Estimation of roughness effects on wind turbine blades with vortex generators

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ABSTRACT

- Leading edge (LE) ***erosion*** leads to ***drop in AEP by approximately 4%***.[1]
- Blade add-ons like vortex generators ***(VG) improve aerodynamic performance***.

- Quantify the impact of LE roughness and VGs on aerodynamic performance.
- Investigate if VGs would compensate for the losses due to roughness.

OBJECTIVES

- Investigate effect of LE erosion on airfoils.
- Investigate effect of VGs on clean and rough airfoils.
- Use the TNO in-house Blade Optimisation Tool (BOT) to analyse impact of erosion and VGs on power production of the AVATAR reference turbine.

METHODOLOGY

Fully turbulent simulation on DU-97-W300 airfoil in clean conditions as a baseline case

Implement, verify and validate roughness models for SA and SST turbulence models in SU2[2].

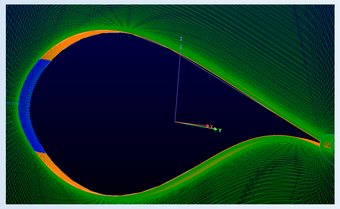
Perform fully turbulent simulation on DU-97-W300 airfoil with VG and validate against experimental data.

Apply roughness model to DU-97-W300 airfoil

Fully turbulent simulation on DU-97-W300 airfoil with roughness and VGs.

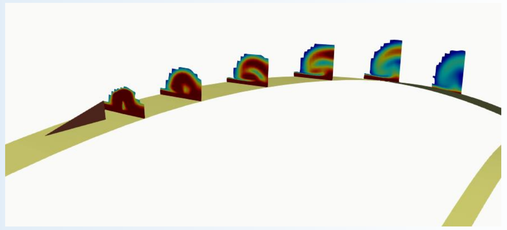
Compare aerodynamic performance against baseline case.

Compare power output with rough section against baseline case using BOT



Clean (orange) and rough (blue) surfaces on DU-97-W300

Vortex shedding behind the VG



Roughness simulation in SU2

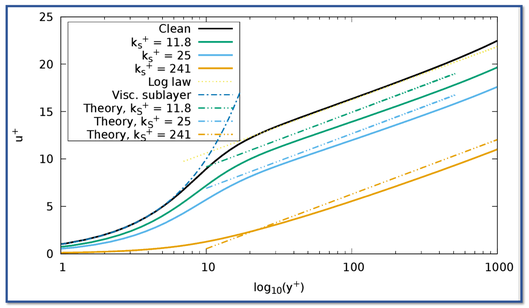
Step 1 Find statistical information of real roughness(k) of a surface

Step 2 Use empirical relations to find equivalent sand grain roughness (k_s)

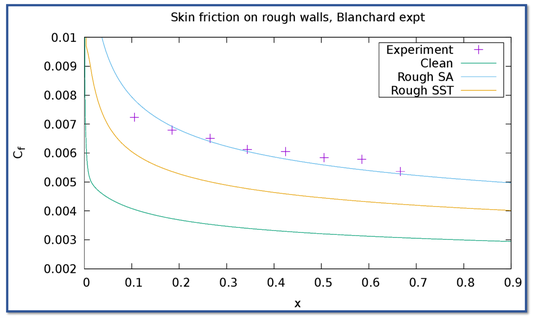
Step 3 Run SU2

RESULTS

- Boundary layer profile verification (SA)



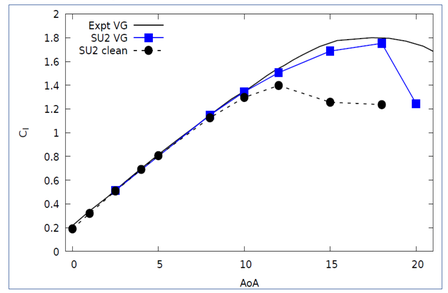
- Experimental validation [3] (SA and SST)



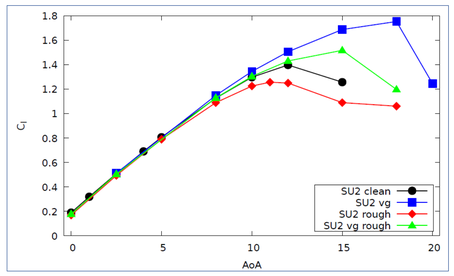
SA roughness model performs better

RESULTS

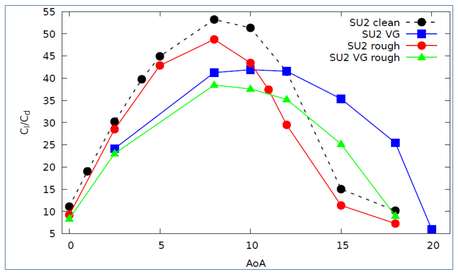
- Comparison of lift for fully turbulent flow against experiments[4] and other CFD codes[5]



- Comparison of lift for fully turbulent flow under different conditions



- Comparison of **aerodynamic efficiency** under different conditions



CONCLUSIONS

- Roughness leads to early separation, stall and ***loss in aerodynamic efficiency***.
- ***Reduction in power by up to 2.5%*** due to roughness in the AVATAR turbine blade.
- VGs can ***recover lost efficiency*** only at ***higher angles of attack.***

REFERENCES

[1] Herring R, Dyer K, Martin F and Ward C 2019 Renewable and Sustainable Energy Reviews 115 109382.

[2] Palacios F, Padron S, Tracey B, Manosalvas D E, Aranake A, Copeland S R, Variyar A, Alonso J J, Lukaczyk T W, Lonkar A K, Naik K R and Economon T D 2014 52nd Aerospace Sciences Meeting AIAA 2014-0243

[3] Aupoix B and Spalart P 2003 International Journal of Heat and Fluid Flow 24 454-462

[4] Baldacchino D, Ferreira C, Tavernier D D, Timmer W and van Bussel G 2018 Wind Energy 21 745-765

[5] AVATAR 2017 Avatar: Results and deliverables http://eera-avatar.eu/publications-results-and-links/index.html,