Reply on RC1

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We thank the reviewer for the time invested analyzing the manuscript and for their comments to further enhance the content of the manuscript. The paper has been changed attending the referee suggestions, the typo errors corrected and more descriptions added. In addition, the answers to the different questions are summarized next.

1. **The novelty of the paper should be listed.**

   Thanks for the suggestion. The novelty of this work is based on three main pillars:

   - Advance in meshing techniques to introduce erosion and vortex generators simulating accurately the boundary layer without high loaded meshes
   - Demonstration of the advantages of low drag vortex generators versus conventional ones
   - Assessment of the capacity of vortex generators of annual energy recovery in rough or eroded blades

   This facts have been addressed in detail in the new version of the manuscript.

2. **You need to cite references for your statements in the introduction. Your discussion in the introduction goes too fast to 2D quantification. A general discussion about blade roughness and erosion for wind turbine blades is interesting.**

   Thanks for the comment. The introduction has been expanded in the manuscript to improve the initial discussion quality. In addition, new references have been added in many of the topics.

3. **"moving upwards": what direction is upwards?**

   We agree with the reviewer that the selected expression for this statement is not clear enough, this expression has been replaced by the following one in the manuscript:

   > Roughness distribution on airfoil surface affects its performance by degrading the airfoil aerodynamic behaviour. If rough elements are located near the leading edge zone, laminar to turbulent transition upper and lower points are displaced towards the leading edge.

4. **Line 28: What is "non specified airfoil"?**

The only geometrical data specified for the airfoil at Standish et al. (2012) is the relative thickness (18% airfoil thickness). The airfoil's nomenclature or airfoil family are not mentioned. However, we also consider that the expression "non specified" is confusing and we have changed it by "unknown" on the following way:

> Standish et al. (2012) performed experiments and simulations of an unknown airfoil of 18% thickness. The simulations were made using ANSYS CFX and roughness effects were accounted for by introducing an equivalent sand-grain roughness on surface patches. Afterwards AEP was calculated to evaluate the effect of roughness on power production.

5. **Line 103: What turbulence model is "the turbulence model"?**

Thanks for your suggestion, we agree that this sentence is not clear. It has been changed in the manuscript by the following one:

> The blade chord is 1 m, the number of nodes in the airfoil are 434 and the minimum size of the elements close to the surface is $5e^{-6}$ m for the clean cases mesh in order to obtain y+ value below 1 to ensure the proper performance of the turbulent (SST k-w) and transitional (k-kl-w and eN) models.

6. **Section 2.1: What is k-k1-w transition model? A short description with reference is required. Same comment for the transition model of eN.**

Thanks for your comment, a more elaborated description of the models used are included in the manuscript. The k-kl-w transition model (Walters and Cokjat 2008) is an eddy-viscosity turbulence model of three transport equations (the specific dissipation rate w, and the turbulent k_T and laminar k_L kinetic energy equations) based on k-w turbulence model.

The eN transition model is a semi-empirical method based on linear stability theory suitable for transonic and low Reynolds number airfoils. The upper and lower transition points from laminar to turbulent boundary layer are calculated using XFOIL (Drela and Giles, 1989), a panel method that incorporates a modified version of the eN transition model (van Ingen,1956). For the introduction of those transition points in the CFD simulations, a modified version of the 4 equations SST-Transition turbulence model is used. The intermittency is switched from 0 to 1 at XFOIL's calculated transition points locations to force the transition from a laminar to a turbulent boundary layer.

7. **Line 113: When you use a wall model for the rough surface part, what wall boundary condition do you use for the rest part of surface? Do you use a similar mesh resolution for both parts?**

The *nutkWallFunction* wall function is set for the clean airfoil part, whereas for the rough part the modified *nutkRoughWallFunction* wall function based on Cebeci (1977) is set (*nutkRoughWallFunction* condition inherits the traits of the *nutkWallFunction* boundary condition.). The parameters k_s and C_s are defined to set the roughness wall functions. k_s is the sand-grain roughness height (0 for smooth walls) and C_s is the roughness constant with values from 0.5 to 1.

These modified wall functions are applied when the y+ has a value greater than 11.25. To avoid the uncertainty of being at the buffer layer when the model applies logarithmic wall functions, the meshes used in this work are designed with a larger cell height along all the airfoil at the wall in order to obtain a y+ of around 30. All this information has been added to the manuscript to make it clearer.

8. **The stall part of the lift and drag forces is not captured. Any suggestion for improvement?**

   Thanks for the comment. In the conclusions of the paper, the last one refers to the uncertainty regarding the CFD simulations for high angles of attack. In this work the simulations were performed with steady state solver (simpleFoam) but the flow for high angles of attack is unsteady. An improvement will be obtained if a transitory solver is used in the simulations (pimpleFoam), however the authors decided to use the faster steady state simulations that reproduce correctly the airfoil performance at angles of attack used in normal production case used to estimate the annual energy production in clean/rough/eroded blades with and without VGS. For the sake of clarity the last conclusion of the paper that refers to this point has been expanded.

9. **In the rough cases, what turbulence model did you use?**

   The SST k-w turbulence model was selected for the rough cases computations. In order to make it clearer, we have modified the manuscript on the following way:

   > On the other hand, for the rough cases performed with the SST k-w turbulence model, the y+ values close to the airfoil surface are around 30, these y+ values are needed for the correct performance of the modified rough wall functions.

10. **In the erosion cases, you need to make a mesh sensitivity study as the small erosion parts are not easy to be captured as there are no measurement data to compare with.**

    This is an interesting point to be addressed in all CFD studies, specially when simulating eroded blades, thanks for the comment. During the performance of this work, many effort has been done to mesh accurately the erosion types maintaining a balance between accuracy and efficiency in the simulations (not too loaded meshes). That is the reason why ANSYS was used for meshing the eroded blades instead ICEMCFD that was used for he 2D baseline airfoils. A sensitivity study was performed giving special attention to the size of the fist cell close to the wall to achieve the y+ values needed for the accurate simulation of the effect of erosion on blade sections performance. This study was not included in the first version of the manuscript since the main goal is to demonstrate the AEP recovery due to the use of VGs. A summary of the sensitivity analysis will be included in the second version of the manuscript.

11. **Many captions are miss-leading. For example, in Figure 8, in the first two cases it is indicated with the turbulence model, but not in the other cases.**

    We fully agree with the reviewer, all graphs' captions have been modified and the turbulence model is indicated for all the simulated cases. Thanks for the comment.

12. **Section 4 on AEP is extremely short. Some details about the code and blades are required. What wind conditions do you consider? How do you use the 2D CFD results for rotor computations? Any corrections were performed?**
Thanks for the suggestion, we appreciate it and the section has been expanded in the manuscript adding a more detailed description of the code BladeOASIS and including a reference to a publication in which the code has been described. In addition the wind condition will explained: stationary wind is used and the Weibull parameters are c=7.5 m/s and k=2. In addition, the process used to include the CFD results has been elaborated in detail (mainly the computed polar curves are used in the BEM part of BladeOASIS). The Glauert tip loss correction used has been used.