WIND TURBINES: A STUDY OF THE NACA 63-415 AND NACA 6412 PROFILES AND THEIR APPLICATIONS

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Abstract. *Power generation has been a major point of concern for centuries. Recently, as fossil fuels are seen as exhaustible resource and cause of climate changes, researches for self-sufficient production of sustainable energy are increasing. Wind energy is a clean solution for this problem; however, a deepest study in the area needs to be done. In this context, this paper presents a qualitative analysis about blades' profile of wind turbines. Its importance is justified due its role in the main element used for energy removal, the rotor. The rotor blades are in direct contact with wind, spinning to transfer fluid energy to mechanical energy, which will be transformed into electricity. In this essay, two profiles were used for computer simulation, the NACA 63-415, a symmetric one, and NACA 6412, an asymmetric. Graphs about the changes in velocity, temperature, pressure and turbulence for both types of blades were plotted and simulated using the software ANSYS. After the analysis, it was found that for zero degrees angle of attack, asymmetric profile is the most indicated.*

Keywords*: Blades' profile, computer simulation, clean energy, wind turbines.*

1. INTRODUCTION

Energy is an essential resource for making the most daily activities, and leisure options. As the main source of power generation (fossil fuels) is a non-durable source and affects the environment, the search for new forms of energy has increased on the global stage. In this context, research on wind energy as a renewable alternative is growing. In this context, the research about wind power as renewable alternative is growing. Consequently, studies of turbines have been earning attention, not only because the wind removal is a clean solution for power generation, but also because there is a considerable amount of wind regions with installation potential for the power plant.

Some data shows that in the coming years the use of this wind potential will increase. Over the past decade, the production of wind energy capacity doubled every three years. Moreover, from 1980 to the present days, the cost of producing electricity from wind energy was reduced to one-sixth of the value, and there is a tendency to continue this reduction costs. It is worth mentioning that about 80% of wind capacity used worldwide is installed in five countries: Germany, USA, Denmark, India and Spain. However, the use of technology is spreading worldwide. The demand for energy is growing and the technology is still inefficient in terms of power generation, both in production capacity and in degree of sustainability.

This article will describe the use if one of the technologies used in the exploitation of wind potential: wind turbines. The next topics will provide an overview about wind turbine, including its constitution, principal characteristics, its types and some information about blade's profile. Furthermore, comments are made about the ANSYS, software that will be used for the simulations made during this work.

2. METHODS

This article is a descriptive analysis of blades sizing calculations obtained in a design performed previously by Pires and Oliveira (2010), seeking to discriminate some important coefficients for that purpose it was necessary prior knowledge in calculations for sizing of the blades, so was first performed a bibliographic research to raise formulas already determined for the calculation of the design of the blades.

Every step of the design were described and analyzed in general terms, in order to know the strengths and weaknesses of this type of design. Thus this study is limited to the design of Pires and Oliveira (2010) it cannot be used as the standard for design of turbine blades. After analyzing the design, was conducting a simulation of the chosen profile for sizing.

In this simulation, we use ANSYS software, which models and simulates the behavior of systems using the finite element method. Two profiles were chosen, a symmetric (naca-63415), and one asymmetric (naca-6412). The Cartesian coordinates of each profile were necessary to draw them in software. After drawing them, the simulation parameters were chosen first wind speed of 50 m/s. Angles of attack of 0 ° and 10 °, and then the temperature of 300 k. These parameters served as the entrance to the Transition SST Equation. The equation is the mathematical model used to find the values of the drag and lift coefficients for each case and make a comparison of the results obtained. The results were used to plot the speed change diagram, temperature, pressure and turbulence of the two profiles. With these data can obtain the best applications in industry for this type of profile.

3. WIND ENERGY AND TURBINES REVIEW

Amid the alternatives to provide energy, the wind power is a renewable source of energy that has shown great featured. Lately, the wind farms number have increased and turbines are becoming extensively used around the world.

3.1 The wind power

Wind energy is the kinetic energy resulting from the circulation of air masses. It is generated by converting the kinetic energy present in air translational kinetic energy of rotation which moves the shaft which in turn is transformed into electrical energy. This energy contained in the wind varies with the cube of its speed, therefore understand the characteristics of the wind is very important (Burton at al., 2001).

The most important feature is its variability. The wind is very variable, both geographically and in time. The variability describes the fact that there are different climatic regions in the world, boasts some wind in abundance while others do not. Therefore a study in the area where the wind farm will be located is necessary for understanding how these variations occur and whether it is really feasible the implementation of the plant in that particular field (Burton at al., 2001).

3.2 Turbine overview

Figure 1 shows a simplified diagram of a wind turbine generator system in accordance to S. Arinaga et al (2011), in which case the tower is the support element of the rotor and nacelle [10]. The rotor is the component that performs the transformation of the kinetic energy of the wind into mechanical energy of rotation. The turbine blades are fixed in the rotor and all these components are connected to a shaft which transmits the rotation of the blades to the generator. In order to accommodate the entire engine, which may include gearbox, brakes, clutch, bearings electronic control and hydraulic system, there is a magazine called nacelle and this compartment is installed on the top of the tower.
The component in charge to convert the mechanical energy of the shaft into electrical energy is the generator. Wind turbines are designed to provide rated output according to the prevailing wind speed, namely average nominal speed which occurs more frequently during a certain period of the day. In order to control the intensity of the wind there is a measuring system called anemometer. Ultimately the wind turbines consist of rotor blades that capture the wind and convert its power to the rotor center and a direction sensor in order to obtain the best direction to the turbine.

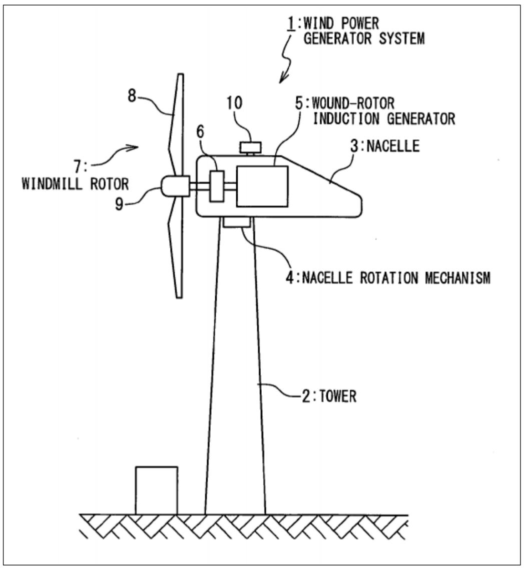

Figure 1. Configuration of a wind power generator system (Arinaga at al., 2011).

3.3 Blades design

In order to design the blades of a wind turbine it is necessary to know the location where it will be installed because the speed and the wind frequency are extremely important for this system. The directly affected component by these features is the rotor which is moved by a constant air flow. The paddles are found in the rotor, and other mechanical components, and they can have many different profiles.

The profiles of wind turbines are standards defined measures, studied and catalogued their relations in order to standardize and facilitate the design stage [12] (Fig. 2). One of the most popular patterns is the NACA, which gets its name from the institution of study in aerodynamic profile and catalogues [11] (National Advisory Committee for Aeronautics).

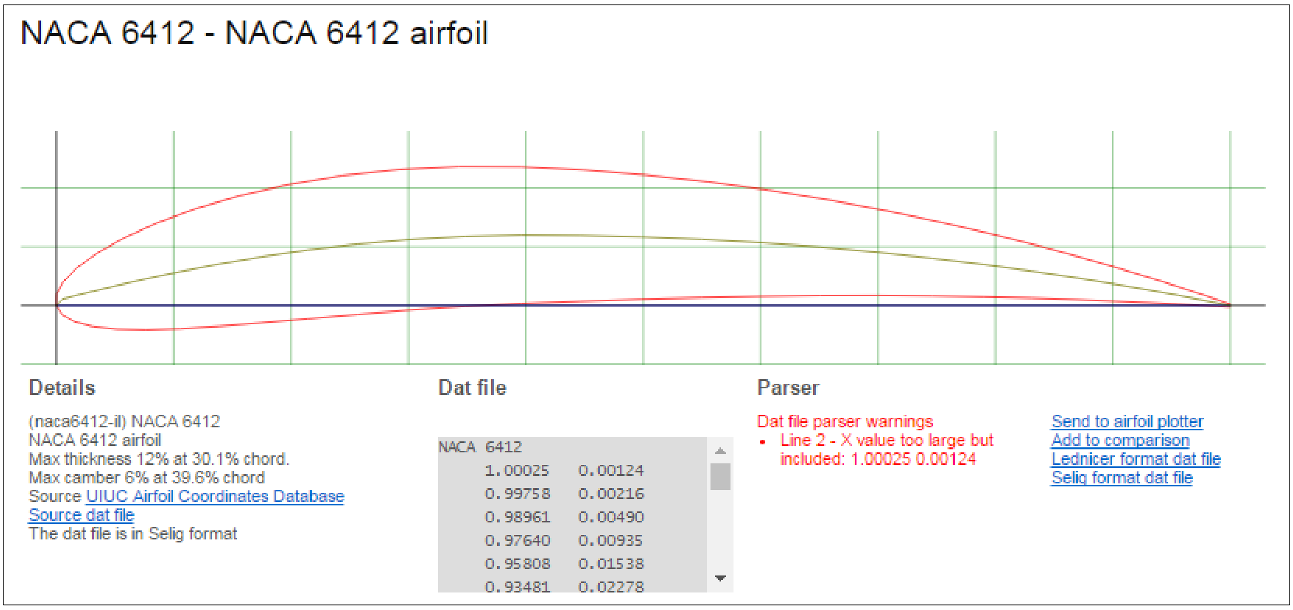

Figure 2. NACA 6412 profile of wind turbine (Airfoil tools, 2016).

The main factor in defining the profile of the wings is the availability of information about that profile that are necessary to the project and to indicate that it meets the demands of the project. The minimum data necessary for this choice are lift coefficient; drag and moment according to the angle of attack and the ratio between lift coefficient and the drag.

4. PROFILE DESIGN AND THE ANSYS

In this work the software ANSYS will be used for reproduce a specific profile and simulate. It is a package finite element modelling of general use, which solves a wide variety of mechanical problems. These problems can be static or dynamic, structural analysis (linear and nonlinear), or heat transfer fluids as well as electromagnetic and acoustic problems. The engineering simulation product provides a complete set of behavioral elements, materials and designs equation solver for a broad range of mechanical design problems (Yoshimoto at al., 2006).

As this article is about wind farms, and the wind being the most important feature, the most appropriate software is The ANSYS Computational fluid dynamics (CFD). CFD is software that makes simulations of the flow of a fluid. Dynamic simulation gives users a complete view of the fluid behavior and its effect on the mechanical component providing all the necessary tools to produce visual effects insightful solutions, including 3-D images, giving users everything they need to view and analyses their results (Yoshimoto at al., 2006).

5. DISCUSSION

One of the function of simulation confront the theory through the use of concepts and mathematical models [16].Through the use of simulation can save resources and time on testing to validate and study prototypes.

For this work two profiles, NACA 63-415 and NACA 6412, were plotted in ANSYS simulation program. After that they were subjected the same simulation conditions (50 m / s angle of attack of 0 ° and 300k temperature), graphs of symmetrical and asymmetrical profiles of speed is obtained, shown in figures Fig.. 3.A and Fig. 3.B, pressure, Fig. 4.A and Fig..4.B, and turbulence, Fig. 5.A and Fig. 5.B.

For the analysis of an airfoil can divide it into upper and lower part, these parts will be passing a stream of air, and the amount at the beginning of the profile must be the same in both the end parts. In NACA 63-415 shown in Fig. 3.A, there is a small difference between the flow velocity at the top and bottom due to the length of both sides in contact with the fluid, are very close. In NACA 6412 shown in Fig. 3.B, the speed between the top and bottom are distinct due to the length of these portions possess a significant difference, generating this disparity.

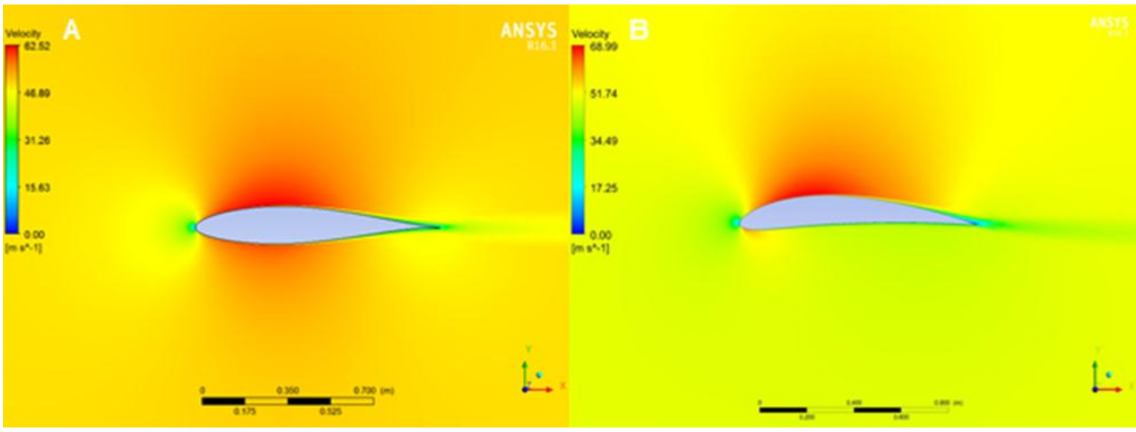

Figure 3. (A) NACA 63-415 and (B) NACA 6412 with the velocity gradient.

Knowing the velocity gradient across the profiles surface is possible to analyze the variation of pressure. Using Bernoulli's equation, we can perform simplifications in order to facilitate understanding of the relationship between pressure and temperature.

$$\frac{v_1^2}{2} + gh_1 + \frac{p_1}{\rho} = \frac{v_2^2}{2} + gh_2 + \frac{p_2}{\rho} \tag{1}$$

Where can be defined as the fluid velocity, g stands for gravity, h is the height in relation to a reference, p is the pressure over the container and the density of the fluid.

Simplifications were made considering constant gravitational force and a constant height, so it is possible observe the simplified equation as follows.

$$\frac{v_1^2}{2} + \frac{p_1}{\rho} = \frac{v_2^2}{2} + \frac{p_2}{\rho} \tag{2}$$

As can be inferred from the simplified formula for a constant V1 and P1, higher the speed 2 value will result in lower pressure two numbers. Therefore, the pressure difference in the symmetrical profile is smaller than the asymmetric one, as shown in the Fig, 4 A and Fig. 4 B.

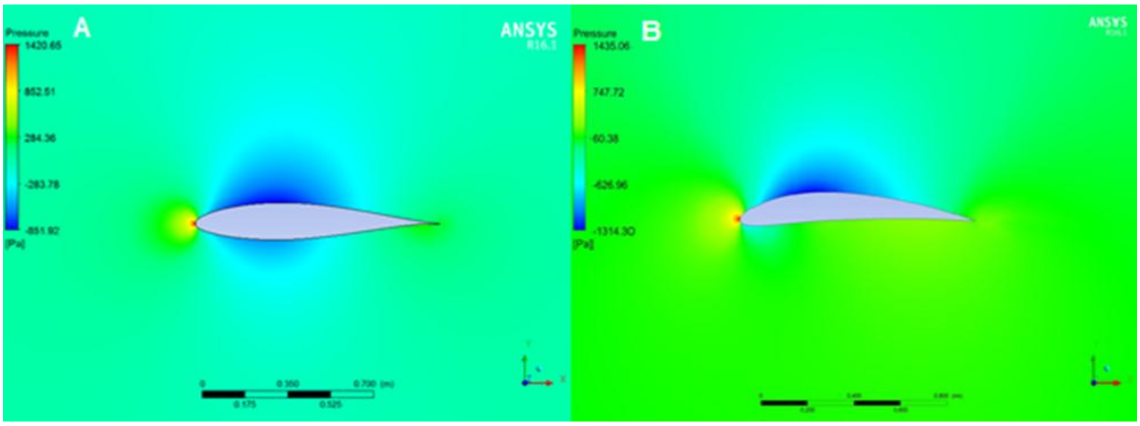

Figure 4. (A) NACA 63-415 and (B) NACA 6412 with the pressure gradient.

The air speed is also a needed to calculate the value of the Reynolds number, which establishes the flow patterns of the fluid. An analysis with software help is the distribution of fluid turbulence after passing the blade. It is noticed that in the first case, turbulence is aggravated due to the symmetrical profile having a higher surface speed than the lower asymmetric profile.

$$R_e = \frac{\text{inertial forces}}{\text{viscous forces}} = \frac{\rho v L}{\mu} \quad (3)$$

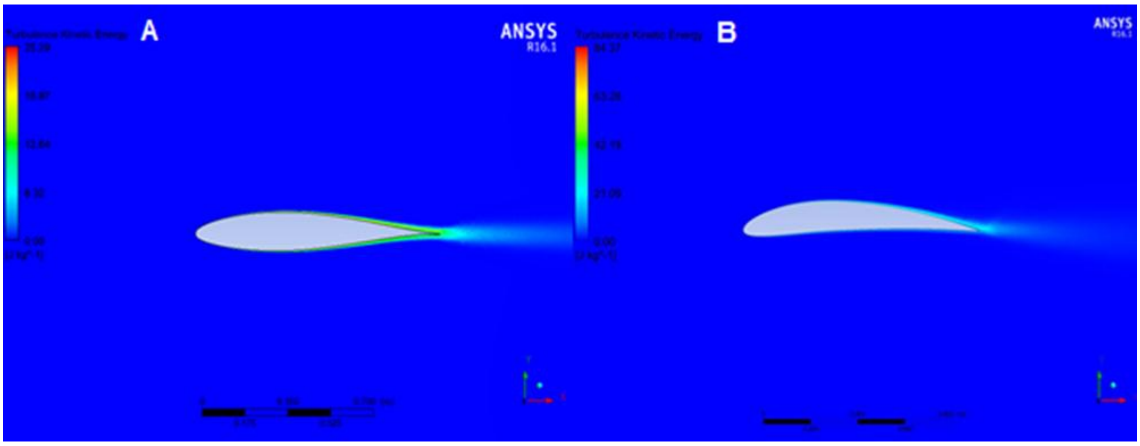

Figure 5. (A) NACA 63-415 and (B) NACA 6412 with the turbulence gradient.

From the comparison of the images shown in the beginning of the article, it is seen that the difference in speeds that run along the profile surface is the main tool of influence on the object under study and its purpose. With the apparent change in pressure, the NACA 6412 has the highest pressure variation between your top and bottom and it determines that the lift, which will operate in profile 6412, will be much higher than the symmetrical profile NACA 63-415. In other words, the lift force is a positive vertical vector to act in helping the wind turbine rotation considering a wind angle of attack of 0 degrees.

In relation to the turbulence in both studied cases, figures Fig. 5 A and B, it is notable higher the turbulence in the first one, what is alarming in two situations. Turbulence is a disturbance in the flow of air when it begins to act in an uncontrolled way, the increase of this factor may cause unnecessary fatigue in the material of the blades by forces acting chaotically. This problem can also cause increased noise and discomfort due to near populated area.

6. CONCLUSION

The airfoils facilitate decisions projects of wind turbines blades, providing a reliable database regarding the standards of each form. In this paper aerodynamic profile NACA 63-415 and NACA 6412, which are distinguished by their bottom, and symmetrical and asymmetrical second first were used. The air displacements in asymmetric profile have a smaller distance to be traversed than symmetrical one. Knowing the mass flow that traverses the profile is constant; the speed at the bottom of the profiles will be different, being the most NACA 63-415.

Provided the ratio of Bernoulli's equation, it is known that the pressure is inversely proportional to speed, so the speed is greater where the pressure is lower. As shown in figures 11.A and 11.B, there is a pressure difference between the top and bottom of both profiles. This gap is responsible for generating the lift force. In wind turbines this force is responsible for performing the movement of the rotor, acting directly in spades, so in this case and conditions on the use of the NACA 6412 profile is the most recommended.

It should be noted that the study between profiles is relevant to comparative and qualitative analysis between them, and to define the profile to be used on the shovel should take into account the shovel as a whole because its geometry is not constant and has a twist to amplify the lift used in the system.

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