Parametric study of a Microtab on a DU airfoil

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Abstract: - A parametric study for design and analysis of a microtab (MT) on an airfoil is presented. These flow control devices consist of a small tab placed on the airfoil surface close to the trailing edge and perpendicular to the surface. Numerical simulations applied to this concept solve the governing Reynolds-averaged Navier-Stokes equations on structured mesh. The aim of the current study is to find the optimal position to increase airfoil aerodynamic performance, therefore a parametric study of a MT mounted on the pressure surface of an airfoil DU91W(2)250 has been carried out. This airfoil has been selected because it is typically used on multi megawatt wind turbines blades, such as the 5 MW wind turbine of the NREL. To that end, 2D computational simulations have been carried out at Re= 7.10^6. Procedure and best cases are presented.

Key-Words: - Microtab, Aerodynamics, Flow Control, Airfoil, Wind Turbine.

1 Introduction

Currently, with environmental impact concerns and future shortage, the generation of electrical energy using non-polluting energy systems has regained momentum; wind energy for example. Global trends have shown that wind energy is the most financed and implemented non-polluting energy technology with operating installed capacity nearing 48.000 MW in 2007. At the end of 2014 the energy produced by wind farms was approximately 370 GW [1], what was around the 5% of the global electricity needed. The new global total at the end of 2015 was 432,9 GW [2]. In USA for example, it has become the renewable energy choice. Since some companies are devoting new resources for wind turbine researching and development, many other companies are building larger and heaviest turbines in an attempt to stop wind energy growing.

Wind energy is the fastest growing source of energy, with an average growth rate around 30% per year. It can be assumed that wind energy technology will continue growing. After setting new records in 2014, the wind power industry surprised many observers with another record breaking year in 2015, passing the 60 GW mark for the first time in a single year; and this after having broken the 50 GW mark for the first time in 2014. Once again, the big story was China, installing an astonishing 30.8 GW [2] against the backdrop of a slowing economy and nearly flat demand. Europe and the United States had surprisingly strong years; and Canada, Brazil, Mexico and other ‘new’ markets continued to develop.

Even thought for some industry, wind energy is the best cost option in order to keep renewable energy economically competitive in the market, important improvements have to be done. One way to low the cost of the energy will be improving wind turbine aerodynamic performance. These techniques are divided into two types:

- Active control devices: external energy or assisting power is required.
- Passive control devices: any external energy source is not needed. Inside passive control devices two groups are made. On the one hand, turbine control devices and on the other hand, flow control devices like vortex generator or microtabs.

The microtabs (MTs) consist of a small tabs situated near the TE of an airfoil, which projects perpendicular to the surface of the airfoil a few percent of the chord length (1%-2% c) corresponding to the boundary layer thickness.

The small movement of these MTs jets the flow in the boundary layer away from the blade’s surface, bringing a recirculation zone behind the tab, as can be observed in Figure 1 affects the aerodynamics shifting the point of flow separation and, therefore, providing changes in lift. Lift improvement is obtained by deploying the MT downwards (on the pressure side) and lift reduction is obtained by deploying the MT upwards (on the suction side).

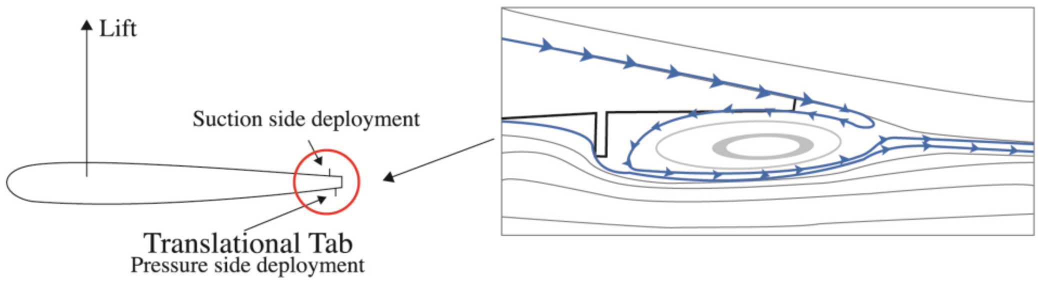

Figure 1: *MT concept and detail of the streamlines around a trailing-edge region during tab pressure side deployment [3].*

The implementation of this device near the airfoil trailing edge (TE) provokes changes in the flow, causing modifications in the recirculation of the flow on the airfoil. The effective camber of the airfoil is modified, promoting changes in the lift and drag forces. Placing a MT at the pressure surface the lift is increased, however if it is placed on the top, the opposite effect is reached. The main advantages of MTs are: small size; low energy needed for its activation; low cost of manufacturing; easy implementation without major modifications in the current techniques used for the manufacture of aerodynamic profiles.

Multiple studies into this topic were made by [4] and [5], including wind-tunnel experiments in order to determine their optimal distribution height and location. In that study, some appealing features for wind turbine control applications:

1. Small size.
2. Low power requirements for its activation.
3. Simplicity of the design (low cost).
4. They can be installed without significant changes in the actual techniques to manufacture the profiles.

The aim of the current study is to find the optimal position to increase airfoil aerodynamic performance, therefore a parametric study of a MT mounted on the pressure surface of an airfoil DU91W(2)250 has been carried out. This airfoil has been selected because it is typically used on multi megawatt wind turbines blades such as the 5 MW reference wind turbine of the NREL [6]. To that end, 2D computational simulations have been carried out at Re= 7.10^6.

2 Computational Configuration

In the current work, steady state simulations were carried out and performed with a structured finite-volume flow solver using RANS equations. The convective terms are discretized using the third order Quadratic Upstream Interpolation for Convective Kinematics (QUICK) scheme [7]. For these computations the k - ω *SST* Shear Stress Transport turbulence model by Menter [8] was used. Figure 2 illustrates the computational setup with the current setting consisting of a DU airfoil. The dimensions of the computational domain normalized with the airfoil chord length are also shown in Figure 2

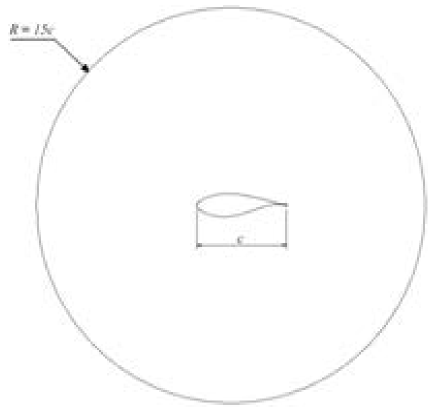

Figure 2: *Computational domain.*

The Reynolds number based on the airfoil chord length of c = 1m is Re= 7.10^6. The computational setup of the simulations consists of a block structured mesh of 200.000 2D cells with the first cell height $\Delta z/c$ of 1.5×10^{-6} normalized by the airfoil chord length. It was calculated to have a dimensionless distance less than 1 ($y^+ < 1$) on the airfoil wall. Figure 3 shows the cell distribution around the MT and in the near wake of the trailing edge.

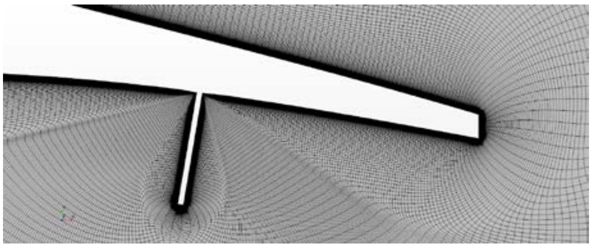

***Figure 3:** Mesh distribution around the MT.*

2.1 Microtab lay-out

Figures 4 and 5 show the MT position in the airfoil, dimension x represents the position from the LE and y represents the height of the MT, both in percentage of *c*. 12 cases have been established depending on the distance measured respective to the LE in %*c*, see Table 1. These cases are: 93%*c*, 94%*c*, 95%*c* and 96%*c*. The MT height relative to the length of the chord measured in percentage is 1%*c*, 1.5%*c* and 2%*c*. The MTs are placed on the pressure surface and have been studied for ten different angles of attack, from 0º to 9º. The combination of all these positions for the MTs gives 120 different cases to study, [9].

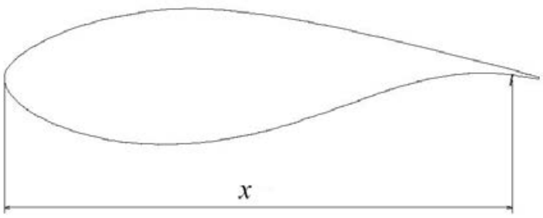

***Figure 4**: Position relative position of the MT to the leading edge x.*

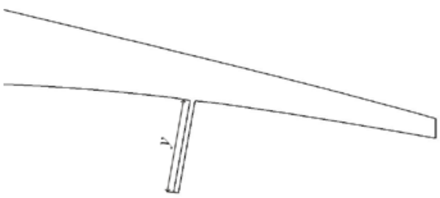

***Figure 5**: Height of the MT y.*

***Table 1:** MT cases and denominations*

Case	y (%c)	x (%c)	Case Name
0	No MT	No MT	DU91W(2)250
1	93	1.0	DU91W2250MT9310
2	93	1.5	DU91W2250MT9315
3	93	2.0	DU91W2250MT9320
4	94	1.0	DU91W2250MT9410
5	94	1.5	DU91W2250MT9415
6	94	2.0	DU91W2250MT9420
7	95	1.0	DU91W2250MT9510
8	95	1.5	DU91W2250MT9515
9	95	2.0	DU91W2250MT9520
10	96	1.0	DU91W2250MT9610
11	96	1.5	DU91W2250MT9615
12	96	2.0	DU91W2250MT9620

3 Results

First of all, computational simulations of the DU91(2)250 airfoil without any MT have been carried out and validated against the calculation made by Xfoil from DOWEC [10] and [11]. The Lift-to-drag ratio was calculated for ten the angles of attack from α= 0 to α= 9 degrees. Figure6 shows the results of the CFD computations against the Xfoil results for all angles of attacks of the airfoil. In the linear part of the curve, the CFD results follow reasonable good the trend of DOWEC results.

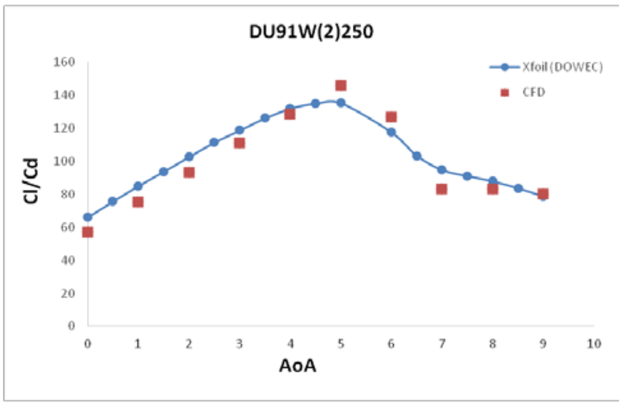

***Figure 6:** C_L/C_D ratio comparison from α= 0º to 9º.*

Afterwards, a parametric study to find the optimal MT position on the airfoil at Re=7x10^6 was carried out. According to the cases presented in Table 1, 12 cases have been studied with MT and each case has been performance for ten different degrees of AoA, from 0 to 9º. Figure7 illustrates all the lift-to-drag ratio C_L/C_D evolution for every AoA. In the left column the evolution of the C_L/C_D along the location of the MT from the airfoil leading edge *x* is represented. Right column represents the C_L/C_D evolution against the MT height *y*. Both *x* and *y* are represented in terms of percent of the airfoil chord length *c*. The black dashed line represents the Lift-to-drag ratio of the airfoil without MT for each angle of attack.

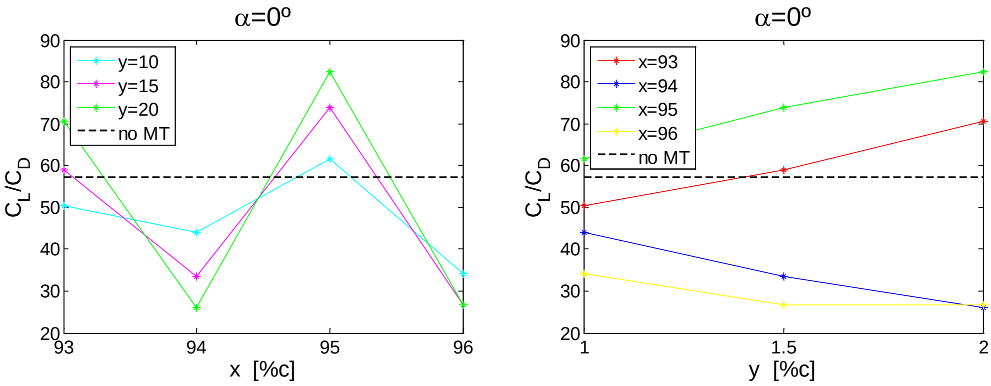

***Figure 7a**: Lift-to-Drag ratio for α=0º of AoA.*

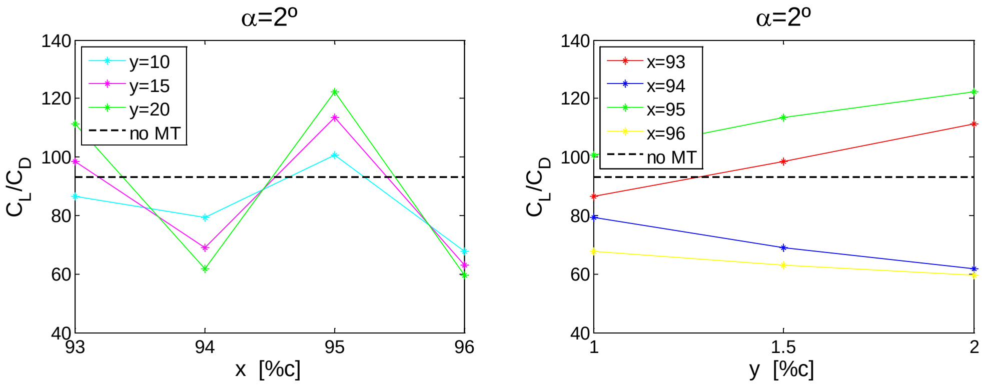

***Figure 7b**: Lift-to-Drag ratio for α=2º of AoA.*

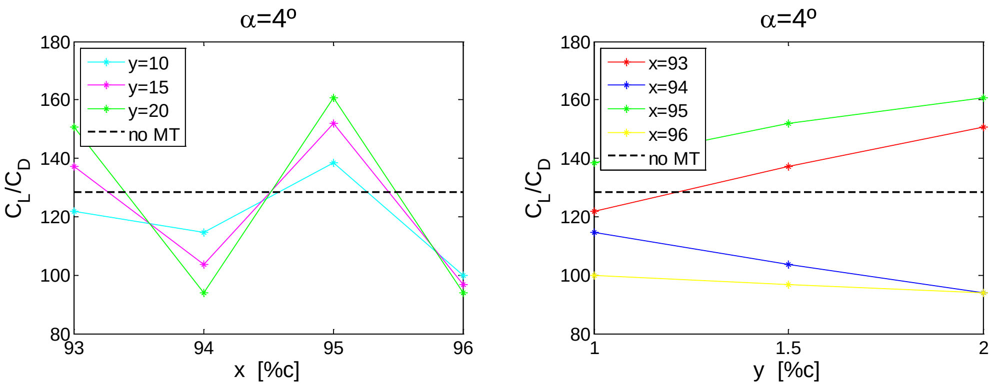

***Figure 7c:** Lift-to-Drag ratio for α=4º of AoA.*

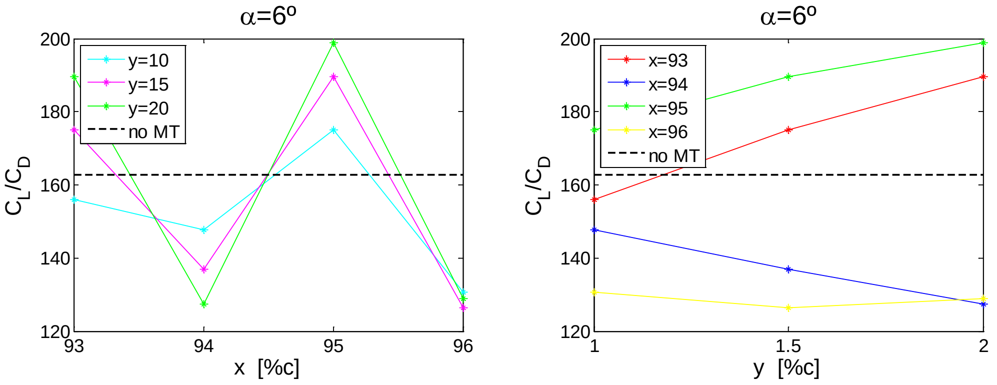

Figure 7d: *Lift-to-Drag ratio for α=6º of AoA.*

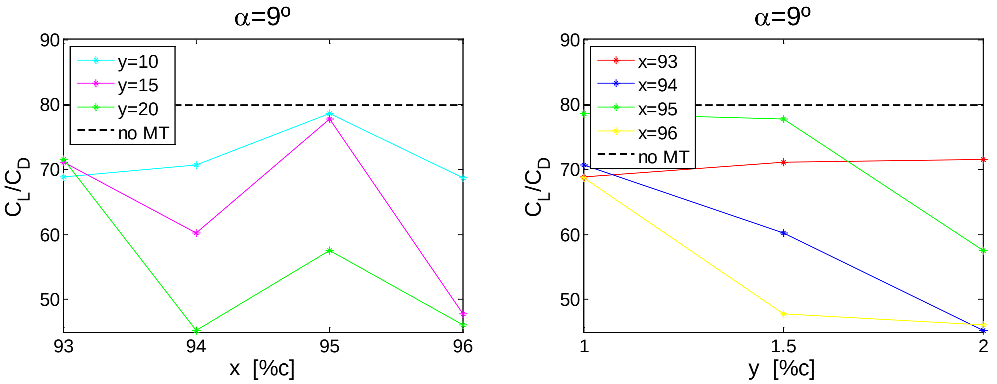

Figure 7e: *Lift-to-Drag ratio for α=9º of AoA.*

Figure 7: *Lift-to-Drag ratio for all AoA of the airfoil. In the left column is represented the evolution of the C_L/C_D along the location of the MT from the leading edge x. Right column represents the C_L/C_D evolution against the MT height y.*

For low angles of attack, from 0º to 6º, the best values of the C_L/C_D ratio are reached by the cases MT9510, MT9515 and MT9520. But, as can be seen in the left column plots, the highest values are reached around the x=95% of the chord length. On the right column plots, it is clear again that the best values of the Lift-to-drag ratio are reached by x=95% of c, and the highest ones by the MT height of *y*=10% of c. So, for that range of angles of attack, the best case is the one defined by: *x*=95% and *y*=20% of c. The case DU912250MT9520, according to the name classification of Table 1. In this case, the reached C_L/C_D ratio keeps up to the ratio of the clean airfoil. Figure 8 illustrates the Lift-to-drag ratio values of the case DU912250MT9520 in comparison CFD and DOWEC results with a clean airfoil.

However, at 9º of angle of attack, this is not fulfilled. At that angle, all the cases are below the ratio of the clean airfoil with no MT.

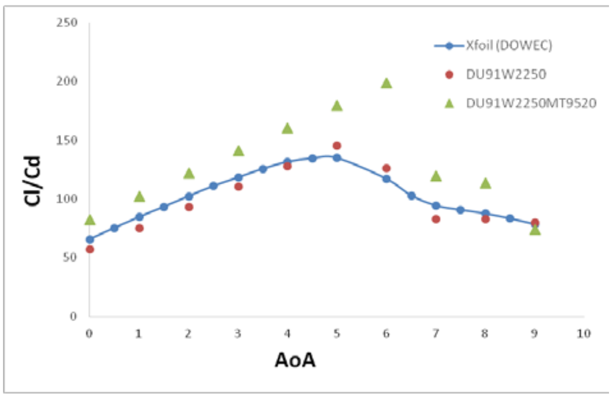

Figure 8: *Lift-to-Drag ratio comparison with the case named DU912250MT9520.*

4 Conclusion

A parametric study for design and analysis of a MT on an airfoil has been carried out. To that end, 2D computational fluid dynamic simulations haven performed at Reynolds number of Re=7x10^6, based on the airfoil chord length. The MT design attributes resulting from the simulations have allowed the sizing and positioning of the passive device based aerodynamic performance.

Comparisons of the computational simulations and the DOWEC results have been made and verified the effectiveness of the MTs as flow control devices to increase the aerodynamics performance. The case named DU912250MT9520 with the MT positioned at 95% of *c* and with the height of 20% seems to be the best case for the DU91(2)250 airfoil at Re=7x10^6 at the AoA from 0º to 6º. However, more angles of attack are needed to investigate. Finally, active controlled MTs will be considered for future investigations.

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