

# Analysis on Wind Turbine Blade Using Composite Materials

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**ABSTRACT:** Turbine blade design plays very important role in overall performance enhancement of wind turbines. Proper blade design is required to obtain desired cross section to generate maximum torque for driving wind turbine generator. In this paper, the performance characteristics of four different composite materials are studied. Detailed analysis of the standard wind turbine blade is carried out using ANSYS Workbench. The materials are tested for Total Deformation, Equivalent (Von-Mises) Stresses and Maximum Shear Stress and result is concluded.

**KEYWORDS:** Turbine blade, Composite Materials, ANSYS, Total Deformation, Equivalent (Von-Mises) Stresses, Maximum Shear Stress.

## I. INTRODUCTION

The system that accomplishes the conversion of wind energy to electricity is called as a wind turbine. Wind turbines convert the kinetic energy in the wind into mechanical power. [1] One of the primary goals for blade research is to keep blade weight growth under control. The efficiency of the wind turbine depends on the material of the blade, shape of the blade and angle of the blade. Therefore, the material of the turbine blade plays a vital role in the wind turbines. The material of the blade should possess high stiffness, low density and long fatigue life features [2]. In any material selection, the following requirements are important:

- High material stiffness, to maintain optimal shape of performance.
- Low density, to reduce gravity forces.
- Long-fatigue life is needed to reduce material degradation [3] [4]

Composite materials are becoming more important in the construction of blade structures. Modern composite materials such as glass fibre-reinforced-plastic (GFRP), carbon fibre-reinforced plastic (CFRP), Epoxy material and Aramid fibres are replacing the traditional wooden units. Further chapter describes about the materials selected and the methodology adopted for the analysis.

## II. PERFORMANCE ANALYSIS USING ANSYS

The standard model of Wind Turbine Blade is imported [5]. To study the performance characteristics of Blade Structure, Static Structural Analysis is been carried out using ANSYS workbench. The analysis is been done for E-Glass, E-Fiber, Kevlar, Carbon Fiber Reinforced Plastic (CFRP) materials.

### Load Calculation:

For load calculation, all assumptions are been made at standard atmospheric conditions. Average temperature at offshore is 22<sup>o</sup> Celsius. The wind speed at offshore is assumed to be 30 m/s

From geometry of Wind Turbine Blade Design,

- Exposed Surface area of Blade ( $A_s$ ) = 100m<sup>2</sup>
- Length of Blade ( $L_b$ ) = 42m
- Skin Thickness = 0.04m
- Spar Thickness = 0.02m

We know,

$$m = \rho \times A_s \times V$$

International Conference on Recent Trends in Engineering & Science (ICRTES 2017) Thus,  $m = 3600$  Kg

$$W = m \times g$$

Thus, Weight ( $W$ ) = 36000 N

This is the Total Load acting on the upper overall span of Wind Blade.

Therefore, Load per unit length is,

$$L = W/L_b$$

Hence,  $L = 857.142$  N

#### Material Data:

Table 1: Material properties [6] [7]

Material	Density	UTS	Yield Strength	Modulus of Elasticity	Poisson's Ratio	% Elongation at Break
	Kg/mm <sup>3</sup>	MPa	MPa	GPa		
<b>E-Glass Fiber Generic</b>	2.57e-6	3448	2050	72	0.20	4.8
<b>DuPont™ Kevlar®</b>	1.44e-6	3000	N/A	112	0.36	2.4
<b>Carbon Fiber Reinforced Polycarbonate</b>	1.3e-6	150	110	13	0.32	4.5

#### Analysis:

For adverse conditions, analysis is been carried out with Loading of 870 N. The blade is considered as cantilever beam under vertically download loading.

Criteria used for material analysis are:

- Total Deformation
- Equivalent (Von-Mises) Stresses
- Maximum Shear Stress

The proceeding sections shows the ANSYS results and readings obtained thereby. Maximum and Minimum values of the parameters are found for the considered materials.

**Epoxy Glass**

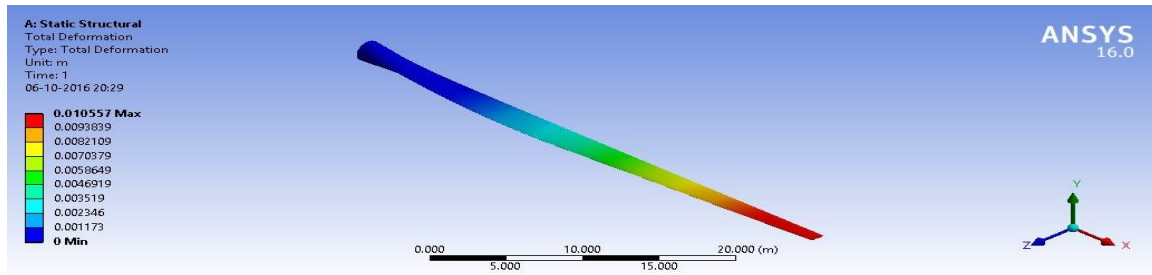


Figure 1(a): Total Deformation

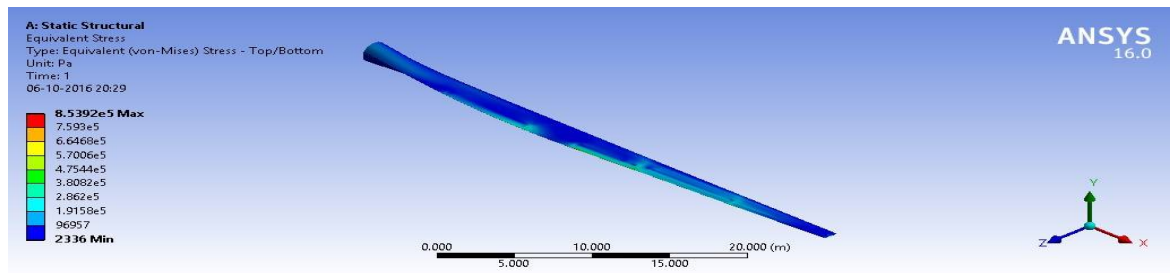


Figure 1(b): Equivalent (Von-Mises) Stresses

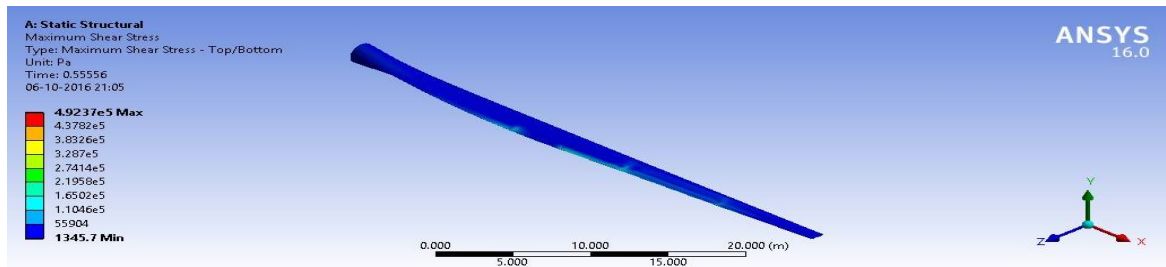


Figure 1(c): Maximum Shear Stresses

From the analysis we got the total deformation of Epoxy Glass at maximum case is 0.010557 m and the minimum is 0 mm. The Equivalent (Von-Mises) stress under static structural analysis maximum is 8.5392e5 Pa and minimum is 2336 Pa. Maximum Shear Stress is 4.9237e5 Pa (max) and 1345.7 Pa (min).

**Epoxy Carbon**

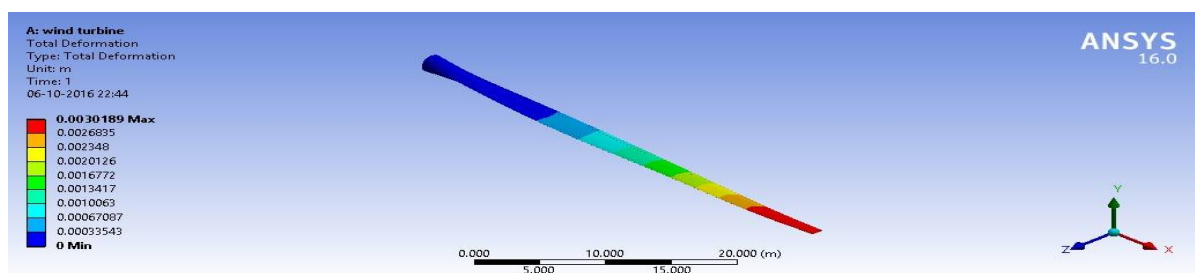


Figure 2(a): Total Deformation

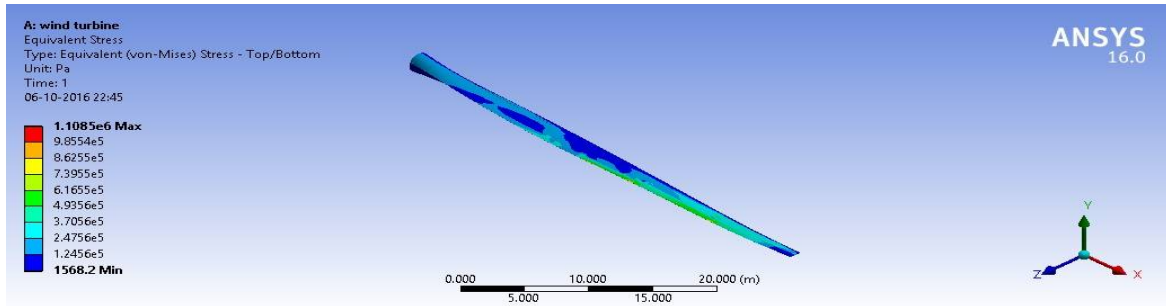


Figure 2(b): Equivalent (Von-Mises) Stresses

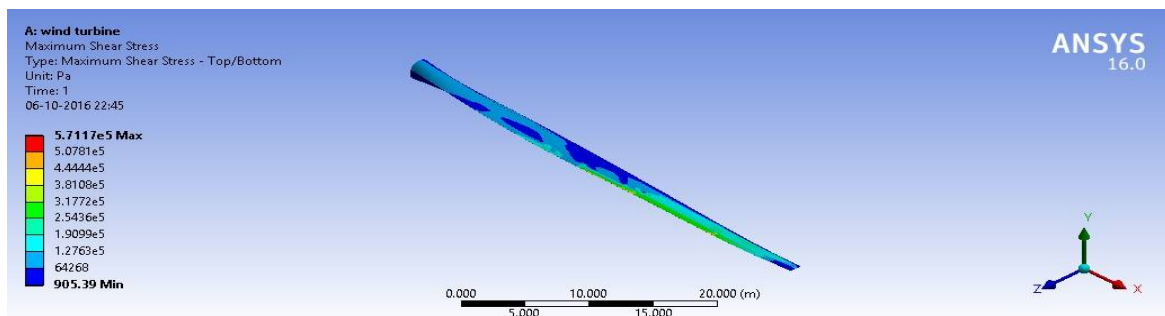


Figure 2(c): Maximum Shear Stresses

From the analysis we got the total deformation of Epoxy Carbon at maximum case is 0.0030189 m and the minimum is 0 mm. The Equivalent (Von-Mises) stress under static structural analysis maximum is 1.1085e6 Pa and minimum is 1568.2 Pa. Maximum Shear Stress is 5.7117e5 Pa (max) and 905.39 Pa (min).

### Kevlar

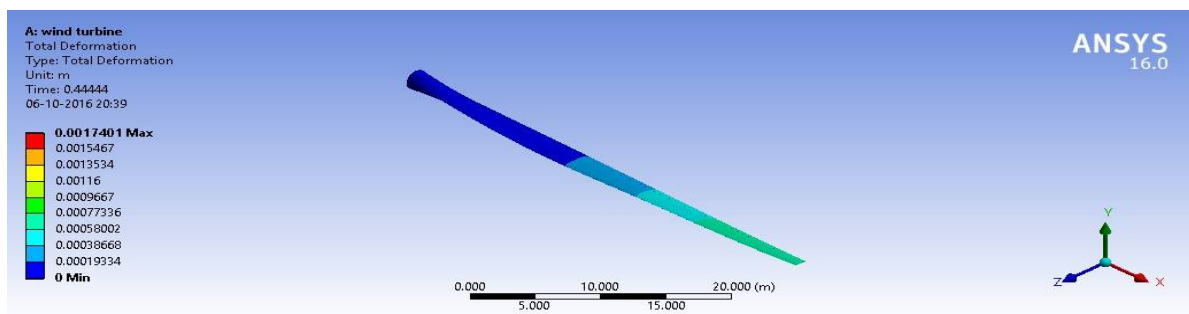


Figure 3(a) Total Deformation

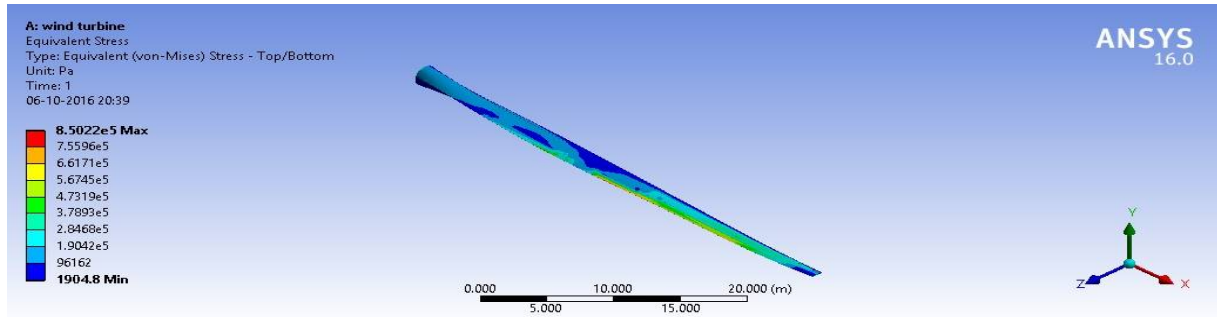


Figure 3(b): Equivalent (Von-Mises) Stresses

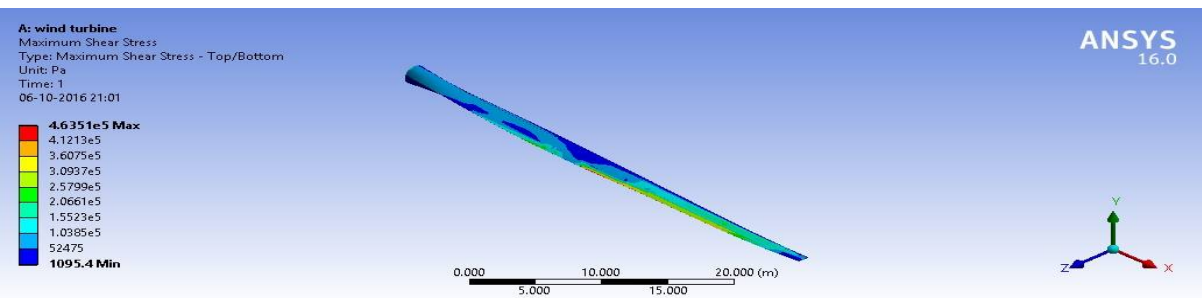


Figure 3(c): Maximum Shear Stresses

From the analysis we got the total deformation of Kevlar at maximum case is 0.0017401 m and the minimum is 0 mm. The Equivalent (Von-Mises) stress under static structural analysis maximum is 8.5022e5 Pa and minimum is 1904.8 Pa. Maximum Shear Stress is 4.6351e5 Pa (max) and 1095.4 Pa (min).

### Carbon Fibre Reinforced Plastic

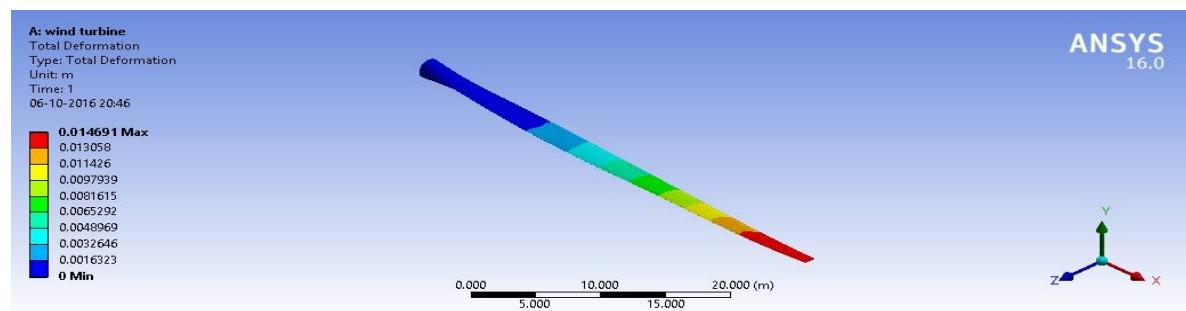


Figure 4(a): Total Deformation

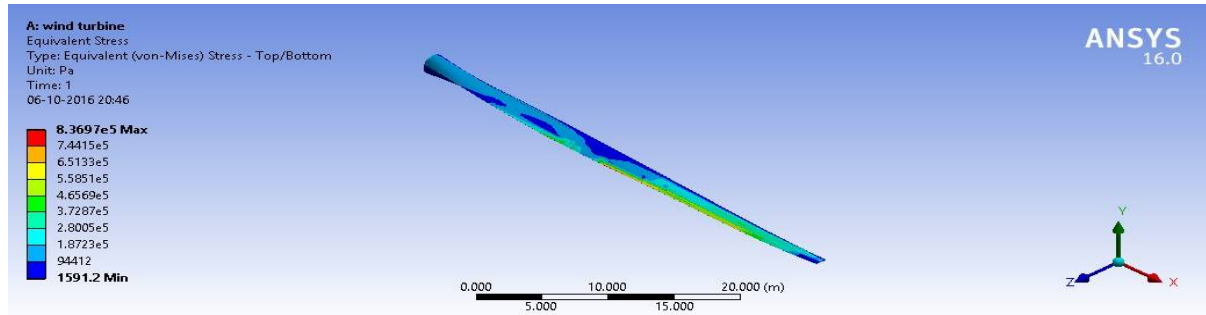


Figure 4(b): Equivalent (Von-Mises) Stresses

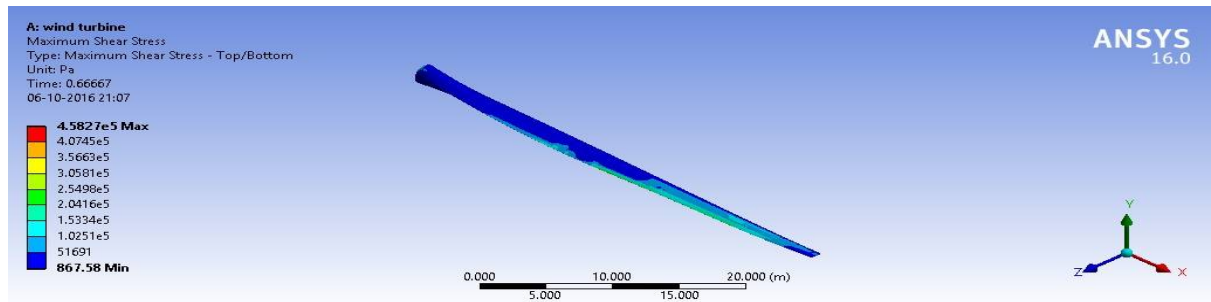


Figure 4(c): Maximum Shear Stresses

From the analysis we got the total deformation of Carbon Fibre Reinforced Plastic (CFRP) at maximum case is 0.014691 m and the minimum is 0 mm. The Equivalent (Von-Mises) stress under static structural analysis maximum is 8.3697e5 Pa and minimum is 1591.2 Pa. Maximum Shear Stress is 4.5827e5 Pa (max) and 867.58 Pa (min).

**Comparative Analysis of Ansys Result:**

Following table shows the comparative analysis of the Ansys Result.

Table 2: Comparative Analysis of Ansys Result

	Epoxy Glass		Epoxy Carbon		Kevlar		Carbon Fibre Reinforced Plastic	
	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
<b>Total deformation (m)</b>	0.010557	0	0.0030189	0	<b>0.0017401</b>	0	0.014691	0
<b>Equivalent (Von-Mises) stress (Pa)</b>	8.5392e5	2336	<b>1.1085E6</b>	1568.2	8.5022E5	1904.8	8.3697E5	1591.2
<b>Maximum Shear Stress (Pa)</b>	4.9237e5	1345.7	5.7117E5	905.39	4.6351E5	1095.4	<b>4.5827E5</b>	867.58

### III. RESULT

Less deformation shows the undesirable effect on the structure. For a good and safe design, deformation should be minimum. A detailed analysis of the standard wind turbine blade is been carried out using ANSYS Workbench. The performance characteristics of four different materials are studied.

- The Static Analysis results indicates that, Kevlar material yields minimum deformation of 0.0017401m as compared to the other material.
- The Minimum Von-misses Stress of 1.1085e6 Pa was observed in epoxy carbon material as compared to the other material.
- Analysis of wind turbine blade illustrates epoxy carbon is one of best material for wind turbine blade under specified conditions.

### IV. CONCLUSION

As per the review, it is clear that new polymer resins and reinforcement fibres of glass, carbon and aramid (Kevlar) are most effective performance enhanced materials. This work of wind turbine blade analysis shows best results for material Kevlar for total deformation and Epoxy Carbon for equivalent (Von-Mises) shear stresses also Carbon Fibre Reinforced Plastic for Maximum Shear Stress (Pa)

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