Vortex identification methods applied to wind turbine tip vortices
Reply to Referee #2
Received and published: 10 November 2021

Dear Referee #2, On behalf of all the authors, I would like to thank you for the review of our paper. All your comments will be addressed in the final version, you can find below the reply (blue) to each remark (black).

The authors should explain their contribution to the field more clearly. The paper definitely needs more description in terms of its novelty and how it distinguishes itself from previous literatures. In particular, the methods and their applications have been already addressed by other researchers; hence, the authors should demonstrate their contribution.

- Reply: We see your point, thank you for highlighting that the novelty was not clear enough. We will clearly state that the methodologies are assessed for the first time simultaneously with several VIMs/schemes, which provides explicit comparability. Additionally, we investigated how these methodologies can impact the definition of the properties of the vortex, such as jittering, convection velocity and core radius, these findings will provide valuable guidelines for future wind tip vortices analysis. This improvement will enhance the paper and its novelty in the revised submission.

In the introduction section, the authors addressed different PIV measurements performed by previous investigators particularly those focused on tip vortex flow. However, to this reviewer, there are more studies, also worked on the behavior of tip vortices, that can be included in the literature review.

- Reply: Thank you. The authors focused the literature review on PIV and tip vortices. It was decided to only include studies where sufficient information about the VIM and the numerical scheme were available. In some cases, where published reports did not include the required information, we contacted the authors and, if the Information was provided, the study was considered. Nevertheless, we agree that the literature review is a significant part of any study, and we would like to have it as complete as possible. We will improve the literature review in the revised manuscript.
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The authors have presented an extensive description of VIM methods which predict vortex behaviors. It would be very informative to include analytical approaches such Rankine model which predict tangential velocity profiles of vortex and compare your results with those that can be obtained from those models.

- Reply: Thank you. Indeed, it would be very informative, but the referred Rankine model is not the only one [please refer to Rodriguez, S., Espinoza, F., Steinberg, S., & El-Genk, M. (2012). Towards a unified swirl vortex model. In 42nd AIAA Fluid Dynamics Conference and Exhibit (p. 3354).] and including such models would extend the paper in an analytical benchmark direction, which is not the purpose of our research.

The authors are well familiar with the fact that there are two governing parameters, i.e. local Reynolds number and tip speed ratio that affect the flow structure of the turbine including tip vortices. The authors need to discuss further about the role of tip speed ratio in their assessments of vortex location, vortex core radii and vortex jittering.

- Reply: Thank you for your comment. In this work, the tip speed ratio and inflow are fixed. Only one vortex age is analyzed. The Reynolds number based on the circulation is Re=108000 classified as fully turbulent [see Ramasamy, M., & Leishman, J. G. (2006). A generalized model for transitional blade tip vortices. Journal of the American Helicopter Society, 51(1), 92-103]. This will be included in the final version of the manuscript.

*The authors have employed the results obtained from a PIV measurement to perform their analysis. However, they should present more specifications of the PIV test such the sampling rate of the measurement, the phase phase-lock process and the number image pairs per second for each azimuth angle of the blade.
*Page 7, line 145: what is the tip speed ratio of the turbine? Is it smaller or bigger than the design tip speed ratio?
*Page 7, line 150: More clarification about the experiment set-up and process is required, such as the sampling rate, frequency of the laser and camera as well as error analysis.
*Page 7, line 155: How was the process of phase-lock measurements performed?
*Page 7, Figure 2: the location of the camera is not clear in the figure.
* The authors should demonstrate more clearly that how the convection velocity has been estimated, particularly from the PIV data. Did you consider the sampling rate of the measurements for each azimuth angle of the blade? How did you make sure that you are tracking the same vortex as moving from one image pair to the next one?

- Reply: Thank you for pointing out this. In the interest of brevity, we did not include all details in this manuscript, as it is already available in [Soto-Valle, R., Alber, J., Manolesos, M., Nayeri, C. N., & Paschereit, C. O. (2020, September). Wind Turbine Tip Vortices under the influence of Wind Tunnel Blockage Effects. In Journal of Physics: Conference Series (Vol. 1618, No. 3, p. 032045). IOP Publishing.].
  However, we see your point and for completeness, we will include the required details in the revised version.

The authors should provide enough information if during the measurements the turbine was subjected to any blockage effect in the wind tunnel or not. Regarding that, they should calculate blockage ratio of the turbine based on the tunnel cross section area and considering the tip speed ratio at which the turbine is performing, they should discuss whether the turbine is experiencing blockage effect. If the blockage effect is high, it would affect the experimental results including the velocity field and wake expansion (which also determines the vortex location) significantly.

- Reply: Thank you, the turbine experience 40% blockage. In fact, the effects of the blockage were analyzed in previous research work [Soto-Valle, R., Alber, J., Manolesos, M., Nayeri, C. N., & Paschereit, C. O. (2020, September). Wind Turbine Tip Vortices under the influence of Wind Tunnel Blockage Effects. In Journal of

Physics: Conference Series (Vol. 1618, No. 3, p. 032045). IOP Publishing]. Part of the conclusions evidence that the tip vortex travels farther downstream and more inboard compared to simulations and similar experiments with considerably less blockage. Nevertheless, the goal of this research is to study how much the position and characteristics of the vortex change due to the application of different VIMs/ schemes and as such the conclusions from the present work will not be altered by blockage effects.

We will explicitly state this, in the revised manuscript, and propose that the applied VIMs and schemes can be evaluated in a test rig with lesser blockage as further work.

Page 3, line 70: what is ΘM?

- Reply: Thank you for highlighting the missing description. This angle is referred to in Fig. 1. The description will be added to the final manuscript.

Page 10, line 195: what is v(x,y)? it is mentioned that v(x,y) is induced velocity; however, at line 185 induced velocity is represented by u'(x,y). Which one is the correct one? It is confusing.

- Reply: Thank you. You are right, the symbol misses the " ' ". The correct notation is: velocity U=(u,v) and induced velocity U'= (u', v')

Page 11, line 230: It is mentioned that "the presence of the multiple maxima and the ring-like distribution of the parameters ω and Q can be explained through different hypothesis. On one side, the cause could be the level of noise in the vortex core because the lack of seeding." If this can be one of the reasons, why you do not get the similar behavior in Figure 6?

- Reply: Yes, a single peak is visible in Fig. 6. We will add this point in the same paragraph. Part of this led us to the artifact conclusion of some of the schemes applied with vorticity and Q-criterion.

  Multiple peaks because of small structures combined within the core and Grafiteaux's method will be revisited in the final manuscript.