Determination of the Angle of Attack on a Research Wind Turbine Rotor Blade Using Surface Pressure Measurements

Reply to Handling Associate Editor Dr. K. Dykes
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Dear Dr. Dykes, thank you for the detailed review of our paper. The comments are addressed in the final version. Please find below, the answers to your comments.
The supplementary documents attached are:

- manuscript_wes-2020-35.pdf: is the last version of the paper
- manuscript_wes-2020-35_tracked_changes.pdf: contains additions in blue and deleted text in strike-through red.

Abstract
- The abstract doesnt speak explicitly to the value of the contribution – what is the potential impact?
R: The abstract was rewritten and is given below for convenience.

"In this paper, a method to determine the angle of attack on a wind turbine rotor blade using a chordwise pressure distribution measurement was applied. The approach used a reduced number of pressure tap data located close to the blade leading edge. The results were compared with the measurements from three external probes mounted on the blade at different radial positions and with analytical calculations. Both experimental approaches used in this study are based on the 2-D flow assumption; the pressure tap method is an application of the thin airfoil theory, while the probe method applies geometrical and induction corrections to the measurement data.

The experiments were conducted in the wind tunnel at the Hermann Föttinger Institut of the Technische Unversität Berlin. The research turbine is a three-bladed upwind horizontal axis wind turbine model with a rotor diameter of 3m. The measurements were carried out at rated conditions with a tip speed ratio of 4.35 and different yaw and pitch angles were tested in order to compare the approaches over a wide range of conditions.

Results show that the pressure tap method is suitable and provides a similar angle of attack to the external probe measurements as well as the analytical calculations. This is a significant step for the experimental determination of the local angle of attack, as it eliminates the need for external probes, which affect the flow over the blade and require additional calibration."

Introduction

- Typo line 53 should be as not has
R. The typo was changed. The sentences is given below for convenience.

"Different computational methods use this information as a source to estimate the AoA".

- Typo 57 probes' not probes
R: The typo was changed. The sentences is given below for convenience.

"This method was implemented by ECN, NREL, DTU projects, obtaining similar results with their respective estimations based on probes".

Methodology

- Why were the particular locations along the blade span chosen and why pressure tabs and 3HP at the respective locations? I don't think again the motivation for why everything is set up as it is is fully developed. The section is more descriptive than analytical
R: The information has been added in the methodology section and is given here for convenience.

"Due to manufacturing reasons (internal structure, holes spacing), the pressure taps could only be located at a single spanwise location, which was at 45\% of the blade span. Each pressure tap was connected through silicone tubes inside the blade to a pressure box located in the hub which contains all sensors."

"The blade was also provided with three trailing edge flaps with 10\%R span length and 30\%c chord length and located consecutively from 60\% to 90\% along the span. Each 3-hole probe was aimed to give feedback information to choose flap movements. However, the flaps were fixed without any deflection for all test cases presented in this study."

- Line 182 has a typo, either when it is or when applied but not when is
R: The typo was changed. The sentences is given below for convenience.

"The main idea is to compare the results obtained by the method proposed by Gaunaa and Anderson (2009) when it is applied to the pressure tap data against the AoA from 3-hole probe measurements and analytical calculations."

- Typo line 202, while the pressure tap uses the static pressure in…
R: The typo was changed. The sentences is given below for convenience.

"The pressure sensors measure the differential pressure P_{si}. The 3-hole probes use the inner tube as a reference, while the pressure taps use the static pressure in the test section".

- Line 227 typo, because the blade itself induces…
R: The typo was changed. The sentences is given below for convenience.

"The latter angle differs from α, which is the effective AoA of the blade section, because the blade itself induces a velocity on its surroundings".

- Line 324 to keep the
R: The sentence was changed and is given below for convenience.

"During the measurement campaign, while the changes on the pitch or yaw angle were made between test cases, the tunnel was left open to allow for fresh air to enter the tunnel circuit. As a result, the temperature and relative humidity were kept within $18 \pm 1.5°C$ and $40 \pm 5\%$, respectively."

Results and discussion
- Long sentence line 334 is hard to read.
R: This paragraph was rewritten:

"For the aligned case, $\psi = 0°$, the relative dynamic pressure remains relatively constant at $q_{rel} = 4.5q_\infty$, while the pressure difference at 12.5%c exhibits four marked behaviors :

Initially, $0° \leq \phi \leq 90°$, it remains relatively constant at $\Delta P(12.5\%c) = 9.8q_\infty$. Then the dynamic pressure drops, to reach a minimum at $\phi = 180°$ $(9.3q_\infty)$, while an increase follows from $\phi = 180°$ to $\phi = 290°$. At that point, the dynamic pressure reaches its maximum value $(10.3q_\infty)$ before it starts dropping to reach $9.8q_\infty$ at $\phi = 360°$."

- Figure 14 seems to have incomplete caption. Should explicitly say what each figure represents in the caption not just the text
R: Yes, thank you for highlighting this. After the first revision, the figure on the right was added without updating the caption. This has been corrected and the figure is given below for your convenience

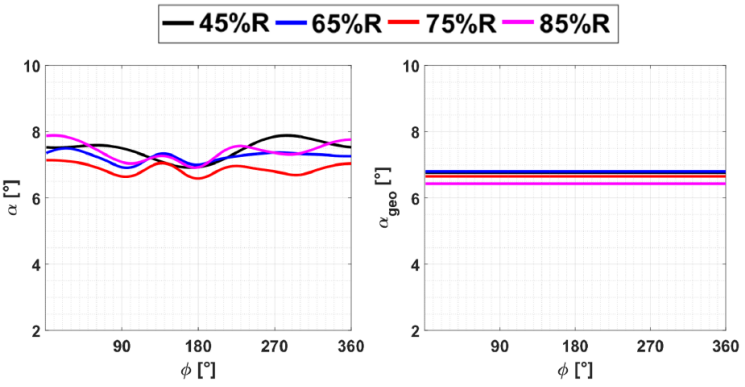

Figure 14. AoA results for yaw angle $\psi = 0°$ and pitch angle $\theta = 0°$. Pressure taps and 3-hole probe approaches (left). Analytical calculations (right).

- Typo line 384

R: The sentence was rewritten:

"These variations, $\Delta U_\infty = \pm 0.2 ms^{-1}$ (see Fig. 2), can have the same influence as the tower over the AoA estimations. The geometrical estimation (α_{geo}) under such inflow variations, results in an AoA difference of $\Delta\alpha_{geo} = \pm 0.4°$, which supports this statement"

- The discussion and interpretation of the differences between the results and to prior publications could be more fully developed – and perhaps help provide the paper with more analytical substance. Right now, the results section reads very descriptive rather than identifying and pulling out key insights

R: The results are discussed in more detail and in an analytical manner in the sections listed below. In the interest of brevity, we consider this is suitable for this paper.

Lines 359-371: Explain with details the effect of the discrete taps in the chordwise surface.
Lines 391-394: Explain and highlight the fact of the non-uniform inflow incidence.
Lines 399-401: Evidence that the differences of previous studies is the blockage, as the model implemented in the analytical approach includes that effect.
Lines 441-444: Explain why the pitch angle and angle of attack do not present a one to one linear relation, highlighting the inherent axial induction factor dependency.

-On Introduction: starts nicely and lays out the complexity of the problem. The literature review is very thorough. However, the literature review and introduction fail to make the case for the unique contribution of this work. What is unique about the approach that makes is journal publication worthy? What is special about the BeRT blade? It still is unclear at the end of the introduction what the point of this paper is from the perspective of scientific contribution.

-On Methodology: This seems to be the first introduction of the point of this paper on line 181 why is this a significant contribution? Elaborate! Also, Why is this intent not discussed at the beginning of the introduction? You need to reiterate the point of the paper in the abstract, introduction and in the conclusions. Don't expect the reader to dig it out for themselves

On Conclusions: Finally in lines 459-470 the paper gets to the point. This was not obvious throughout the paper. Please think about how to strengthen the paper in lifting up and highlighting the novel contributions.

R: The suggestion of the paragraphs of the methodology has been taking into account, now the impact and contribution is explicitly in the abstract, introduction and conclusions.

Abstract:

"[…]. Results show that the pressure tap method is suitable and provides a similar angle of attack to the external probe measurements as well as the analytical calculations. This is a significant step for the experimental determination of the local angle of attack, as it eliminates the need for external probes, which affect the flow over the blade and require additional calibration."

Introduction:
"[…]. To the authors' knowledge, this method has not been applied on a rotating blade yet. Given the good agreement between 2-D and 3-D pressure distributions away from the root region, this paper presents an alternative method of determining the AoA by means of pressure tap measurements. The present investigation aims at providing experimental verification for one such surface pressure method (Gaunaa and Anderson 2009) on the rotating blade".

Conclusions:
"[…] Overall, it is found that the pressure tap method applied here to determine the AoA, provides reliable data, with good performance for both aligned and misaligned cases. Hence, the presented method is a promising alternative to the use of external probes, which affect the flow over the blade and require additional calibration".