Reply on CC1

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We thank the reviewer for the time invested reviewing the manuscript and for their comments to further enhance the content of the manuscript. The different suggestions are explained below and the manuscript has been extended to create the second version.

1. **Could you please provide a glossary of terms, symbols and include definitions for acronyms or abbreviations used throughout the paper**

   In the manuscript, the first time that one acronym was used in the text, it was given it's definition. But in order to make it's search easier and to answer to the requested suggestion, a glossary of terms and symbols including it's definitions is provided at appendix A. Thanks to the reviewer for this suggestion.

   Appendix A: Abbreviations

AEP	Annual energy prediction
AoA	Angle of attack
BEM	Blade Element Moment
c	Chord length
CFD	Computational fluid dynamics
Cd	Drag coefficient
Cf	Skin friction coefficient
Cl	Lift coefficient
Cp	Pressure coefficient
h_s	Equivalent sand-grain roughness
im	Intermittency
k	Turbulence kinetic energy
kl	Laminar turbulence kinetic energy
kt	Turbulent turbulence kinetic energy
nut	Turbulent viscosity
RANS	Reynolds-Averaged Navier Stokes
SIMPLE	Semi-Implicit Method for Pressure-Linked Equations
SST	Shear stress transport
S-M	Structured mesh
Re	Reynolds number
p	Pressure
U	Velocity
U-M	Unstructured mesh
U^+	Dimensionless velocity
ω	Turbulence specific dissipation rate
y^+	Dimensionless wall distance
VG	Vortex generator

2. **On page 3, line 73 –Any reference to support your statement: "More recently vortex generators are being included in the tip area of the blades to improve efficiency in rough or eroded conditions."**

Thanks for your comment. This sentence is supported by the chart on slide 3 of the presentation made by Jesper Madsen (LM Wind Power) in the Annual Event 2017 of Wind Energy Denmark. In that slide, it is stated that LM´s vortex generators could be installed in the first 90% of the blade span, and in the tip area to mitigate aerodynamic impact of eroded blades.

This reference has been added to the manuscript´s references list.

3. **On page 4, line 102 –Please include the chord length of the airfoil**

   Thanks for the suggestion, it has been included in the manuscript in the following way:

   > 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 turbulence model.

4. **On page 4, line 108 – What value of Ncrit was used for the eN transition method? Please include in text**

   A Ncrit=9 value was set, it has been included in the manuscript in the following way:

   > The eN transition method from van Ingen (2008) to simulate clean conditions is implemented in OpenFoam v8 by modifying the turbulence model intermittency factor and transition location for each angle of attack is imposed trough a connection with the panel method XFOIL Drela (1989). In order to get the upper and lower transition locations with XFOIL a N_{crit}=9 was set.

5. **On page 4, line 109 – The CFD model setup description is insufficient, could you please provide more information on convergence criteria, boundary conditions, force and residual history plot? and the order of models and solvers used for the computation. Please specify the residual drop, i.e. by how many orders of magnitude the residuals dropped for all equations. This is important if the order of magnitude of initial residuals is not 1 for all PDEs (i.e. are these residuals normalized?).**

   We completely agree with the reviewer and we find necessary to add that information in a new section as follows:

   The OpenFOAM CFD code was employed for the presented simulations. Steady-state time scheme and RANS (Reynolds-Averaged Navier Stokes simulations) turbulence models were used for all the computations performed. The incompressible solver *simpleFoam* based on SIMPLE algorithm (Semi-Implicit Method for Pressure-Linked Equations) of Caretto et al. (1973) was used.

   The selected solvers and smoothers for solving the different terms equations are shown in the Table 1.

Table 1. Selected solvers and smoothers.

Equation	Solver	Smoother
p	Geometric-algebraic multi-grid (GAMG)	Diagonal incomplete-Cholesky (DIC)
U	Solver using a smoother (smoothSolver)	Gauss-Seidel (GaussSeidel)
k		
ω		
kl		
kt		

In this article different turbulence models have been used in order to consider different flow conditions, these turbulence models are introduced in the following sections. However, the assigned boundary conditions associated with the different variables employed by each model are shown in Table 2 and their meaning is explained at Appendix A.

Table 2. Assigned boundary conditions for the different performed simulations.

Patch	U	p	k	ω	nut	kl	kt	im
Farfield	freestream	freestream	inletOutlet	inletOutlet	calculated	fixedValue	fixedValue	inletOutlet
smoothAirfoil	fixedValue	zeroGradient	wallFunction	wallFunction	wallFunction	fixedValue	fixedValue	fixedValue
roughAirfoil	fixedValue	zeroGradient	wallFunction	wallFunction	roughWallFunction	fixedValue	fixedValue	fixedValue

In the different simulations a fixed number of iterations was established, in order to achieve convergence for high angles of attack, since these are the most problematic ones. For the convergence criteria, the stabilisation of aerodynamic coefficients (C_l, C_d and C_m) was used. The main reason to choose this criterion is to avoid the early ending of the simulations while the aerodynamic coefficients keep still changing due to a bad selection of residuals' values, and also to avoid misleading cases of false convergence due to excessively low relaxation factors. Once the different coefficients values keep oscillating around the same value, the simulations were considered converged.

Although residuals were not considered as convergence criteria, they were reviewed at some simulations (Fig. 1) in order to do not omit any strange behaviour. The obtained residuals are normalized (L_1 norm) and scaled (the initial residual values is 1). Residuals drop varies depending on the angle of attack, the larger the angle of attack is, the lower the residuals drop is. Regardless of the size of residuals' drop, the aerodynamic coefficients converge. For high angles of attack the aerodynamic coefficients oscillate remarkably due to the non stationary flow nature.

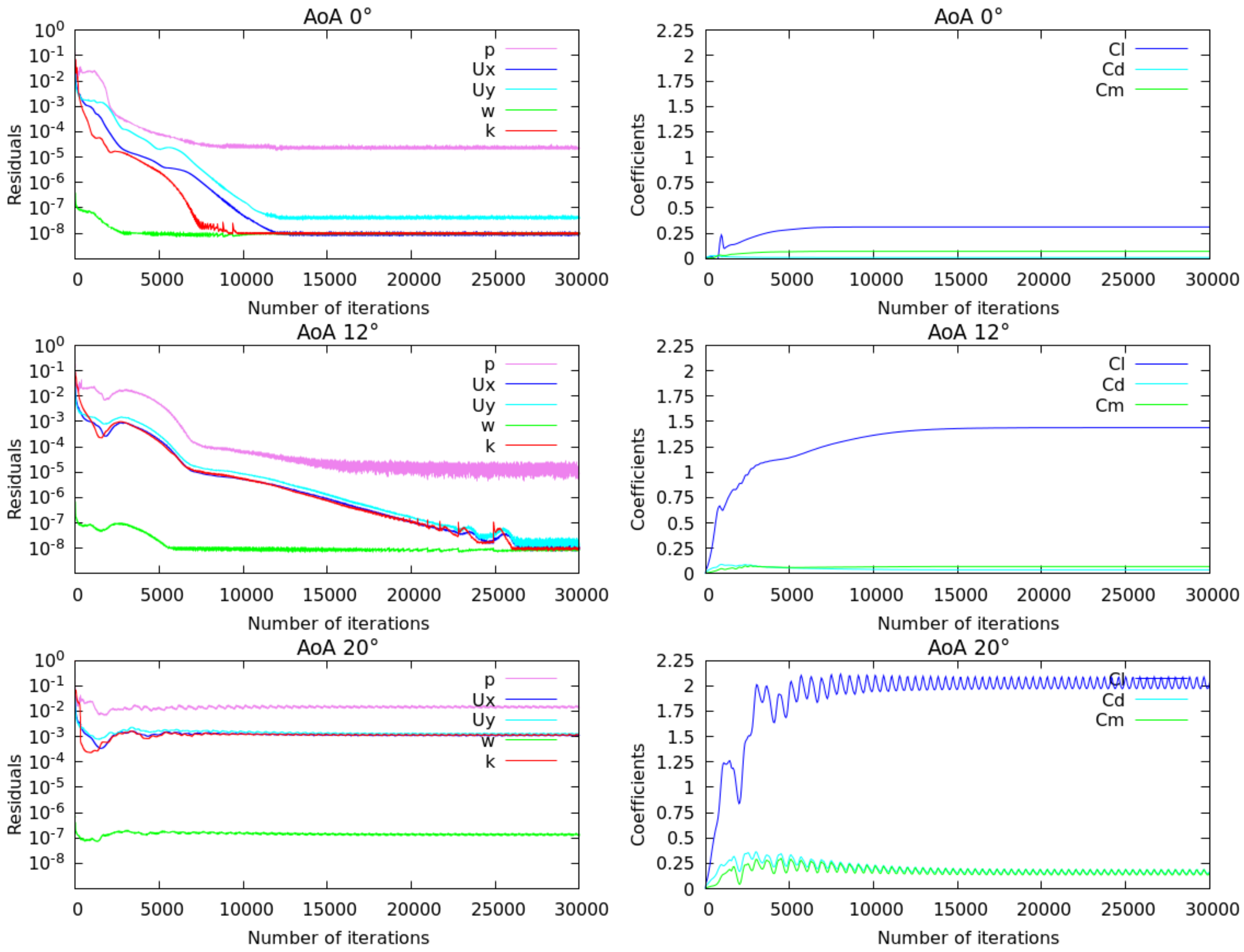

Figure 1. Residuals and aerodynamic coefficients evolution during the simulations for angles of attack of 0º, 12º and 20º; and the SST k-w turbulence model.

6. **On page 4, line 113 – What relationship was used to determine the equivalent sand grain value, please provide a reference**

Thanks for the comment, the following information and references have been added to the manuscript.

The equivalent sand grain approach links the real roughness h to an idealized roughness with reference to Nikuradse's experiments . The height of the equivalent sand-grain, h_s, is deduced from the real roughness shape with the help of the empirical correlations proposed by Dirling and Grabow and White . These correlations are summarized next:

$$\frac{h}{h_s} = \begin{cases} 60.95\Lambda^{-3.98} & \text{for } \Lambda < 4.92 \\ 0.00719\Lambda^{1.9} & \text{for } \Lambda > 4.92 \end{cases} \tag{1}$$

with Λ being the roughness shape parameter defined as

$$\Lambda = \frac{l}{h}\left(\frac{A_s}{A_p}\right)^{4/3} \tag{2}$$

with l being the average distance between the roughness elements, h their average height, A_p the element frontal area and A_s the element wet surface. The h_s parameter is dependent of the real roughness elements size and the area covered and would be the one used in this study to evaluate the roughness effect on the airfoil aerodynamics.

Nikuradse J. Strömungsgesetze in rauhen Rohren (Laws of flow in rough pipes - NACA TM 1292) VDI-Forschungsheft, Tech. Rept. 361, 1933

Dirling Jr R.B. A method for computing rough wall heat transfer rates on reentry nosetips Proceedings of the 8th Thermophysics Conference, AIAA Paper 73-763, 1973.

Grabow R.M. and White C.O. Surface roughness effects on nosetip ablation characteristics AIAA Journal, Vol 13, 1975

7. **Page 5, line 121 – Please provides some images of the difference between the (S-M) and (U-M) grids**

Thanks for the comment. A new figure showing the structured and unstructured meshes is included.

> In order to justify the selection of the k-kl-w transition model as baseline in this work a comparison of the eN and k-kl-w method is presented in Fig. 3 comparing with the experiments available from Pires (2018). In addition structured meshes (S-M) and unstructured meshes (U-M) are compared, Fig. 2 shows the difference between both types of meshes.

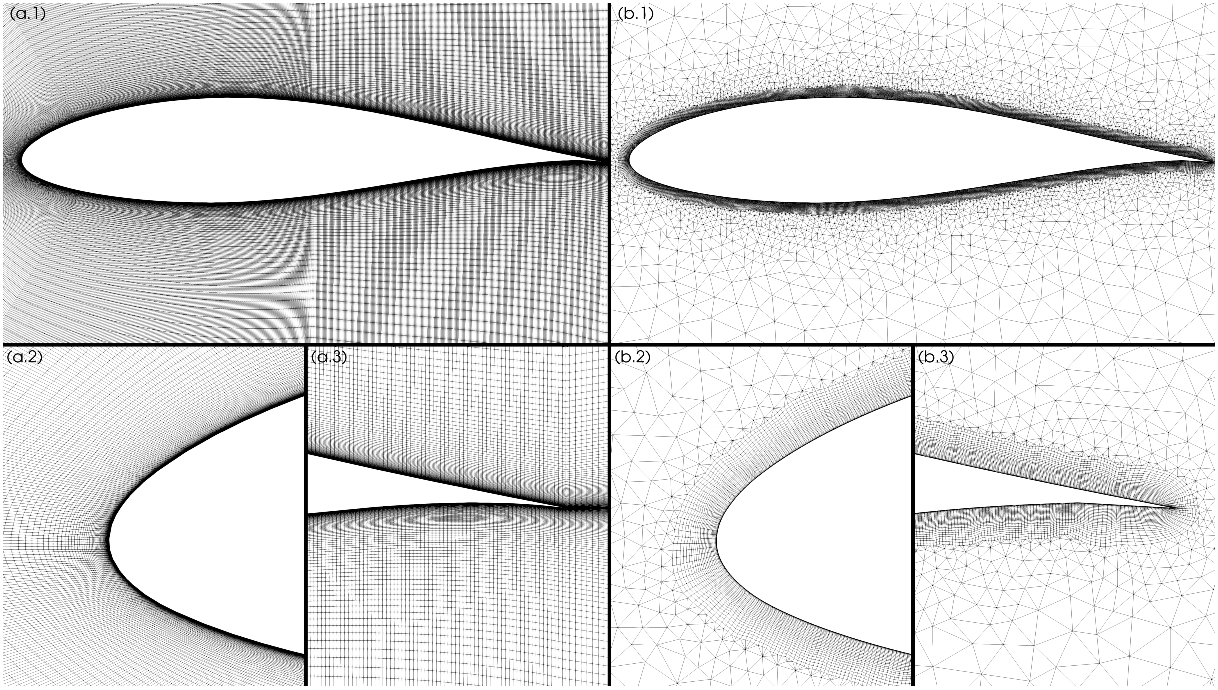

Figure 2. Meshes for NACA 63_3418: (a.1) S-M main view, (a.2) S-M leading edge, (a.3) S-M trailing edge, (b.1) U-M main view, (b.2) U-M leading edge, (b.3) U-M trailing edge.

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8. **Page 15, Figure 13 – Please include the chord location of the VGs in the caption**

Thanks for the suggestion, it has been included in the manuscript in the following way:

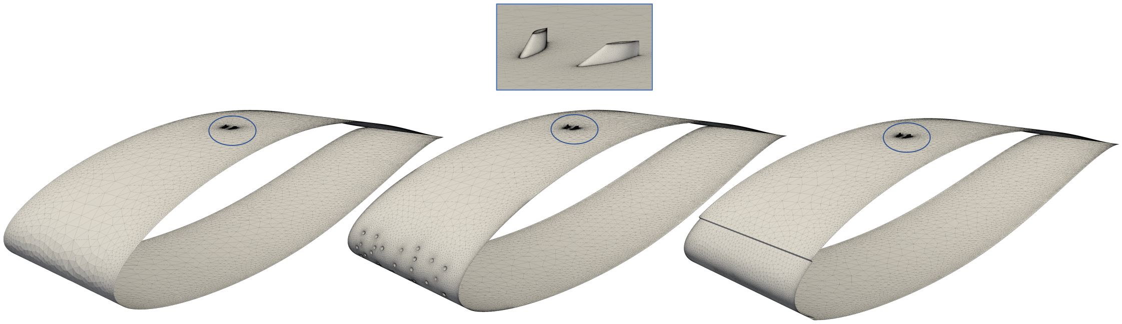

Figure 13. Mesh for rough (left), type 1 eroded (middle) and type 2 eroded (right) cases with CENER´s Low Drag VGs (30 %c).

9. **Page 15, Line 194 - Please provide a table with the dimensional information of the different VGs, such as the vane angle, the lateral distance between the vanes and height with respect to the chord and/or local boundary layer thickness**

   Thanks for the suggestion. The dimensional information of the VGs is included in the new version of the manuscript. The VG height is 5 mm, their chord is 12.5 mm and the angle of attack to the incoming flow is 18 degrees. The separation between the VGs trailing edge is 12.5mm.

10. **Page 15, Line 195 – What was the metric used to determine the best VG location along the airfoil chord, please provide the results from the parametric study.**

    Thanks for the comment, we agree that it is very interesting to add this information to the manuscript.

    The code presented by Delphine du Tavernier in her work has been used to make a parametric study that helps to select the best location of the VG pair. This reference has been added to the manuscript and the description of how the best location for the VGs has been included. The best location has been selected for the clean airfoil case, so it is assumed by the authors that for the other configurations the 30% value may change. It has been maintained throughout the work in order to compare the AEP values obtained in the last part of the paper.

    Tavernier, Baldachino, Simao 'An integral boundary layer engineering model for vortex generators implemented in XFOIL' - Wind Energy (https://doi.org/10.1002/we.2204), 2018

11. **Page 21, Line 225 – Please provide more detail about the AEP model, was it via BEM calculations? was drag contribution added to the induction calculation? Which wind distribution was considered, and which mean wind-speed was used?**

    Thanks for the suggestion, we appreciate it and the section will be 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 tip loss correction from Glauert has been used.