EU projects in German Dutch Wind Tunnel, DNW

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1 Introduction

In this paper two projects are presented in which measurements have been, or will be performed in the German Dutch Wind Tunnel DNW.

- Project 1: DATA, 'Design and Testing of Aeroacoustically Optimised Airfoils'. This project has been performed within the EU JOULE III program. The project started in October 1998 and ended in October 2000;
- Project 2: MEXICO, 'Measurements and Experiments under Controlled Conditions'. This project has been proposed for the EU 5th Framework program. Although at the time of writing this paper, the project is not officially approved yet, it is expected that it will start in the beginning of 2001 and end in the beginning of 2004.

1.1 DATA project

In the DATA project the following partners participated:

- University of Stuttgart (coordinator, FRG);
- National Aerospace Laboratory, NLR (NL);
- TNO, Institute for Applied Physics (NL);
- LM Glassfiber Holland (NL);
- Netherlands Energy Research Foundation, ECN (NL).

In the project, aero-acoustic tests have been carried out on three model rotors, which were placed in the German-Dutch Wind Tunnel DNW. The difference between the three model rotors is in the blade outer part (i.e. r/R $>$ 0.55) for which three different airfoils are used:

- The NACA64418 profile. This profile is used on many nowadays used wind turbines and in the sequel this airfoil and its associated rotor blade are often identified by the 'reference' profile and the 'reference' blade;
- Two special purpose tip profiles which are designed in the present project. The design goal of these profiles was to reduce the noise level where the loss in aerodynamic performance should be limited compared to rotors which use nowadays state of the art aerodynamic profiles (for example the NACA64418 profile). The special purpose profiles are identified by the X3 and X5 profiles and the associated blades are identified through the X3 and X5 blades.

The overall emphasis in the DATA project was on the acoustic behaviour of the model rotor. This paper however, describes the ECN tasks in the project, which were focussed on the aerodynamics of the model rotors. More specific the following ECN tasks will be described:

- The aerodynamic design of the model rotors, i.e the design of the rotor blades in terms of the chord and twist distribution (section 3);
- The comparison of power calculations with power measurements (section 6). This comparison should be considered as important spin-off of the project: It offered a unique validation opportunity for ECN's aeroelastic code, due to the controlled, well defined and stationary conditions in the wind tunnel, which are never experienced in the free field.

1.2 MEXICO project

In the MEXICO project, the following partners will participate:

- Netherlands Energy Research Foundation, ECN (Coordinator, NL);
- Delft University of Technology, DUT (NL);

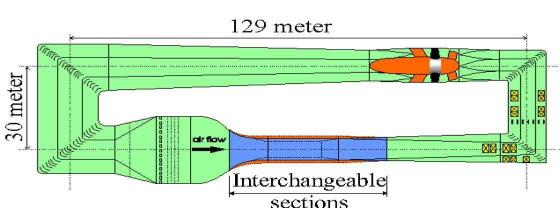
- Aerpac B.V. (NL);
- National Aerospace Laboratory, NLR (NL);
- RISØ National Laboratory (Dk);
- Danish Technical University, DTU (Dk);
- FFA, The Aeronautical Research Institute of Sweden (S);
- National Technical University of Athens, NTUA (Gr);
- Centre for Renewable Energy Sources, CRES (Gr);
- Israel Institute of Techonology, Technion (Isr)

Opposite to the situation from the DATA project, the emphasis of the Mexico project will be put on the aerodynamic analysis of a model rotor in the DNW.

As already reported before, the MEXICO project has not started yet and therefore this paper only presents a short introduction to the project (section 8. In addition a brief comparison will be given between the measurements which are planned in the MEXICO project and the measurements which have already been performed by NREL in the United States in the NASA-Ames wind tunnel.

2 DNW tunnel

A picture and the sizes of the DNW tunnel are shown below:



- The specifications of the applied measurement section are:
  - Open section;
  - 9.5 * 9.5 m^2;
  - Max. air speed 30 m/s;
- For the open test section, the aerodynamic features are [2]:
  - Local pressure deviations < 0.3% of total pressure;
  - Local flow angularity +/- 0.3 degrees;
  - local temperature deviations < 1.0 K;
  - Turbulence intensities <0.5%.

3 DATA: Aerodynamic design of the model rotor

The basic aim at the design of the model rotor was to maximise its energy production. This optimisation has been performed with the program PVOPT, [1]: PVOPT is a program which optimizes the chord and twist distribution along a wind turbine rotor blade, such that the maximum energy yield is obtained for stationary, axisymmetric flow conditions and for a wind climate which is characterized by a Weibull distribution. PVOPT assumes the turbine construction to be rigid. Constraints on chord and twist can be imposed.

The approach at the design of the model rotor has been to follow a procedure which is as much as possible comparable to a 'full scale' procedure. Nevertheless it should be realised that, despite the relatively large size of the DNW tunnel, the scale and environment of the wind tunnel rotor are still substantially different from the size and environment which is experienced by a full scale turbine. Hence inevatible concessions have to be made to the representativeness of the model rotors.

The basic problem in maintaining the similarity between a wind tunnel wind turbine and a full scale wind turbine is given by the fact, that the Reynolds number, the solidity and the local tip speed ratio should be comparable to the full scale situation.

A similar Reynolds number yields comparable viscous effects around the rotor blades. This is of particular importance for the tip Reynolds number, since the aero-acoustics of a turbine are mainly driven by the tip flow. A straightforward way to increase the Reynolds number of a small wind tunnel model up to full scale values, would be to increase the chord or the rotor speed. However at the same time the tip speed ratio ($\Omega \cdot r/V$) and the solidity ($B \cdot c/2\pi r$) should be representative in order to yield the correct global flow field (i.e. angle of attack, inflow velocities) around the rotor. This obviously limits the rotor speed and the chord. Hence the requirements on Reynolds number, tip speed ratio and solidity impose opposite demands on the tip chord and the rotor speed and a compromise was inevatible.

After a number of preliminary optimisations, the final optimisation were then based on the following assumptions:

- Diameter 4.5 m;
- Two bladed;
- Tip speed = 100 m/s;
- Tip Reynolds number = 1.7 Million. In conjunction with the tip speed of 100 m/s this results in a constraint for the tip chord of 0.24 m. This yields a tip solidity which turned out to be 2 to 3 times the optimal unconstrained tip solidity of a representative full scale rotor.
- Airfoils:
  - r= 0.0 to r = 0.5: No aerodynamic profiles are prescribed (i.e. no aerodynamic loads are modelled on this part of the blade)
  - r = 0.5 to r = 0.9 m: DU91-W2-250
  - r = 0.9 to r = 1.2 m: FFA-W3-211
  - r = 1.2 to r = 2.25 m: NACA64418, X3 or X5 airfoils. Although the airfoils will not be presented in this paper, it is important to know that the X3 profile differs from the other airfoils due to a much higher camber.

  For most airfoils, measured 2D profile data were available which could be used in the calculations. For the DU91-W2-250 and FFA-W3-211 airfoils, these measurements were available from open literature ([3] and [4]). For the NACA64418 and X3 airfoils, wind tunnel measurements have been performed by the University of Stuttgart. The X5 airfoil data were derived from XFOIL calculations.

  The optimisations have been performed for a rotor with clean blades. As such the 2D profile data, as prescribed to PVOPT, are based on measurements for clean airfoils. However, rotating measurements have also been performed on model rotors with tripped blades. These measurements have been simulated with ECN's aeroelastic code, as will be discussed later. Obviously these calculations required tripped airfoil data. Thereto the University of Stuttgart has also measured the profile coefficients of the NACA64418 and X3 airfoils at tripped conditions. The tripping of the airfoils in the 2D wind tunnel measurements was similar to the tripping which was applied to the blades at the rotating test: Tripping was done with simple (2-dimensional) Scotch tape of 0.13 mm thickness and 2 mm width. The tripping was applied at 5% chord on both suction as well as pressure sides.
- Wind climate: It is obvious that a hypothetical (and consequently an arbitrary) wind climate needed to be prescribed to the optimiser.

The result of the optimisation yielded a negative taper: The optimiser tries to compensate the very large tip solidity (due to the constraint on the tip chord) by a much smaller solidity at the inner part of the blade. A negative taper was considered to be very unrepresentative. For this reason the chord was constrained to c = 0.24 m for all radial positions. Hence the final blade design is untapered with optimised twist. For the X3 and X5 blade, the twist on the inner part of the blade ($r < 1.2$ m) was fixed to the optimised twist of the reference blade and the twist at the outer part of the blade is optimised only. Note that the optimised X3 blade showed a jump in twist between the outer part (with X3 profile) and the inner part (with FFA profile) This is a result of the much higher camber of the X3 profile: The jump in twist causes the profile coefficients to behave continuous at the transition between the X3 and FFA airfoils, despite the differences in camber.

4 DATA: PHATAS calculations

In order to estimate the design loads and resulting power on the model rotor, and to provide input for the aeroacoustic calculations which were made by the other participants, some calculations have been performed using ECN's aeroelastic code PHATAS ([5] and [6]). In this paper, the PHATAS power calculations are presented only.

Note that the original design calculations have been performed at the end of 1999 and the beginning of 2000 with the third version of PHATAS (PHATAS-III) before the measurements were available. After the measurements have been performed, the fourth version of PHATAS had become available (PHATAS-IV) and some of the calculations have been repeated with this version. Differences between PHATAS-III and PHATAS-IV are various but for the present project the most important differences are:

- A different modelling of the mass flow through the rotor at yawed conditions;
- Debugging.

The differences between the PHATAS-III and PHATAS-IV calculational results at aligned conditions turned out to be small: At aligned conditions the PHATAS-IV power was approximately 2% higher. For yawed conditions however, the differences between PHATAS-III and PHATAS-IV calculational results turned out to be substantial. Hence for all calculations at aligned conditions the PHATAS-III results are presented, where for the yawed cases the PHATAS-IV results are presented.

5 DATA power measurements

5.1 DATA measurement conditions

In the following sections the power measurements are discussed and compared with the calculations. Unless otherwise stated, the measurements are taken at conditions which are given in bold letters below. Although the majority of data have been taken at these conditions, a limited number of additional measurements have been performed at different conditions.

- Tunnel speed:
  - **14 m/s**;
  - Additional: V = 10.8 m/s and V = 15.9 m/s
- Rotor speed Ω:
  - **425 rpm**;
  - Reference rotor; Additional: 539 rpm
- Tip speed ratio λ (= ΩR/V): The tip speed ratios follows from the combination of tunnel speed and rotor speed:
  - **7.15**;
  - Additional: 6.26, 9.1
- Pitch angle θ:
  - Reference and X5 rotors: **-2 deg** (This turned out to be the optimal pitch angle); Additional: -3.5 and -0.5 deg.
  - X3 rotor: **-1 deg** (This turned out to be the optimal pitch angle); Additional: -2.5 and +0.5 deg
- Yaw angle ϕ_y:
  - **0 deg**;
  - Reference rotor; Additional: + 10, -5, -10, -15, -20, -25 deg
  - X3 and X5 rotors; Additional: -15 deg
- Transition:
  - **Clean blades**;
  - Additional: Tripped blades, see section 3.

Note that the measurement turned out to be very repeatable. Some light scatter could be observed in the data which mainly can be attributed to variations in tunnel and rotor speed. Obviously the precise values of tunnel and rotor speed were measured.

It turned out that the rotor speed could differ with approximately $\pm$ 5 rpm from the adjusted rotor speed. The figures in this report, which present data as function of wind speed, pitch angle or yaw angle, are a selection of the measurements which are closest to 425 rpm.

The tunnel speed could differ with approximately $\pm$ 0.1 m/s from the adjusted tunnel speed. The figures in this report, which present data as function of rotor speed, pitch angle or yaw angle, are a selection of the measurements which are closest to the adjusted tunnel speed.

Note that also some differences were apparent in the air density at the different campaign. Therefore all measurements have been translated to a standard air density of 1.225 kg/m^3.

5.2 DATA power measurements: Effect of different tip profiles (clean blades)

In figure 1 the power measurements are given for the three different rotors with clean blades. Note that RE denotes the reference profile. It is recalled that only three wind speeds are measured: V ≈ 11 m/s, 14 m/s and 16 m/s (section 5.1). The measurements are performed at the optimal pitch angles which are given in section 5.1. The following observations can be made:

- The power of the X5 rotor is comparable to the power of the reference rotor. At 16 m/s the power of the X5 rotor is even slightly higer.
- The power of the X3 rotor is slightly lower compared to the power of the two other rotors. The difference is in the order of 5%. This does not necessarily imply a poor aerodynamic performance of the X3 profile, but it may also be caused by the fact that the outer part of the X3 blade is not compatible to the prescribed inner part. The incompatibilities are due to the much larger camber of the X3 profile, compared to the camber of the profiles on the inner part of the blade (section 3).

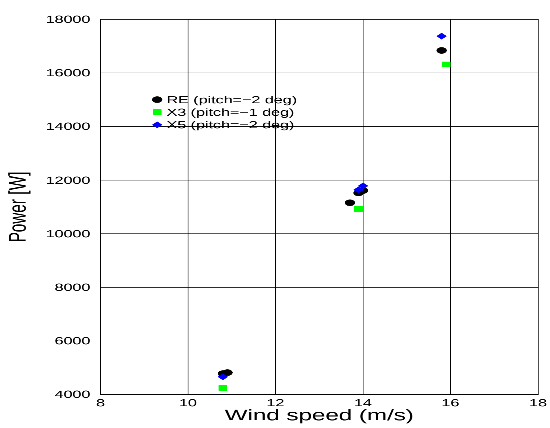


Figure 1: Measured power curves for three tip profiles (clean blades, no yaw, 425 rpm)

5.3 DATA power measurements: Effect of different tip profiles (tripped blades)

In figure 2 the power measurements are given for the three rotors with tripped blades. The observations on the difference between the tripped rotors are similar compared to the observations given for the clean rotor:

- The power of the X5 rotor is comparable to the power of the reference rotor;
- The power of the X3 rotor is approximately 5% lower than the power of the reference rotor.

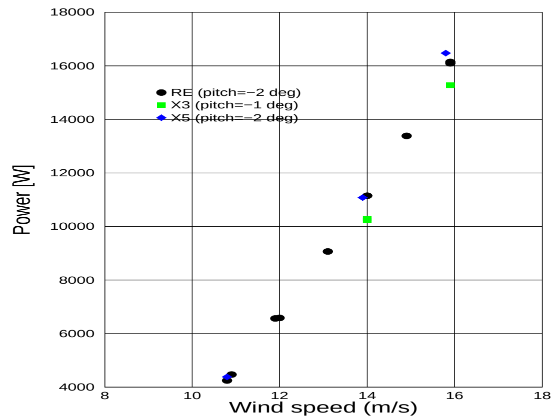


Figure 2: Measured power curves for three tip profiles (tripped blades, no yaw, 425 rpm)

By comparing figure 1 with figure 2 the following observations can be made:

- The loss in power due to tripping the reference blade is in the order of 3 %.
- The loss in power due to tripping the X3 and X5 blade is slightly more: 4 to 6 %.

6 DATA comparison between calculated and measured power

In the sequel the comparison is shown between the calculated and the measured power for several configurations and conditions (i.e. different tip profiles, different rotor speeds, different pitch angles, different yaw angles and for clean and tripped blades).

6.1 DATA comparison between calculated and measured power: Different tip profiles, clean

In the figures 3 to 5 the comparison between calculated and measured power is given for the different tip profiles (clean blades). The following observations can be made:

- The agreement between calculated and measured powers for the reference and X5 rotor is very good at all wind speeds;

- The agreement between calculated and measured powers for the X3 rotor is less good: Differences are in the order of 5%. As a matter of fact, the calculated power of the X3 rotor is equal to the power of the reference rotor. However as described before, the measured power of the X3 rotor is lower than the measured power of the reference rotor. These differences may be attributed to the modelled jump in twist between the X3 profile at the tip and the FFA profile at the inner subsections. This causes the modelled lift distribution to be continuous and almost similar to the lift distribution on the reference blade (section 3). The real X3 blade however shows a more gradual change in twist and airfoils, which as such differs from the modelling.

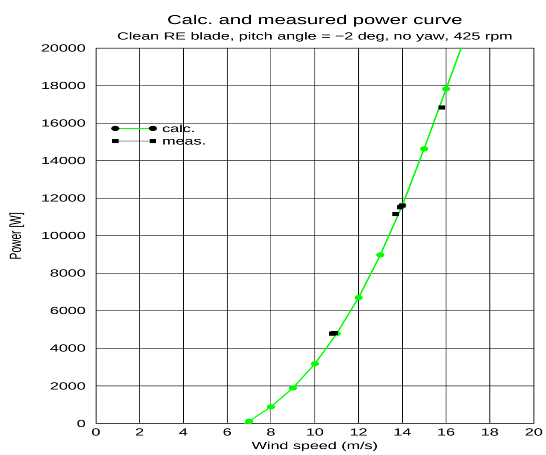


Figure 3: Comparison between calculated and measured power (RE profile, clean)

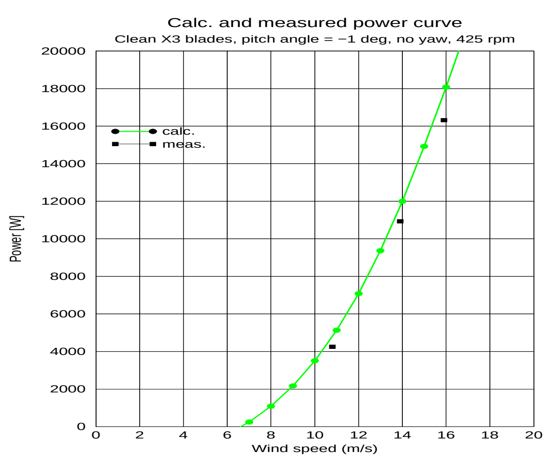


Figure 4: Comparison between calculated and measured power (X3 profile, clean)

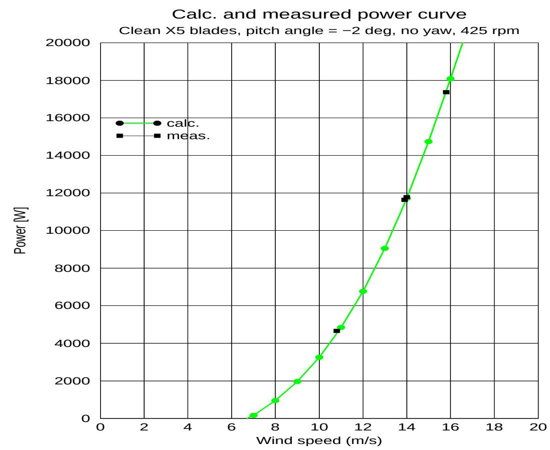


Figure 5: Comparison between calculated and measured power (X5 profile, clean)

6.2 DATA comparison between calculated and measured power: Different tip profiles, tripped

In the figures 6 and 7 the comparison between calculated and measured power is given for the different tip profiles with tripped blades. It should be realised that no tripped X5 profile data were available and hence this blade could not be calculated. Furthermore it is important to note that the effect of tripping was only taken into account for the tip profile (from r = 1.2 m to r = 2.25 m), for which the appropriate tripped airfoil data were available.

Despite the fact that the effect of the tripped inner side of the blade is not included, a good agreement is found between calculations and measurements. The agreement for the X3 rotor is less, which was also observed for the clean rotor. Possible explanation for the larger discrepancies are given in section 6.1.

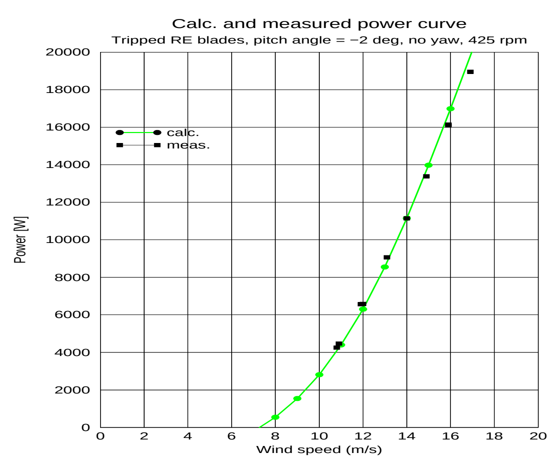


Figure 6: Comparison between calculated and measured power (RE profile, tripped)

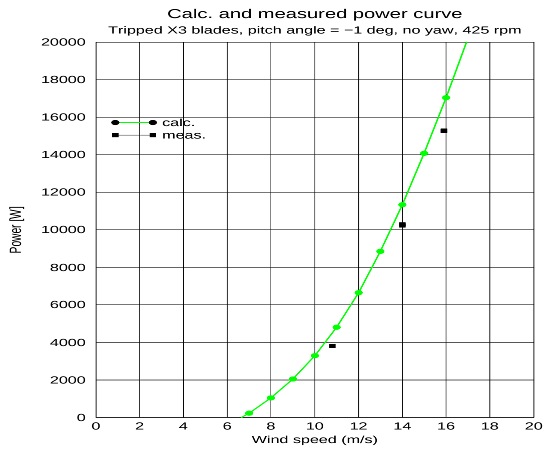


Figure 7: Comparison between calculated and measured power (X3 profile, tripped)

6.3 DATA comparison between calculated and measured power: Different pitch angles

In the figures, 8 to 10 the comparison is given between the calculated and measured power for different pitch angles (clean blades, V = 14 m/s). It can again be concluded that the agreement between calculations and measurements is poorest for the X3 blade. For the reference and the X5 rotor, the differences between calculated and measured power remain limited ($<$ 5%) for all pitch angles. Nevertheless the deviations between calculated and measured power at the non-optimal pitch angles turn out to be larger than the deviations which were observed at the optimal pitch angles. Furthermore the calculated trend between power and pitch angle does not always follow the measured trend.

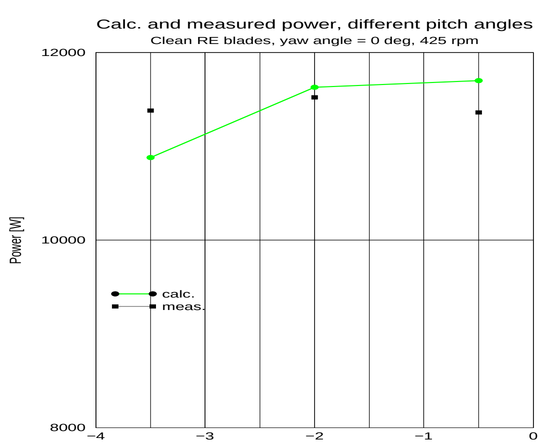


Figure 8: Comparison between calculated and measured power for different pitch angles, RE blade, clean

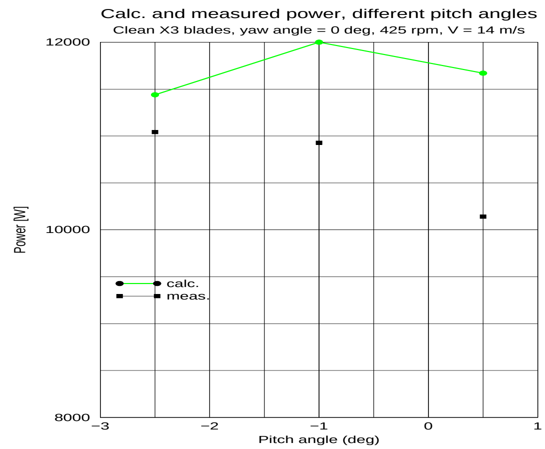


Figure 9: Comparison between calculated and measured power for different pitch angles, X3 blade, clean

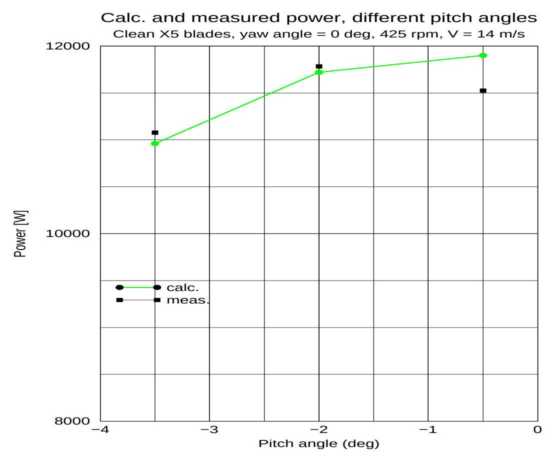


Figure 10: Comparison between calculated and measured power for different pitch angles, X5 blade, clean

6.4 DATA comparison between calculated and measured power: Different yaw angles

In the figures 11 to 13 the power is presented as function of yaw angle (clean blades, V= 14 m/s). It is recalled that the calculations at yawed conditions are performed with a different version of PHATAS (section 4).

Note that for the X3 and the X5 rotor only a very limited number of yaw measurements are available. As a matter of fact, for these rotors, measurements are only available at aligned conditions and at a yaw angle of -15 degrees.

The following observations can be made:

- The measured drop in power due to yawed conditons is in the order of $\cos^{1.8}\phi_y$;

- The calculated drop in power due to yawed conditions is much less;
- As a result the power is overpredicted at yawed conditions and the discrepancies increase rapidly with the yaw angle.

The differences between calculations and measurement at yawed conditions may be due to the fact, that because of the large rotor speed, the loading on the turbine (i.e. the axial induction) is relatively high. As a consequence the turbine is (partly) assumed to be in the turbulent wake state. This state is modelled through an empirical relation, the validity of which is not known at yawed conditions. Another reason for the discrepancies may be an overprediction of the mass flow through the rotor at yawed conditions.

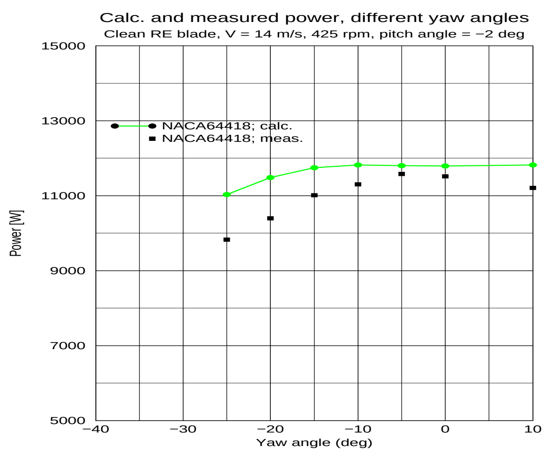


Figure 11: Comparison between calculated and measured power for different yaw angles, RE blade, clean

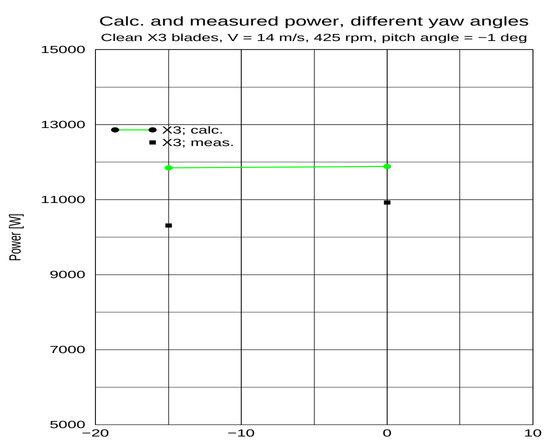


Figure 12: Comparison between calculated and measured power for different yaw angles, X3 blade, clean

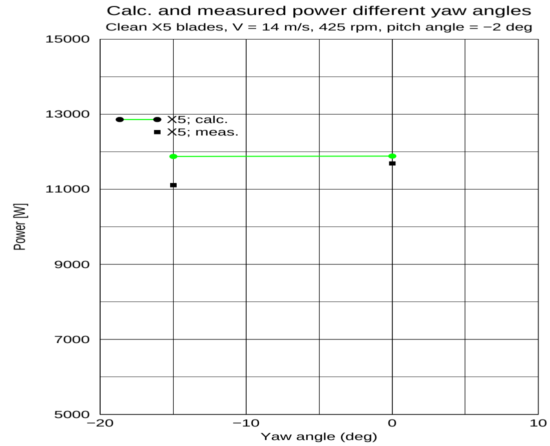


Figure 13: Comparison between calculated and measured power for different yaw angles, X5 blade, clean

6.5 DATA comparison between calculated and measured power: Different rotor speeds

In figure 14 the comparison is presented between the calculated and measured power for two different rotor speeds: 425 and 538 rpm (V= 14 m/s, clean blades). This comparison can only be given for the reference rotor, since the other rotors were only measured at a single rotor speed. It can be observed that the decrease in power, due to the increase in rotor speed is predicted well: The agreement in power is good at both rotor speeds.

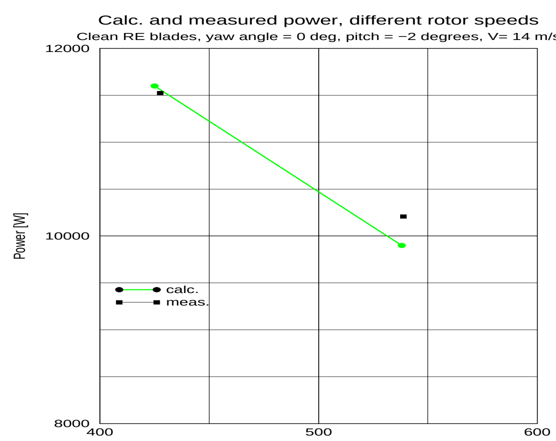


Figure 14: Comparison between calculated and measured power for different rotor speeds, RE blade, clean

7 Conclusions from ECN's tasks in the DATA project

- Three model rotors have been designed on which aero-acoustic measurements have been performed in the German Dutch Wind Tunnel, DNW. The difference between the rotors is in the airfoils at the outer part of the blade;

- The design of the model rotors has been made as much as possible representative for a full scale rotor. Thereto attention has been paid to yield representative tip Reynolds numbers, tip speed ratios and solidities;

- For the final design the tip Reynolds number, the tip speed ratios and the tip solidity turn out to be:

  – Tip Reynolds number: 1.7 10^6;
  – Tip speed ratios: Between 6 and 9 (on basis of the DNW tunnel speeds at the experiments);
  – Tip solidity: 0.03

  The resulting tip solidity is 2-3 times the tip solidity of a representative full scale rotor. This large tip solidity was accepted: It was considered as an inevatible concession which had to be made due to the difference between the wind tunnel and the full scale environment;

- The power of the rotor with the X5 profile is comparable to the power of the reference rotor with the NACA64418 profile;

- The power of the rotor with the X3 profile is 5% smaller than the power of the reference rotor. This may be due to the fact that the prescribed inner part of the blade is not optimal in combination with an outer X3 airfoil;

- The loss in power due to tripping the blade is in the order of 5%;

- The measured drop in power due to yawed conditions was in the order of $\cos^{1.8}\phi_y$;

- As spin-off of the acoustic experiments, a unique validation opportinity was offered for the aeroelastic program PHATAS.

  – At aligned conditions the agreement between the (blind) PHATAS calculations of the power and the measured power turned out to be very good (difference $< 5\%$). It should be noted however that these comparisons are done at attached flow. It is expected that the deviations become larger in stalled conditions;
  – At yawed conditons the power is overpredicted and the disagreement between calculations and measurements increase rapidly:

8 MEXICO project

8.1 MEXICO, goal and duration

The principal goal of the Mexico project is defined as the creation of a well documented database of aerodynamic measurements, which are taken under controlled and hence known conditions, and which will be used to validate or improve calculational methods (BEM methods, free wake methods and CFD methods). Thereto measurements will be taken on a model rotor in the DNW. The project duration is three years.

8.2 MEXICO: working procedure, model design, instrumentation and measurements

The following information will serve as global guidelines for the definition of the model design, the instrumentation and the measurement program, the details of which still need to be established:

- The rotor will be three bladed;

- The design of the rotor will be performed in a similar way as was done in the DATA project: A rotor will be designed which is as representative as possible to a full scale rotor. It is expected that the diameter of the model rotor will be in the order of 4-4.5 m (similar to the size of the DATA rotor) and that the Reynolds number will be in the order of 1.0 10^6. The rotor size is maximised to the existing tunnel geometry without incurring unpractical blockage corrections by means of calculations. Moreover the model rotor is designed with regard to structural reliability and stiffness criteria. Possibly this implies that for some cases the Reynolds number will be slightly smaller than 1.0 10^6. This may be true for the stalled cases, which require a low tip speed ratio. The low tip speed ratio in conjunction with the relatively high rotational speed which is associated with a Reynolds number of 1.0 10^6, yields high tunnel speeds and possibly too high structural loads.

Note that because of the higher tunnel speed, the design loads on the MEXICO rotor are anyhow expected to be much larger than those on the DATA rotor.

- Pressure distributions will be measured with fast Kulite transducers at (probably) 4 radial positions along one of the blades. As a consequence, no tubing (with inevatible damping and phase shifts) is required;

- The inflow and near wake will be measured with '5hole' Kulite probes at (probably) 4 radial positions;

- Flow visualisation will be performed (the selected techniques still need to be determined);

- Dynamic load measurements will be performed with root strain gauges;

- 2D wind tunnel measurements will also performed, the data of which will serve as reference for the rotating tests;

- The measurement matrix will be defined in consultation with the complete project group: Measurements will anyhow be performed at aligned conditions, yawed conditions (up to 45 degrees), stalled conditions, and probably at the turbulent wake and at fast pitching changes;

- Measurements will be performed on the rotor with clean blades, tripped blades and with boundary layer manipulators (such as vortex generators and stall strips);

- The measurements will be performed in two tunnel entries. The total DNW tunnel time will be 7.5 working days. Extensive testing of the test set-up and the instrumentation will be performed before the DNW measurements will be carried out;

9 MEXICO project related to the NREL's NASA-AMES project

It is interesting to compare the tests which are scheduled for the MEXICO project with the measurements which have already been performed by the National Renewable Energy Laboratory (NREL) in the worlds largest wind tunnel at the NASA Ames Research Center. The size of the measurement section is 24.4 by 36.6 meter and the diameter of the turbine was 10-meter. The wind turbine was extensively instrumented to characterize the aerodynamic and structural responses of a full-scale wind turbine rotor. Measured quantities included inflow conditions (relatively far upstream), airfoil aerodynamic pressure distributions, and machine responses. The aerodynamic pressure distributions were measured with pressure scanners which were connected by means of tubes to the pressure taps.

An extensive range of pitch angles, pitch motions, yaw positions, and wind velocities were tested. The 3-week test was completed in May 2000 with the turbine operated in over 1700 different test conditions.

In the table below the characteristics of NREL's NASA-Ames experiments are given and compared with the MEXICO test for a number of aerodynamic aspects. The table does not only contain the MEXICO and NASA-Ames wind tunnel measurements, but also the remaining 'state of the art' in aerodynamic experiments on wind turbine rotors, i.e.:

- Full scale aerodynamic field experiments, (see i.e. [7]);
- Measurements which have been taken in the FFA-CARDC wind tunnel (see i.e. [8] and [9]).

The characteristics of all these experiments are given for three different aerodynamic aspects:

- Time averaged blade flow (i.e. 3D effects in stall);
- Near wake flow and induction near the rotor;
- Unsteady blade flow (i.e. dynamic stall).

Aerodynamic aspect	State of the art	NASA-AMES	Mexico
Time averaged blade flow	Field experiments: Ambient inflow only statistical Re ≈ 3 10^6 FFA- CARDC: 2 bladed; Ambient inflow known Re ≈ 0.5 10^6	2bladed, Ambient inflow known Re ≈ 1.5 10^6	3bladed Ambient inflow known Re ≈ 1.0 10^6
Near wake/induction	Hot wire measurements small wt. models (i.e. DUT)	Not measured	Detailed meas. of flow in rotor plane and wake
Unsteady blade flow	Field measurements: Difficult due to lack of inflow details Re ≈ 3.0 10^6 FFA: Relatively slow Re ≈ 0.5 10^6	Rel. slow tubing No correlation with flow in rotorplane Re ≈ 1.5 10^6	Fast blade pressure measurements Correlation with flow in rotor plane Re ≈ 1.0 10^6

The survey shows that the MEXICO project is expected to yield important information, which is partly similar and partly additional, to the information from the NASA-Ames measurements and the 'state of the art' experiments. It should be realised that even the MEXICO information which at first sight looks similar to the information from other experiments, is only similar in a global sense: From experience is known that, due to the complexity of the phenomena which are associated with rotor aerodynamics, the understanding and the general modelling of aerodynamic aspects requires measurements on more than one configuration.

Additional information is in particular expected from the measurements which will be taken with the fast pressure transducers and which will deliver measurements with a very high resulution. In the other tests the resolution is poorer (although not always insufficient). Furthermore additional information is expected from the near wake measurements: They will yield important information on the understanding of yaw aerodynamics and they make it possible to correlate the global flow field around the rotor with the pressure measurements on the blade.

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