Analysis of Wind Turbine Blade of Composite Material Subjected to Different Loads by Identifying its Natural Frequency

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Abstract: Blades are being developed in composite materials in order to achieve low-weight and high strength construction. Composite blades are made with unidirectional fibers parallel to the blade's long axis. This project examines the modal analysis techniques applied in experiments using a uniform and a stepped beam. These simplified shapes are representative of a wind turbine blade. Natural frequencies have been identified, therefore designers can ensure those natural frequencies will not be close to the frequency of the main excitation forces in order to avoid resonance.

The turbine blade is approximated by a cantilever. Therefore, it is fully constrained where attached to a turbine shaft/hub. The specimens i.e, uniform beam is modeled in CATIA and analysis is done in ANSYS. Analysis of static, modal, harmonic and transient are carried out. The results obtained from analysis of uniform beam by changing material with steel and carbon epoxy is compared.

Keywords: Wind Turbine Blade, Natural Frequency, Composite Materials, Failure Analysis

1. INTRODUCTION

Recently, wind energy has become one of the most important forms of alternate energy sources. In a wind power production system, turbine blades are used to convert wind energy to electric energy. In general, turbine blades are required to be light in weight with high strength to width stand extreme wind loads and have a little mass moment of inertia so that they can start to rotate at low wind speed. On the other hand, a wind power system has to survive severe environment for at least 20 years. During its lifetime, a wind blade may experience strong wind with speed as high as 60m/s and in such condition, the blade should have enough strength to sustain the extreme wind load. By considering these requirements, the reliability of wind turbine blade has become an important research work. Recently, many research papers have been devoted to the study of different aspects of wind turbine blades including design, structural and theorical analysis at different wind loads. A method established on the basis of ANSYS software on two shapes of blade and two different composite materials. Analysis is done on static, model, harmonic and transient.

2. WIND BLADE CHARACTERISTICS

The shape of the wind turbine blade is considered as uniform beam. The wind turbine blade is modeled in CATIA and then it is imported to ANSYS Software with

dimensions as specified below. We consider wind turbine blade with composite materials of mild steel and epoxy carbon. Different loads are applied for analysis.
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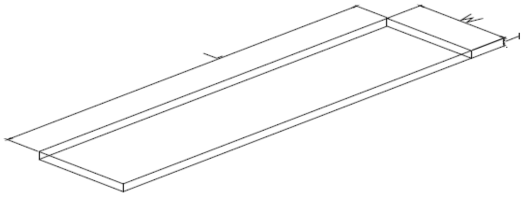
Model of Uniform Beam



Geometrical data for uniform beam

Geometric properties			Material properties (mild steel) [10]		
$L(mm)$	$W(mm)$	$T(mm)$	$E(mN/mm^2)$	$\rho\,(kg/mm^3)$	ν
795	40	4.45	206×10^6	7.85×10^{-6}	0.3
L: length *W*: width *T*: thickness			*E*: Young's modulus ρ : density ν : Poisson's ratio		

Considering carbon epoxy as material the properties are as follows
Carbon Fiber-Epoxy Resin Matrix
E_{xx}=138 GPa;
E_{yy}=8.96 Gpa
G_{xy}=G_{yz}=G_{zx}=7.1 Gpa;
υ=0.3

Load data applied on the beams

Static cases:

Wind load:

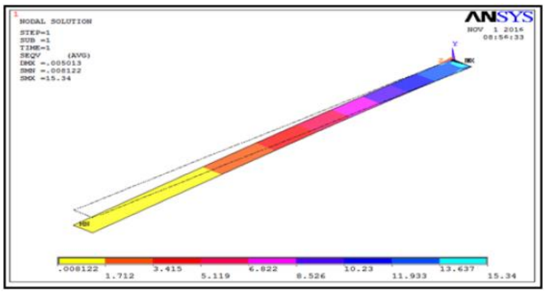
Wind Pressure=Pw= 0.6* V*V
Velocity of wind=16 m/s2
Wind pressure= 153.2 N/M2

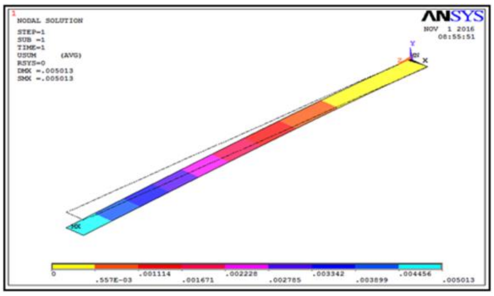
Dynamic cases:

Model- Calculate Natural frequency
Harmonic – freq rages from 0 to 10KHz
Transient- load impact for 1sec, Random increase

3. 1 Analysis of Uniform Beam with Steel as Material

1. Static Analysis of Uniform beam with steel as material



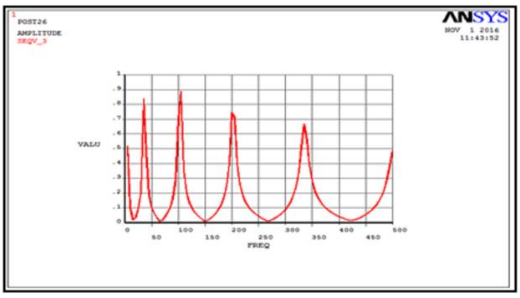


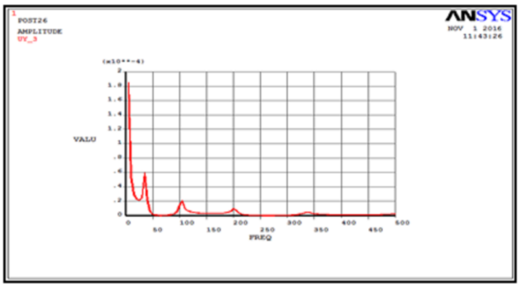
Vonmisses stress and Deformation for steel, uniform beam has maximum at free end

2. Model analysis of Uniform beam with steel as material

SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE
1	5.8532	1	1	1
2	36.701	1	2	2
3	52.364	1	3	3
4	102.92	1	4	4
5	202.18	1	5	5
6	225.25	1	6	6
7	325.39	1	7	7
8	335.04	1	8	8
9	502.96	1	9	9
10	676.71	1	10	10

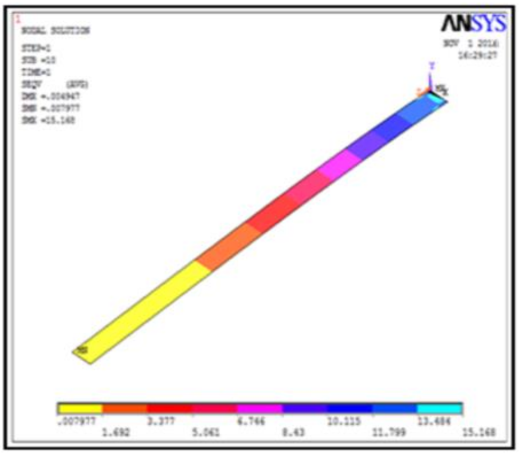
3. Harmonic Analysis of Uniform Beam with Steel as Material



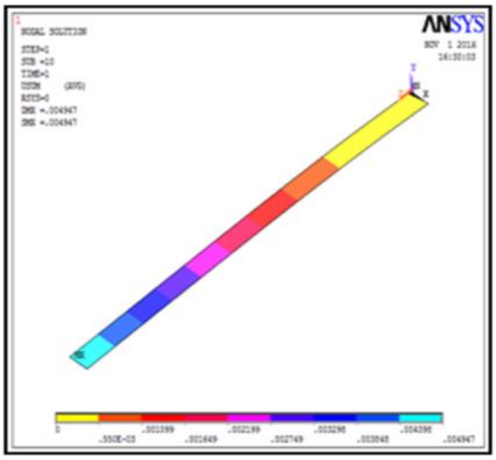


Stress is maximum at frequency 100 Displacement is maximum at frequency 0

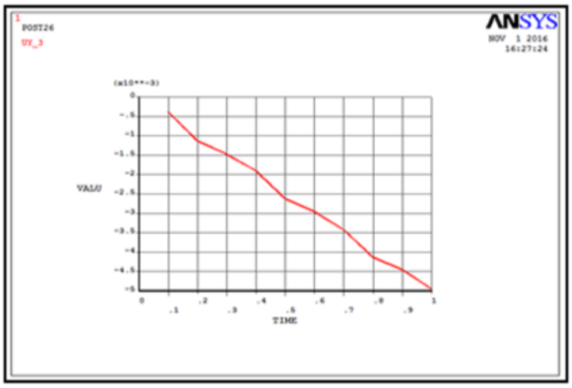
4. Transient Analysis of Uniform Beam with Steel as Material



Vonmisses stress



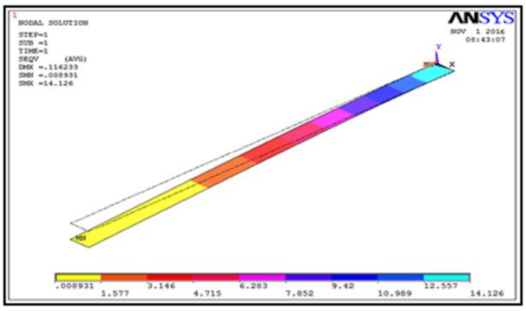
Deformation

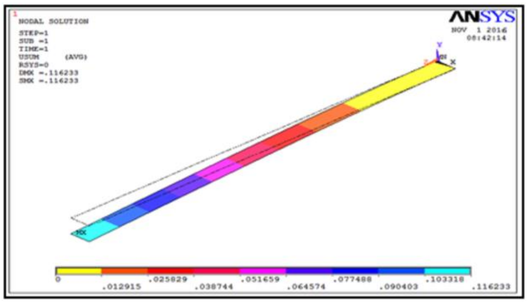


Time- Amplitude

3.2 Analysis of Uniform Beam with Carbon Epoxy as Material

1. Static Analysis of Uniform beam with Carbon Epoxy as material





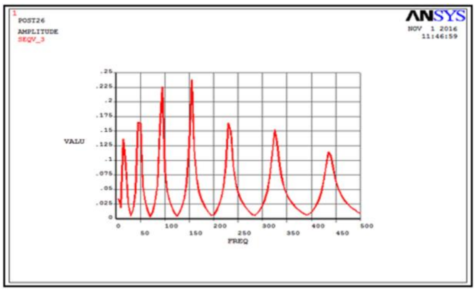
Vonmisses stress and Deformation for epoxy carbon has maximum at free end

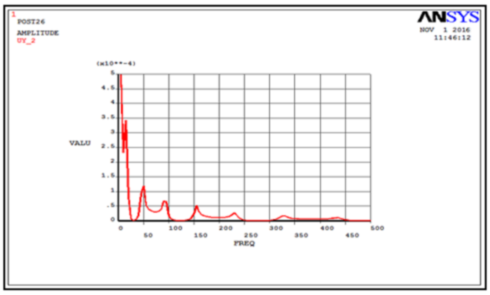
2. Model analysis of Uniform beam with carbon epoxy as material

SET	TIME/FREQ	LOAD STEP	SUBSTEP	CUMULATIVE

1	2.6924	1	1	1
2	16.892	1	2	2
3	24.172	1	3	3
4	47.385	1	4	4
5	93.108	1	5	5
6	150.2	1	6	6
7	150.82	1	7	7
8	154.46	1	8	8
9	231.75	1	9	9
10	325.37	1	10	10

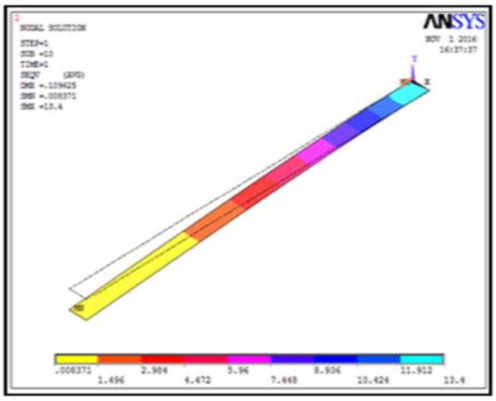
3. **Harmonic analysis of Uniform beam with Epoxy carbon as material**



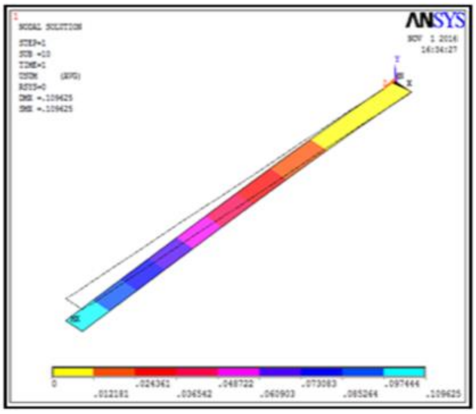


Vonmisses stress at fixed end has maximum at frequency at 150 and Deformation has maximum at frequency at 0

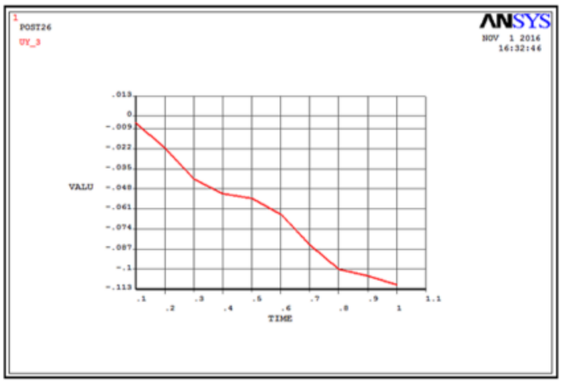
4. **Transient analysis of Uniform beam with Epoxy carbon as material**



Vonmisses stress



Deformation

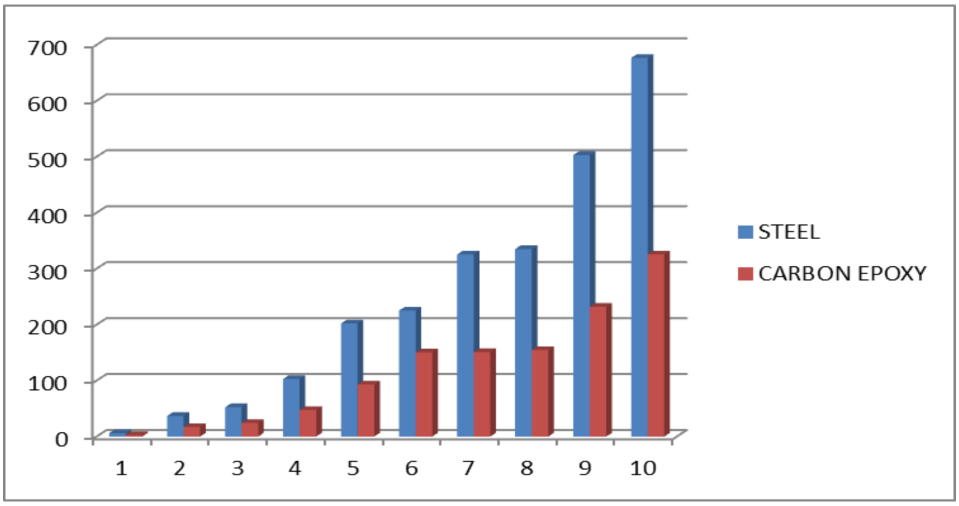


Time-Amplitude

Comparison of natural frequencies for Uniform Beam with Steel and Carbon Epoxy materials

S.NO.	STEEL	CARBON EPOXY
1	5.8532	2.6924
2	36.701	16.892
3	52.364	24.172
4	102.92	47.385
5	202.18	93.108
6	225.25	150.2
7	325.39	150.82
8	335.04	154.46
9	502.96	231.75
10	676.71	325.37

Graphical representation of natural frequency of uniform beam for two materials



Comparison of transient analysis for both the materials

TRANSIENT ANALYSIS	Uniform Beam	
	STEEL	CARBON EPOXY
AMPLITUDE OBTAINED	0.5	0.009

7. CONCLUSION

The project works on the analysis of wind turbine blade for uniform shape beam. This shape has modeled in CATIA and analysis done in ANSYS for two different materials, one is steel and the other is carbon epoxy material. The analysis carried out are model, harmonic and transient for determining the best suited material for the particular shape of the wind turbine blade.

For uniform beam with steel as material from static, harmonic and transient analysis, Max stress observed is 15.34 Mpa, amplitude is 0.89 and Time-amplitude is 0.5 respectively. For uniform beam with carbon epoxy as material from static, harmonic and transient analysis, Max stress observed is 14.126 Mpa, amplitude is 0.235 and time-amplitude is 0.009 respectively.

For uniform beam, the values of stress and amplitude obtained from different analysis for carbon epoxy material are less in comparison to steel material. Hence it is concluded that "Carbon Epoxy composite material is the best suited material for uniform beam of the wind turbine blade than steel material".

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