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MODAL ANALYSIS OF WIND TURBINE BLADE USING FE MODELLING

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ABSTRACT
As the requirements for improved stiffness, reliability, fatigue life and efficiency increase, there are challenges of developing innovative design solutions. This theory mainly focuses on the design of wind turbine blade where the analytical and FEM modal analysis approach was implemented to analyze baseline design. Here dynamic analysis was performed to obtain the different modes of natural frequencies of wind turbine blade. Three Dimensional model was created using CATIA and was imported to FE software ANSYS for discretization and analyzed to obtain expected solution. The results were obtained through modal analysis for different modes of vibration in terms of natural frequencies and deformations was observed to be under safer condition for CFRP and Aluminium alloy model. Finally by considering the weight and natural frequencies of the blade CFRP material is more appropriate.

KEYWORDS: Wind Turbine Blade, Modal Analysis, Vibration Mode Shapes, FEM.

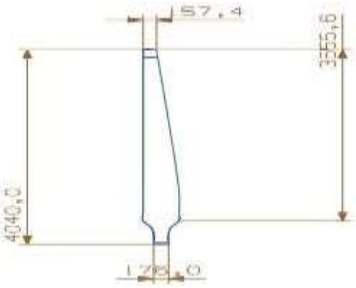
INTRODUCTION
CFRPs are expense to produce but are generally utilized wherever high strength to-weight proportion and rigidness are required, such as automotive, civil engineering, sports products, aerospace and an maximizing number of other customers and technological applications. In this instance the composite classifies two sections: a matrix and reinforcement. In CFRP the reinforcement is carbon fiber, which gives the strength. The matrix is generally a polymer resin, for example, epoxy to bond the reinforcement together. Since CFRP contains of two distinct components, the material properties depend upon these two components.

Composites have been the material chosen for wind turbine blade development for few decades, partially because of their better fatigue performance when comparing with different materials. In many design processes, structural segments are embedded utilizing adhesive bond lines. Entirely these materials are influenced in some way by fatigue loads.

The modal analysis is a rough technique to concentrate the dynamic features of the structure, the modal is the natural vibration characteristic of the structure, every modal has a particular, damping ratio, natural frequency and mode shapes. This theory will take horizontal axis wind turbine as example, and utilize parametric language APDL of ANSYS for directly modelling then set the fundamental parameters of the material, meshing and discussing about modal analysis, in conclusion lead a detailed examination of the results. Modal analysis has been utilized to distinguish damping characteristics, natural frequencies and mode shapes of wind turbine blade.

GEOMETRY MODELLING OF WIND TURBINE BLADE
The present work was carried out on the analysis of the wind turbine blade and structural optimization of the turbine blade. This work mainly focus on Finite Element Analysis and weight reduction of wind turbine blade. The work involves the geometrical modelling of the wind turbine blade and later blade was meshed using ANSYS and was analyzed for different load conditions. The same model was later on reinforced into the matrix which forms the turbine blade composite. The results from the FE analysis are comparing with two different materials i.e., CFRP and Aluminium. The parameters like stress, deformation, strain are obtained for different load conditions.

Figure: 1(a) & (b)



(a) Geometry of wind turbine blade

(b) 3D model of wind turbine blade.

FEM ANALYSIS

The required model created in catia was imported to Ansys 14.5 analysis software and the required material properties, boundary conditions are fixed and Hexa dominant element was used for the element type. After the pre-processor work solution is obtained by the application of desired pressure of 2.5e2MPa for both the materials of CFRP and Aluminium Alloy. The post processing work of obtained results are analysed and compared for natural frequencies of CFRP and Aluminium Alloy materials.

RESULT AND DISCUSSION

Modal Analysis

Modal analysis was used to identify the natural frequencies under different mode shapes of wind turbine blade. A modal analysis was carried out after fixing the one end of the wind turbine blade. Based on the boundary condition the analysis was done and optimization was carried out. Here in order to analyze we consider two different materials results. The model which is optimized should perform its function and meet all the requirements like modal frequencies and keep the total weight to minimum.

Figure: 2(a) & (b)

Tabular Data

	Mode	Frequency [Hz]
1	1.	5.6414
2	2.	13.219
3	3.	18.775
4	4.	38.334
5	5.	59.082
6	6.	72.533

(a) Frequencies at different modes for CFRP

Tabular Data

	Mode	Frequency [Hz]
1	1.	8.0106
2	2.	18.771
3	3.	26.644
4	4.	54.397
5	5.	83.926
6	6.	102.93

(b) Frequencies at different modes of Aluminium Alloy.

MODE 1:

Figure: 3(a) & 3(b)

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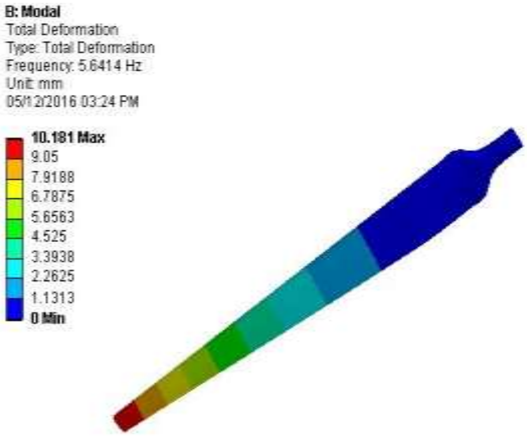
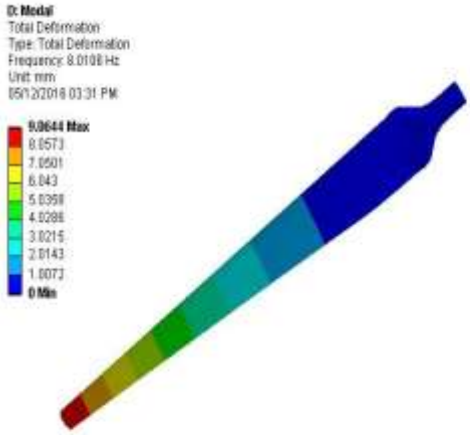


(a) Total deformation of 1st mode of CFRP

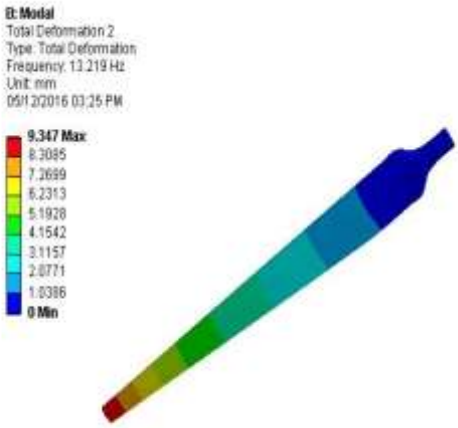


(b) Total deformation of 1st mode of Aluminium Alloy.

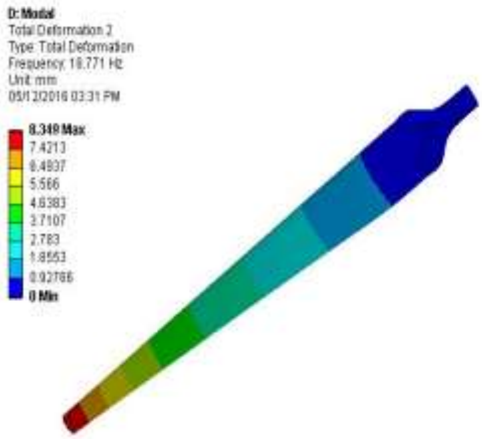
From figure 3(a) and 3(b) the frequency obtained from the deformation of first mode was observed to be 5.6414.hz and 8.0106 Hz and maximum deformation was 10.181mm and 9.0644mm in case of CFRP and Aluminium Alloy respectively.

MODE: 2

Figure: 4(a) & 4(b)



(a) Total deformation of 2nd mode of CFRP



(b) Total deformation of 2nd mode of Aluminium Alloy.

From figure 4**(a)** and 4(**b)** the frequency obtained from the deformation of first mode was observed to be 13.219.Hz and 18.771 Hz and maximum deformation was 9.347mm and 8.349 mm in case of CFRP and Aluminium Alloy respectively.

MODE: 3

Figure: 5(a) & 5(b)

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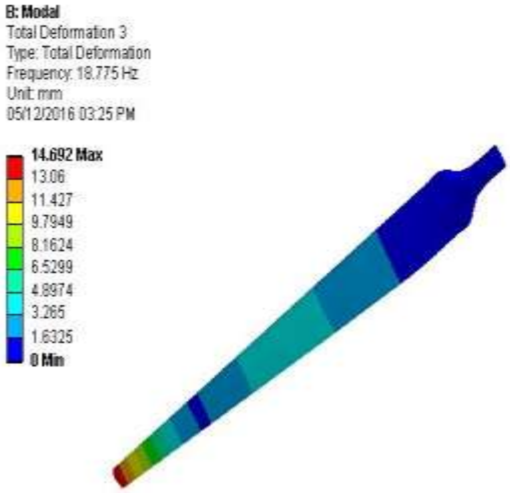
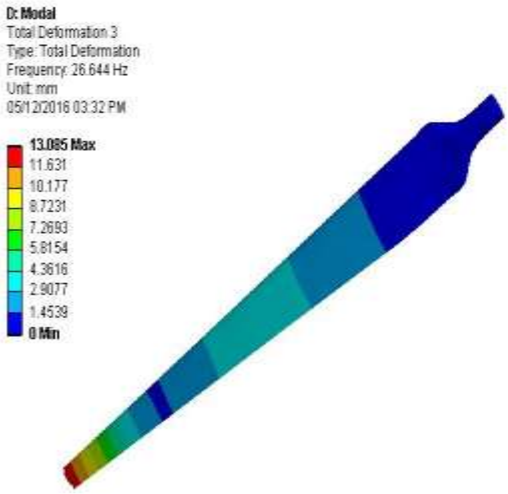
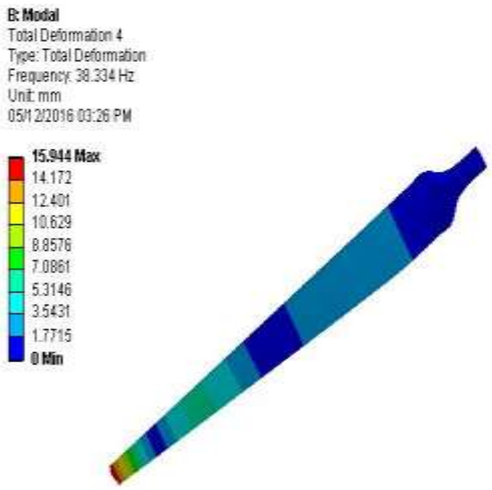


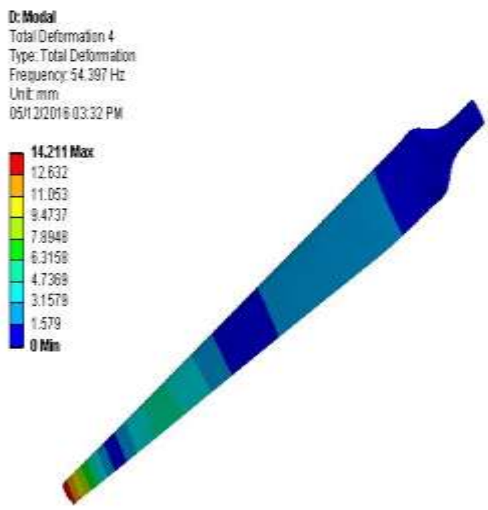


(a) Total deformation of 3rd mode of CFRP *(b) Total deformation of 3rd mode of Aluminium Alloy.*

From figure 5(a) and 5(b) the frequency obtained from the deformation of first mode was observed to be 18.775.Hz and 26.644 Hz and maximum deformation was 14.692mm and 13.085 mm in case of CFRP and Aluminium Alloy respectively.

MODE: 4
Figure: 6(a) & (b)





(a) Total deformation of 4th mode of CFRP *(b) Total deformation of 4th mode of Aluminium Alloy.*

From figure 6(a) and 6(b) the frequency obtained from the deformation of first mode was observed to be 38.334.Hz and 54.397 Hz and maximum deformation was 15.944mm and 14.211 mm in case of CFRP and Aluminium Alloy respectively.

MODE: 5
Figure: 7(a) & 7(b)

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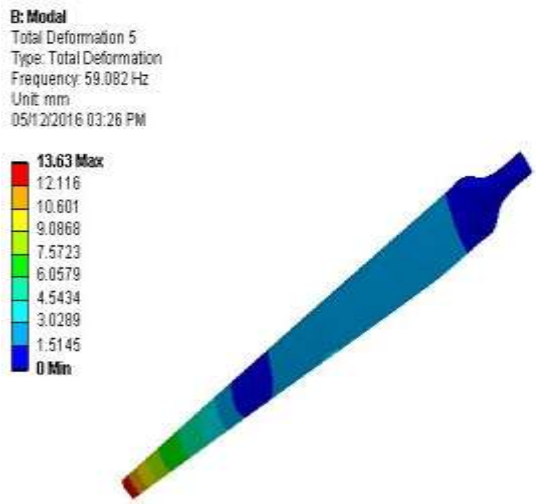
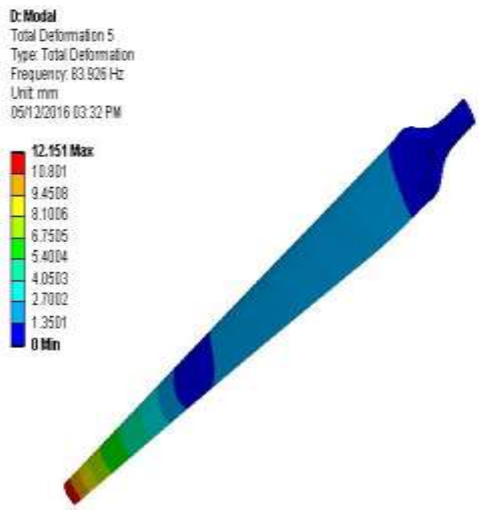
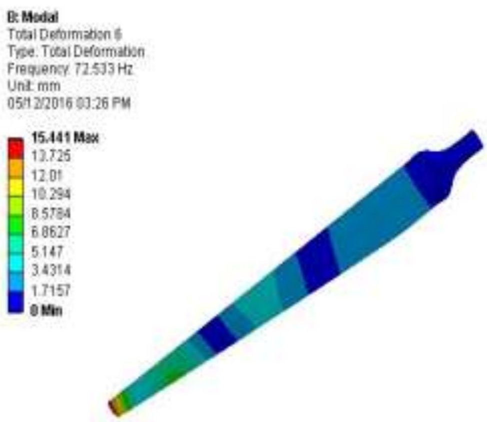


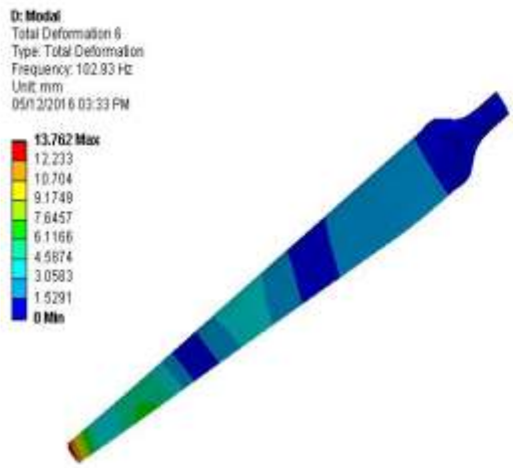


(a) Total deformation of 5th mode of CFRP ***(b) Total deformation of 5th mode of Aluminium Alloy.***

From figure 7(a) and 7(b) the frequency obtained from the deformation of first mode was observed to be 59.082.Hz and 83.926 Hz and maximum deformation was 13.63mm and 12.151 mm in case of CFRP and Aluminium Alloy respectively.

MODE: 6
Figure: 8(a) & (b)





(a) Total deformation of 6th mode of CFRP ***(b) Total deformation of 6th mode of Aluminium Alloy.***

The modal analysis of the wind turbine blade in Ansys resulted in giving the values of the first 6 natural frequencies of the wind turbine blade. These values were compared between the CFRP and AL materials. The mode shapes of the beam are shown in Figures 8(a) to 8(b) in order of their harmonics. A comparison Table of natural frequency values was shown in the table.

Table 1: Comparision of modal frequencies results b/w CFRP and Aluminium Alloy.

	Natural Frequencies in Hz	
Mode	**CFRP**	**Aluminium Alloy**

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1	5.6414	8.0106
2	13.219	18.771
3	18.775	26.644
4	38.334	54.397
5	59.082	83.926
6	72.533	102.23

Table 2: Linear static analysis stress obtained for the pressure of 2.5e2Mpa for CFRP and Aluminium Alloy.

	CFRP	Aluminium Alloy
Equivalent stress(von-mises)	131.51mpa	131.56mpa
Max principal stress	131.83 mpa	136.04 mpa
Min principal stress	32.233 mpa	37.718 mpa
Total deformation	614.6 mm	242.31 mm
Mass	143.48kg	180.66kg
Reduction in Weight	37.18Kg (20.58%)	

Table 3: FE ANALYSIS RESULTS FOR CFRP AND ALUMINIUM ALLOY.

Details of "Solid"

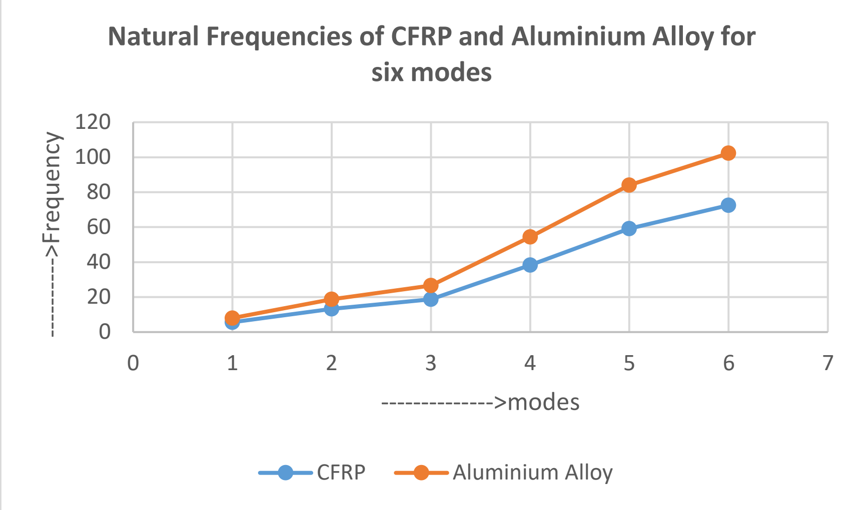
Assignment	CFRP 2
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Properties	
Volume	6.522e+007 mm³
Mass	143.48 kg
Centroid X	157.04 mm
Centroid Y	-43.436 mm
Centroid Z	1354.5 mm
Moment of Inertia Ip1	1.3399e+008 kg·mm²
Moment of Inertia Ip2	1.3486e+008 kg·mm²
Moment of Inertia Ip3	1.0881e+006 kg·mm²

Details of "Solid"

Assignment	Aluminum Alloy
Nonlinear Effects	Yes
Thermal Strain Effects	Yes
Bounding Box	
Properties	
Volume	6.522e+007 mm³
Mass	180.66 kg
Centroid X	157.04 mm
Centroid Y	-43.436 mm
Centroid Z	1354.5 mm
Moment of Inertia Ip1	1.6871e+008 kg·mm²
Moment of Inertia Ip2	1.698e+008 kg·mm²
Moment of Inertia Ip3	1.37e+006 kg·mm²
Statistics	

FE analysis is conducted on the composite material CFRP and Aluminium Alloy that are used in a wind turbine blade for the pressure of 2.5e2 Mpa for both the materials and the equal stress values of 131.51MPa obtained which is much lesser than yield stress but mass used for CFRP is **143.48Kg** and for the Aluminium Alloy is **180.66Kg.**

Figure: 9



Natural frequencies of CFRP and Aluminium Alloy for six modes

CONCLUSION

In the present work the Modal analysis for different natural frequencies and modes shapes are carried out successfully. Earlier static analysis for both the materials was carried out for the stress value of 131.51Mpa and the pressure value of 2.5e2Mpa and the masses of materials required for CFRP is 143.48Kg and Aluminium Alloy is 180.66Kg where in 20.58% of weight was less for CFRP compared to Aluminium Alloy. The Natural frequencies of the CFRP for the six modes considered is lesser than the Aluminium Alloy but the difference in natural frequencies obtained for the both the materials is comparatively less. Finally by considering the weight and natural frequencies of the blade selecting CFRP material is more Advantageous.

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