Review of *Ducted wind turbines in yawed flow: A numerical study* by Vinit Dighe et al.

Reviewer: M. Paul van der Laan, DTU Wind Energy

The authors perform 2D Unsteady Reynolds-averaged Navier-Stokes (URANS) simulation of a ducted Actuator Disk (AD) in yawed configurations for two different duct shapes. The 2D simulations are verified with a grid refinement study and with 3D simulations.

Please note that I am invited as a new reviewer, and I have not participated in the previous review rounds. Therefore, I have reviewed the latest revision as a first review, but I have also looked through the earlier reviews.

It is good that you have added a comparison between 2D and 3D simulations. Although, I am surprised to see that they agree so well for the yawed cases, since the flow problem is not symmetric, as pointed out by a previous reviewer. It is unclear to me how your AD forces are modelled in the 3D simulations. I guess you have used a uniformly loaded AD without tangential forces to make the comparison with the 2D simulations more fair? I expect that a more realistic thrust load distribution and tangential forces could have a significant effect on the results and I recommend to investigate this in the present work.

I have listed main and minor comments below, which should be addressed in order to accept the article as a publication for Wind Energy Science.

Main comments

1. What is the reason for performing URANS simulations? Couldn't you perform (steady-state) RANS simulations and obtain the averaged quantities directly? Or is the ducted AD an unsteady flow problem because of airfoil (that describes the cross section of the duct) is operating in stall for large yaw angles?

2. You mention that you model an AD with a uniformly distributed thrust load in the 2D simulations. Using a uniform loaded AD is often fine for wind farm simulations, where one is interested in (far) wake interactions. However, the current work focuses on the aerodynamics of a ducted AD and then I would recommend a more realistic AD model, especially when you investigate the effect of yaw misalignment on the forces. Have you investigated more realistic loading distributions? For 3D simulations, you could use an AD based on airfoil data. In case you lack airfoil data, you could also use an AD based on a Joukowsky rotor as proposed by Sørensen et al. (2020), which performs similarly as an AD based on airfoil data for conventional wind turbines (at least without a diffuser). Both AD loading models also provide the power directly by integrating the tangential forces instead of using an estimate (eq. 6).

3. It is unclear to me how your AD forces are modelled in the 3D simulations. Do you also assume a constant thrust load and no tangential forces? If yes, could this have been the reason why the 2D and 3D simulations compare well?

4. I was wondering if there exist literature where a ducted wind turbine has been simulated by resolving the geometry of both the duct and wind turbine in the numerical grid. If one had such a model available, then one could verify the loading of the present setup where the wind turbine is modeled as an AD.

5. Page 3, Line 16: You mentioned that you model the AD with an infinitesimal width, which makes sense for a 2D simulation, but not for 3D simulation. Please clarify in the text.

6. The domain size is not very large or at least much smaller than typical 2D airfoil simulations that my colleagues perform using DTU's inhouse CFD code EllipSys and an o-grid with a radius of 40 to 50 chord lengths. Have you investigated

the effect of this relatively small domain on the results (C_T and C_P)? A small domain could induce additional blockage effects that could lead to an increased mass flow through your AD.

7. You could split the methodology section in to two subsections, describing the 2D and 3D CFD setups, separately, which could clarify some of my previous questions.
8. What are the Reynolds numbers of the all validation cases and how do they compare with the typical Reynolds number of utility scale urban wind turbines?
9. Page 4, Line 10: You mention that the Betz limit of C_P can be exceeded for a ducted wind turbine, which is indeed true. You could refer to the work of Sørensen (2016), where analytic formulations of C_P are discussed in Section 3.4 (in case you can access this reference).
10. You could add 3D CFD results in Figures 9 and 10, since they are you most important figures that support your main conclusions.

Minor comments

1. Line 21: This is $\rightarrow$ There are.
2. You could rephrase the title of Section 4 as *Numerical verification and validation*, since you both verify the model (using a grid refinement study and a 3D setup) and validate the model with wind tunnel measurements.

References

Sørensen, J.: General Momentum Theory for Horizontal Axis Wind Turbines, Research Topics in Wind Energy, Springer, 2016.

Sørensen, J. N., Nilsson, K., Ivanell, S., Asmuth, H., and Mikkelsen, R. F.: Analytical body forces in numerical actuator disc model of wind turbines, Renewable Energy, 147, 2259, https://doi.org/https://doi.org/10.1016/j.renene.2019.09.134, 2020.