Replies to the reviewer 2:

We would like to thank the reviewer for his/her very constructive suggestions/corrections to our manuscript. Below are the point-to-point replies to the comments raised by this reviewer. As notified by the Associate Editor, we are required to address the comments from the reviewers to a satisfactory level before the revised manuscript can be submitted. We hope we can have the chance to show the reviewers our revised manuscript after considering all the comments from them.

	Comments	Answers
1.	The use of "concurrent" in the title and text is a bit unclear to me, what exactly is concurrent in the context of this work?	In our case, we considered the five different schemes with the combination of different types of aerodynamic design variables, such as shape, twist, chord, dihedral. We optimize groups of parameters simultaneously which is called concurrent optimization, in contrast to the traditional sequential optimization by one after another.
2	L17: This sentence does not make sense: "To use CFD in the design optimization process, where lower-fidelity approaches like blade element momentum (BEM) are more popular, but new tools to increase the accuracy must be developed as the latest wind turbines are larger and aerodynamics and structural dynamics become more complex"	Modified: As the latest wind turbines are larger and aerodynamics and structural dynamics become more complex, new tools must be developed to use CFD to increase the accuracy in the design optimization process for which lower-fidelity approaches like blade element momentum (BEM) have been more popular.
3	L22: "A multidisciplinary design optimization tool called DAFoam": to the best of my knowledge DAFoam is a discrete adjoint solver for the SIMPLE solver in OpenFoam, please be more specific as to what you mean by multidisciplinary?	The official definition/name of DAFoam is as follows: Discrete Adjoint with OpenFOAM for High-fidelity Multidisciplinary Design Optimization. This is how the tool is named by our developers and it can also optimize the objects both aerodynamically and structurally. In this study, we have implemented/developed a procedure for quasi-3D multidisciplinary design optimization of an airfoil with DAFoam in the framework of OpenMDAO, which is an open-source high-performance computing platform for systems analysis and multidisciplinary optimization, written in Python. Currently, we are extending this research for fully 3D transient wind turbine multidisciplinary design optimization with VLES turbulence modeling and 2-way dynamic fluid-structure interaction.

4	L28: “excellent results are achieved”: Please leave it to the reader to judge the excellence of the results, and instead be more specific on what results you have achieved.	This sentence has been reworded.
5	L34-39: This may be a matter of taste, but I don’t find it particularly relevant to provide a historical view on the use of wind energy or it’s relevance to overcome the climate crisis. These are well-known facts and not relevant to your specific work.	These lines have been removed.
6	L45: “optimizing the blade design is the most difficult aspect of wind turbine optimization”: while I am also very biased towards and enthusiastic about aerodynamic optimization, I don’t think you should state that the blade design is the most difficult aspect of turbine design. Use instead “highly challenging”.	Gratitude for the suggestion and the original one is modified as suggested.
7	L47: Matlab is not a wind turbine optimization tool.	This sentence has been reworded as “the optimization toolbox in Matlab is used”
8	L48: “while in certain research, XFoil, NACA airfoils, and AirfoilPrep are used to simulate the aerodynamics of the blades in conjunction with Matlab ”: You’re mixing tools and specific airfoil geometry series. Xfoil is the only tool mentioned that can compute aerodynamics of airfoils. Matalab is a programming platform.	NACA airfoils and Matlab are removed from this sentence as the AirfoilPrep is used to generate the airfoil data files.
9	L52-53: “One of the most effective methods…”: I’m not entirely sure what is meant by this sentence. Are you talking about airfoil design?	Yes, we are talking about the airfoil design as it is kind of 2D design and easier to implement compared to the 3D case.
10	L73: first sentence: this is stating the obvious.	This sentence is removed.
11	L74: most critical -> highly critical	Revised accordingly.
12	L75: “…determining the rotor shape and forecasting the rotor's aerodynamic performance”: vague sentence. Determining the rotor shape wrt which criteria?	This sentence has been reworded as “determining the rotor shape with respect to the power output”.
13	L92: “…it is accurate enough for many flow conditions…” -> it is NOT accurate enough I guess you intend to write.	It is revised accordingly.

14	Section 2.1 overall: The literature review on low-fidelity aerodynamic design optimization is very selective and in my view missing a significant amount of important references (some of which also deal with full aerostructural design of a rotor). This section should either be improved significantly or removed.	This section has been improved and some parts have been removed. (We are working on the improvement of the whole literature review part)
15	L109 full paragraph: I don't understand why this paragraph is placed in this section. It describes fundamental analytical properties of rotating helicoidal wakes, but you don't state how this relates to the blade design? And I would not categorize this as "medium fidelity".	The whole section has been removed.
16	L114-117: Why discuss BEM and CFD in this section? I would also think that a lot has happened since 1952 wrt applicability of CFD in design, so couldn't you find a more recent reference?! I would simply delete the sentences starting from "And BEM is still well-established…".	
17	L125 onwards: The main advantage of adjoint based techniques is that they are largely independent of the number of design variables, but scale with the number of constraints and objectives, that is often less than the number of design variables in aerodynamic design. The main challenge with gradient-free methods is that they scale very poorly with the number of design variables.	Yes, it has been moved up to place held by L125 originally.
18	L138: Ok, you mention the advantage of adjoints here. I'd move that up to where you mention it first, L125.	
19	L171: "flap-wise bending momentum" -> "flap-wise bending moment"	Revised accordingly
20	L198: "double-bladed" -> "two-bladed"	Revised accordingly
21	L220: structural meshes -> structured meshes, non-structural meshes->unstructured meshes	Revised accordingly
22	L230: Here you mention using a wall function-based turbulence model, and in L236 state that you use the SA model. Is that indeed with a wall	Yes, the wall function is applied and they are epsilonWallFunction for epsilon, nutUSpaldingWallFunction for nut,

	function or modelled all the way to the surface? If the latter, a y+ of 10 is not sufficient.	kqRWallFunction for k, and omegaWallFunction for Omega. Now, it is added in the paper.
23	L249: Figure 4 does not show torque values, only Cp	Revision is made and "the torque" at the beginning of this line has been removed.
24	Table 1: Consider also doing a Richardson extrapolation to estimate the numerical error of the three meshes compared to a theoretical infinitely fine mesh. You should see second order convergence of the solution, but this can however, be difficult to achieve for complex flows.	We will definitely consider. In fact, we have conducted mesh convergence study.
25	L343: You refer to "lelist and telist" points, but this naming isn't used anywhere else in the paper, and you need to describe what they represent in more detail.	The volume and thickness constraints are set up by creating a uniformly spaced 2D grid of points. These points are then projected onto the upper and lower surfaces of the blade. The grid is defined by providing points (using leList and teList) and by specifying the number of spanwise and chordwise points (using nSpan and nChord). Typically, leList and teList are given such that the two curves lie in a plane.
26	L347: You refer to a coordinate direction but haven't introduced the overall coordinate system used.	The spanwise direction is *x*, chordwise direction is *y* while thickness direction of the blade is *z*. And this is mentioned in the paper now.
27	Section 3.1.2: You don't discuss the issue of flow solver numerical convergence, which you highlight as a challenge in the work of Vorspel et al. Can you converge the RANS solver deeply or do you see limit cycle oscillations?	The RANS solutions have all been made converged to a final whole field total non-dimensional residual value of at least 1E-6 and the torque value remains stable after the convergence.
28	Section 3.3: Please be more specific with the geometric constraints. It is quite unclear what e.g. the thickness constraints entail and how they limit the design space.	Plane created with a uniformly spaced 2D grid of points is then projected onto the upper and lower surfaces of the blade to calculate the thickness and volume. And the volume and thicknesses calculated will be scaled by the initial values (i.e., they will be normalized). Therefore, lower=1.0 in this example means that the lower limits for these constraints are the initial values (i.e., if lower=0.5 then the lower limits would be half the initial volume and thicknesses). The corresponding revision is added to the paper.
29	In Table 2 you list the various optimizations you've carried out, and I am a bit puzzled as to why you chose this set of optimizations. Why split the optimization of shape with chord and twist into two optimizations? As mentioned above, I think particularly	At first, we planned to run our optimization for the full blade which includes the shape and whole planform optimization concurrently. However, due to the enormous computational power requirement, we tried to reduce the number of design variables by just implementing the optimization for selected combinations of the

	for opt S2 you will obtain design features heavily influenced by the limitation in the design space from not considering chord. Also, for the S4 optimization, you have no way to discern the effect from optimizing including dihedral, since you don't have an optimization with shape only in your test matrix.	design variables shown in Table 2 for computational efficiency, such as shape and twist, shape and chord, shape and dihedral. As for the shape alone, it was implemented in the tutorial, therefore it wasn't considered in our case. Ultimately we plan to perform full concurrent multidisciplinary design optimization with all geometric, structural and operational parameters and FSI on our new large HPC cluster which is still be tested.
30	Section 4.1, L372: "Despite the fact that the improvement in torque is 5.34 %, the optimality is less than 0.0002, while the optimality tolerance is 1E-7." Indeed, with such few optimization iterations, it seems like this optimization is not converged. In fact, the design variable change between iteration 3 and 4 is very large. You don't describe why you stop the optimization prematurely, not reaching the optimality criterium, or at least a visually converged objective function.	Typically, during simple optimization we can easily reach the optimality tolerance 1E-7 while it is very challenging to reach it for the complicated optimization process. The iterations shown in the figure are the major iterations not the minor iterations. And the optimization process we used is automatic and maximum iteration number is 100. The optimizer exits whenever it finds the optimum value it can. Thus, we did not encounter the issues of premature stopping or not reaching the optimality criteria.
31	Section 4.2:In this optimization you run 10 iterations, and appear to reach closer to a flattening of the objective function, at least visually. As requested above, could you please state why you don't run the optimization for longer? If you compute the rotor power coefficient, the optimized rotor has a Cp of approx. 0.361. You need to discuss why you can't increase it further, keeping in mind that a regular rotor would have a Cp in the range 0.45-0.50. This could indeed be because shape and twist alone cannot compensate for the very low rotor thrust coefficient you start from. You only show a comparison of surface pressure of the original and optimized blade, but you don't show the resulting shape, which is highly relevant! Why? Judging from the pressure distributions, the shapes must be quite strange, seeing you have a pressure spike at 40% chord. I therefore find it very difficult to trust that these results indeed are of sufficient quality to publish.	
Answer to 31	This question is answered in the last reply: we did not encounter the issues of premature stopping or not reaching the optimality criteria. The optimization process was automatic, and optimizer exits when it finds the optimum value even though the maximum number of iteration we set was 100. There might be 3 reasons why we did not get the overall maximum power coefficient: 1. we are using two-bladed wind turbine which cannot capture the power as well as 3-bladed wind turbines. 2. The initial torque of the course mesh we used for the optimization is 648.4 Nm and there is 17.27 % error compared to the NREL experiment. 3. We didn't consider the tip speed ratio in the optimization exercise as it is an operational parameter, not a geometric one, but which is the most influential factor for maximizing the	

	power coefficient. Currently we are mainly concerned with geometric optimization. We can consider this factor by running the multi-point MDO optimization in the future. In the revised manuscript, surface pressure comparisons are replaced with the cross-sectional shapes for all schemes. We doublechecked the optimization and reran the optimization. Below is the cross-sectional shape comparison during the shape-twist optimization for r/R = 63%.  Original shape Optimized shape **Figure 1. shape-twist optimization at r/R = 63%.**
32	Section 4.3: Yes, your objective function flattens out visually, and you reach a higher Cp than for opt S2, but still rotor Cp is only 0.372. I would expect the chord to increase significantly but you observe a reduction in chord. Please provide your interpretation of this result. As in the previous S2 optimization, you don't show the cross-sectional shape, and judging by the pressure distribution the shape is highly "unconventional", and again leads me to conclude that the results are not of sufficient quality to publish.
Answer to 32	Thank you for pointing out this issue to us. We found out we had a problem with the results of this section, and we did not set the lower and upper limits for the chord in the right way. Therefore, we observed the reduction in the chord length and at same time we got an abnormal spike in the pressure coefficient. Therefore, we set the lower and upper limits of the chord again and repeat the optimization process. The new results show that the torque increase of the combination the shape and chord is now 27.9%. We believe the quality of the results is worthy of publication in WES. And in our manuscript, the surface pressure comparisons are replaced with the cross-sectional shapes as shown below for this scheme (shape + chord). By presenting this figure, we show the improvements in the results.    Pre-optimization at 30% Pre-optimization at 63% Pre-optimization at 95%

Post-optimization at 30% Post-optimization at 63% Post -optimization at 95%

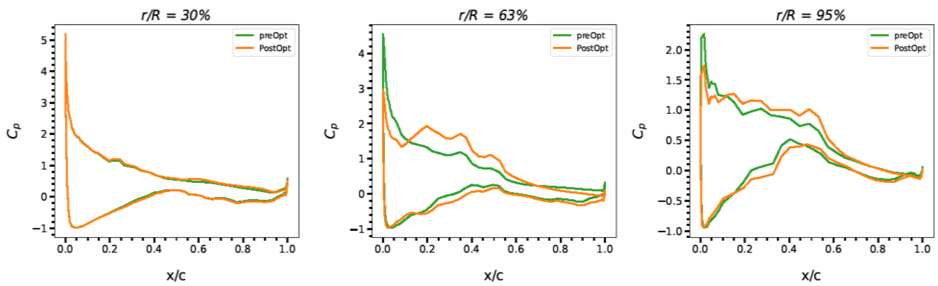
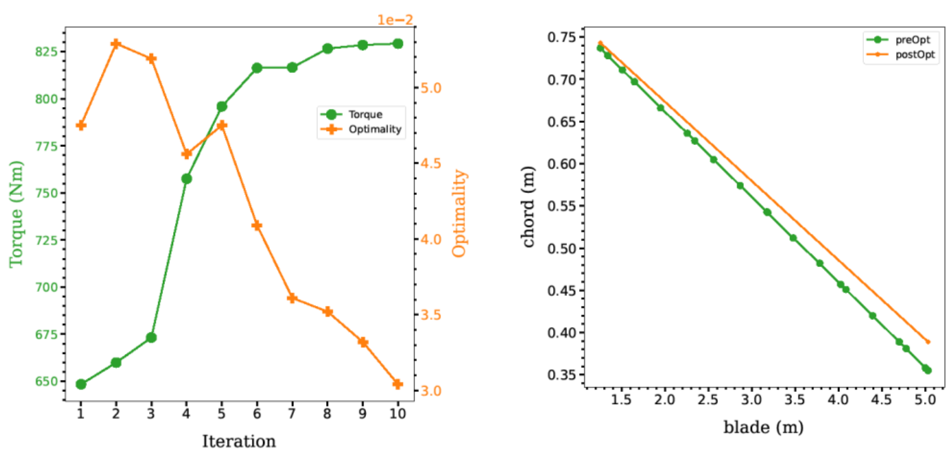


Figure 2. Comparison between the baseline and optimized blade in terms of S3 (shape and chord)



(a) (b)

Figure 3. a) Optimization process with respect to S3 (shape and chord); b) Chord length variation with respect to S3 (shape and chord)

33	Please comment on whether running 10 major iterations is a consequence of a limit set by you, or a consequence of a crash of the CFD code or the optimizer exiting), bounds on design variables limiting the design freedom or something else?	This question is answered in the above replies: we did not encounter the issues of premature stopping or not reaching the optimality criteria. The optimization process was automatic, and optimizer exits when it finds the optimum value even though the maximum number of iteration we set was 100. We also have the bounds for each of the design variables which set the lower and upper

<table>
<tr><td></td><td></td><td>limits for the design variables at the same time we have volume and thickness constraints.</td></tr>
<tr><td>34</td><td colspan="2">Section 4.5: Your results show almost no change in chord and twist, which is highly surprising to me. As stated earlier, I would expect large changes in chord to increase loading. Your objective function seems no where close to converged either, please explain this.</td></tr>
<tr><td>Answer to 34</td><td colspan="2">Thanks a lot for pointing out. Due to the upper limit of the chord, we didn’t have any change in chord here. We reran the optimization again and have the following results. And we have a little change in the twist and chord, where the change in the twist is around 0.4˚. And the increase in the chord of the root is 0.0087m while the increase in the chord of the tip is around 0.0058m.

As for the little change in the chord and twist compared to the dihedral, the baseline might be close to the optimum value in terms of these two factors by using the low-fidelity methods in Qblade, which cannot consider 3D effects effectively, such as the dihedral angle. This explains the optimization mainly happens in the dihedral angle.

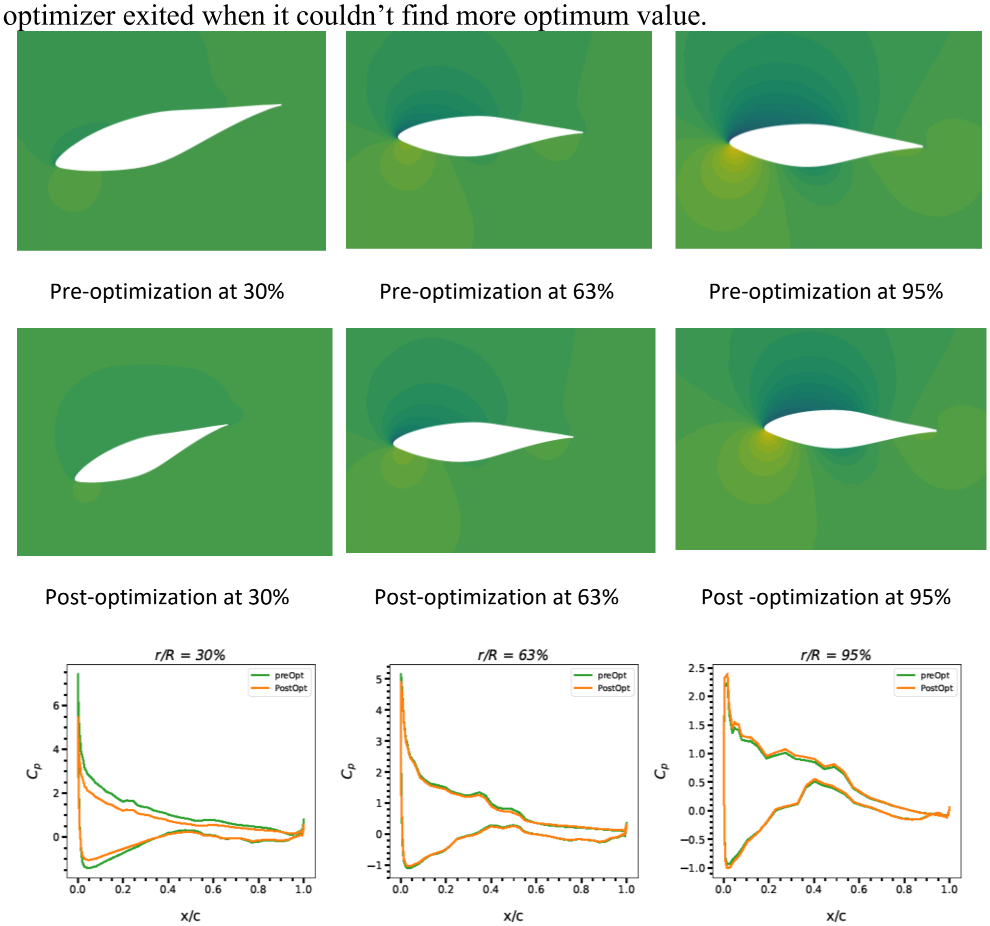
As stated above, our optimization is automatic with the appropriate maximum major iteration numbers (100) and bounds, which won’t affect the convergence of the optimization, and the optimizer exited when it couldn’t find more optimum value.


Figure 4. Comparison between the baseline and optimized blade in terms of S5 (twist, chord and dihedral)</td></tr>
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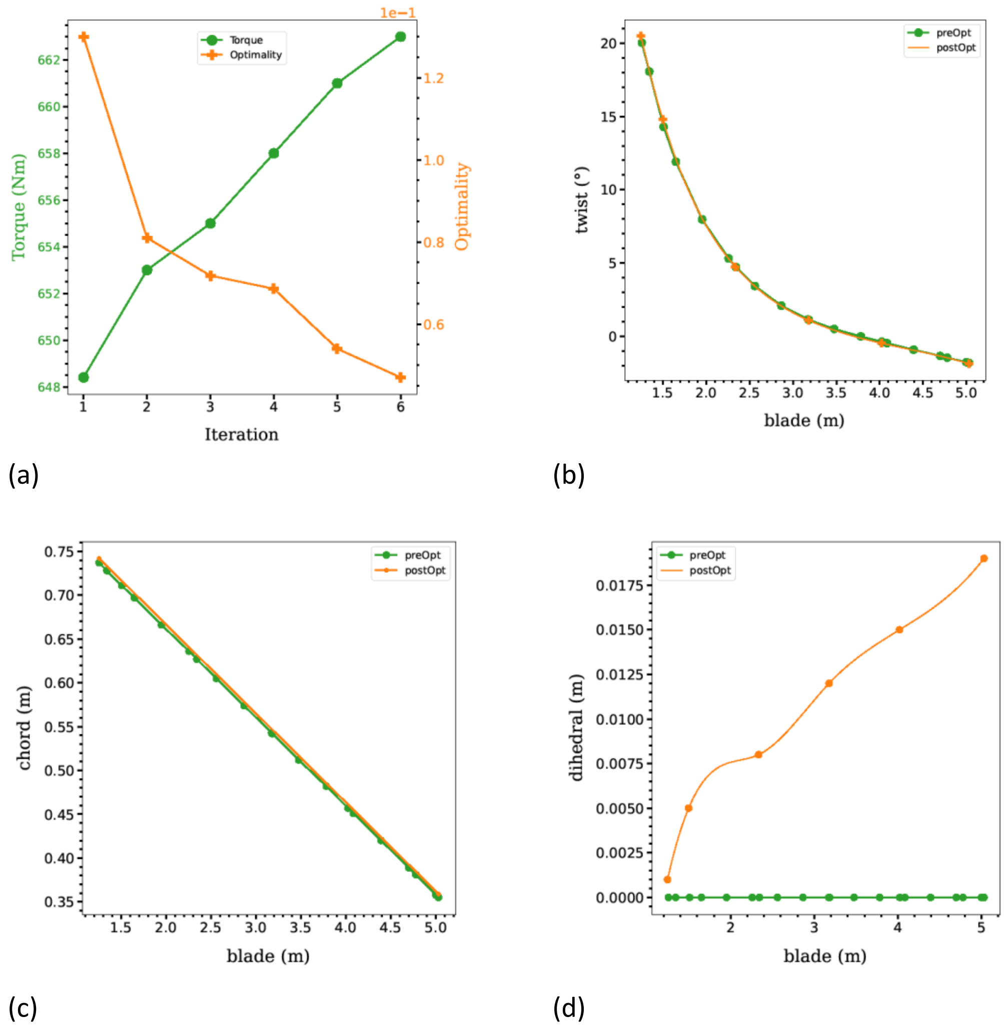

Figure 5. Optimization process with respect to S5 (twist, chord and dihedral); b) Twist variation with respect to S5 (twist, chord and dihedral)); c) Chord length variation with respect to S5 (twist, chord and dihedral); d) Dihedral variation with respect to S5 (twist, chord and dihedral)