WES 2023-81 paper review (2): Wind turbine rotors in surge motion: New insights into unsteady aerodynamics of FOWT from experiments and simulations

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General comments

The paper focuses on the rotor aerodynamics of a floating wind turbine based on both wind tunnel experiments and numerical approach. The study shows the results of well-conducted wind tunnel testings with a wind turbine model, featuring a moving rotor capable of translating in surge with $f_r = fD/v_0$ up to 1.09 at a high Re of 125K. The experimental results confirm the numerical simulations carried out using free vortex methods. Extensive numerical simulations that complement the experiments show the importance of the returning wake effect on the local aerodynamics of a floating wind turbine. The paper presents a number of new findings that are valuable to the wind energy community and clarifies some points already addressed by previous studies, as follows:

- The relevance of the three parameters namely the rotor reduced frequency f_r, tip speed ratio λ and motion to inflow velocity b_{vel}. As shown in detail in the paper, these three parameters must be taken into account when describing the local aerodynamics of a FOWT and cannot be isolated from each other.
- The importance of the returning wake effect on unsteady aerodynamic of FOWT.
- The ranges of rotor reduced frequency f_r, tip speed ratio λ and motion to inflow velocity b_{vel} which produce a different aerodynamic response of the rotor. Similar results are shown for quite different rotor sizes (the TUHH rotor, the OC6 rotor and the IAE 15 MW turbine) which shows the universality of the results.

This work is important to the community and deserves publication in the wind energy science journal. As part of this second round of revision, I acknowledge the authors' responses to previous comments, which have been well addressed and responded to. However, some points remain and I raise them in the following.

2nd review

Abstract

The abstract now states more clearly the findings.

Theoretical background

I agree with the changes, as discussed in the first round of revisions, and with the need to describe the various unsteady phenomena sufficiently for the reader to understand. I would like to suggest an idea for the section on the returning wake effect. Since you mention the change in local lift with surge motion during a cycle, you could add some other elements to figure 1. Perhaps an indication of the lift versus local wind speed as seen by the blade, which depends on v_0, axial induction and $v_m(t)$. How it changes between each image (lift first increases then decreases). And connect the change of lift with the shed vortices at each step. If it doesn't require too much effort, this could complement the explanations in the text (but this is only a suggestion from me)

minor: you could remove figure 3, I don't think it adds more to the understanding (also it is not even mentioned in the text).

minor: in note [4] (page 7) " motion motion" is written. This needs to be changed.

Previous numerical and experimental works

In §3.1, you write about the impact of b_{vel} on the amplitude of the power and thrust oscillations but it certainly also depends on f_r itself (as seen later in the paper), i.e for a given b_{vel}, a lower f_r is likely to satisfy quasi-steady behaviour whereas a higher f_r not. Could you comment on the results for increasing f_r from the existing literature?

minor: in line 345, "transient" needs to be changed by unsteady.

§5.4 and §6.1

Figures 8 and 9 somehow show the same information. You might put figure 8 in appendix and just refer to it.

I agree with the answer to the comments on Figure 10. You could draw the error bars of the experiments in the graph.

You should try to remain consistent with the notations of the axes of your graphs, either write the mathematical expression or the name, but not for one figure the expression then the next the name... You use the same term "normalised torque amplitude" in figures 9, 11 and 12 with a different normalisation. It took me a while to work out the meaning of each (even though it is clearly written in your text, you should avoid it to avoid confusion). Since you define Q^*_{amp}, why not write it on the y-axis in Figure 12? You could also define an expression, something like $A^*_Q = A_{Q,\ motion}/Q_{steady}$ (1) for the "normalised torque amplitude" of Figures 9 and 11, and then write in the legend: "with A^*_Q the normalised torque amplitude defined in equation (1)". This will remove any doubts.

I continue with Figures 9, 11 and 12 and their interpretations. According to Figures 9 and 11 and as indicated in your text (line 502-503), the normalised torque amplitude A^*_Q depends only on b_{vel} independently of f_r up to $f_r = 1.9$ in this case (up to 1.09 with the experimental data, I suppose that corresponds to the maximum you can test and that this result should agree with the simulations for higher f_r if you were able to do the experiments). This makes sense to me and shows, as you mention, that the aerodynamic response follows a quasi-steady state (QS) for all

these cases (and again for this specific turbine). So, mathematically: $A^*_Q(f_r, b_{vel}) = \text{function}(b_{vel})$, even if b_{vel} depends on f_r, as long as b_{vel} is kept constant, the aerodynamic response does not depend on f_r (up to 1.9), which is a strong result.
Moving on to Figure 12, you plot Q^*_{amp}, the ratio between $A^*_Q(f_r, b_{vel})$ and $A^*_Q(f_r = 0.02, b_{vel})$, where b_{vel} is kept constant and with f_r gradually increasing. In the range $f_r = 0.02$ (QS) up to $f_r = 1.9$, we observe an increase in Q^*_{amp} up to 1.08, i.e. a difference of 8 % between the two cases considered to have no difference. This seems to be in contradiction with the previous results: "the rotor torque oscillations can be considered as quasi-steady and can be determined by b_{vel} exclusively in the applied range of motions" (lines 502-503). If we take a closer look at graph 11, we see small differences between the lines for $f_r = 0.5$ and $f_r = 1.9$, since this is another normalisation, the differences are visually less pronounced but still present. By plotting the results for $f_r = 0.02$ in Figure 11, you would see the differences between the cases more clearly. I highlight this point to ask you whether an 8% difference between the most quasi-steady case ($f_r = 0.02$) and the case with $f_r = 1.9$ is small enough to conclude that $f_r = 1.9$ still falls into the quasi-steady category. Do we expect some form of unsteadiness for $f_r > 0.5$ here? I understand that there might not be a straightforward explanation, but could you at least comment on this?? Especially as you write on lines 539-540: "this behaviour clearly indicates the presence of unsteady aerodynamic phenomena. Otherwise, all curves would follow a constant trend over the rotor reduced frequency".

It could be interesting to plot the normalised power coefficient from the simulations for $f_r = 1.9$ and $f_r = 3.8$ and see how it changes compared to lower f_r of figure 10. I understand this is not in the scope of this paper but could be useful for further understandings of the effect of motions on the power production.

No further comments on the rest of the paper.