Review of Manuscript "Investigating the Dynamics of Floating Wind Turbine Wakes Under Laminar Flow Using Large Eddy Simulations

by

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Overall Review

This journal manuscript presents computational fluid dynamics results of wake flow from a simulated floating offshore turbine with prescribed motion over many degrees of freedom, such as pitch, sway, surge, etc. The simulation is of a wind-tunnel scale turbine in uniform inflow. The motion is completely prescribed and deterministic and not coupled with a hydrodynamics solver.

Two different forcing frequencies of the motion were simulated, and the results show that the higher simulated forcing frequency caused interesting and notable differences in how the wake becomes turbulent and then recovers. The authors point at this frequency possibly exciting a resonance effect.

The work is interesting and addresses the effect of floating platform motion on wakes. The conditions are very idealized, though, so I do wonder how extensible to realistic turbulent conditions the results are. The manuscript is very dense and long. It reads more like a technical report than a journal article. The manuscript would highly benefit from cutting down some of the very detailed explanation of results. I also have many specific comments below aimed at improving the paper. For these reason, I will select "reconsider for publication with major revision." See below for detailed comments.

Specific Comments:

1. Overall: The manuscript is long and dense. It would highly benefit from removing some non-essential material and making description of the results more succinct.

2. Page 2, Line 45: Here you talk about a low-frequency frequency content seen in wind turbine wakes associated with bluff body vortex shedding. Later on (and in the abstract), you talk about Strouhal number. You do not make an explicit connection between this wake meandering frequency and Strouhal number. Or do you mean something different by Stouhal number (see my comment 12 that I wrote after reading further).

3. Page 2, Line 47: Clarify what you mean by "counter-rotating shear layers." Do you mean that if looking within a plane cutting through the wake in the streamwise direction, the vorticity vector is opposite in the outer versus inner shear layers? Or are you referring to something having to do with wake rotation caused by rotor torque?

4. Page 3, Line 60: When talking about the work of De Cillis et al., you say that the tip and root vortices almost always transfer energy from the wake into the shear layer, slowing recovery. I do not really understand this statement. I think of the tip and root vortices as lying within the shear layer and that

they transfer energy from the wake to the outer flow and from the outer flow into the wake. I do not understand how energy would be transferred from the inner flow into the relatively thin shear layer itself.

5. Page 3, Line 63: What do you mean by "Kolmogorov-like flows?"

6. Page 3, Line 67: You say: "The research also established that the near-wake tip vortex sheet isolates the wake from the free flow, preventing momentum exchange and slowing down the wake recovery." How do you conclude that the tip vortex sheet somehow acts as a barrier between momentum inside and outside the wake? Is it not simply that even without tip vortices in the shear layer sheet (imagine an actuator disk in the flow), the small scale turbulence just doesn't efficiently transfer momentum relative to the Kelvin-Helmholtz-like rolls that take some distance to form at the wake edges and the subsequent strong turbulence that the rolls break down into that are very efficient in transferring momentum from inside the wake to outside and vice versa?

7. Page 3, Section 1.2: In my first pass through this section, I finished feeling confused. There are so many facts given from a lot of different sources that it becomes difficult for the reader to synthesize all of this into a coherent background. Also, some of the sentences are confusing, for example this one: "The mechanism identified as the enhanced recovery drivers were meandering structures for sway." I find this a confusing sentence because I don't understand what you mean by "meandering structures for sway." When I think of meandering structures, I think of the wake meandering horizontally vertically. When I think of "sway," I think of the turbine/floater moving side to side. I can see a connection between moving a turbine side to side which would give the wake an initial side-to-side meandering that might become amplified.

8. Page 3, Section 1.2: It would be helpful to split this section into paragraphs. Each time you talk about the research of another research group, start a new paragraph.

9. Page 3, Line 73: You say: "The perturbations in the domain were maximized for certain pairs of inflow perturbation amplitude and frequency." Please clarify what you mean. When I read this, it sounds like perturbations are maximized as a function of amplitude and frequency, but then it is unclear what is being maximized. You then go on to say "For those pairs, the dominant frequency, ..., was the inflow frequency." Again, this is unclear. What dominant frequency? What do you mean by "inflow frequency." My point is that without going and getting Mao and Sørensen's paper, I am having a hard time visualizing their numerical experiment.

10. Page 4, Line 118: In the sentence, "All these investigations demonstrate that upstream periodic perturbations within certain frequency and amplitude ranges modulate the wake by amplifying its meandering and anticipating the shear layer breakdown," I do not think the word "anticipating" is the right word choice. Maybe "accelerating" is the correct word.

11. Page 5, Line 144: How is the solver 4th-order spatially when it uses an unstructured mesh with finite volumes?

12. Page 8, Equation 3: With this definition of Strouhal number, it made me question my interpretation of Strouhal number in the earlier part of this paper. In the earlier part, you just refer to it as St, not St_p, and I was thinking you meant a Strouhal number of wake meandering (you refer to bluff-body wake behavior). But now I question myself. Please make all of this clear and consistent to the reader.

13. Page 7-8: Your variables have various subscripts, such as "prc" or "rp." I assume "p" means "prescribed" but it is not explicitly said for all these letters. The reader should not have to guess.

14. Page 8, Line 186: I don't understand what the length and velocity scaling factors, λ_L and λ_U, are used for. Please clarify.

15. Figure 6: Why is the top of each contour plot cut off (it appears as black)?

16. Page 11, Line 235: You say, "...excludes the central jet that does not occur in reality." I think it is important to remember that the "central jet" does not form just because the simulation lacks a hub/nacelle, but more because the inner sections of the blade do not apply much thrust force on the flow, so these inner sections do not act very much as a momentum sink, especially where the blade section is circular. So, it is not true to say that the inner jet does not occur in reality.

17. Page 11, Line 243: I do not understand this quantity "excess wake recovery speed." Please elaborate more about what it is and why it is relevant. Is it just a normalized measure of the difference in velocity gradient between each case and the fixed bottom case, and you are saying that the steeper the gradient, the faster the wake recovery? What if it is a case in which the wake has recovered much faster than the FB case so at some point downstream its gradient then becomes less than in the FB case and the excess wake recovery speed becomes negative?

18. Figure 7 (c): What happens to excess wake recovery speed at $x* = 4$ where all cases are shifted downward?

19. Section 3.2: I think it is important to distinguish between "turbulence intensity," which is just a statistic that is caused by true turbulence versus wake motion from prescribed rotor motion. Very near the rotor, before the wake has broken down into a turbulent state, the contour plots still show turbulence intensity which follows the prescribed motion (for example, you see it on the sides of the rotor disk for sway motion or on the top/bottom for pitch motion, but this is not really turbulence.

20. Page 16, Line 322: I do not understand what you mean where you say "$|\cdot|$ denotes the complex number modulus and the frequency f was nondimensionalized into St." Please clarify. I think you are saying two distinct things here: (1) The vertical bars mean that you take the FFT and then take the complex modulus of the real plus imaginary number you get at each frequency. (2) The frequency you plot spectrum against is replaced by Strouhal number because Strouhal number contains frequency. Is that correct? If so, please say it more explicitly.

21. Page 16, Line 330: In "These oscillations moderate relative," you are missing an "are."

22. Page 21, Line 415: You say, "The shear layer is a key aspect of the wake recovery because it isolates the wake from the free flow, hindering momentum entrainment and slowing the recovery down." I disagree that the shear layer acts as this isolating layer. There is nothing about it that isolates the wake flow and hinders momentum entrainment. Without a shear layer and its instability, which must be triggered with perturbations that grow with time/distance, the mixing would not occur. I think it is more accurate to say that "the shear layer is a key aspect of wake recovery because it feeds the instabilities that break down into turbulence that cause the momentum transfer that drives wake recovery."

23. Page 22: Figure 16: It is not totally clear what this figure shows. I am assuming you are tracing out the y-location of the inside and outside edge of the shear layer. Please say that very explicitly. I also do not think it right to say that the shear layer "growth rate sharply decreases at around $x^* = 5$." As you say next, this coincides with the merging of the inner and outer shear layer, so the shear layer can no longer grow, hence the sharp decrease. I would just stop the inner line at the point of merger, and indicate that this is the point of merger.

24. Page 23, Line 454: I do not think it correct to say that the wake center jet is because you don't model the nacelle. Even with the nacelle, you'll still have a jet because of the aerodynamically unloaded inner sections of the blade.

25. Page 23, Line 456: You say, "When the merger happens, the shear layer is no longer capable of expanding inwards and only expands outwards, leading to the recovery." I do not understand how the shear layer only being able to expand outward itself causes recovery? Looking at the instantaneous flow field, it seems that shear layer merging happens because the shear layer instabilities have broken into full turbulence at that point, and only then is there sufficient mixing to get wake recovery underway.

26. Page 24, Line 498: You say, "The amplitude in the y-direction is much larger than that in the z-direction but no considerations can be drawn from this fact since the wake is rotating." What does wake rotation have to do with this? Also, can't it be explained by the lower and upper walls constrain the z-motion, but the wake is free to meander in the y-direction?

27. Appendix A: You should state up front that you derive position by integrating velocity. Because that fact comes at the very end, I found myself stopping to see if I had missed something because I did not understand where the error comes from. If you state that position is derived up front, then you give the reader context as to why you do this error analysis.

28. Appendix B: It is not clear to me how you did averaging. Are you saying that you time averaged over the second half of the simulation? Your blue and green lines indicating mean and variance appear more as moving averages than the convergence of the average over the whole time period. You indicated a forward moving average, but you also say that you use the second half of the simulation for averaging. By "'converged" do you mean the initial transients are gone or the averaging length is long enough.

29. Appendix C, Line 633: Where you say, "An extensive comparison between these data and the results of many participants," who are the many participants?

30. Appendix C, Line 634: Where you say, "Results for a setup similar to the one used in this paper are included in the latter," what is "latter" referring to. It would be better to just explicitly say it instead of using "latter."

31. Appendix C, Line 635: Where you say, "Experimental data is available...," it should be "Experimental data **are** available..." The word data is plural, so just do a search for the word "data" in the manuscript and make sure the verb reflects this.

32. References, Line 745: Hojstrup should be **Højstrup**.