<u>Author Response: Reviewer #2</u>

Reviewer Comments in black text and author response in red text.

Review of the paper entitled: "Flutter Behavior of Highly Flexible Two- and Three-bladed Wind Turbine Rotors" by M Chetan et al.

General comment

The paper deals with a remarkably interesting analysis of the flutter margins for wind turbine blades of different lengths. After analyzing the flutter margins of existing blade designs, the Authors proposed a re-design methodology aimed at improving the flutter margins themselves.

The tools used for estimating the flutter onset (Theodorsen unsteady aerodynamic theory and p-k method for the computation of blade eigenvalues) are suitable for the scope of the work.

The paper is well-written and, mostly, enjoyable to read. It contributes to state of the art in this field and has good citing potential.

This said, I have a list of issues that should be addressed before that final acceptance of the paper (see "important comments"). Finally, there are also some minor comments, that the Authors should also consider in the amended version of the manuscript.

My recommendation is "minor revisions."

The authors would like to thank the reviewer for taking the time in reviewing the article, and we appreciate the feedback provided.

Important comments

1. The title of the paper creates an extremely high expectation. In fact, reading it, one may think that the work deals with a flutter analysis of the entire rotor also including hub and shaft (and in general an even simple flexible supporting structure). In the end, the analysis considers only the isolated blade. This means that only the mutual interaction of the blade modes is analyzed in the work. Other possible flutter sources, e.g., those coming from interactions blade, tower, and whirling modes, are not considered, since whirling modes exist only if the supporting structure of the rotor is assumed. Moreover, the words "three-" and "two-bladed" can lead readers to expect an analysis which considers different hub-typology for the two-bladed configuration (for example with a teeter hinge). All these issues should be fixed and, accordingly, I request the Authors to slightly modify the title.

Thank you for the detailed feedback. Yes, the focus of this work is limited to the flutter stability of an isolated blade in still air. This assumption allows the blade designer to concentrate on the detailed design of the blade while still having a quick tool to compute the flutter margins of the blade. A full turbine flutter prediction tool introduces a large number of degrees of freedom that identification of the actual flutter modes become a more difficult task. Two- and three-bladed designs are a focus of this study to provide an understanding of the difference at a detailed blade design level. Following the suggestions by both reviewers, the title has been changed to "Flutter Behavior of Highly Flexible Blades for Two- and Three-bladed Wind Turbines".

2. Directly connected to the previous point: it could be important to declare the typology of the hub (hinged or fixed teeter) of the analyzed blades. This could lead to a deeper interpretation of the results. Given the status of the paper, the two-bladed configuration differs from the three-bladed one only for the longer length of the blade. From this point of view, Figure 8 shows a clear trend

in the flutter margins that depends on the sole length of the blade, whereas a different behavior between the two rotor configurations is not visible.

In this work the blade is considered to be rigidly fixed at the root. This is detailed in Section 2, the difference between the two- and three-bladed designs explored here is the inherent structural differences and aerodynamic design variations contributing to the various aero-elastic instabilities. Studying the typology of the hub is important for two-bladed designs, but a full system turbine aero-elastic stability analysis is out of the scope of this work. A continuation of this paper should address the full system aero-elastic-instabilities. The future work in Section 6 has been updated to reflect this.

3. In the redesign section, it should be fair to say that the blades are not redesign with the same constraints of the nominal one. Hence, all design constraints (maximum tip deflection or fatigue) should be verified after the redesign.

Yes, the blades in Section 5 are not designed to the same constraints as the nominal designs. The LE/TE parameter study aims at understanding the flutter trends for the sweep of LE and TE reinforcement layers. The next steps in the process would be to apply appropriate constraints to reduce the number of candidate designs; before proceeding with the final blade design. This has been noted in the last paragraph of Section 5.

Minor comments:

1. Line 5/Abstract: "two-bladed rotors" and "downwind configurations" are both listed as "new rotor concepts". They are not new, but rather "unusual". Please, modify the sentence.

The manuscript has been updated to replace "new rotor concepts" with "non-traditional rotor concepts".

2. Line 111: I think that the name of the flutter computation process is "p-k method" and not "p-f". I could be wrong but, in any case, it is important to indicate the chapter and the section where the method is illustrated in Wright's and Cooper's book.

Thank you, the manuscript has been updated and this typo has been corrected.

3. Line 327: "From these observations of the trends study we note the benefits of additional LE layers to increase the flutter speed versus the TE layers". This is something that could be also foreseen, as a forward motion of the sectional center of gravity is typically beneficial in terms of flap-torsion flutter speed. But my question is: Do Authors think that these results depend on the forward motion of the sectional gravity center or on other structural reasons?

There is a dual effect, one due to the sectional center of mass moving forward, and the general increased stiffness of moving the material from the TE to the LE. And, the impact of these choices on the overall blade mass (which is proportional to blade cost) while examining the trend of flutter margin is shown from this analysis.

4. Line 328: "Similarly, we can have blade designs that are lighter than the baseline structure but have a higher flutter speed". This sentence may be misleading. In fact, the re-design consists in a re-arrangement of the internal blade layout, while other design constraints are not verified (e.g., maximum tip deflection, fatigue etc.…). Hence, it is hard to say that a lighter design is obtain

because the process is performed using the very same constraints of the nominal blade. Please, clarify or remove the sentence.

Yes, the blades in the LE/TE parameters trends study are not designed to the same constraints as the nominal designs. The sentence has been modified to reflect the "trends study" nature of this study, which permits an examination of maximizing flutter speed while minimizing blade mass. Additionally, the last paragraph of Section 5 has been modified to reflect this.

5. Line 377: "it is possible to increase the flutter margins while maintaining or reducing the mass of the blade". Here again, the sentence is clear but prone to misinterpretation as written in the previous comment.

Thank you, this was addressed in the last paragraph of section 5.

6. Conclusions: if relevant, the study of the flutter of the entire turbine could be mentioned within the possible extensions of the present work.

The future work section of this paper has been updated to reflect that a full turbine aero-elastic in-stability analysis is an important extension of this work.