Determination of the Angle of Attack on a ResearchWind Turbine Rotor Blade Using Surface Pressure Measurements.

Reply to Uwe Paulsen (Referee)

Received and published: 27 April 2020

Dear Dr. Paulsen (Referee), below you can find the answers to your comments

Abstract: May be rephrased due to conclusions, based on edititorial issues.

- Reply: It will be rewritten based on the applied changes.

1 Introduction:

L16: please make it more clear why is AoA a challenge? There are practical solutions to measure inflow, but is it aoa? The sentence/question should be open up for some reflections essential for the motivation. It would be great for the reader to have a (tablar) listing of available methods.

- Reply: This will be implemented.

L31 At Risø(DTU) inflow measurements on a real turbine was conducted already in 90ties by Risø Nat. labs, and NREL around same time.

- Reply: These references will be included as part of the introduction.

L46 it depends on the blade length and scaling; a 20mm pitot tube in comparison with a 60m blade-please adjust this against wind tunnel testing.

- Reply: Agreed, this will be rephrased including the scaling reference mentioned.

L48 no references given.

- Reply: will be included.

L51 unclear sentence: with a pitot pressure sensors you know the position geometrically.

- Reply: Agreed, the sentence wants to point out that the pressure taps and probe are not exactly in the same radial position, therefore the AoA provided by the probe is not the AoA at the pressure taps. This sentence will be rephrased.

2 Experimental setup

Figure 2 is missing definitons (Ut, Un, Urel), as well as t/c.

- Reply: This will be included.

L109: explain 'on a comparable level', e.g what is the implicit effect of Turbulence (1.5%)?

- Reply: An additional explanation will be included in order to fullfill the turbulence calculation and its repercussions.

The choice for using ClarkY is not clear(high drag airfoil), see f.example DOI: 10.2514/6.2006-33 Conference: 44th AIAA Aerospace Sciences Meeting and Exhibit

- Reply: Additional information about the used airfoil will be provided. Regarding the high values in the Cl/Cd plot are for small Reynolds number (<10^5). The latter is not the case when the turbine is set at rated condition (Reynolds number based on the blade chord and relative velocity is in the range of 1.7-3.0 x 10^5)

L113: Model Blockage and consequences for interpretation of results?

- Reply: The blockage effect has been modelled computationally and it was found sinificant in terms of power and thrust, compared to field conditions. The latter,

it motivated the pitch steps, checking the sensibility of the estimations approaches, supporting that the pressure taps method will be able to capture a realistic expansion in the absence of walls. The blockage effect will be discussed in the revised submission.

L115: is the turbine yaw fixed or free?

- Reply: Is fixed and the change can be done only manually before any measurements. This will be explicit in the final document.

L124: the statement of placement of pressure taps is not constant=0.45-why straight line placement?/why is it in this small scale experiement not following constant radius?

- Reply: This is correct. They are in a straight line perpendicular to the spanwise line from the root until 45%R at x/c=0.3. The curvature error is considered small ($\Delta r < 25mm$). However, it was considered when the pressure was corrected by centrifugal effect as shown L165. This will be explicit.

L126: what is the max frequency (3 dB limit) of the detectable signal

- Reply: This will be included.

L129:specs?

- Reply: The spectra from the three-hole probes will be included.

L134: A miss why the use of flaps with consensus on title /intro & science objectives

- Reply: The TE-flaps were set in their neutral position for all the experiments, and they are exposed only for completeness of the equipped blade information.

3 Methodology

L157: using a 3 hole probe-no side slip detection. What about the flow conditions when the turbine is in yaw?

- Reply: In the case of the cross-flow presence, the calibration loses its one-to-one relationship with a probe in a yaw angle (becoming multi-valued). This is the case of a combination of a large angle of attack and yaw angle or an excesive yaw angle. For the study cases, the angle of attack remains below ~11° for every azimuth, yaw, and pitch angles which suggest a small influence, this error will be included, regarding both misalignment (Figure 4 of Pisasale, A. J., and N. A. Ahmed. "A novel method for extending the calibration range of five-hole probe for highly three-dimensional flows." Flow Measurement and Instrumentation 13.1-2 (2002): 23-30.)

L171: what is the explanation behind seeing the 1P in the signal for the interpretation?

- Reply: 1P corresponds to the tower effect.

L174: This is a surprising statement about resonator box system that doesn't damp frequencies.30 Hz filter? The cited reference(Berg) offers fig 21(assuming small tubes) with considerable amplitude and phase lag properties.This needs clarification.

- Reply: This will be discuss in detail, including the lag and amplitude ratio estimations from the reference cited.

Fig 8: What is the difference between the black-dashed and red points around x/c=0.3..and onwards?

- Reply: The difference will be discussed in the next version.

L237: the discussion of cross flow(sideslip) for the 2D probe is missing. Or may be your statemnt is to use a 2D probe in the 3D inflow as a representation of the normal (tangential) velocity components? Clarification and error calculation is needed.

- Reply: This will be discussed and supporting references will be provided, such as the one in the previous reply of side slip detection from L157.

L253: temperature increases in the flow during experiments effects on the pressure sensors (standard calibration at 25deg nom)? As I recall the HCL's have +-0.25%FS nonlinearity & hysteresis. So i would assume higher uncertainty on aoa.

- Reply: According to the manufacturer the $\pm 0.25\% FS$ is in the maximum case, the nominal value is $\pm 0.05\% FS$. Nevertheless, the experiments were performed measuring the wind tunnel temperature, which resulted between 17.5-19.5°C. Part of the protocol „between cases“ was to leave the accesses to the tunnel opened meanwhile the change in pitch or yaw was made. This will be explicit in the new version.

Table1 needs to state that uncertainty is [fraction/%] of FSR

- Reply: This will be implemented.

4.1 Pressure distribution

The question is if yaw affetcs the pressure in the dynamic inflow field, observed here with a 2D-probe.

- Reply: As it was mentioned before, this will be addressed with more detail

The results are expressed in Pascal, may be it is more clear to show it relativel (normalisation), speaking of uncertainty and also from a point of measurement range.

- Reply: This will be implemented.

Figure 11: add of result for 0 yaw missing

- Reply: This will be implemented.

4.2 Angle of attack estimation

Fig12:Odd.with the 2-2½P variations(L316), except for the tower influence.Check! and L334: Could this be the damping effects from the resonating tubes characteristic ?, same P variation issue as above

- Reply: This will be checked in concordance with the additional comments on pressure damping.

5 Conclusion: may change in details.

- Reply: Overall and specific changes will be reflected in the final conclusions.