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STRUCTURAL & VIBRATIONAL ANALYSIS OF 1 KW WIND TURBINE BLADE

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ABSTRACT

In this project, we will carry out structural & vibrational analysis of 1 kw wind turbine blade. In this we will make a 3D model of the blade by using CATIA software. We are using Ansys software for the structural analysis of blade in which we will be using Harmonic Analysis. We will use fast fourier transform analyser (FFT) for the vibrational analysis of the blade. The blade is made from composite glass fiber material. The size of airfoil blade is 1.525 m. The Chord length of the blade is 0.1656m. From this analysis we can extract the natural frequencies and the mode shapes results corresponding to it. More over geometry, physics setup, numerical solution and numerical results of the turbine blades made of composite glass fiber are calculated and evaluated.

Keywords: Ansys, Composite Glass Fiber, FFT, Harmonic Analysis, Mode shapes, Wind turbine

I.INTRODUCTION

Using wind turbine as electricity generator has some advantages and disadvantages. Some advantages of using wind turbines for electricity generation are electricity generation without any pollution, fast installation and commissioning, and also expense for maintenance. Although electricity generation by the wind turbine has some advantages, it has some disadvantages too, that its main disadvantage is the temporary nature of wind flow. Therefore, utilising efficient equipment is necessary in order to get as much energy from wind during the limited period of time that it flows strongly.

1.1 LITERATURE REVIEW

Development and application of wind turbines and the related issues such as structural design ,aerodynamic design, and material selection as well as manufacturing issues, including fatigue, optimization, and aeroelastic stability have attracted researchers' attention. Jureczko presented a model for the design and optimization of wind turbine blades and development an ANSYS program that implements a modified genetic algorithm enables optimization of various objective functions subjective to various constraints such as thicknesses and main dimensions of the model blade. Guo studied weight optimization and aeroelasticity of aircraft wing structure analytically and numerically and compared the results with experimental results. Veers considered the design,

manufacture, and evaluation of wind turbine blades. They also verified and improved blade design with detailed stress analysis. Baumgart presented a mathematical model for an elastic wind turbine blade and compared analytical and experimental results. Nonlinear rotor dynamic stimulation of wind turbine by
parametric excitation of both linear and nonlinear terms caused by centrifugal and Coriolis forces was investigated by Larsen and Nielsen

The fundamental aspects and the major issues related to the design of offshore wind turbines were outlined by Petrini. They considered the decomposition of these structural systems, the required performance, and the acting loads. Lee numerically investigated the load reduction of large wind turbine blades using active aerodynamic load control devices, namely trailing edge flaps. Tenguria studied the design and analysis of large horizontal axis wind turbine, and NACA airfoils were taken for the blade from root to tip.

Every structure under the influence of aerodynamic forces has specific performance that can change its properties and structure constants such as stiffness coefficient and natural frequencies. Therefore, the structure is faced with strong instabilities that cannot be prevented even by increasing the reliability of the design. This destruction has been created due to a specific force, and this value of force is created because of a specific relative velocity of flow that is called flutter phenomenon, and the fluid speed destruction is called flutter speed . Recognizing the flutter speed, we can ensure the safety of structure under aerodynamic forces. In structures such as a plane, flutter speed is considered as the limiting velocity. Limiting velocity is the velocity which must not be reached by an aircraft under any circumstances.

To ensure the safety of aerospace structures against aeroelastic instability, the Joint Aviation Requirements (JAR) standard is used. Based on JAR-23, preventing flutter in the vicinity of fluid velocity can be ensured, if natural frequencies of the bending and torsion are isolated. Shokrieh and Taheri conducted a numerical and experimental study of aeroelastic stability of composite blades of aircrafts based on this standard. Baxevanou described a new aeroelastic numerical model, which combines a Navier-Stokes CFD solver with an elastic model and two coupling schemes for the study of the aeroelastic behavior of wind turbine blades undergoing classical flutter. Fazelzadeh studied the coupling of bending torsional flutter of a wing containing an arbitrarily placed mass under a driving force. Results are indicative of the important influence of the location and magnitude of the mass and the driving force on the flutter speed and the frequency of the aircraft wing. Lee investigated the performance and aeroelastic characteristics of wind turbine blades based on flexible multibody dynamics, a new aerodynamic model, and the fluid-structure interaction approach. They proposed a new aerodynamic model based on modified strip theory (MST).

Some researches have been done on the fatigue phenomenon of the blades. In the most of them, in the first step, load spectra obtained by digital sampling of strain gauges which read the strain at a specific location near the root of blade has been used. In the second one, the weight of each load spectrum is obtained by its rate of occurrence. Finally, total load spectrum, which is obtained by the summation of all weighted load spectra, is used to estimate fatigue damage in the blade using Miner's rule. This rule has some defects that linear nature is its main weakness. Investigations have shown that Miner's rule is not proper for fatigue consideration in both metals and composites. Also, another shortcoming of this rule lies in simulation of the load sequence and history of load events which is seen in the difference of predicted lifetimes of blades with two orders of magnitudes for two load cases with different load sequences. Admittedly many researches have considered the fatigue simulation of the composite blades, but the most of them have focused on the deterministic approach. Furthermore, there are other problems for fatigue in the blades by these methods such as recognizing a place to install the strain gauges in order to extract the load spectrum and also using a massive and high-cost material fatigue database.

The main reason to create fatigue in the wind turbine blades is cyclic loads. Variation of wind speed, annual gust, rotation of rotor, and variation of weight vector direction toward the local position of the blade are the production sources of the cyclic loads. These sources have different effects on the cyclic load. The two first sources change the total amount of the load. Also, rotation of rotor produces fluctuating load with a frequency identical to the rotor rotation frequency. Last one is the effect of wind shear which arises from change of wind speed by changing in height.

Considering the effect of wind shear in the design process is not necessary, because its influence on the fatigue damage is negligible. Moreover, gust phenomenon is studied annually based on the Germnaschier Lloyds standard. During gust occurrence, vibration is created Composite Blades of Wind Turbine: Design, Stress Analysis, Aeroelasticity, and Fatigue in the blade due to the gust impact effect, which arises the linear combination of its mode shapes. Eggleston and Stoddard investigated engineering design of wind turbine. The results of their study showed that the first mode shape had the most significant role in displacements. Furthermore, the effect of wind direction on the turbine blades is not considerable, because the turbine always stays upwind and with changing the wind direction, the active yaw control system will adapt the turbine with new direction of wind vector as quickly as possible. Therefore, after defining cyclic loading sources, all corresponding applied stresses are derived from full range static analyses covering all events.

Designing, stress analysis, aeroelasticity, and fatigue of a composite blade wind turbine are investigated in this chapter. First, the geometry of blades is designed using the finite element method (FEM) for considered materials and layups. Then, using the static and dynamic analyses of the blades, the critical zone and flutter phenomenon are considered. Also, the damage is estimated utilizing accumulated fatigue damage modeling.

II. PROBLEM DESCRIPTION

This project considers the deformation due to aerodynamic loading of a wind turbine blade by performing Modal & Harmonic analysis.

A wing with a NACA 23012 airfoil section is supported such that one end is fixed and the other end is free. The wing has a chord of 0.1656 meter, a span of 1.525 meters, and an angle of attack is 65.59 degree. The wing is glass fiber having density 2540 kg/m^3, Youngs modulus is 85000 Pa & Poissons ratio is 0.23. Find the first 6 modes of vibration of the airfoil using ANSYS Workbench & the mode shape results.

III.DESIGN OF THE BLADE

In order to find the airfoil shape we must use the website Airfoiltools and specify certain parameters likes chord , radius, thickness, origin, pitch, X-grid, Y-grid. We create CSV files for co-ordinate then after updating Macro settings in Excel one can generate Airfoil shape in CATIA.

IV.MODAL AND HARMONIC RESPONSE ANALYSIS

4.1 Pre-Analysis & Start-Up-

Open ANSYS Workbench by going to Start > ANSYS > Workbench. This will open the start up screen seen as seen below. To begin, we need to tell ANSYS what kind of simulation we are doing. If you look to the left of the start up window, you will see the Toolbox Window. Take a look through the different selections. We are doing a modal analysis simulation. Load the Modal(ANSYS) box by dragging and dropping it into the Project Schematic.

Engineering Properties-

Engineering Proper Now we need to specify what type of material we are working with. Double click Engineering Data and it will take you to the Engineering Data Menus. If you look under the Outline of Schematic : Engineering Data Window, you will see that the default material is Structural Steel. The Problem Specification states we will be using glass fiber. To add a new material, click in an empty box labeled Click here to add a new material and give it a name. Our Material is glass fiber. On the left hand side of the screen in the Toolbox window, expand Linear Elastic and double click Isotropic Elasticity to specify and In the Properties of: glass fiber window, Set the Youngs modulus unit to pascal and set the Poisson Ratio to 0.23.

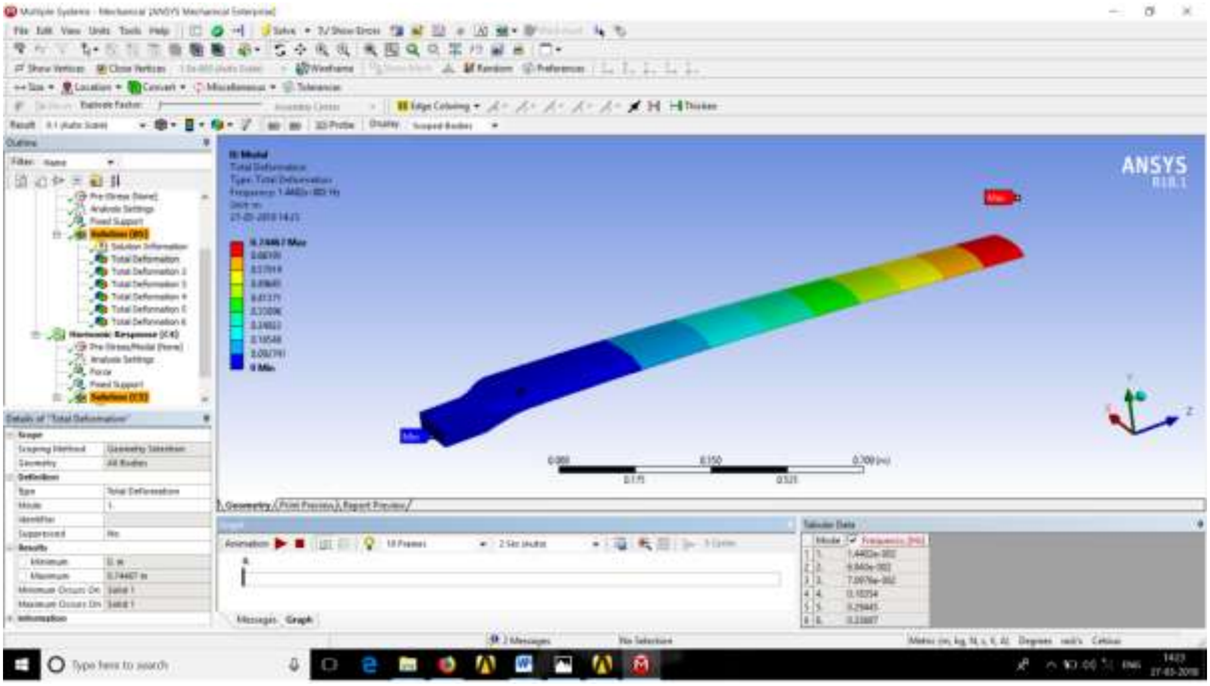
We will need to define the density as well. Expand Physical Properties and double click density. In the Properties of: glass fiber window, a density bar will have appeared. Define it as being 2540 kg/m^3.

4.2 Geometry-

For this problem, we are going to import the mesh into ANSYS through Finite Element Modeller.

4.3 Fixed Support-

Next, we will apply the boundary conditions to the geometry. In the graphics window, click the positive Z Axis on the compass to look at one side of the airfoil. In the Outline window, select Modal to bring up the Setup Menu. In the Setup Menu, select Supports > Fixed Supports. Make sure the face Selection Filter is selected, select the base of the airfoil you are looking at. In the details window, select Geometry > Apply.



4.4 Numerical Solution-

ANSYS will by default solve for the frequencies of the first 6 vibration modes; however, we would also like to see how this affects the geometry. We can accomplish this task by looking at the total deformations of the airfoil to see where the nodes occur and how the geometry deforms. To tell ANSYS to solve for the deformation, first select Solution in the Outline window to bring up the Solution Menu bar. In the Solution Menu, select Deformation > Total. In the Details Window, notice that the deformation is solving for Mode 1. Rename Total Deformation to Mode Shape 1. Create another instance total deformation and rename it Mode Shape 2. Select it, and change Mode > 2. Now, you will be solving for the deformation of the 2nd Mode. Repeat this step until you are solving for the total deformation of all 6 modes.

4.5 Harmonic Response analysis-

In this step we will copy the fixed support from the modal because the values do not differ and we shall add a force by selecting the edge selection filter and selecting the negative Y axis on the tip of the blade geometry and defining the magnitude of the force in newton. The solution is obtained by selecting the frequency response curve and generating it.

4.6 Trial Analysis

In this we have taken the fixed support at the base of the root of the blade and a force of magnitude of 1000N in the negative Y-direction at the tip of the blade while the material being Glass Fiber.

Result Summary

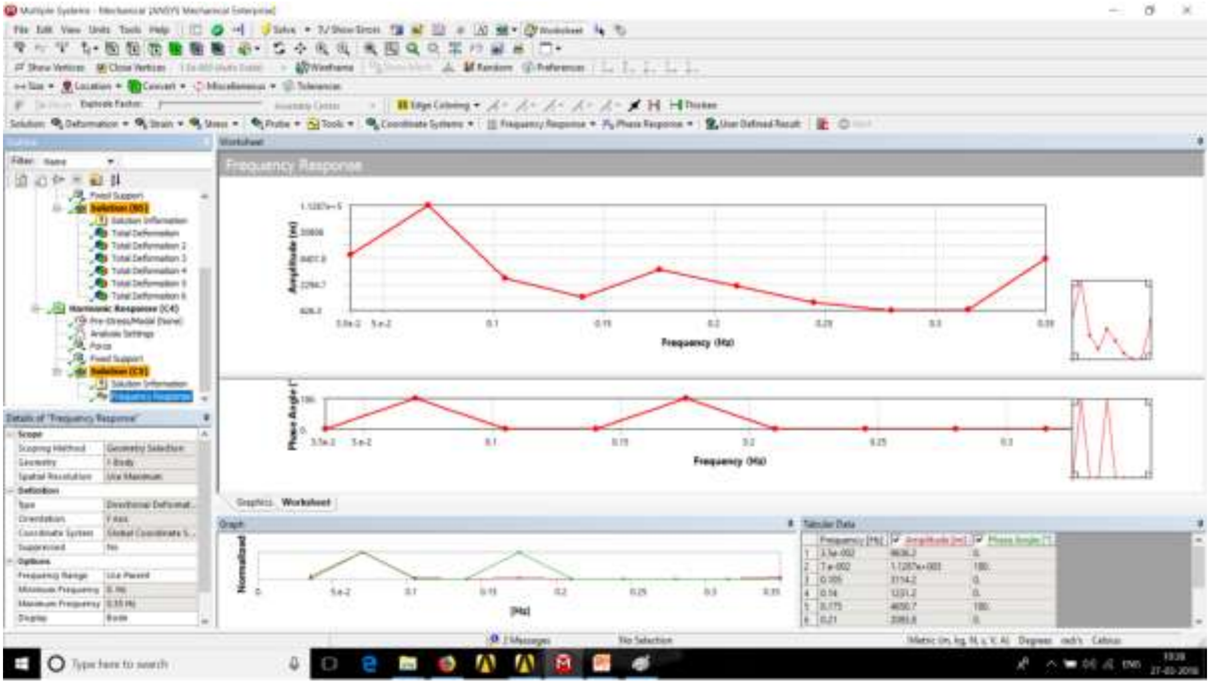
Properties	Value
Volume	4.5998e-003 m^3
Mass	11.683 kg
Nodes	55761
Elements	264499
Relevance Center	Coarse
Element Size	Default
Smoothing	Medium

Natural Frequency

Mode	Frequency [Hz]
1	1.4402e-002
2	6.943e-002
3	7.0976e-002
4	0.18354
5	0.29445
6	0.33697

Material Properties

Properties	Value
Density	2540 kg m^-3
Young's Modulus Pa Poisson's Ratio	85000 0.23
Material Used	Glass Fiber
Bulk Modulus Pa	5.2469e+010



V.VIBRATIONAL ANALYSIS

The Fast Fourier Transform spectrum analyser uses digital signal processing techniques to provide in depth waveform analysis by converting continuous time domain into frequency domain with greater flexibility than other methods.

5.1 How the FFT works

The FFT is a complicated algorithm, and its details are usually left to those that specialize in such things. This section describes the general operation of the FFT, but skirts a key issue: the use of *complex numbers*. If you have a background in complex mathematics, you can read between the lines to understand the true nature of the algorithm. Don't worry if the details elude you; few scientists and engineers that use the FFT could write the program from scratch.

In complex notation, the time and frequency domains each contain *one signal* made up of *N complex points*. Each of these complex points is composed of two numbers, the real part and the imaginary part. For example, when we talk about complex sample *X*[42], it refers to the combination of *ReX*[42] and *ImX*[42]. In other words, each complex variable holds two numbers. When two complex variables are multiplied, the four individual components must be combined to form the two components of the product. The following discussion on *"How the FFT works"* uses this jargon of complex notation. That is, the singular terms: *signal, point, sample*, and *value*, refer to the *combination* of the real part and the imaginary part.

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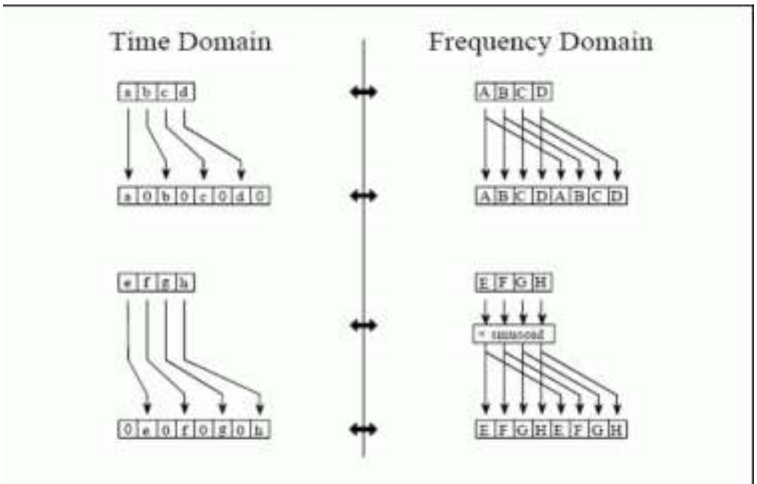
The FFT operates by decomposing an *N* point time domain signal into *N* time domain signals each composed of a single point. The second step is to calculate the *N* frequency spectra corresponding to these *N* time domain signals. Lastly, the *N* spectra are synthesized into a single frequency spectrum.



The FFT synthesis. When a time domain signal is diluted with zeros, the frequency domain is duplicated. If the time domain signal is also shifted by one sample during the dilution, the spectrum will additionally be multiplied by a sinusoid.

5.2 Advantages-

I.Fast capture of waveform.

II.Waveform can be stored.

III.Able to analyse single form.

IV.Able to capture non-repetative event.

VI. CONCLUSION

In this project, we have calculated the various dimensions of wind turbine blade by using website airfoiltools.

In this project, we have made 3D model of wind turbine blade in CATIA and we have done the modal and harmonic response analysis on ansys.

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