Comments to Reviewer #1
Dear Reviewer

First of all we would like to thank you for your constructive review of our article. Please find below our responses (in red) to your comments (in blue) and article updated text (in brown). Please find also attached a marked-up version showing all changes in the article.

Yours sincerely

H. Aa. Madsen and co-authors

This is a very interesting paper with a unique measurement on a full scale wt. I have only three small comments/recommendations:
Thank you for your review of the article and comments.

1) In Fig. 6b the green tape is hardly visible. It would be nice if a close-up photo could be included.
A close-up photo of the green tape on the serrations has been included as figure 4c (clarification comment, the figure has now number "4" instead of "6").

2) If any turbulence data from the met mats are available they should be mention in chapter 3.
Information for the met-mast measurements is provided in the references, however, no met-mast data is used for the analysis pertinent to this article, therefore no further details are given. Note also the following text of the article in the "Turbine Instrumentation" subsection: "...as the met-mast used specifically for phase 4 of the test was no longer in operation the days when the wake-rake test was conducted."

3) The existence of the VGs should be mentioned already in section 2.3.2
Text mentioning the VGs is added in 2.3.2. Furthermore, it is explained why the VGs were removed for this specific test with the following text addition:
Furthermore, the blade has vortex generators (VGs) mounted on the suction side. However, these VGs were removed prior to the execution of the test in question as discussed in section 2.3.2 to avoid spanwise variations of the wake velocity deficit coming from the upwash and downwash structures trailed from the VG vanes.

Comments to Reviewer #2
Dear Reviewer

First of all we would like to thank you for your constructive review of our article. Please find below our responses (in red) to your comments (in blue) and article updated text (in brown). Please find also attached a marked-up version showing all changes in the article.

Yours sincerely

H. Aa. Madsen and co-authors

General comments: A very nice article about the evolution of an innovative measurement technique that contributes to closing the gap between the wind tunnel results used in design and unknown sectional performance in the field. From this viewpoint the article provides new and valuable insight and is worthy of publication. The storyline is clear and well conveyed. It is recommended to follow up on the below suggestions for improvement:
Thank you for your general comments.

-p4/5 section 2.2.1 Can the authors comment on the applicability of Jones' method in a rotor setting? In particular concerning static pressure assumptions made by this method and the static pressure variations that might be present due to rotor blockage.
If one imagines a control volume surrounding the local airfoil, then Jones' method should be applicable irrespective of the rotor blockage, this is because the static pressure is being measured also in the rotor plane (and not at an undisturbed upstream position). However, Jones' method is generally not proved to be applicable to unsteady 3D flows and the static pressure measured at the wake rake will also vary during a rotor revolution. To highlight this uncertainty, we have inserted the following text in the paper:
However, we use the same formula for the derivation of the drag coefficient in turbulent flow, and the accuracy of this needs to be further investigated in future tests.

-p5 section 2.2.1 Some illustration of the mentioned results from the parameter variations are recommended. In addition to that, has the influence of the downstream position of the wake rake on the result also been verified?
The influence of the downstream position of the wake rake has been investigated in the wind tunnel as mentioned in 2.2.1 but not on the rotor.
See line 110 on page 5 of the manuscript: "– The cd measurement is only slightly affected by the downstream distance from the trailing edge (0.1 m to 0.5 m)

-p12 section 2.3.6 and section 4 The block and moving averaging procedure is explained to act as a low pass filter. In the end the results are presented by means of sectional polar plots like fig.10, which appear quite steady without hysteresis. In how far does the post-processing procedure filter out the dynamics present in the field? What is the non-dimensional frequency k at this section based on 1P? Would it be interesting to also show a polar plot like figure 10 without the pre-processing procedure (based on raw data),or would that result in a rather large cloud op

points?
No block and moving averaging would result in large scatter in the polars and the time-series plots becomes unclear. Since the interest lies in comparison of 'static' polars, the method is considered adequate. The estimated reduced frequency is low : k= omega*0.5c/Vrel, about 0.009 for Vrel = 40m/s and omega =0.73 (quasi-steady assumtion valid generally for k<0.05).

-p13 section 2.3.7 Uncertainty Pressure measurements on wind turbines are often complicated by drift due to, e.g. temperature changes and the difficulty of a providing a stable reference pressure. Although there is a referral to a previous paper from 2022 about this measurement system, could the authors comment on these challenges in relation to their system?
No known drift due to temperature changes has been observed. The reference pressure is taken as the static pressure from the wake rake. The inflow/belt pressures are differential pressures, in the case of absolute pressure, care must be taken to compensate both for barometric pressure changes as well as hydro-static, but this is fortunately not the case for this experiment.

Furthermore, from the 16 channel miniature Evoscanner data sheet the following information is given regarding temperature compensation: *"Integrated temperature sensors provide useful data, but also apply temperature correction to every pressure sensor, at source, to ensure optimal performance and minimal ambient temperature effects."*

-p16 section 4 A discrepancy in the drag coefficient between field and wind tunnel is noted. Is the same offset present between RTR and wind tunnel?
There was also an offset in Cd between WT/RTR. In the full scale case there is also a pressure gradient due to centrifugal effects, so small flap angle difference to wind tunnel which is partially responsible for the Cd offset. In both cases, the difference can probably be attributed to field test flow and surface conditions.
However it should be noted that due to the comments from Reviewer #3 the measured airfoil characteristics from the RTR have been left out to focus fully on the difference between wind tunnel and full-scale airfoil characteristics.

-It is mentioned that the turbine has been instrumented to measure loads and power. It would be helpful if the influence of the added external sectional instrumentation on the loads and power can be quantified. Also, have the effects of flaps and zz-tape on power and loads also been measured or were these effects too small?
The effects on loads and power of the instrumentation on the power and load levels of the turbine are minimal and such differences would not be quantifiable unless a medium-term duration side-by-side test with a similar machine would be conducted, similar as when small changes in blade configurations are performed, e.g. when installing add-ons. The following text has been added describing that.
The impact of the installed instrumentation of the blade is expected to have a minimal impact on the operation on the turbine..

Comments to Reviewer #3
Dear Reviewer

First of all we would like to thank you for your constructive review of our article. Please find below our responses (in red) to your comments (in blue) and article updated text (in brown). Please find also attached a marked-up version showing all changes in the article.

Yours sincerely

H. Aa. Madsen and co-authors

Summary of major issues : The paper present an important work with wind tunnel, tests ring and field test measurements, that are however most of the time not sufficiently described, not sufficiently justified and analyzed. This is also difficult to make a link between wind tunnel tests/ test ring and wind turbine tests as there is either no quantitative results, only the Cl/Cd curve or only the Cl/Cd time series . . . I recommand authors to maybe focus more on one set of tests and to provide a more detailed analysis.

Response:
We acknowledge that the reviewer finds that the article presents important work. However, we do not understand the argument of the reviewer that the link between wind tunnel tests and turbine tests is difficult to follow due to the lack of quantitative results. Figures 9, 10, 11, 12, and 13 present all quantitative results.

The key objective of the article is to compare the airfoil characteristics measured in the wind tunnel and on the full-scale rotor presented in Figures 10, 11, 12, and 13. The test on the rotating test rig was just included and briefly described because we find that it is an important part of the development and research work that led to the application of the wake rake on a full-scale turbine.

However, to make it clear that the main objective is to compare the full-scale rotor airfoil characteristics (Cl and Cd) with wind tunnel data, we have rewritten and shortened Sections 2.2.1 and 2.2.2 to show that in the present article we just want to describe that this part is to test the functionality and operation of the wake rake in a rotating environment with turbulent inflow.

1-Introduction : Authors underline the lack of knowledge on blade aerodynamics on solely three mechanisms : high Reynolds numbers, roughness state at the surface of the blades, outer-flow state (turbulence inflow) that acts on the laminar to turbulent transition on the airfoil surface. However, differences between wind tunnel and field tests can come from more than these 3 mechanisms. Indeed, wind tunnel turbulent inflow do not necessarily match inflows encountered in blade real operating conditions and not only regarding turbulence level. Mean inflow velocity gradients combined with different turbulent inflows may lead to different operating AoA. This can induce important load variations and even flow separation (even small) which induces 3D and unsteady flow over the airfoil and thus load variations. When the flow separates other aspects such as the airfoil aspect ratio, and the centrifugal forces play an important role in differences with wind tunnel measurements. Centrifugal forces are reproduced by the rotating test ring, however, the aspect ratio is very low (2) on both wind tunnel and rotating test ring.

Response:
First we mention that we did not write **"solely"**, but we write: *... in the lack of knowledge of,* ***"e.g."*** *the characteristics of the ....*

However, we propose to change the original formulation:

"Together, these three mechanisms have an important influence on the boundary layer transition characteristics."

Changed to:

"Together, these three mechanisms have an important influence on the boundary layer transition characteristics, but other effects like three-dimensional flow effects in combination with local separation are also important."

You write further:

Please reformulate hypothesis of this study in the introduction : - The author place themselves in the hypothesis with no inflow inhomogeneity (mean or turbulent) along the blade in real operation (there is no inflow measurements able to measure the presence of any mean or unsteady velocity gradient). Only two points are measured in the near blade inflow (in the blade induction zone?) using the 5 hole pressure sensors. - The AoA is sufficiently low for the flow to stay attached.

Response:
If we understand correctly this is the imagination of the rotor in wind tunnel flow, e.g. like the experiment NREL carried out in year 2000 placing a 10 m rotor in the giant NASA Ames wind tunnel. In this case, comparing the characteristics of the wind tunnel and the rotor airfoil characteristics would show the impact of stall, three-dimensional flow effects, and centrifugal effects among others. Back then, there was much focus on the stall effects as much of the turbines were stall-regulated.
However, in our present experiment we have taken a big step further and measured the airfoil characteristics on a pith-regulated full-scale rotor operating below stall except in few instantaneous moments. Previous detailed measurements have pointed to the impact of atmospheric turbulence moving forward the point of transition and, e.g., contributing to the increase in drag.
We therefore find that the present introduction describes the key objective of the article in a clear way.

2 - Experimental set-up :
Figure 1 is unclear. It is very difficult to see how the rake is installed relatively to the blade. Please provide a clearer view (maybe add a sketch).

Response:
We agree that it might be difficult to see the wake rake setup in the wind tunnel. This is mainly

because the wind tunnel was in an acoustic version with fiber cloth semi-transparent walls.

We propose to remove the photos.

Due to all the instrumentation (wake rake plus 5 hole pressure sensors), the flow over the airfoil might be 3D even if not separated (low AoA). This could happen especially due to the low aspect ratio (equal to 2).
How the two dimensionality is checked (wood tuft ? Visualization??) ?

Response:
The flow over the blade section is certainly three-dimensional over most of the span but at the mid span section where the pressure taps are installed the flow is expected to be approximately two-dimensional.

However, as mentioned above, Section 2.2.2 has been shortened and does not longer included measurement of airfoil characteristics.

The wake rake composition is not given clearly in section 2.2. A picture appears only in L120, with no explanation on the location of « static tubes », « total pressure tubes » or « head of pitot tubes » that seems to compose the wake rake as given from L116 to L119. Please provide a clear description/composition of the wake rake (on figure 2), at section 2.2.
Please justify the choice of this composition.

Response:
We have inserted text on the photo of Figure 2 marking the four static probes and the two different spacings of 5 and 10 mm between the total probes.

The geometry of the airfoil section is not given. This is a very important matter as the state of the flow over the airfoil depends largely on the airfoil geometry. $15\mathrm{deg}$ is certainly a separated state, and depending on the airfoil geometry (thickness, curvature), this correspond to a deep stall or a slight trailing edge flow separation . . . Also, there is no means to evaluate the drag without the wake rake (no reference case). This could be a an xfoil simulation (valid only at low AoA) or drag measurements using a balance system.
Please provide the airfoil geometry that is tested, and at least a reference case with measurement of Cl, Cd versus AoA.

Response:
The airfoil is a 21% thick airfoil designed specifically for wind turbine application by Siemens Gamesa and the design is confidential. However, Section 2.2.2 has been rewritten and shortened and does not longer include measurement of airfoil characteristics so that the details of the airfoil shape are not important.

L110-114 : « measurement is only slightly affected by ». How can you conclude on this as there is no « reference case » ? Also, please provide a more quantitative description.
• L113 « The cd is only slightly affected by the pressure orifices, but largely affected by the

five-hole Pitot tube connection »
This is to me a major issue for drag measurement. Please develop more for which configurations this sentence applies ? Please provide a quantification of this impact. At last, justify more why using 5 hole pressure sensors, and give possible solutions for future work. • Nothing is said on impact of AoA (8° and 15° were tested) on drag measurements

Response:
As mentioned in the description of the test parameters, the wake rake was tested in the following different vertical heights:

– Vertical position: 1.0 m (behind pressure orifices), 1.15 m (slightly above pressure orifices), 1.38 m (maximum height, closer to the connecting tubes for the five-hole Pitot tube).

It is on the basis of these measurements that the conclusions were made.

As concerns the drag from the five hole pitot tube we do not consider this as a problem as we position the five hole pitot tube well away from the measurements of the drag, e.g. assuming the wedge of the wake from the five hole pitot tube has angle of +-10 deg.

Nothing is said on impact of AoA (8° and 15° were tested) on drag measurements Please provide Cd error quantification for both AoA.

Response:
Not relevant any more as the graph with CD characteristics from the RTR has been deleted.

Section 2.2.2 • L136 « Detailed tests were carried out in different wind conditions ... » Please provide detailed informations on tested configurations (give values of velocity, pitch and flap angles, together with calculated AoA – and provide method used to compute AoA). • P6 L137 : There is no description of the VG and of the surface roughness (shape, location on the blade, wind tunnel tests etc . . .) used for figure 4. Also this figure is out of the main paper subject. Either the authors give more information on these tests, or the figure should be removed. Also, why not providing a comparison between wind tunnel drag measurements and test ring measurements (and then field tests measurements) ? Isn't is the purpose of the paper ?

Response:
Not relevant any more as Section 2.2.2 has been rewritten with focus only on the test of the functionality of the wake rake attached to a rotating blade section.

Section 2.2.3 • L144 «
it was decided to design and manufacture a new frame for attachement of the wake rake on the full scale blade » I do understand this difficulty, however, do you have reproduced this set-up in wind tunnel (at least once) to evaluate this impact of this new mounting system ? If not, how do you expect this mounting to change results ? Please give more details.

Response:
We did not test the frame for the attachment of the wake rake on the full scale turbine in the PLC wind tunnel as this is physically not possible due to the size. This had at least to be done on a downscaled model.

However, we do not expect major disturbances from the frame at the three measurement positions. 1) the inflow measured with the five hole pitot tube attached at the leading edge of the blade. 2) The wake rake was positioned spanwise away from the disturbed wake flow behind the flyboard carrying the five hole pitot tube. 3) The pressure belt, although placed below the carbon circular tubes, but in a distance of several tube diameters. Also, bearing in mind that the blade was operated in attached flow in an AoA range from 0 to 10 deg. The attachment frame for the wake rake was designed to carry the centrifugal loading on the rame and the wake-rake itself, to be light-weight and non-intrusive to the blade strucutre, and to provide a highly stiff structure to avoid vibrations of the frame during the measurements. Furthermore, the space between the structural elements of the frame and the measurement instruments was kept as large as feasible.

Minor comments :
• L21-22 : « This is due to . . . 2D wind tunnel flow and unsteady, turbulent 3D flow experienced on the wind turbine blade » I agree that there exist major differences from wind tunnel experiments and field measurements, but I won't say that the inflow is 2D in wind tunnels. In wind tunnels the flow is homogeneous and with low turbulence intensity, unless customized differently (passive or active grids, gust or other generated perturbations . . .). please be more specific

Response:
We find that this is an accepted terminology to describe wind tunnel flow as two-dimensional. Of course, three-dimensional flow exists at the interface between the blade section and the tunnel walls and at high AoA with separated flow. However, to modify the statement we propose to write:

.... different operating conditions for a 2D airfoil section tested in the steady wind tunnel flow ....

L54 : « This is commonly measured ... »
This is not clear what « This » refers to. One could think that the wake rake measure only the viscous drag. Please reformulate.

Response:
Text changed to:

The total drag (pressure drag + viscous drag) is commonly measured with a so-called wake rake measuring the momentum loss in the near wake behind the trailing edge of blade section.

• « Experimental set-up » section :
The description of experimental set-up is made of bullet points, which is unusual and rather adapted to technical reports. Please provide sentences rather than bullet points.

Response:

Section 2.2.1 has been rewritten and two tables inserted with the information previously presented in bullet points.