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Stress Distribution Analysis of A New Horizontal Axis Wind Turbine Blade using Siemens NX 10.0

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***Abstract*— This paper introduces a modeling experimental analysis for a new Horizontal axis wind turbine using Siemens NX 10 software. The HAWT wind turbine's geometrical model was created based on a real parameter of the type of airfoil, the length of the chord, the angle of twist as well as the location of the centers of the airfoil in each radial segment. The analyzed wing profile of the object was designed using NREL's S823 and S822 airfoils. A numerical analysis was performed in order to determine the reliability of the structure evaluated under specific wind velocity *V*=20 m/s (wind sped). Also understanding in depth, the stress distribution in wind turbine blades could improve the design of wind turbine blade. The structure displacement in the wind turbine rotary blade maximum is 1.99E+006mm and the structure display stress element maximum is 1.12E+006MPa.**

Index: *Siemens NX 10, HAWT, NREL's S823 and S822 airfoils.*

I. INTRODUCTION

In terms of versatility, a blade for a wind turbine can be divided into two fields of concern, as seen in Fig.1. The first one the field applies to the aerodynamic aspects of the blade-Aerodynamic field, while the second one refers to the aerodynamic region resistance of the blade-structural region [1].

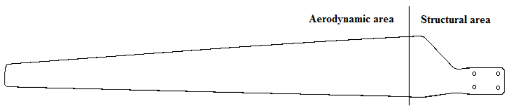
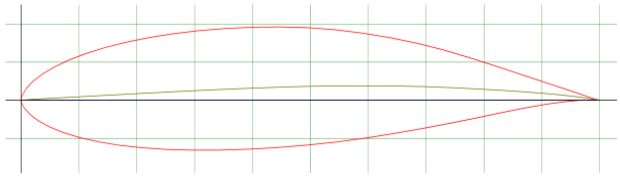


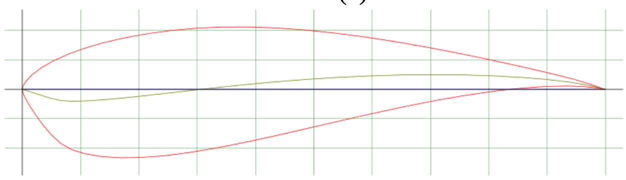
Figure 1. HAWT blade's areas.

When designing an aerodynamic area, the primary objective is to transfer wind kinetic energy into lift, which is used to produce torque. The structural area, on the other hand, is designed to withstand high bending torque values that reach a peak value at the hub, where the blade is attached to the central shaft.

The wind turbine blade configuration requires the selection of a set of airfoils with defined geometrical parameters, i.e., the type of airfoil, the length of the chord, the angle of twist as well as the location of the centers of the airfoil in each radial segment. [2] There are various basic airfoils which can be selected according to the specified specifications from open access databases. Aerodynamic airfoils generally have a chord length of the unit and are commonly accessible via their x and y cartesian coordinates. For instance, Figure 2 [3,4] airfoil S823 are displayed, which are commonly used in the development of wind turbines.



(a)



(b)

Figure 2: (a) NREL's S822 Airfoil. (b) NREL's S823 Airfoil

The airfoil type, chord length, twist angle as well as the position of 2D airfoils are scaled and twisted according to airfoil centers in each radial section during the first design phases of a wind turbine blade. However, there are many motives on a conical surface, the wind flow encountered by any segment of regular airfoils that can be picked from open access along a blade, which could be condensed to a cylinder [5]. The radial distance of the segment of the airfoil to the center of rotation allows the original 2D airfoil to be transformed into a 3D airfoil which could enhance aerodynamic efficiency

In order to support the work of designers, the rapid technological development of computers has introduced a number of tools to the engineering industry. In addition to computer-aided design (CAD) and development (CAM) systems, computer-aided engineering (CAE) is one of the methods for eliminating unnecessary costs arising from design errors. It allows sufficient strength checks to be carried out and the weakest areas of the system to be identified [6,7].

In literature review, Work has proposed simulation experiments using software based on the Finite Element Method (FEM) [8,9]. The efficiency and aerodynamic location of the vertical wind turbines axis (VAWT) is presented. The results of the wind speed, number of rotor blades and diameter of the rotor were investigated. The effect of blade material on the performance of wind turbines was compared in article [10]. The subject of wind turbine simulation research that has been

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addressed most often is computer fluid dynamics (CFD) in progress [11]. The effect of the turbine enclosure was studied in paper on the torque characteristics of a vertical axis wind turbine with a straight blade [12]. The Antonius-rotor vertical axis wind turbines were analyzed numerically using Fluent software [13,14]. Displays the FEM study under working conditions of composite wind turbine blades [15].

This paper studies the rotary blade of the wind turbine using Siemens NX 10. A geometric model was developed based on a real object included using NREL's S823 and S822 airfoils, selected material of wind turbine blade is fiberglass reinforced plastic GR. In order to establish the strength of the structure tested at the particular wind speed and stress distribution in HAWT.

II. Blade Shape Parameters And Material Properties

The geometry sections were modelled as shown in figure 3 then skin loft was applied to generate a shell based on the five cross-sections as shown in the figure. In order to realize the structure, the first step is the CAD model of the blade of the turbine in Figure 4, which is achieved by importing the curves that form the aerodynamic airfoils. At the Table 1. For each segment of interest, the main characteristics of the blade are provided as well as the type of airfoil used [1].

: PARAMETERS OF AIRFOIL'S BLADE

Section	Radius [m]	Chord [m]	Twist Angle [°]	Airfoil Type
S1	0.28	0.183	16	S823
S2	0.29	0.188	16	S823
S3	0.39	0.178	14	S823
S4	0.55	0.162	11	S822
S5	0.855	0.132	2	S822
S6	1.5	0.067	-2	S822

Apart from parameters of Airfoils blade, to find the coordinated of X and Y axis of Airfoil's S822 and S823 according to Airfoils Tools website. After that we use code section each parameter to realize model on Siemens NX 10.0 software.

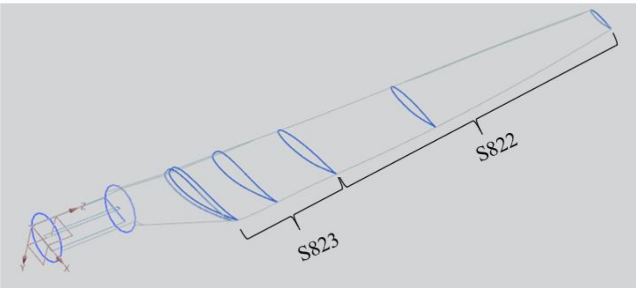

Figure 3: Sketch of the airfoil distribution along the blade

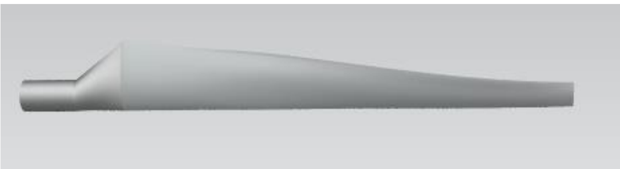

Figure 4: 3D CAD model of the blade

In this paper, material of wind turbine blade is fiberglass reinforced plastic GRP. Its physical and mechanical properties are given below [16].

- Density =1800 kg/m3
- Modulus of Elasticity = 20700 MPa
- Tensile Strength at break = 85 MPa
- Compressive Strength at yield or break = 200 MPa
- Poisson's Ratio = 0.3

The force F acting on the wind turbine blades can be determined using the formula for aerodynamic resistance [17,18]

$$F = \frac{1}{2}\rho A V^2 C_D \quad (1)$$

where: ρ is the density of air, A is a variable reference area, V is the wind velocity and C_D is a dimensionless drag coefficient.

III. SIMULATION TESTS

The paper presents only simulation tests of a wind turbine rotary blade, which after using the appropriate Siemens NX10.0 tools provide a full description of mechanical phenomena in the analyses horizontal wind turbine. Simulation tests included static and dynamic analysis of the tested structure.

In static analysis it was assumed that the model (Fig. 5) was affected by the force of gravity and centrifugal force caused by blade's rotation. The wind force was also taken into account in accordance with formula (1). It was assumed that the blade's coating (shell) was made of fiberglass. Cyclic symmetry fixture was set as the boundary condition, which allows simplification of the simulation model by analyzing only one rotary blade. The generated mesh of finite element simulation was a curvature-based mesh with 323 445 nodes and 175 719 elements in figure 6. For the purposes of simulation, the following measures were adopted: *V*=20 m/s (wind speed), T=15 980 kNm (torque), *n*=60 rpm (rotor speed).

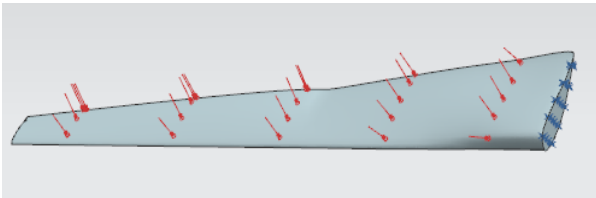

Figure 5: Boundary conditions (blue color) and loads (red color) during simulation

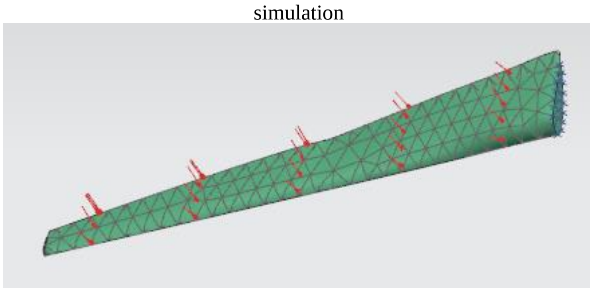

Figure 6: the element nodes display in the body

In figure 7, the total deformation displacement in millimeter along the blade length. The maximum total deformation is at the tip of the blade and is about 1.99E+006mm. This blade has airfoil cross section NREL's S823 airfoils. Figure 8 displayed the highest stress value equals 1.12E+006 MPa were noticed at the place of the blade and turbine hub connection. An increase in stress at the transition point of S6 to S5 were also observed.

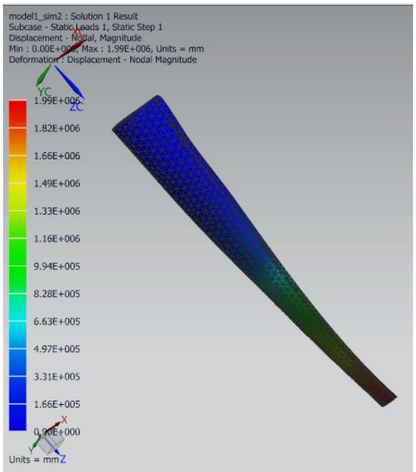

Figure 7: The structure displacement in the wind turbine rotary blade Maximum is 1.99E+006mm

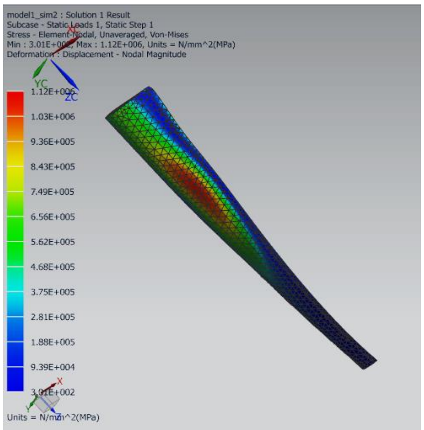

Figure 8: The structure display stress element Maximum is 1.12E+006MPa

This research can be expanding by performing CFD analysis and longitudinal scale model testing in the wind tunnel using the PIV system. Fatigue research is also predicted to assess the running time of the wind turbine being analyzed.

IV. CONLUSION

The study addresses a geometrical model and a horizontal axis wind turbine simulation test. The geometric model was arranged using the Siemen NX.10 software based on a real HAWT object. On the basis of obtained knowledge, NREL's S822 and S823 airfoils rotary blade profile has been determined. The material of wind turbine blade is fiberglass reinforced plastic GRP. For mechanical analysis, the Simulation module of the Siemen NX.10 software was used. The model was separated by the curvature-based mesh in tetrahedral parabola. The stresses have been defined based on the HAWT fixed point. The wind power effect has been determined by the aerodynamic drag force.

The relation of the spinning blade to the center of the turbine is an interpretation of the numerical simultaneous effects (Fig. 8). At the tip of the rotor blade the greatest displacement (Fig. 7) was observed. The reduction in the cross section along the blade length is responsible. The results obtained explicitly show that efficient stresses on the measured turbine do not surpass the permitted stresses. This ensures that the turbine analyzed will carry out work at wind rates 20m/s

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