dynamic stall
- Laminar turbulent transition

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Experiments

A series of experiments are available

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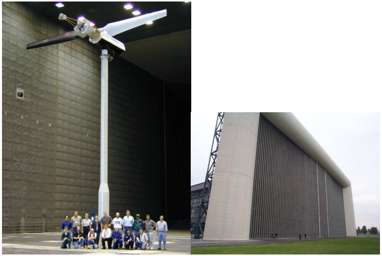
Experiments

A series of experiments are available

- Nrel Phase-VI



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Experiments

A series of experiments are available

- Nrel Phase-VI
- MEXICO

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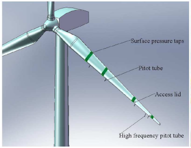
Available Experiments

Experiments

A series of experiments are available

- Nrel Phase-VI
- MEXICO
- DAN-Aero



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Experiments

A series of experiments are available

- Nrel Phase-VI
- MEXICO
- DAN-Aero
- Topfarm

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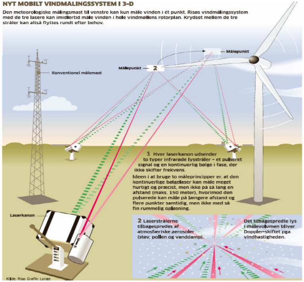
Experiments

A series of experiments are available

- Nrel Phase-VI
- MEXICO
- DAN-Aero
- Topfarm
- LIDAR/Wind-Scanner



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Experiments

A series of experiments are available

- Nrel Phase-VI
- MEXICO
- DAN-Aero
- Topfarm
- LIDAR/Wind-Scanner
- Siemens Full Scale

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Experiments

A series of experiments are available

- Nrel Phase-VI
- MEXICO
- DAN-Aero
- Topfarm
- LIDAR/Wind-Scanner
- Siemens Full Scale
- Tunnel data, e.g. LM-Glasfiber

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Milestones

The following milestones were defined within the present package, or are related to the work

- M1: Parametric study of two modern turbines in atmospheric shear. **Month 12**
- M2: Evaluation of the importance of cross flow instabilities for modern wind turbine rotors. **Month 24**
- M3: Parametric study of two modern turbines in yaw. **Month 24**
- M4: Development of refined 'engineering' yaw model. **Month 36**
- M5: Evaluation of dynamic stall models and airfoil characteristics with respect to dynamic inflow and inflow turbulence. **Month 48**
- M6: Simulation of various unsteady inflow conditions for the NM80. **Month 36**
- M12: Parametric study of wake/wake interaction between two or more turbines. **Month 36**

Ph.D. and Post Doc.

Ph.D. and P.D. related to AED,Risø-DTU

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Task-1: Ph.D's and Post Doc's

Planned Ph.D. activities connected to Rotor Aerodynamics

	2010	2011	2012	2013	2014	2015
AED-PhD			12	12	12	12
RISØ-PhD2		12	12	12	12	
AED-PD					12	12

Connection to Task's

	TASK-0	TASK-1	TASK-2	TASK-3	TASK-4	TASK-5
AED-PhD		36				
RISØ-PhD2			12	24		
AED-PD					12	12

- TASK-1: Rotor/ABL Aerodynamics (NNS)
- TASK-2: Wind Turbine Wakes and Clusters (JNS)
- TASK-3: Wind Farms (JNS)
- TASK-4: Siting in Forested and Complex Terrain (JM)
- TASK-5: Atmospheric Boundary Layers (JM)

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RISØ-PhD2

RISØ-PhD2 details

- Shared financing between Risø-DTU and DSF
- Connected to TASK-2 and TASK-3, Turbine Wakes and Farms
- We will try and start this Ph.D. one year early, in 2011
- The detailed work description must be made in the spring 2011

AED-PhD

AED-PhD details

- Shared financing between Siemens, Risø-DTU, and DSF
- Connected to TASK-1, Rotor/ABL Aerodynamics
- We will try and start this Ph.D. one year early, in 2012
- The detailed work description will be made in the second half year 2011

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Ph.D. and Post Doc.

AED-RISØ-PD

AED-RISØ-PD (Post Doc.)

- Purely financed by DSF
- Planned to be connected to TASK-4 and TASK-5
- No real planning yet, will first start 2014

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First Year, Resume

Planed activities:

Focus on milestone M1: Parametric study of two modern turbines in atmospheric shear

Actual activities, first year:

- Mexico axial flow cases, investigating differences with measurements
- Mexico yaw cases
- NREL Phase-VI dynamic stall computations during standstill
- Rotors in partial wake and in shear
- Finding and extracting data sets from the DAN-AERO exp.

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Status of work

International Dimension

- Close collaboration with NREL, regarding dynamic stall and static stall
- Large effort to explorer the unique Mexico data set, in close collaboration with ECN
- Chalmers University of Technology, (Exchange of Ph.D. students)
- Collaboration with University of Glasgow, Department of Aerospace Engineering.

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Technical Results

Selected Technical Results

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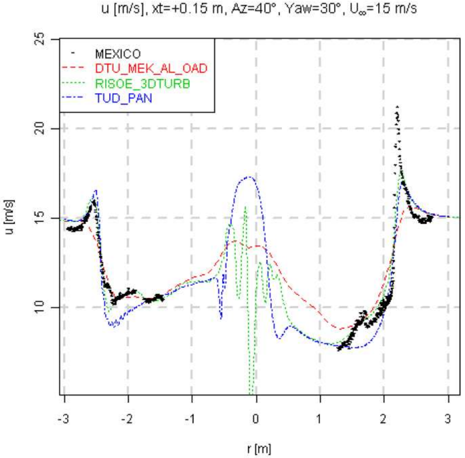
Mexico, Yaw Computations

Mexico 30 degrees Yaw, W=15 [m/s], Axial-Velocity.



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Specification of the case

The tested configuration is based on the NREL-Phase-VI turbine during standstill

- The blade is parked straight up, zero azimuth position.
- The geometrical AOA is defined as the angle between the local chord and the test section center line
- The mean AOA given below is for the 47% section

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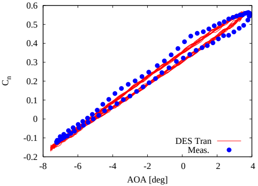
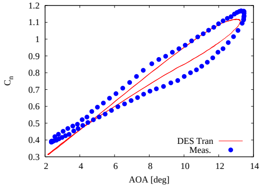
Technical Results *Nrel Standstill Pitch*

CASE 47040, Low AOA case

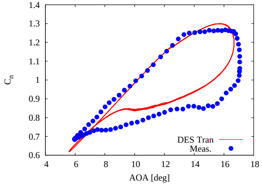
r/R=0.30



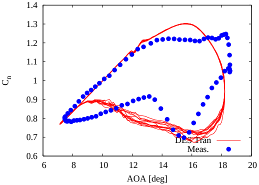
r/R=0.47



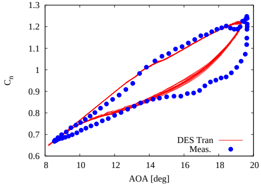
r/R=0.63



r/R=0.80



r/R=0.95



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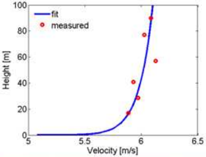
Dan-Aero, Axial Flow Conditions

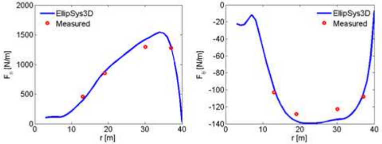
Measured and computed results at nearly uniform inflow condition:

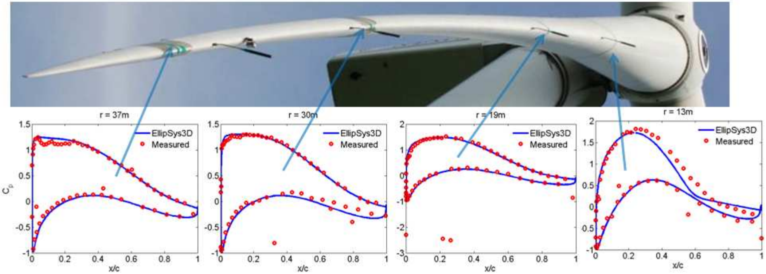
$$V_0(z) = V_\infty \left(\frac{z}{H}\right)^\alpha$$

$\alpha = 0.02$
$V_\infty = 6.2\, m/s$
$TI \approx 10\%$



Normal and tangential loads along blade:





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DAN-Aero, Estimation of 3D airfoil Data

Integrated forces:

Figure 3 compares respectively the normal and tangential force coefficient measured at the rotor (r=20m) with the corresponding measurements in the wind tunnel.

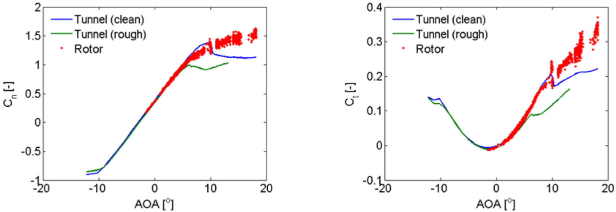

Figure 3: Normal force (left) and tangential force (right) coefficient vs. AOA. Blue curve is tunnel measurements on a clean airfoil, green curve is tunnel measurements on an airfoil with leading edge roughness and red dots are measurements at r=20m on the rotor.

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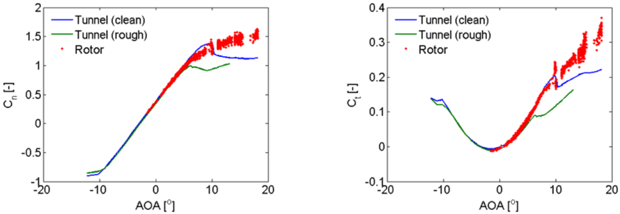

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Conclusion

The work is progressing

- Data sets from the DAN-Aero experiment has been identified and will be used to study axial flow cases
- Further data sets will be identified to treat more complex flow situations
- The full scale data will be supplemented with tunnel data, NREL, Mexico, LM
- We need to get industry more involved in the actual studies
  - Work on common cases, eg. Dan-Aero and Mexico
  - Work on bilateral cases, using industries partners own cases