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Computational characterization of a Gurney flap on a DU91(2)W250 airfoil

Unai Fernandez-Gamiz1*, *Iñigo* Errasti[1], *Ekaitz* Zulueta[2], *José Manuel* Lopez Guede[2], *Ana* Boyano[3]

1 Univ. Basque Country (UPV/EHU), Nuclear Eng. and Fluid Mechanics Dept., 01006 Vitoria, Spain
2 Univ. Basque Country (UPV/EHU), Automatic Control and System Engineering Dept., 01006 Vitoria, Spain
3 Univ. Basque Country (UPV/EHU), Mechanical Engineering Dept., 01006 Vitoria, Spain

Abstract. The considerable increase of wind turbine rotor size and weight in the last years has made impossible to control as they were controlled 20 years ago. The cost of energy is an essential role to maintain this type of energy as a viable alternative in economic terms with traditional or other renewable energies. Through the last decades many different flow control devices have been developed. Most of them were shaped for aeronautical issues and this was its first research application. Currently researchers are working to optimize and introduce these types of devices in multi megawatt wind turbines. Gurney flap (GF) is a vane perpendicular to the airfoil surface with a size between 0.1 and 3% of the airfoil chord length, placed in the lower or upper side of the airfoil close to the trailing edge of the airfoil. When GFs are appropriately designed, they increase the total lift of the airfoil while reducing the drag. Thanks to the implementation of the of this flow control device the efficiency of a wind turbine improves, which results on an increase in the power generation.

1 Introduction

In the last fifteen years, it has been a considerable growth in the installation of wind power in Europe. Of course, this increase has also affected to multi-megawatt wind energy. In the study of Fernández-Gamiz et al. [1], an overall increase on the average wind turbine power output was found due to the implementation of GFs and VGs at different blade stations. At lower average wind speeds of NTM5 (Normal Turbulence Model with averaged speed of 5 m/s) the increment in the power output wanders around 10% for different passive devices configurations. That increase decays to 3% at 10 m/s (NTM10) of average wind velocity, which is still significant. The best results, in terms of average power, were reached by the case denoted by ID25. The rise in the average wind turbine power production was 10.4%, in comparison with the clean wind turbine at a wind speed of NTM5 and 3.5% at NTM10.

This increase in offshore wind energy installations shows the relevance of research in the field of flow control for large wind turbines. However, it is difficult to control the turbines as they were controlled 20 years ago due to the huge increase that the rotor size and weight have suffered. Nowadays, wind turbine rotors of about 120 meters or even longer ones have been installed. As Aramendia et al. [2] mentioned, the higher the size of a wind turbine is the higher the structural and fatigue loads are.

Some of the most important flow control techniques were compiled by Johnson et al. [3]. This could be used in wind turbines to achieve a most favorable operation under different atmospheric conditions. The objective was to maximize the lifetime energy captured by the wind turbine. In the last decades, different flow control devices have appeared and most of them were created for aeronautical sector. Nowadays, research is focused in the optimization to introduce these types of devices in multi-megawatt wind turbines.

The flow control devices can be classified as active or passive, depending on their operating principle control techniques. On the one hand, passive flow control devices generate an increase in the efficiency of the turbine and reduce load without additional energy consumption. On the other hand active ones need an external energy source, so the desired improvement can be obtained. Some of the most important passive control devices are vortex generators, microtabs, serrated trailing edges, fences, spoilers and Gurney flaps. As active control techniques, there are devices like trailing-edge flaps, synthetic jets and air jet vortex generators.

In the current study, a computational characterization of a GF on a DU91(2)W250 has been carried out at Reynolds number of Re=2 million, based on an airfoil chord length c=1m.

The general designation of the DU airfoils is DU yy-W-xxx where DU represents Delft University, followed by the year when the design was developed, W indicating wind energy application and the last three number to specify the maximum thickness of the airfoil in percent of the chord.

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* Corresponding author: unai.fernandez@ehu.eus

The DU91(2)W250 airfoil is a design developed by Delf University of Technology [4]. Airfoils with this kind of geometry are currently used in many wind turbine blades. The main intention was to use this 25% thick DU airfoil in blades for 500 kW wind turbines with rotors of about 40 m diameter, quite common in the early nineties.
Focusing on the flow control devices, the one which is going to be studied is the GF, that belongs to the passive control ones. It consists on a ledge with a height between 0.1% and 3% of the airfoil chord length, located in the trailing edge of the airfoil and perpendicular to its lower or upper surface (Figure 1). The mayor effect of a GF is a significant lift coefficient (CL) increase. Storms [5] showed a lift increase of almost 15% for a 0.5% chord length GF with minimal drag increase.
The main goal of this work is to carry out a study of the effect that a 0.25% chord length GF has in the airfoil DU91(2)W250 with the purpose of assessing the induced flow effects. Consequently, Computational Fluid Dynamics (CFD) simulations have been run with two objectives. Firstly, to validate the CFD model with experimental data and secondly, to compare the CFD lift and drag coefficient (CD) results for two cases: a clean DU91(2)W250 airfoil and DU91(2)W250 with GF.

2 Baseline experimental data

The experimental data of the present study were extracted from Advanced Aerodynamic Tools of Large Rotors AVATAR European project, [6,7] and from the Summary of the Delft University wind Turbine Dedicated Airfoils [4]. For the validation of the computational results the information used are the Measurements in Delft University 1.25x1.80 m Low-speed Wind tunnel of a DU91(2)W250 airfoil.
Taking into account the experimental data available in the AVATAR project and the Summary of the Delft University wind Turbine Dedicated Airfoils, in order to reproduce those experiments on the airfoil DU91(2)W250, the computational simulations have been done at a Reynolds number of Re=2 million with a free stream velocity of U0= 30.222 m/s. The angle of attack (AoA) of the oncoming flow goes from -4° to 10º. The CD has been calculated by computational simulation as well as the application of Equation (1) in the normal direction of the free stream velocity in different wake rakes (WR), according to Jakubowski et al. [8] and Young [9].

$$C_A = \frac{2}{A}\, 2\pi \int_0^\infty \frac{u}{U_0}\left(1 - \frac{u}{U_0}\right) y\, dy \qquad (1)$$

where u is the streamwise velocity component, U_0 the free stream velocity, y the vertical coordinate of the WR and A the area of the airfoil. Both numerical methods have been compared with experimental data in order to validate the results.

3 Computational setup

Two different structured meshes have been designed with Pointwise software and exported to Open FOAM [10]. The first mesh corresponds to a clean airfoil and the second one to the same airfoil with a 0.25% chord GF. Figure 1 illustrates the mesh distribution around the airfoil with the GF. The mesh cells are thinner near the GF and in the edges of the airfoil where the velocity and pressure gradients are large. The further from the airfoil the cells are the coarser they are.

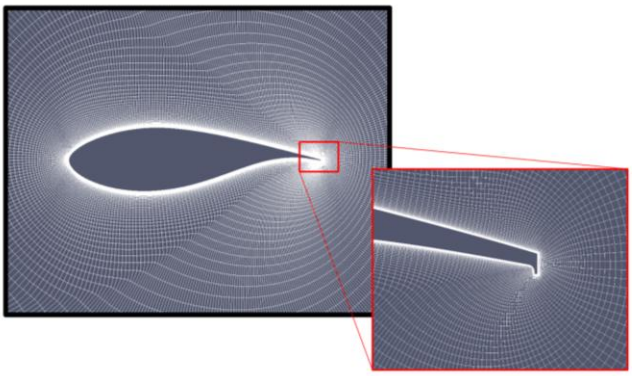

Fig. 1. Refined mesh regions around the GF.

The total number of cells is 24600 for the clean airfoil and 55074 for the airfoil with a 0.25% chord GF. Meshes were designed to fulfil that the dimensionless distance (y+) of the wall for the first layer of cells was less than 1. The simulations were carried out by OpenFOAM which is an open-source code written in C++ used to solve computational continuum mechanic problems. For all the numerical simulations, the solver potentialFoam which solves potential flows, was used to generate starting fields in order to speed up the convergence process. This solver is appropriate to produce initial conditions for more advanced solvers such as the one used in the present work named simpleFoam. This second solver has been used to solve incompressible, steady-state and turbulent flows by the computation of Reynolds Average Navier-Stokes equations (RANS). In addition, the turbulence model applied is the k-omega SST (Shear Stress Transport) model developed by Menter [11]. This turbulence model is a combination of two models: Wilcox´s k-ω model for the near wall region and the k-ε model for the outer region and in free shear flows.
The lift and drag coefficients CL and CD obtained in the simulations will be compared with the measurements achieved in the 1.25 m x1.80 m low speed wind tunnel at Delft University [4].
In Figures 2 and 3, the CL and CD comparisons between experimental data and CFD results in a clean DU91(2)W250 airfoil function of AoA are shown.

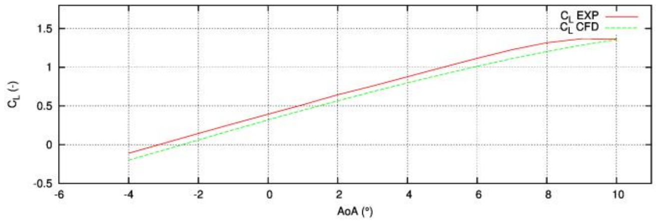

Fig. 2. CFD and experimental CL of a clean DU91(2)W250 function of AoA. CFD (green), experimental (red).

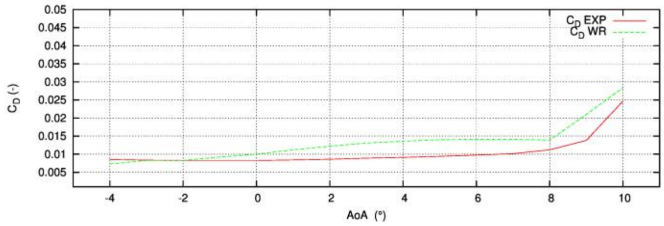

Fig. 3. CFD (computed on the WR) and experimental CD of a clean DU91(2)W250 function of AoA. CFD (green), experimental (red).

As in the previous curves is appreciated, the CFD results match relatively well the experimental data.

3 Results and discussion

In Figures 4 and 5, CFD CL and CD comparisons between a clean DU91(2)W250 airfoil and a DU91(2)W250 airfoil with a 0.25% chord GF function of AoA are shown.

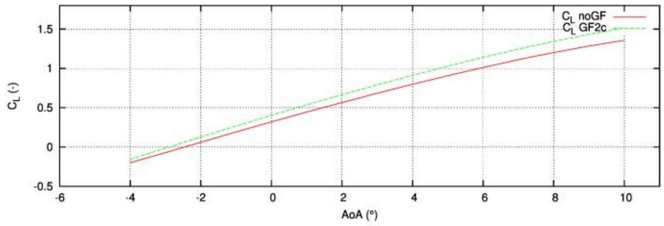

Fig. 4. C_L of a clean DU91(2)W250 and a DU91(2)W250 with 0.25% chord GF function of AoA. Clean (red), GF (green)..

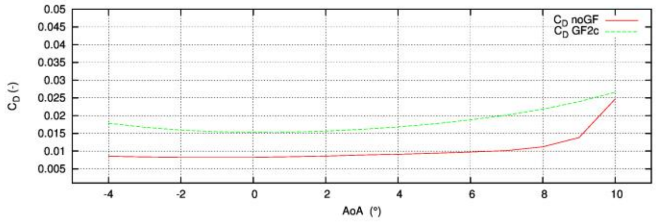

Fig. 5. C_D of a clean DU91(2)W250 and a DU91(2)W250 with 0.25% chord GF function of AoA. Clean (red), GF (green).

The placement of the GF on the airfoil generates a meaningful improvement in the CL while the CD suffers a slightly increase due to a bigger area normal to the flow direction.

In Figure 6, a comparison of the vortex generated between a clean DU91(2)W250 and a DU91(2)W250 with 0.25% chord GF is depicted function of AoA. As expected, two vortexes are formed past the trailing edge, one above the other. The lower is the AoA, the bigger is the upper vortex and the smaller the lower one. Vortexes generated in the GF airfoil are larger than the ones produced in the clean airfoil.

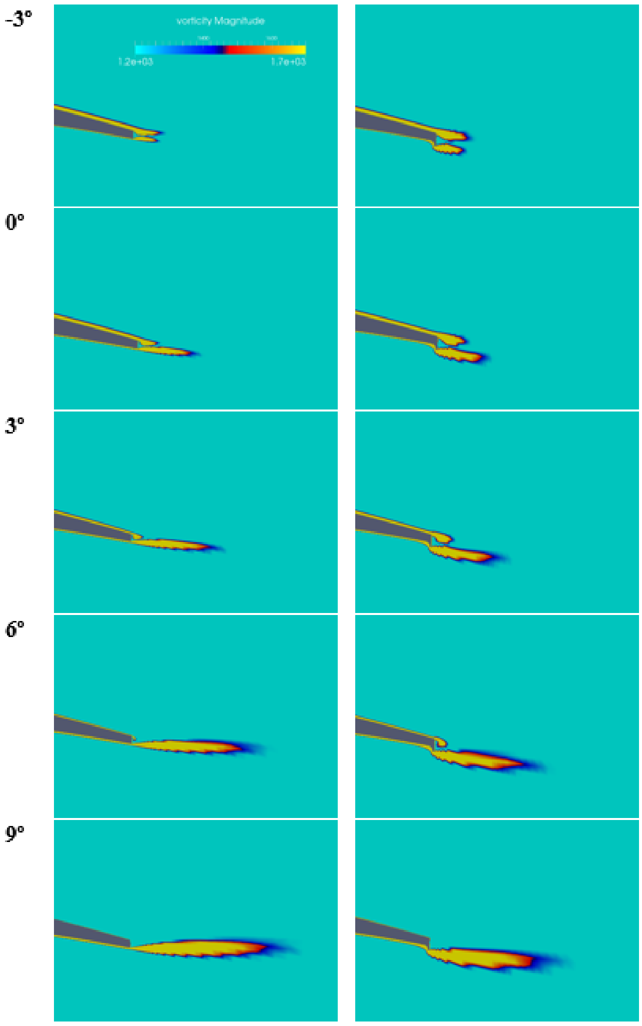

Fig. 6. Vorticity field distribution around a clean DU91(2)W250 and DU91(2)W250 with 0.25% chord GF. Clean (left column), GF (right column).

4 Conclusions

Numerical results achieved in the present research indicate that the placement of a GF at the trailing edge provides an increase in the CL and consequently, a higher torque in the rotor of an offshore aerogenerator. This aerodynamic improvement is related with the delay of the boundary layer separation.

The advantages of the implementation of Gurney Flaps in turbine power generation is indicated by Fernández-Gamiz et al. [1] which firstly shows that a simple geometry modification based on the installation of a flow control device such a GF implies a remarkable increase in the total power generation of a turbine, and secondly, that the implementation of a passive flow control device requires less maintenance than an active flow control device. This fact is an important factor when considering offshore turbines.

References

1. Fernandez-Gamiz, U.; Zulueta, E.; Boyano, A.; Ansoategui, I.; Uriarte, I. Five Megawatt Wind Turbine Power Output Improvements by Passive Flow Control Devices. *Energies (*2017)*,* **10**, DOI 10.3390/en10060742.

2. Aramendia, I.; Fernandez-Gamiz, U.; Ramos-Hernanz, J.; Sancho, J.; Lopez-Guede, J.; Zulueta, E. Flow Control Devices for Wind Turbines. In *Energy Harvesting and Energy Efficiency: Technology, Methods, and Applications*; Bizon, N.; Mahdavi Tabatabaei, N.; Blaabjerg, F.; Kurt, E., Eds.; Springer International Publishing: Cham, (2017); pp. 629-655.

3. S.J. Johnson and C.P. van Dam Active Load Control Techniques for Wind Turbines. (2008)*, SAND2008-4809*.

4. Timmer, W.A.; van Rooij, R.P.J.O.M. Summary of the Delft University wind turbine dedicated airfoils. *J Sol Energy Eng Trans -ASME (*2003)*,* **125**, 488-496, DOI 10.1115/1.1626129.

5. Storms, B.L.; Jang, C.S. Lift Enhancement of an Airfoil using a Gurney Flap and Vortex Generators. *J Aircr (*1994)*,* **31**, 542-547, DOI 10.2514/3.46528.

6. Ferreira, C., Gonzalez, A., Baldacchino, D., Aparicio, M., Gómez, S., Munduate. X., Barlas, A., Garcia N. R., Sorensen, N. N., Troldborg, N., Barakos, G., Jost, E., Knecht, S., Lutz, T., Chassapoyiannis, P., Diakakis, K., Manolesos, M, Voutsinas, S., Prospathopoulos, J., Gillebaart, T., Florentie, L., van Zuijlen, A., Reijerkerk, M. FP7 AVATAR ProjectTask 3.2 : Development of aerodynamic codes for modelling of flow devices on aerofoils and rotors. (2016*), http://www.eera-avatar.eu*.

7. Baldacchino D. Experimental data description for avatar task 3.1: experimental investigation of low-profile vortex generators in a boundary layer wind tunnel. January (2015)*, http://www.eera-avatar.eu*.

8. BEANS, E.; JAKUBOWSKI, G. Method for Estimating the Aerodynamic Coefficients of Wind Turbine-Blades at High Angles of Attack. *Journal of Energy (*1983)*,* **7,** 747-749, DOI 10.2514/3.62730.

9. A.D. Young, B.A. The Calculation of the Total and Skin Friction Drags of Bodies of Revolution at Zero Incidence. (1939), 51.

10. OpenFOAM, https://www.openfoam.org/, 2017.

11. Menter, F.R. 2-Equation Eddy-Viscosity Turbulence Models for Engineering Applications. *AIAA J (*1994)*,* **32**, 1598-1605, DOI 10.2514/3.12149.