Testing of aerodynamic performance of wind turbine airfoils

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1. MOTIVATION

NTNUs Blind Tests on turbine performance have shown significant uncertainties in predicting turbine performance.

Fig.1: *Blind test 2 setup of two model wind turbines in NTNU's wind tunnel*

The highest uncertainties have been found for Turbine 2 operating in the turbulent wake of an upstream turbine

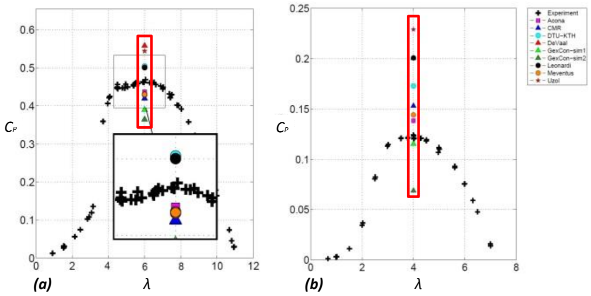

Fig.2: *Blind Test 2: $C_P - \lambda$ curve of* ***(a)*** *undisturbed turbine 1 and* ***[Pierella, 2]***
(b) *turbine 2 operating in the wake of turbine 1*

- ⇨ **Need for a database of aerodynamic lift and drag coefficients for various Re-numbers taking into account different turbulence levels in the incoming flow**
- ⇨ **More accurate prediction of wind turbine performance**

2. METHODS

Surface and wake pressure measurements on 2D airfoils in the wind tunnel

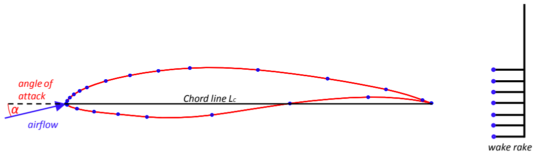

Fig.3: *NREL S826 airfoil with surface pressure taps and wake rake*

Wind tunnel experiments

- Multi-channel dynamic pressure measurements up to 30Hz
  ⇨ pressure distribution on wing surface and in airfoil wake
- New 2D **NREL S826** wing section under construction
- Initial test measurements on a symmetrical **NACA0015** airfoil

Numerical simulations

- Xfoil is a 2D panel method that predicts airfoil performance including the effect of changing the turbulence level in the incoming flow

3. INITIAL RESULTS

3.1. EFFECT OF TURBULENCE IN INCOMING FLOW

Effect of increased turbulence level in incoming flow on 2D airfoil performance is used to investigate influence on 3D rotor power production

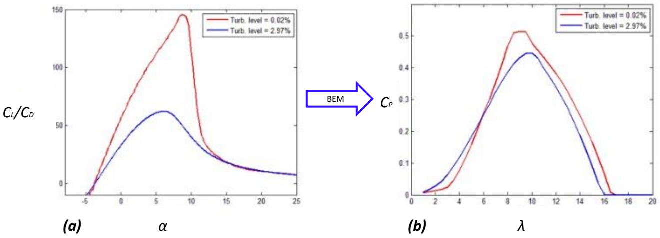

Fig.4: ***(a)*** *C_L/C_D for FX66-17AII-182 airfoil at turbulence levels 0.02% and 2.97% for Re=1e6*
(b) *CP - λ curve for a three-bladed rotor with same airfoil for turbulence levels 0.02% and 2.97%*

⇨ Different ambient turbulence levels strongly affect lift/drag ratio (a)
⇨ Significant influence on turbine performance C_P (b)

3.2. DYNAMIC PRESSURE MEASUREMENTS ON AN AIRFOIL

Wind tunnel study on dynamic surface pressure fluctuations on a NACA0015

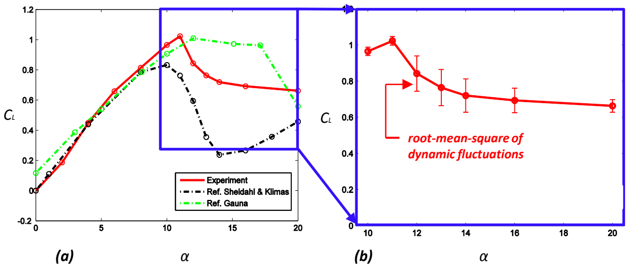

Fig.5: *Lift coefficient C_L of the NACA0015 airfoil measured for angles of attack from α=0°-20°*
(a) *mean lift coefficient,* ***(b)*** *fluctuations represented by root-mean-square*

⇨ Large variations in experimental results of lift coefficient C_L in stall region (a)
⇨ Significant dynamic lift fluctuations in lift between α=12°-16° observed (b)

Visualization of surface pressure fluctuations in transition and deep-stall

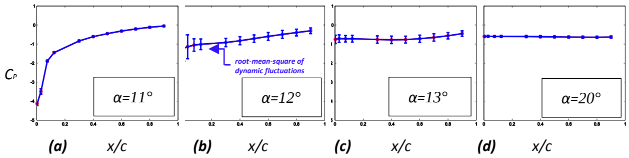

Fig.6: *Fluctuations in pressure coefficient C_P on suction side of NACA0015 airfoil*
(a) *α=11°* ***(b)*** *α=12°* ***(c)*** *α=13°* ***(d)*** *α=20°*

⇨ Major fluctuations near the suction side's leading edge in transition region (α=12°)
⇨ Hardly any pressure fluctuations for attached flow (α=11°) and deep stall (α =20°)

REFERENCES

[1] P-Å Krogstad, P E Eriksen. *Blind test calculations of the performance and wake development for a model wind turbine*. Renewable Energy, 50:325-333, 2013

[2] F Pierella, P-Å Krogstad, L Sætran. *Blind test 2 calculations for two in-line model wind turbines where the downstream turbine operates at various rotational speeds*. Renewable Energy, 2014

[3] P-Å Krogstad, L Sætran, M S Adaramola. *Blind test 3 calculations of the performance and wake development behind two in-line and offset model wind turbines*. Journal of Fluids and Structures, 2014

[4] R Sheldahl, P Klima. *Aerodynamic Characteristics of Seven Symmetric Airfoil Sections Through 180-degree Angle of Attack for Use in Aerodynamic Analysis of Vertical Axis Wind Turbines*. Sandia National Laboratory Report, 1981

[5] M Gaunaa. *Unsteady Aerodynamic Forces on NACA 0015 Airfoil in Harmonic Translatory Motion*. Doctorial Dissertation, Technical University of Denmark , 2002

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