Response to Review

Thank you for your support in improving this manuscript.

We prepared responses to each of your comments in the following in green, highlighted the changes in the manuscript in blue and look forward to the upcoming steps.

Additionally, the manuscript was checked and edited for grammar and spelling mistakes.

The authors,

Julia Gebauer
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Claudio Balzani

Report #1

Thank you for the time and effort you put into the revision of the manuscript. As a last modification, I recommend adding some details about the mesh - in the same fashion of your response to my review - to the new Appendix B. Regarding the domain dimensions, please have a look at this work from Sørensen et al: https://iopscience.iop.org/article/10.1088/1742-6596/753/8/082019

As recommended, we added the discussion about and a figure of the mesh to the paper (Appendix B):

l. 464 – 474: Vitulano et al. (2024) conducted a mesh dependency study for the FFA-W3-211 profile at a Reynolds Number of $1.8 \cdot 10^6$, showing almost no sensitivity between $12 \cdot 10^4$ and $74 \cdot 10^4$ cells in the 2D plane. Kim et al. (2024) presented a mesh sensitivity study for the FFA-W3-211 profile at a Reynolds-Number of $15 \cdot 10^6$, showing that further refinement of the mesh in spanwise direction has a negligible influence on the prediction of the dynamic stall cycles. They used $35 \cdot 10^4$ cells in the 2D plane with 20 cells in spanwise direction of the 3 dimensional model. A more precise comparison with Vitulano et al. (2024) is not possible because they don't report non-dimensional cell sizes and they used a wall-function approach. A mesh dependency study for slim profiles at a Reynolds-Numbers of $0.4 \cdot 10^6$ was done by Ahrens et al. (2022), showing that a mesh with $y+ \leq 1$ and $x+ \leq 700$ is sufficient to investigate integral blade loads during a dynamic stall cycle. So, the cell dimensions used in this paper are assumed to yield mesh independent predictions of lift and drag coefficients, especially in the linear region of XFOIL.

We appreciate the link to the paper from Sørensen et al. We will test the influence of even larger domain sizes, i.e. more than 50 time the chord length in the future. In our past sensitivity studies we did not see a relevant change of results above 50 times the chord length and accepted the "uncertainty" as a compromise between accuracy and efficiency.

Report #2

The authors provided a thorough and well argumented reply to the reviews. The contextualization and scope of the study has been strengthened significantly. However, the interpretation of the results can still be improved, as well as the clarity and conciseness of the text.

We have further revised our manuscript in this regard. Please see below for more details.

In this context, the reviewer recommends the following minor revisions:
- The main message of the study needs to be more clear and precise. The manuscript highlights clearly the weaknesses of the study, and state that future work is needed (see l.405-415). In this context, the relevance of the present work is significantly undermined. In other words, why one should read this paper, instead of waiting for the next one? What is the added value of the present work? This comment can be addressed by thorough interpretation of the results in the light of the methodology used.

We have worked on clearly formulating our main message: The influence of cross-sectional deformations in wind turbine rotor blades on internal loads are marginal for operational conditions with maximum loads in flap- and edgewise direction (i.e., operational loads at the rated wind speed).

This statement was used for the abstract and conclusion. We also went through the manuscript in order to clearly emphasise the main message.

l. 13 – 14: These results show that cross-sectional deformations have a minor influence on the internal loads of rotor blades in normal operation.

l. 395 – 406: The aforementioned relative deviations are associated with a load scenario of normal operation at the rated wind speed and thus with maximum operational loading (i. e., maximum thrust and torque). Nevertheless, the deviations in root bending moments are quite small. It can thus be concluded that the impact of cross-sectional deformations on the aero-elastic response of the turbine is small (and potentially negligible) for normal operation. However, it should be noted that this conclusion is design-specific, meaning that the aero-elastic effect can be more pronounced in other turbines depending on the design philosophy with respect to the blade's stiffness. To derive more general conclusions, different turbines and rotor blades could be analysed. Moreover, higher degrees of loading, e. g., from extreme load cases, may result in higher cross-sectional deformations and thus to higher aero-structural couplings. Hence, a broader variety of load scenarios including combined loading with torsion from extreme conditions should be investigated in future work. Independent of particular results, the methodology presented in this paper could be used to numerically verify the absence of potentially undesirable aero-elastic couplings originating from cross-sectional deformations during the design, which could help to increase the reliability of wind turbines in the future.

- The text needs to be carefully edited to improve the conciseness of the manuscript. This is particularly important for the presentation of the results, which is at times lengthy and convoluted, and prevents the reader to capture the essence of the work efficiently.

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- There is still a lack of connection between the results presented. The authors have only partially addressed my comments on this aspect. To be more precise, having more connection between results means that after reading sections 3.1 and 3.2, the reader can expect the following results. In addition, it means that the results of section 3.4 can be fully understood from the previous sections. This will help with the clarity of the manuscript.

To make the manuscript more concise, we moved some paragraphs in the results section and shortened them. The descriptions in particular are shortened and more attention is paid to the explanations and connections. The modifications can be seen in the manuscript with highlighted modifications (see LatexDiff document). We hope that we have now addressed your comment appropriately.

Minor comments:

- The references should follow WES guidelines. For example, in-text references are cited without parentheses (see l.75)

Thank you for pointing this out. We checked the entire manuscript carefully on citation style.

- l.3-4: "an initial estimation of the extent to which cross-sectional deformations influence the aerodynamic load distribution along the rotor blade." The presented result show results for blade root bending momentum, and not load distribution. Consider replacing the end of the sentence to be more precise, e.g. "... influence the aerodynamic loads on the rotor".

Manuscript was revised accordingly.

- l. 14-16: "Although these values are relatively small, the initial results imply that further investigations should be carried out with more complex wind fields and different rotor blade designs to identify aero-structural couplings that could potentially be critical for the design of rotor blades or other wind turbine components." Please align this statement with the conclusion of the manuscript.

This part was revised. It states now:

l. 13 – 14: These results show that cross-sectional deformations have a minor influence on the internal loads of rotor blades in normal operation.

- l50-51: This paragraph does not seem to be connected to the adjacent paragraphs. Consider adding some glue text or merging this part of the literature review with another paragraph.

This section has been merged with the following paragraph.

- Eq. 1: This equation presents the equation for the relative difference. However, the symbol is not used in the rest of the manuscript. Furthermore, the equation for relative difference is common knowledge. Please remove this equation for conciseness.

We removed the equation and the text parts in which the equation was referenced.

- Figure 4: "The maximum sampling error is 1.84e−2": Please use the notation 10^(-2) and not e^(-2).

Manuscript was revised accordingly.

- Figure 9 and 10: The cut-out on the main figure do not match the cut-outs on the subfigures, which is confusing. For example, for Fig. 9 (a), the cut-out on the main figure seem to span [-20 degrees, +20 degrees] and [0.4 kNm, 0.9 kNm], whereas the cut-out figure has a much larger span. If the cut-outs are not a zoomed version of the main figure, it reduces their significance significantly.

Figure 9 and 10 were revised accordingly. We deleted the zoom figures, as they did not present results other than those shown in the non-zoom figure. We have included the relative errors in the non-zoom figure instead.