Comments on

“Near wake behavior of an asymmetric wind turbine rotor”

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General comments

This paper presents results from a numerical study of the wake of an asymmetric two-bladed rotor (one blade being shorter than the other), characterising the tip vortex dynamics (leapfrogging, merging) and the overall wake evolution and recovery. The novelty with respect to similar previous studies is the consideration of large asymmetries and the additional effect of inflow turbulence on the behaviour induced by the asymmetry. The topic of wind turbine wake control is of interest to the wind energy community and the particular approach studied in this paper is in principle suitable for the WES journal. However, I find that the work shown here presents a number of shortcomings, listed below, which put into question the validity of the results and the relevance of the conclusions, and which make me recommend against its publication.

Specific comments

1) Numerical method
   - Has the code been validated at all, by a convergence study for temporal and spatial resolution and domain size, or by comparison with other codes and/or experiments?
   - The Actuator Line Method requires a smoothing of the induced forces over a distance ε, which is dictated by numerical stability and is therefore related to the resolution of the actuator line discretization. As shown in various studies, this unphysical parameter also determines the size of the tip vortices. With ε chosen here as 5% of the rotor radius, the resulting core size is unrealistically large, which then leads to the observed merging behaviour. In real wind turbine wakes (as in small-scale rotor experiments, by the way), the core sizes are found to be significantly smaller, and merging is generally not observed.
2) 2D point vortex model
   - 2D point vortices can represent 3D vortices that are perpendicular to the 2D plane. Here, the helical vortices are not (locally) perpendicular to the x-z plane of the model, they are inclined in the x-y plane. Therefore, the distances h and δh should be corrected to take this inclination into account (see the discussion in Abraham et al. 2023a).
   - The evolution of the vortex positions in this simplified model can be expressed in a compact form summing over two vortices (see Aref 1995). No need to sum over the two infinite rows.
   - The point vortex model neglects the effect of vortex curvature, which induces an additional self-induced negative velocity in the x-direction. Since in the present paper large differences in the radii of the two helical vortices are considered, this leads to noticeably different self-induced velocities, which would result in larger relative motion than predicted by the 2D model.
3) Tip vortex behaviour
   Delbende et al. (Phys. Rev. Fluids 6, 084701, 2021), not cited here, have analysed in detail the dynamics of two interlaced helical vortices. For the present configuration (low pitch, radial offset of one helix), their results predict a periodic overtaking of the smaller helix by the larger helix. This is basically what is observed here, except for the interference of the (unphysical) merging at small offsets. This rather unspectacular behaviour is linked to the choice of a two-bladed rotor. For asymmetric 3-bladed rotors (Abraham et al. 2023a), the non-linear evolution is non-periodic and considerably more complex.
4) Comparison between simulations and model
   Figure 10 shows a significant discrepancy between the growth rates determined from the numerical simulations and those obtained from the 2D point vortex model. The proposed explanation is the fact that the latter “does not account for 3D effects, convection velocity, or wake expansion”. The effects of vortex curvature and wake expansion are small in the present

configuration, and the effect of convection velocity, as presented here, does not exist (see below). A more likely explanation lies in the fact that the two growth rates were apparently not calculated in the same way. Whereas the one from the 2D model is non-dimensionalised by $\Gamma/(2h_0^2)$ – and not by Γ/h_0^2, as written in the text on page 9 – the one found in the simulations is non-dimensionalised by U_c/D_0, if I understand the description on page 14 correctly, where U_c is the mean convection velocity of the vortices. These two quantities are basically unrelated, and it is even surprising that the two results are as close as they are in figure 10.

5) Effect of convection velocity
In several places, it is argued that the difference in convective velocities of the inner and outer vortices represents an effect influencing the tip vortex evolution which is distinct from the Biot-Savart induction. However, there is no externally imposed velocity gradient in this flow. It is the existence of the vortices which generates the velocity defect behind the rotor, as well as the gradient responsible for the different convection velocities. The evolution of their positions is entirely determined by their mutual and self-induction (plus the constant free-stream velocity) and the described 'convection velocity effect' does not exist.

Technical corrections

1. In figure 1(b), the blade profile should be aligned with the line separating the angles α and γ. As it is sketched, the angle of attack is zero.
2. On page 6, it is stated that lengths are normalised by the rotor diameter. However, the blade length reduction Δr appears to be normalised by the rotor radius. This leads to some confusion in the presentation of the results.
3. What are δx_i and δz_i in equation (8)? Should they not be x_i and z_i?
4. Page 9: the only length scale in the 2D model is h_0. It is therefore meaningless to consider a Δr^*, which is based on the rotor radius. It would be more helpful to provide the value $\Delta r/h_0$.
5. Page 17, bottom: What is a W-tunnel?