# Blade Thickness Effects on Darrieus Wind Turbine Aerodynamics Performances.

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***Abstract*—The energy problem currently causes sharp concerns on many aspects, in particular the reheating climatic, the problem of the environment and the exhaustion of fossil energies. In this fact much of attention and investment are devoted to renewable energies, among those there is the wind energy. In this context, our work is interested here in the type of Darrieus wind turbine.**

**More precisely, the present work is devoted to study the form influence of the blades profile of Darrieus wind turbine on its aerodynamic performances. For this purpose, we carried out two rotor of Darrieus wind turbine. The first one has a NACA0015 profile and the second one has a NACA0012 profile. We measured the aerodynamic coefficients -Cp, $C_D$ and $C_L$, of depression, drag and lift respectively, and thereafter, we deduced the power coefficient CP. We also carried out a numerical simulation using the CFD code *Fluent* which allows us to undertake a comparative study and especially to follow the flow evolution around the rotors model.**

**The comparison of the $C_L$ and $C_D$ evolutions as well the power coefficient CP show that the rotor with profile NACA0012 has better advantages since it presents the strongest depression as well as the strongest lift value and the strongest drag relatively to the rotor with the NACA0015 profile.**

**The numerical simulation gave us an acceptable approach between the numerical and experimental results for the two studied rotors. This simulation also enabled us to follow well the evolution of the flow around the Darrieus rotor.**

**We finally can say that it is henceforth preferable to use blades with less thickness such as NACA0012 profile with which we obtains better aerodynamic coefficients $C_L$, $C_D$ and $C_P$.**

***Keywords*—Aerodynamics, Darrieus wind turbine, power coefficient, NACA profile, renewable energy.**

## I. INTRODUCTION

A new alternative of the Darrieus type wind turbine makes currently much speak about it, announcing an energy production higher of 35% than any other wind turbine placed at the same place and with similar climatic conditions [1].

This new turbine would be also able to produce more electrical current with less wind than those of its competitors, and this, without having to expose it in height, making it possible to bring closer place of production and consumption.

The performance evaluation of the Darrieus wind turbine type requires the knowledge of the aerodynamic coefficients of it's blade for various conditions of operations. The blades carry out a rotation of 360 degrees when the wind turbine functions. During this rotation, the evolution of the flow around the blades varies considerably.

However, all improvements considered later on, concerning the aerodynamic characteristics of the Darrieus wind turbine, have a direct impact on the generated current intensity.

In this work, we studies numerically and experimentally the aerodynamic characteristics evolution of the flow developing around the Darrieus wind turbine through the variation of the form of the profile of blades NACA0015 initially, then NACA0012 in one second stage, for a variety of angles of attack and a fixed flow velocity. The results obtained from the numerical simulations, with the *CFD* code Fluent, are compared to the experimental values; we can thus visualize the interaction between the blades, the transverse and longitudinal evolutions of the pressure at right sections, the velocity vectors and the fluid particles trajectory which are hardly revealed by the experimental work.

## II. EXPERIMENTAL SET UP

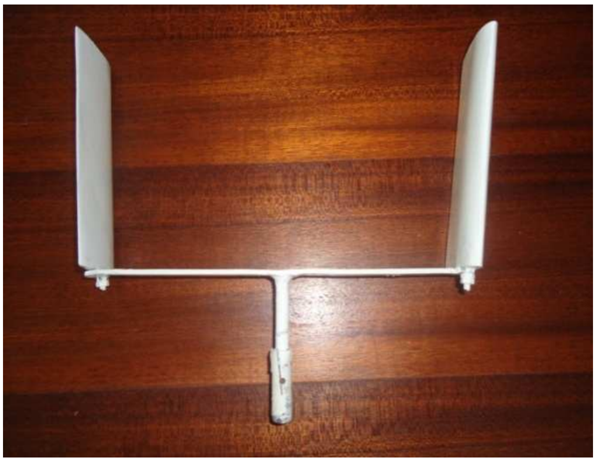
The turbulent flow through the two various configurations of Darrieus rotor at moderate and high angles of attack varying up to 360 degrees were studied at various Reynolds numbers in a subsonic wind tunnel which have a test vein of *28 cm×28 cm* and length of *100 cm*, the velocities are measured with a Pitot tube and the pressure with a multi-manometer with oil columns.

The pressure evolution was measured at the extrados of an insulated blade at various angles of attack for a model NACA0015 and for NACA0012, as outlined in figure.3, we show the effects of the studied profile form experimentally and numerically, we measure also the blade lift and drag. During the experiments, the flow velocity in the test vein was fixed at Vo = *20.3* m/s.

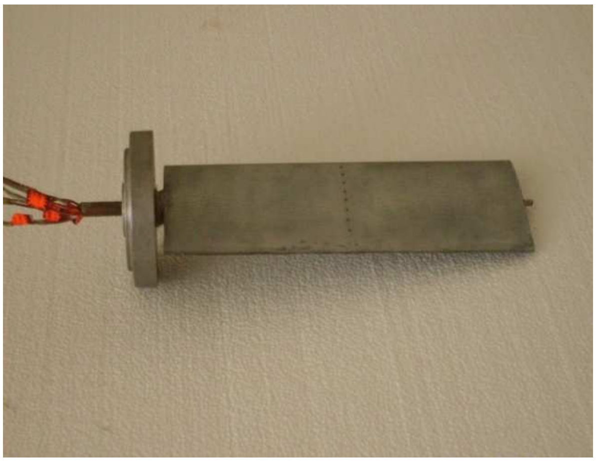
## III. DARRIEUS ROTOR MODELS DESIGN

Two generic models of Darrieus rotor were designed, to study the thickness effects of the blade NACA profile on the wind turbine aerodynamic characteristics, the first model is characterized by blades with profile NACA0015 the second has a profile NACA0012. The two current models have respective median chords length *lo* = 5 *cm, and spans* of blades b = *15 cm*, the same wing surface S = 75 $cm^2$ and an aspect ratio $\lambda$ = 3.07 (figure.2). The blades were designed using a tool of DAO then sent to the workshop as numerical three-dimensional models.

All the blades, subjected to tests in the wind tunnel, were machined from a sheet plate of thickness e=1.*5mm*. On each blade, intended for measurements of pressure, we have eight pressure taps of diameter d = 0.8 *millimeter* located on the suction face (extrados) of the blade (see figures 1 and 2) at remarkable longitudinal positions (*x/lo* = 0.25, 0.35, 0.45, 0.55, 0.65, 0.75, 0.85 and 0.95).



**(a)** Darrieus rotor (for measurement of $C_L$ and $C_D$)



**(b)** Blade with NACA0015 profile (for pressure measurement)

Fig. 1 Geometry of the studied Darrieus rotor model with vertical blades

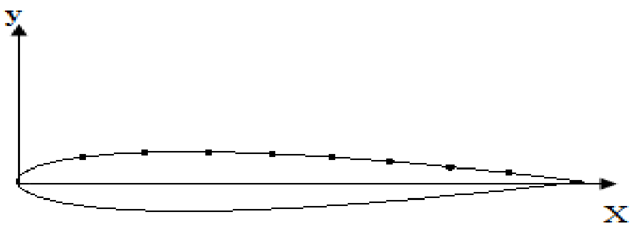



Fig. 2 Distribution of pressure taps along the blade chord of profile NACA0015

## IV. RESULTS AND DISCUSSIONS

The comparison between results obtained with the two models through the evolution of depression coefficient -Cp along the blade chord, lift coefficient $C_L$ and drag coefficient $C_D$ at various angles of attack, for a flow velocity fixed at Vo=20.3 m/s.

### *A. Pressure Distribution at the suction face of the blades*

Figure.3 shows the distribution of the depression coefficient at the blades suction face of the rotor, for an angle of attack of *i = 5 degrees*, for two profiles NACA0015 and NACA0012. we can note on the graphs that the pressure distribution on the suction face changes significantly with coordinate x/*lo*; it decreases quickly starting from its maximum negative peak located just at the vicinity of the leading edge of the blade to an approximate longitudinal position of x/*lo* = 0.25 after which it decreases because of the development of the flow boundary layer at the suction face of the blade. Thereafter more we approaches the trailing edge of the blade, i.e. with x/***lo*** > **0.6**, the values of - Cp tend towards a common value which is - Cp=0.1.

The profile form effect is very clear since the maximum values of - Cp are obtained with the blades with profile NACA0012, as showed for the positions very close to the apex; the values come thereafter corresponding to profile NACA0015.

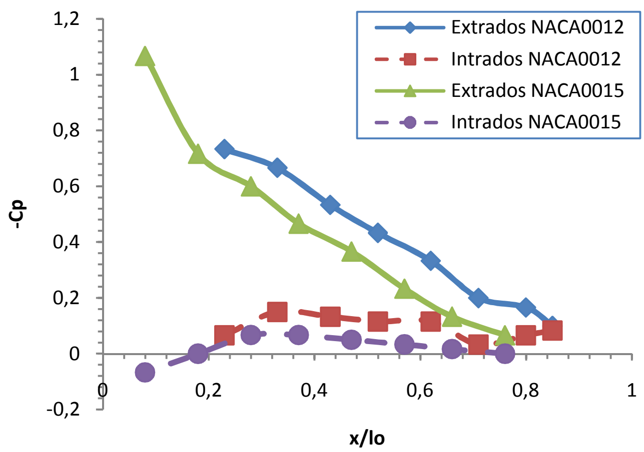



Fig. 3 Depression coefficient - Cp evolution at the suction face of the studied blades at incidence *i* = 5 degrees and Vo=20.3 m/s

### *B. Drag and lift evolution of the two studied rotors:*

For the two studied models, we chose to follow the evolution of lift and drag and the power coefficient CP on the various graphs according to (figures 4, 5 and 6).
The curves of figures 4, 5 and 6 confirm that the Darrieus rotor evolved in a cyclic way each 180 degrees.

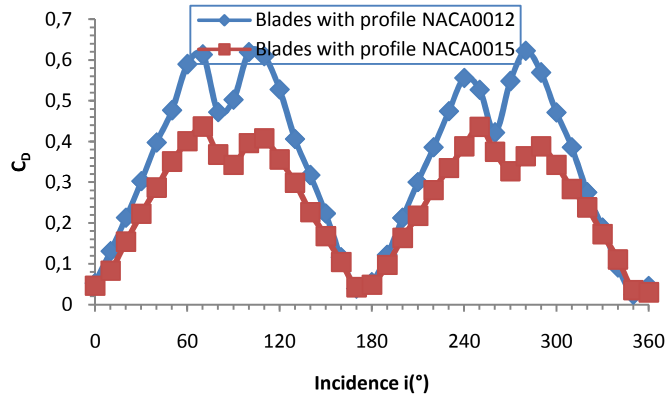


Fig. 4 Drag coefficient evolution at various incidences

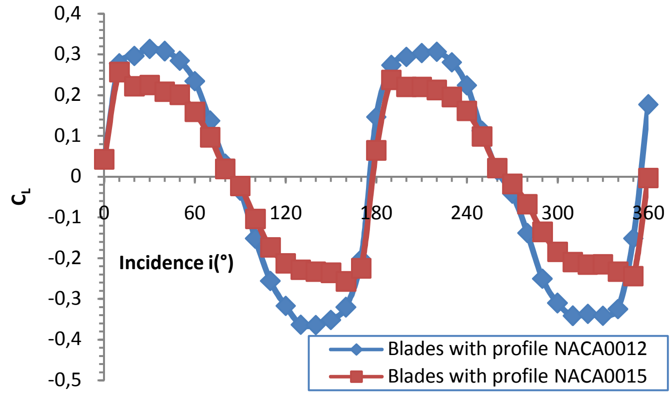


Fig.5 Lift coefficient evolution at various incidences

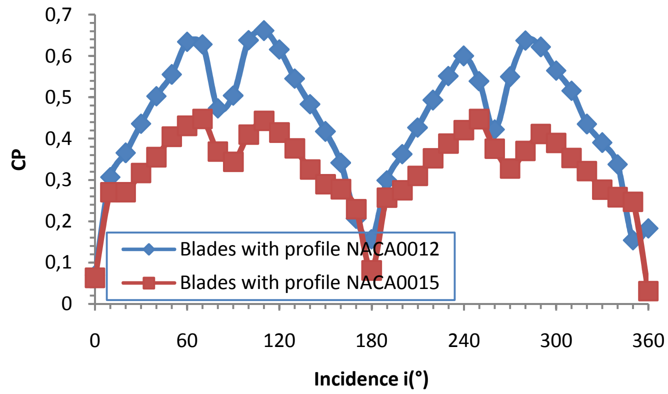


Fig. 6 Power coefficient evolution at various incidences

The figures 4 and 5 present the drag and lift coefficient evolutions according to the angle of attack for the both studied models at Vo = *20.3 m/s*. The evolution of the $C_D$ curves indicates that it has a minimal drag at *i*=0°, 180° and 360 degrees during a complete rotation of the rotor model, theses indications are supported by other work [2;5,7,8]. The curves of the figure 5 prove that $C_{Lmax}$ = 0.3 is reached at incidence *i* = 30° and 140° for the two beaches of incidences positive and negative.

The maximum angle of attack of test is 360 degrees, in this range of angles of attack, the power coefficient evolution was deduced for the two studied rotors, the greatest value is obtained at *i*= 70° and *110°*.

It is noted that the values of the most significant CP are obtained with the blade NACA0012 rotor as well as the strongest lift value and the strongest drag. According to the results obtained by numerical simulation (figures 9.a and 9.b) we notes the existence of a swirling structure developing between the two blades of the rotor what gives us a general idea on the interaction of the two blades at the time of the movement of the rotor at different angle of attack, this is why we suggests to use the visualization technique of the flow by smoke in order to determine exactly the evolution of these new swirling structures.

## V. NUMERICAL SIMULATION

### *A. Boundary conditions*

The best manner of modeling the test conditions in the wind tunnel was to create a square area around the three-dimensional rotor [2, 3]. For the left rectangular side of the square field, the flow admission has a velocity entry Vo=*20.3* m/s and the condition of exit are adopted since it reproduces the conditions in the section of the wind tunnel.

### *B. Model of turbulence*

The model of turbulence *Spalart-Allmaras* with *an equation* was employed during the simulations.

### *C. The field meshing*

The types of grid elements employed, schematized on the figure 7, are triangular. Moreover, the not structured grid was applied. The majority of the flow significant properties to be reproduced are at the vicinity of the airfoil surfaces.

Consequently, the calculation field was refined close to the suction face (extrados) and the under-surface (intrados) of the airfoils and maintained gross in the areas far from the blades in order to decrease the volume of calculations.

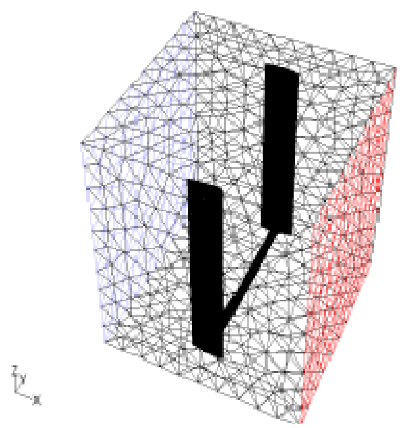
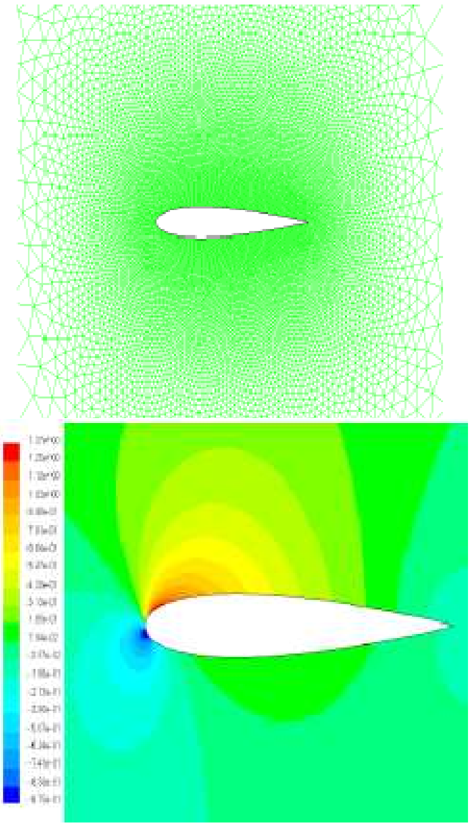
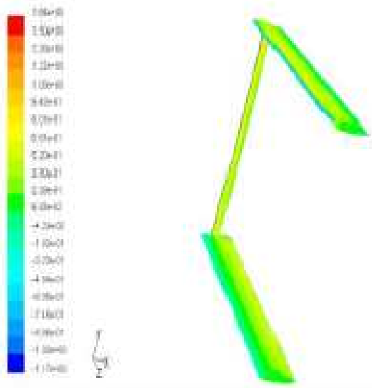


Fig. 7 Mesh of various surfaces of the Darrieus rotor

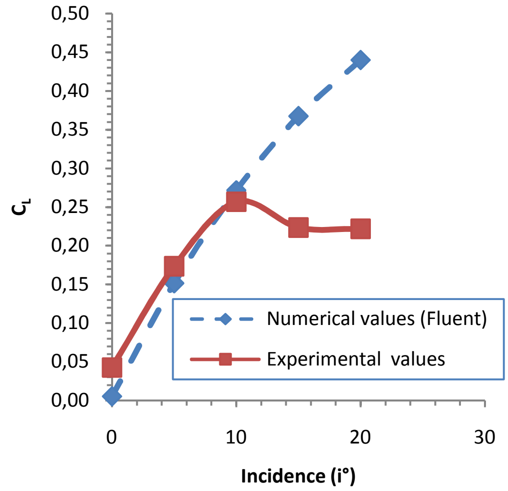


(a) Blade with NACA0015 profile

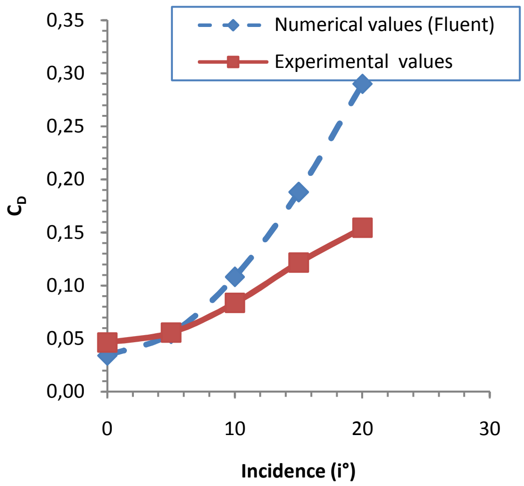


(b) Rotor with NACA0015 blades

Fig. 8 Contours of - Cp obtained at $i$ = 5° and Vo = *20.3m/s*




(a) Lift coefficient $C_L$




(b) Drag coefficient $C_D$.

Fig. 9 Comparison of the numerical and experimental values of the aerodynamic coefficients, for the complete Darrieus rotor

### *D. Validation of obtained results*

According to the figure 8 we notice that the longitudinal evolution of the numerical depression according to the x/*l*o direction, is identical to that obtained in experiments, the figure 9 shows that we particularly have a good agreement between the numerical and the experimental results for the different evolutions of $C_L$ and $C_D$.

## VI. CONCLUSION

The aerodynamic behavior of the two studied models of rotor, placed at various angles of attack, enable us to understand that the model with NACA0012 profile allows obtaining better aerodynamic performances in particular concerning the power coefficient CP.

The rotors model are examined in the same range of angle of attack up to 360 degrees with a step of 10 degrees, for a flow velocity Vo = *20.3* m/s. The aerodynamic coefficients of lift $C_L$, drag $C_D$ and power CP evolve with the angle of attack for a full rotation of the rotor what enables us to validate and to envisage the movement of the pair of blades revealed by visualizations of various contours obtained with the numerical simulation carried out with Fluent CFD code and we note that the aerodynamic performances of the blade NACA0012 rotor are always better.

The experimental and numerical results obtained are in qualitative concordance but with a significant difference in term of sizes. The quantitative differences can be attributed to the simplifications made during the numerical resolution.

This work provides, by direct obviousness, the practical and the theoretical forecasts (numerical) concerning forms of blade profiles to be avoided which can be at the origin of the reduction in the output of the Darrieus wind mill.

Besides the development of green energy production that allows wind turbines, the next step for the industrials is to perform their output and then the cost of the energy.

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