Authors' final response - "Dynamics of floating wind turbine wakes in a wind tunnel setup"

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1 General remarks

The authors thank the reviewer for their valuable feedback and believe that the suggestions have been well implemented in the new version of the manuscript. In the authors' understanding, the main concerns were: (1) the incomplete justification, interpretation and lack of discussion about the constant rotor-speed approximation; (2) the lack of discussion about the impact of the constant rotor-speed approximation on the tip-speed ratio and wake; and (3) the lack of discussion of the wind tunnel confinement effects on pitch motions in particular. All the comments from the reviewer are addressed in this document, and the comments pertaining to the main concerns are addressed first.

2 RC1

2.1 Comment from referee

Regarding the sentence: "This simplification is not expected to have a large impact, since the rotor was operated near rated conditions". I do not think it is sufficiently clear why operating near rated conditions implies that keeping the rotor speed fixed has only a limited impact. I suggest explaining that fixing the rotor speed allows the effect of platform motion to be isolated, since the available control actions (changing rotor speed or blade pitch) also influence the aerodynamic loads (see https://doi.org/10.5194/wes-8-465-2023) and are therefore also likely to affect the turbine wake. In addition, the Authors could discuss the variation of the optimal tip-speed ratio caused by the apparent wind speed fluctuations under a fixed rotor speed. This variation represents the amount of rotor-speed adjustment that is not being actuated by the controller in the experiment. Although relatively small, it is not negligible and helps justify the assumptions adopted in the study.

2.1.1 Authors' response

The authors fully agree with the comments and were wrongly under the impression that rotor speed and blade pitch changes would be negligible for the simulated conditions, given that the peak-to-peak apparent wind speed variation was at most 5% of the free-stream velocity. The justification for the constant rotor-speed approximation is now better explained in "Case definition" and discussed in "Discussion". Moreover, the effect of constant rotor speed on the tip-speed ratio, thrust and wake is also discussed in "Discussion". The language used is based on the reviewer's language in the comment.

2.1.2 Authors' changes in manuscript

Corrected sentence, elaborated the explanation based on the reviewer's language, and added references: L175-L179.

Removed "in the C_P-maximizing region": L234 (in the previous version of the manuscript).

Added "and constant blade pitch": L656-L657.

Discussed constant rotor-speed approximation and its effect on the tip-speed ratio, thrust and wake: L666-L682.

2.2 Comment from referee

The Authors state that the study suggests reduced wake recovery due to blockage and earlier tip-root vortex trail merging in the vertical direction due to the wind tunnel asymmetry, while still capturing the fundamental floating wind turbine wake mechanisms reported in the literature. One additional aspect worth discussing is that flow confinement due to wind tunnel walls may alter the effect of pitch motion. Pitch motion introduces a vertical wake deflection, which in the present setup is constrained by the wind tunnel ceiling. This is not the case for motions that primarily generate lateral wake dynamics (such as sway, roll, or yaw), since the lateral confinement is much less restrictive owing to the asymmetric wind tunnel cross-section. Furthermore, wake recovery occurs through the entrainment of kinetic energy from the surrounding flow. At full scale, this entrainment takes place from both the sides and the top of the wake, with vertical entrainment generally being the dominant contribution. In the present wind tunnel setup, these entrainment mechanisms may be altered by the vertical confinement, as well as by the elevated hub height relative to the floor compared with full-scale turbines. Consequently, the interaction between wake recovery and platform motion may also differ from that in an unconstrained environment.

While I agree that the wind tunnel experiments capture the main physical mechanisms and that the results are qualitatively consistent with previous wind tunnel studies under less confined conditions, as well as with numerical simulations in open environments, I think these limitations should be acknowledged,

particularly when drawing quantitative or generalized conclusions. For example, in the sentence: “The ordering of wake recovery increments among the high-Stp/low-A* cases, with sway and roll highest, pitch and yaw intermediate, and surge lowest, mirrored the ordering of cross-stream turbulence intensity increments, suggesting that the cross-stream component of the motion is the quantity most directly responsible for the recovery benefit.” I think the Authors should be more cautious in interpreting this ordering as a general conclusion, since the relative wake recovery associated with the different platform motions could be influenced by the confinement effects discussed above.

2.2.1 Authors' response

The authors thank the reviewer for their comment, which is a valuable addition to the manuscript. The parts of the manuscript related to the "ordering of wake recovery increments among the high-Stp/low-A* cases" were either removed (abstract) or supplemented by a discussion about the caveats of the wind tunnel confinement ("Wake recovery", "Turbulence intensity", "Discussion" and "Conclusions") based on the language used by the reviewer. In terms of the kinetic energy entrainment consideration, the authors framed it in the context of cross-stream meandering structures (cross-stream being either lateral or vertical) induced by platform motions, instead of arguing that vertical entrainment is generally the dominant contribution, since these structures are the main drivers of kinetic energy entrainment, wake dynamics and recovery in the most favorable Strouhal numbers.

2.2.2 Authors' changes in manuscript

Removed sentence linking cross-stream motions to enhanced wake recovery and turbulence intensity from the abstract: L14-L15 (in the previous version of the manuscript).

Indicated potential caveats in the ordering of wake recovery increments and pointed to the following subsection for discussion together with the turbulence intensity results: L344-L346.

Discussed caveats in the ordering of wake recovery increments and cross-stream turbulence intensity increments: L415-L422.

Discussed caveats in the ordering of wake recovery increments and cross-stream turbulence intensity increments: L646-L655.

Noted caveats in the ordering of wake recovery increments and cross-stream turbulence intensity increments: L721-L724.

2.3 Comment from referee

Regarding the Introduction, I suggest slightly softening the following statement: "While the overarching conclusions are broadly consistent with the existing literature on floating wind turbine wakes and are not novel, the simultaneous coverage of points (1), (2) and (3) has not been carried out on the scaled version of the DTU 10 MW reference wind turbine in the Politecnico di Milano wind tunnel, especially in terms of the tip and root vortex trail analysis, to the authors' best knowledge." I would instead write: "The overarching conclusions are consistent with the existing literature on floating wind turbine wakes. Moreover, to the best of the Authors' knowledge, the simultaneous investigation of points (1), (2), and (3) has not previously been carried out using the scaled DTU 10 MW reference wind turbine in the Politecnico di Milano wind tunnel, particularly with regard to the analysis of the tip and root vortex trajectories." I also suggest moving the following paragraph, which presents the overarching goals of the study, into a separate paragraph so that its purpose is more clearly emphasized.

2.3.1 Authors' response

The authors thank the suggestion and have replaced the previous text excerpt with the one proposed by the reviewer almost verbatim. The overarching goals paragraph was moved into a separate paragraph.

2.3.2 Authors' changes in manuscript

Replaced old excerpt with new excerpt: L87-L90.

Moved overarching goals paragraph into a separate paragraph: L91-L96.

2.4 Comment from referee

Finally, regarding the sentence: "These phenomena are expected to be enhanced for more favorable Strouhal numbers." I found this statement unclear. Specifically: it is not evident which range of Strouhal numbers the Authors consider to be "more favorable"; it is also unclear whether "these phenomena" refers to the confinement effects or the effects of platform motion on wake evolution.

2.4.1 Authors' response

The authors were referring to the effects of platform motion on wake evolution but recognize that the sentence was not clear. The authors decided to remove the sentence, since it did not add any new information, although it is expected that the effects of the platform motion will be amplified for Strouhal numbers in the range of 0.1–0.9 in the simulated setup, as mentioned at the end of the "Discussion" (L689-L690).

2.4.2 Authors' changes in manuscript

Removed sentence: L694 (in the previous version of the manuscript).