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DESIGN AND ANALYSIS OF WINDMILL BLADES FOR DOMESTIC APPLICATIONS

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ABSTRACT

The optimum twist of a windmill blade is examined on the basis of elementary blade-element theory. For a given wind speed and blade angular velocity, it is shown that the maximum power efficiency is achieved when the blade is twisted according to a program that depends upon the variation of the sectional lift and drag coefficients with angle of attack. Results for a typical airfoil cross-section show that the optimum angle of attack decreases from the maximum-lift-coefficient angle of attack at the blade root to greater than eighty percent of this value at the blade tip. The materials used were stainless steel, e-glass epoxy and gray cast iron and results were tabulated.

Key words: Wind turbine design, windmill blades design, Structural analysis of wind mill blades.

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1. INTRODUCTION

The utilization of the energy in the winds requires the development of devices which convert that energy into more useful forms. This is typically accomplished by first mechanically converting the linear velocity of the wind into a rotational motion by means of a windmill and then converting the rotational energy of the windmill blades into electrical energy by using a generator or alternator [5]. For purposes here, we can thus view the windmill as a mechanical device for extracting some of the kinetic energy of the wind and converting it into the rotational energy of the blade motion [1]. This is accomplished, in detail, by having the blades oriented at some angle to the wind so that the wind blowing past the blades exerts an aerodynamic force on them and there by causes them to rotate [7].

2. TURBINE AERODYNAMICS

Unlike the old-fashioned Dutch windmill design, this relied mostly on the wind's force to push the blades into motion; modern turbines use more sophisticated aerodynamic principles to capture the wind's energy most effectively [9]. The two primary aerodynamic forces at work in wind-turbine rotors are lift, which acts perpendicular to the direction of wind flow; and drag[8], which acts parallel to the direction of wind flow.

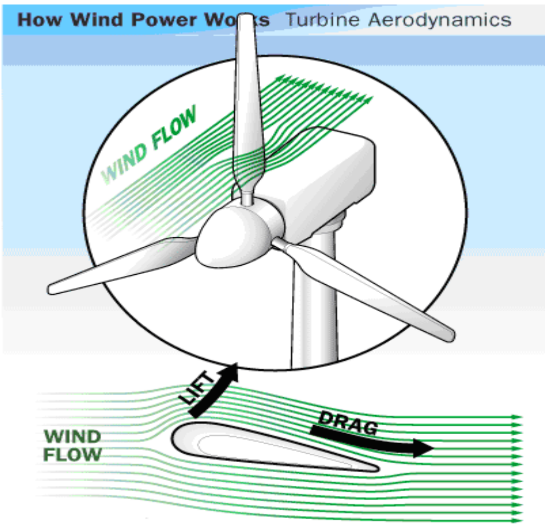


Figure 1 Windturbine Aerodynamics

Turbine blades are shaped a lot like airplane wings - they use an airfoil design. In an airfoil, one surface of the blade is somewhat rounded, while the other is relatively flat. Lift is a pretty complex phenomenon and may in fact require a Ph.D. in math or physics to fully grasp. But in one simplified explanation of lift, when wind travels over the rounded, downwind face of the blade, it has to move faster to reach the end of the blade in time to meet the wind travelling over the flat, upwind face of the blades.

3. PRO-E MODEL OF BLADES:

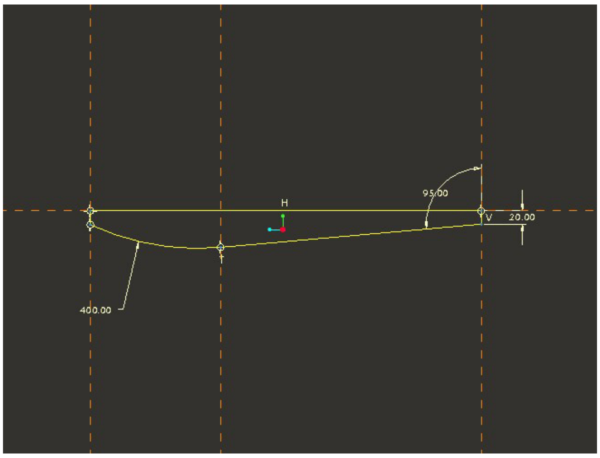


Figure 2 2d sketch for windmill blade

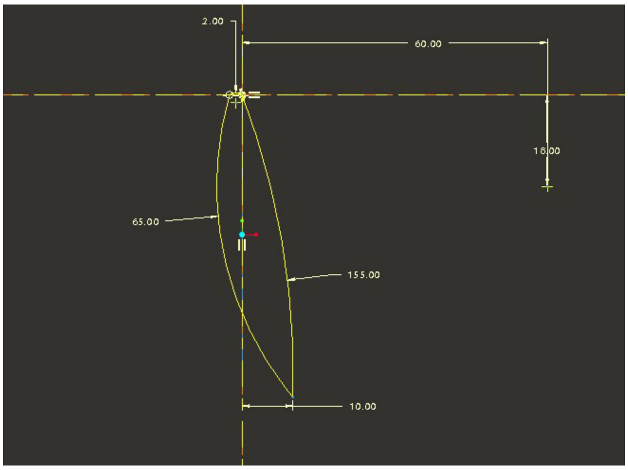


Figure 3 2d sketch for windmill blade

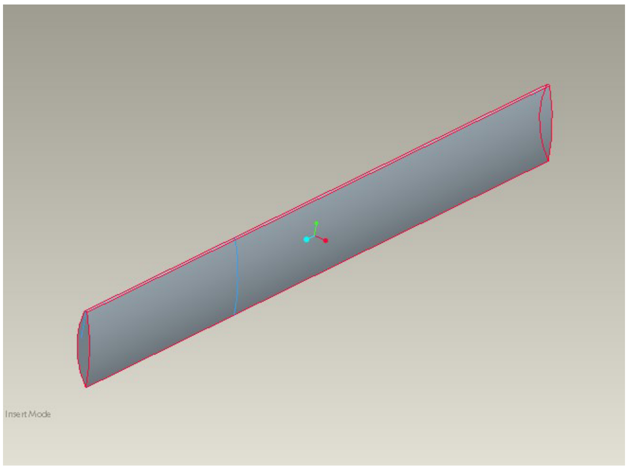


Figure 4. Extruded model of the windmill blade

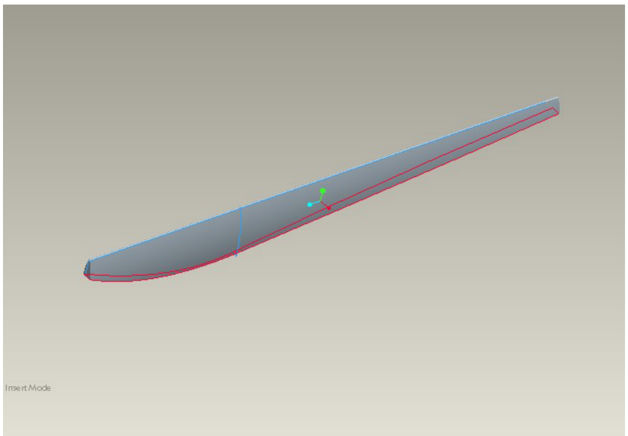


Figure 5. Extruded cut model of the windmillblade

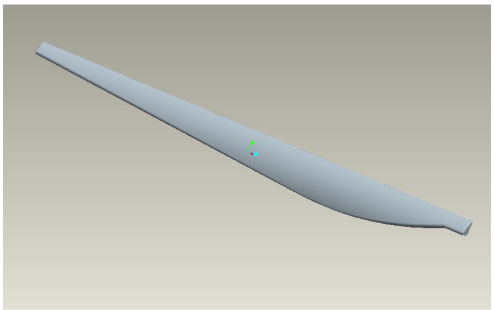


Figure 6. Full Extruded model of the windmill blade

4. ANSYS MODEL OF BLADES

4.1. BY ANALYSIS METHODOLOGY

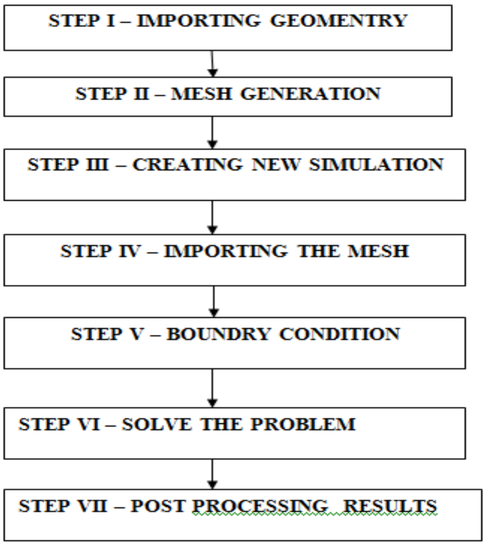


Figure 7 Methodology

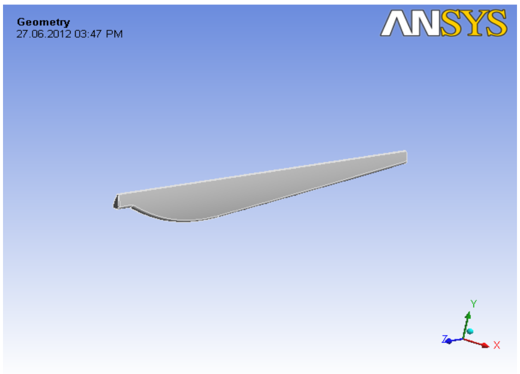


Figure 8 Ansys model of Turbine blade

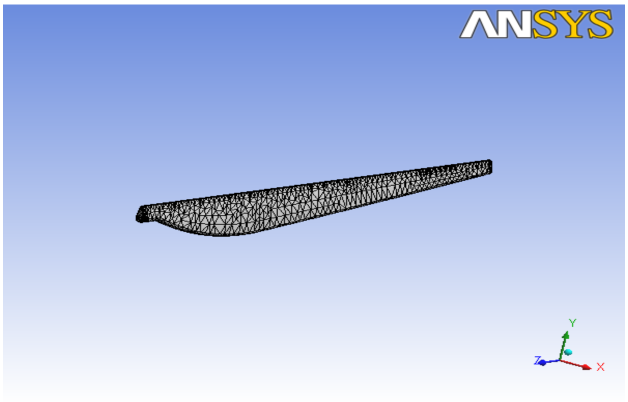
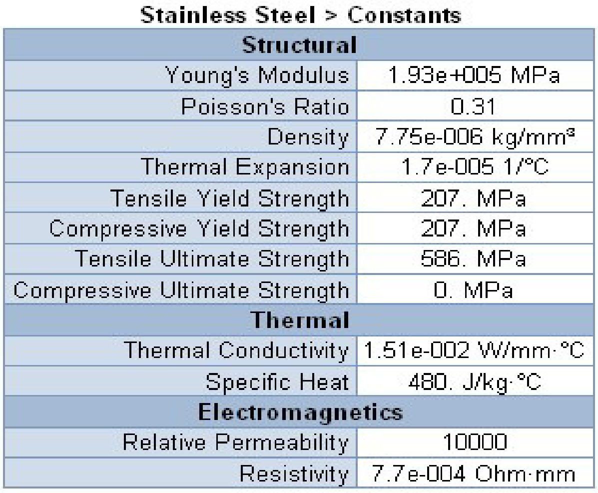


Figure 9 Meshing stragety

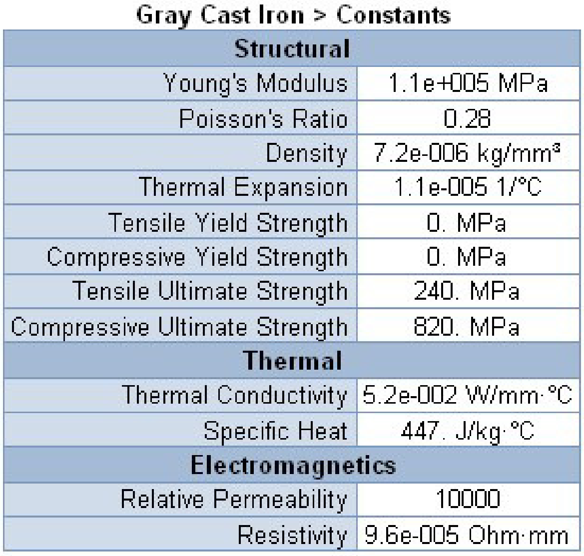
5. MATERIAL PROPERTIES



Stainless Steel > Constants

Structural	
Young's Modulus	1.93e+005 MPa
Poisson's Ratio	0.31
Density	7.75e-006 kg/mm³
Thermal Expansion	1.7e-005 1/°C
Tensile Yield Strength	207. MPa
Compressive Yield Strength	207. MPa
Tensile Ultimate Strength	586. MPa
Compressive Ultimate Strength	0. MPa
Thermal	
Thermal Conductivity	1.51e-002 W/mm·°C
Specific Heat	480. J/kg·°C
Electromagnetics	
Relative Permeability	10000
Resistivity	7.7e-004 Ohm·mm

Figure 10 Properties For Stainless Steel



Gray Cast Iron > Constants

Structural	
Young's Modulus	1.1e+005 MPa
Poisson's Ratio	0.28
Density	7.2e-006 kg/mm³
Thermal Expansion	1.1e-005 1/°C
Tensile Yield Strength	0. MPa
Compressive Yield Strength	0. MPa
Tensile Ultimate Strength	240. MPa
Compressive Ultimate Strength	820. MPa
Thermal	
Thermal Conductivity	5.2e-002 W/mm·°C
Specific Heat	447. J/kg·°C
Electromagnetics	
Relative Permeability	10000
Resistivity	9.6e-005 Ohm·mm

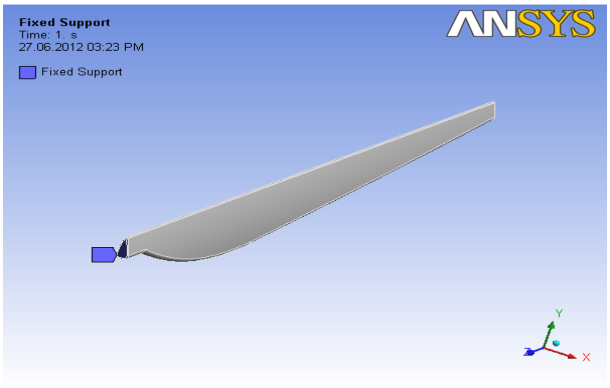
Figure 11 Properties For Grey cast iron

E-Glass/Epoxy > Constants

Structural	
Young's Modulus X direction	6530. MPa
Young's Modulus Y direction	34000 MPa
Young's Modulus Z direction	6530. MPa
Major Poisson's Ratio XY	0.366
Major Poisson's Ratio YZ	0.217
Major Poisson's Ratio XZ	0.217
Shear Modulus XY	2433. MPa
Shear Modulus YZ	1698. MPa
Shear Modulus XZ	2433. MPa
Density	2.6e-006 kg/mm³
Tensile Yield Strength	900. MPa
Compressive Yield Strength	450. MPa

Figure 12 Properties For E-Glass/Epoxy

6. BOUNDARY CONDITION



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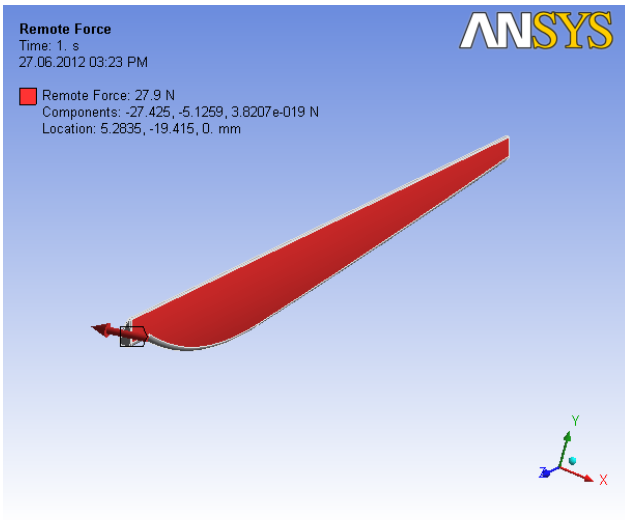
🟦 Fixed Support

Figure 13 Constraint For E-Glass/Epoxy

7. FORCES APPLIED ON THE BLADES



Remote Force
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🟥 Remote Force: 27.9 N
Components: -27.425, -5.1259, 3.8207e-019 N
Location: 5.2835, -19.415, 0. mm

Figure 14 Remote Force 1 Applied On Windmill Blade

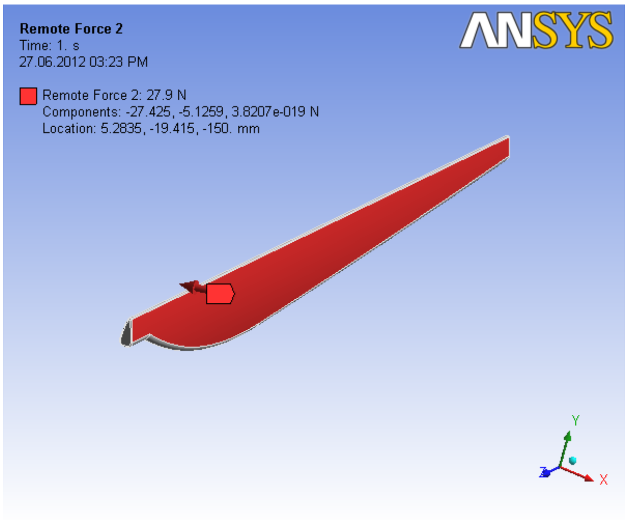

Figure 15.Remote Force 2 Applied On Windmill Blade

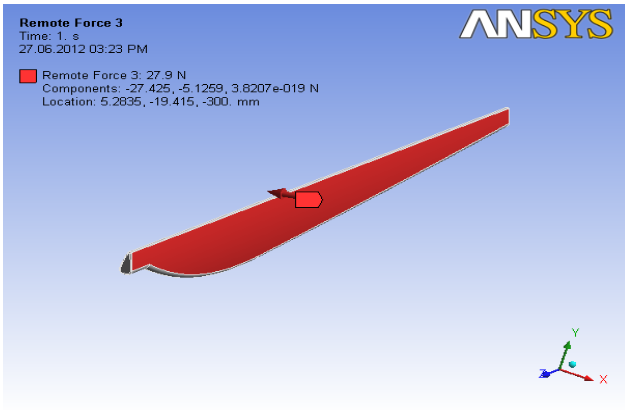

Figure 16 Remote Force3 Applied On Windmill Blade

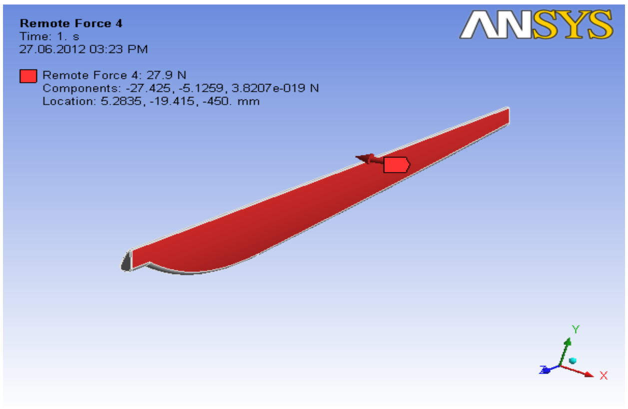

Figure 17 Remote Force4 Applied On Windmill Blade

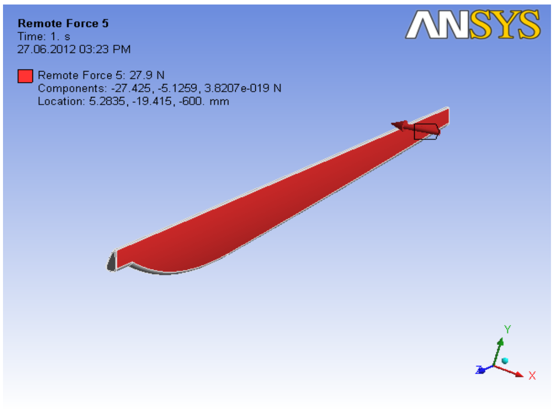

Figure 18 Remote Force5 Applied On Windmill Blade

8. ANSYS RESULTS

8.1. FOR STAINLESS STEEL

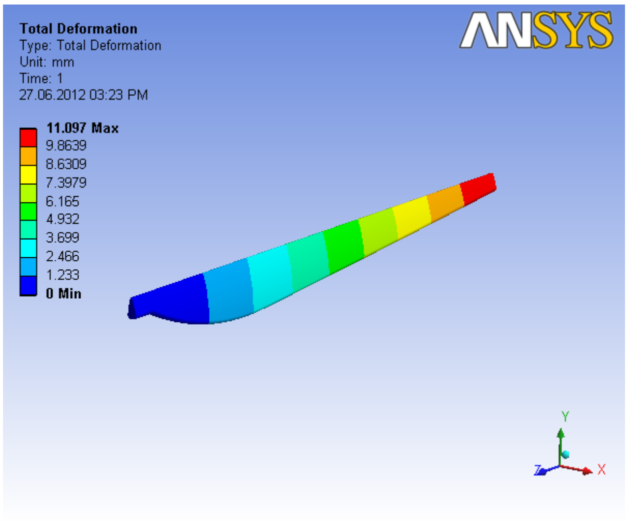

Figure 19 Total Deformation

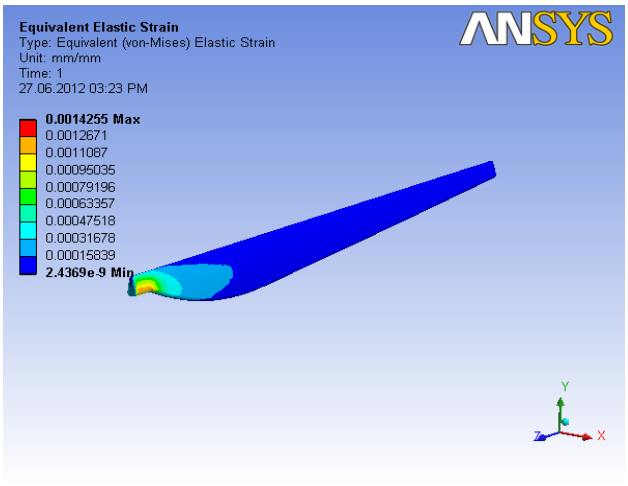

Figure 20 Equivalent Elastic Strain

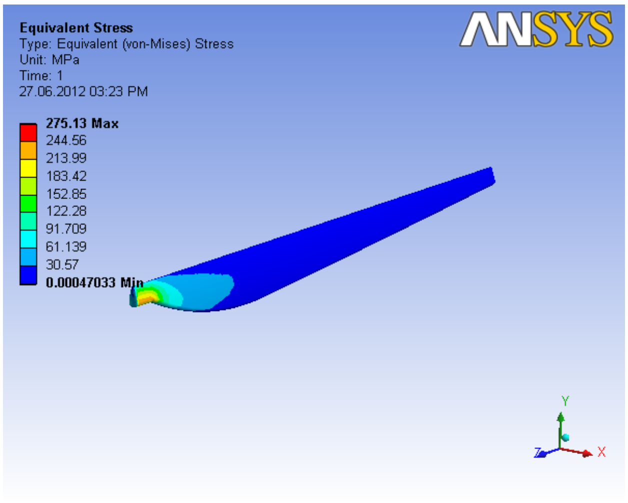

Figure 21 Equivalent Stress

8.2. RESULTS FOR E-GLASS EPOXY

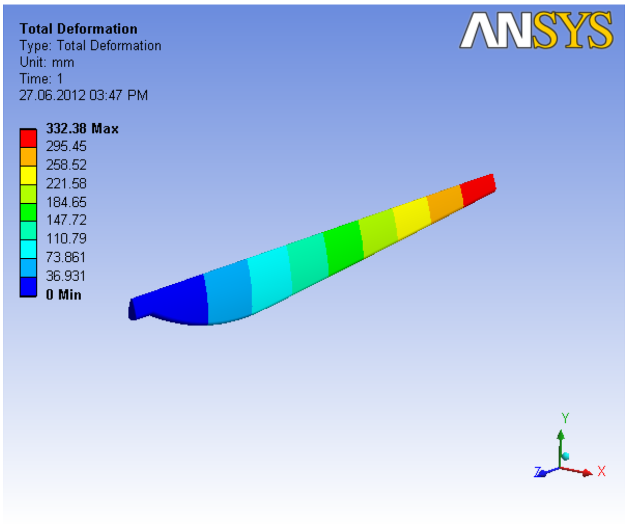

Figure 22 Total Deformation

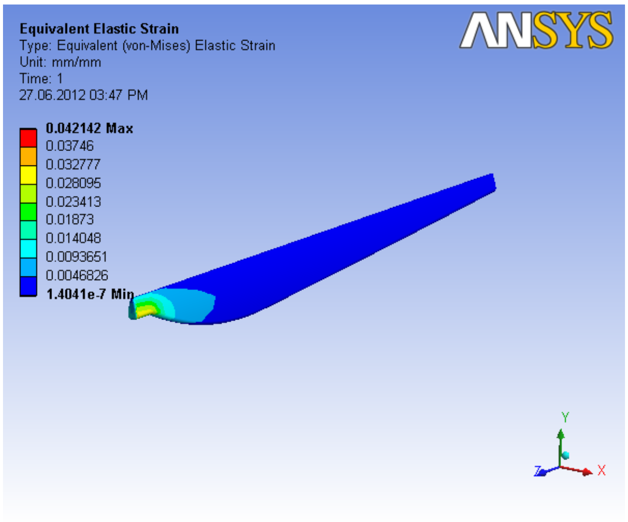

Figure 23 Equivalent Elastic Strain

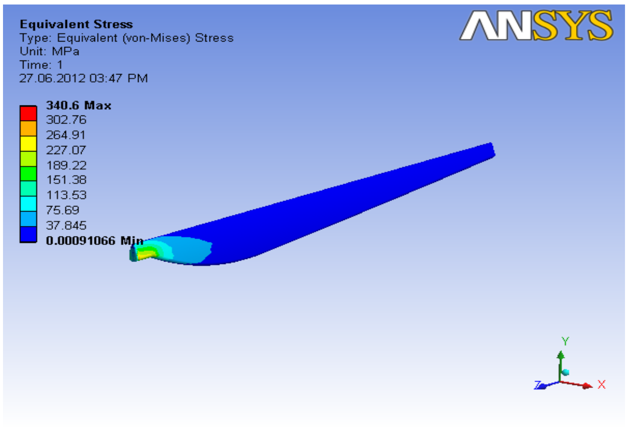

Figure 24. Equivalent Stress

8.3 RESULTS FOR GRAY CAST IRON

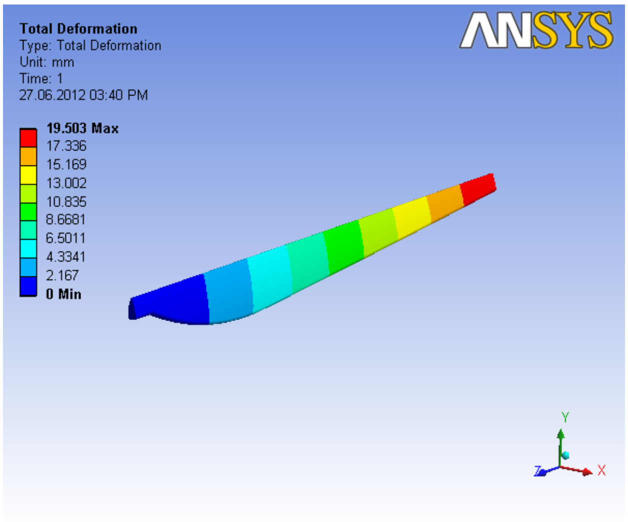

Figure 25. Total Deformation

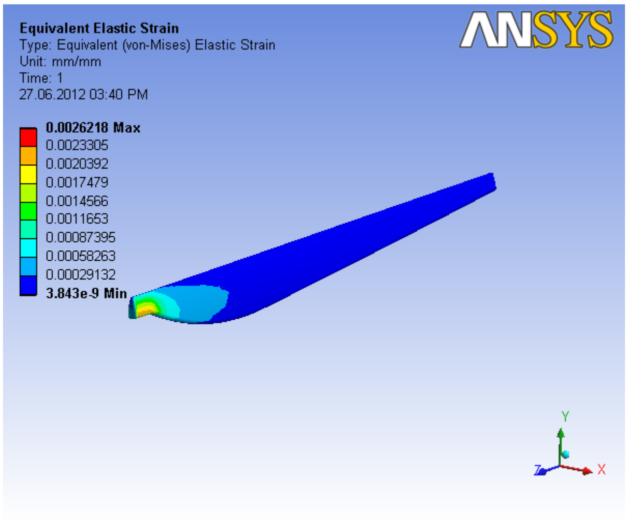

Figure 26 Equivalent Elastic Strain

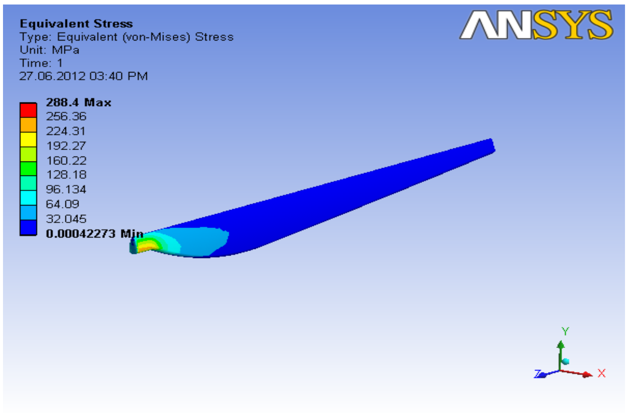

Figure 27 Equivalent Stress

8.4 RESULTS BY COMPARISON

Table 1 Results by comparison from ANSYS

s. no.	particulars	total deformation (m)	equivalent elastic strain (m/m)	equivalent stress (pa)
1	stainless steel	11.097	0.0014255	275.13
2	e-glass epoxy	322.38	0.042142	340.6
3	gray cast iron	19.503	0.0016218	288.4

9. CONCLUSION

The analysis of windmill blade we found that the **STAINLESS STEEL** material have a good physical properties and it have a less deformation under the moment and velocity, than the other two materials and finally the deformation, stress, strain of the STAINLESS STEEL material is **low** compared to the materials.The analysis carried out by us will make an impressing mark in the field of renewable energy.

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