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Design and Analysis of Domestic Windmill Blades Using Composite Materials

V.Maheswara Rao
M.Tech (CAD/CAM) Student
Department of Mechanical Engineering
Avanthi Institute of Engineering and Technology,
Cherukupally, Bhogapuram Mandal, Vizianagaram.

M.Lakshmi Sramika, M.Tech, (Ph.D)
Associate Professor & HoD
Department of Mechanical Engineering
Avanthi Institute of Engineering and Technology,
Cherukupally, Bhogapuram Mandal, Vizianagaram.

P.Purushotama Anil Kumar, M.Tech
Assistant Professor
Department of Mechanical Engineering
Avanthi Institute of Engineering and Technology,
Cherukupally, Bhogapuram Mandal, Vizianagaram.

G.Ramu, M.Tech
Assistant Professor
Department of Mechanical Engineering
Avanthi Institute of Engineering and Technology,
Cherukupally, Bhogapuram Mandal, Vizianagaram.

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.

So we are design the blade using the SOLIDWORKS software and to find out the strength of material to be used for windmill project. To finding the strength of the material we are using ansys software. Optimization using Composite materials are used for Strength Calculations. Validate best Composition for given results.

INTRODUCTION

INTRODUCTION TO WIND ENERGY

Nowadays electricity is the major problem in this world especially in Tamil Nadu, India. In the present era of steadily rising fuel costs, wind energy is becoming an increasingly attractive component of future energy systems. The wind potential of India is very high. The wind turbines have been installed and wind energy is being harvested, predominantly in the high wind velocity areas. However, due to the restriction of space, the comparatively lower wind areas are beginning to populate with similar wind turbines. In order to ensure the extraction of maximum wind potential even at lower wind speeds, these turbine blades have to be designed and analyzed to suit the low wind areas.

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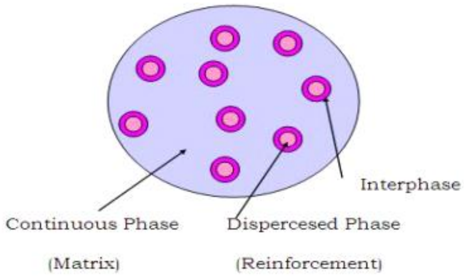
SMALL WIND TURBINES

Growing awareness of rising levels of greenhouse gases, global warming and increasing prices of fossil fuels have led to a shift towards investing into low-cost small wind turbines. Simple structured, compact in design, portable and low noise, the small wind turbines are now vital wind power extracting devices in the rural, suburban and even in the populated city areas where installation of large scale wind turbines would not be accepted due to space constraints and generation of noise. Small wind turbines achieve power coefficients of 0.25 or greater in comparison to large turbines which have been integrated on domestic .house roof tops, farms, remote communities and boats.

In contrast to larger horizontal axis wind turbines (HAWTs) that are located in areas dictated by optimum wind conditions, small wind turbines are required to produce power without necessarily the best of wind conditions. A small wind turbine is one that relies on aerodynamic forces to start-up and has a tail vane for passive yawing. Small wind turbines are categorized as micro (1 kW), mid-range (5 kW) and mini wind turbines (20 kW+). A more detailed description of micro wind turbines is given by Cooper as being rated less than 2.5 kW and commercially produces power in the range of 0.4 kW-1.5 kW at 12.5 m/s wind speed.

INTRODUCTION TO COMPOSITES

A composite is usually made up of at least two materials out of which one is the binding material, also called matrix and the other is the reinforcement material (fiber, Kevlar and whiskers). The advantage of composite materials over conventional materials stem largely from their higher specific strength, stiffness and fatigue characteristics, which enables structural design to be more versatile. Composite constituents are shown in figure 1. By definition, composite materials consist of two or more constituents with physically separable phases. Composites are materials that comprise strong load carrying material (known as reinforcement) imbedded in weaker material (known as matrix)



Composite Constituents

Metal Matrix Composites (MMCs)

Metal matrix composites, as the name implies, have a metal matrix. Examples of matrices in such composites include aluminum, magnesium and titanium. The typical fiber includes carbon and silicon carbide. Metals are mainly reinforced to suit the needs of design. For example, the elastic stiffness and strength of metals can be increased, while large co-efficient of thermal expansion, and thermal and electrical conductivities of metals can be reduced by the addition of fibers such as silicon carbide.

FIBER COMPOSITES

Composites, which contain fibers as reinforcement material, are used for many applications. A common fiber-containing composite is fiberglass, which has polyester polymer matrix and glass fiber fillers for reinforcement. The glass fibers strengthen the resin and make it more impact resistant. Many boat hulls are made of fiberglass that must withstand the constant beating of waves and other hard objects in water such as wood and rocks. These are the composite, which we will be studying in detail.

CARBON FIBERS

They were invented in 1878 by Thomas Alva Edison with cotton fiber and later on were made up of bamboo. Carbon fibers were used in high temperature missiles. They are made using rayon, Polyacrylonitrile and petroleum pitch. The carbon fiber is not organic even though they are formed from organic components. They are the strongest of all reinforcements and work is being done in order to increase their strength. They have resistance to high temperatures, and corrosive

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environment and lack moisture sensitivity. They also have disadvantages that they are brittle and are expensive. They are used in racing vehicles, ships, and spacecrafts and sports goods. Though the carbon fiber reinforcement is high temperature resistant it has been seen that carbon fiber reinforced in thermoplastic matrix at low temperatures collapse and fracture of the beam that is initiated by inter laminar shear and de-lamination At high temperatures large scale inelastic deformation was observed by Ningyun et.al.

GLASS FIBERS

Glass fiber reinforcements were produced for the first time in 1893. Now it is one of the most appealing reinforcements due to its high performance, good properties and low cost. It is made up of silicon oxide and some other oxide. Glass fibers are resistant to high temperatures and corrosive environments and they also have radar transparency. There are two main types of glass fibers: E-glass and S-glass. The first type is the most widely used, and takes its name from its good electrical properties but is prone to fractures in case of acoustic emissions,. The second type is very strong (S-glass), stiff, and temperature resistant. Reinforced glass fiber composite are an ideal material to make boat hulls, swimming pool linings, car bodies, roofing and furniture. Glass fiber reinforcement and polyester matrix has been used in this LCA for construction of the skin for the sandwich structures of the PVC foam.

LITERATURE SURVEY

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 aero elastic stability have attracted researchers' attention. Jureczko et al. 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 aero elasticity of aircraft wing structure analytically and numerically and compared the results with experimental results. Veers et al. 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 et al. They considered the decomposition of these structural systems, the required performance, and the acting loads.

Lee et al. numerically investigated the load reduction of large wind turbine blades using active aerodynamic load control devices, namely trailing edge flaps. Tenguria et al. 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.

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AIRFOIL

An airfoil-shaped body moved through a fluid produces an aerodynamic force. The component of this force perpendicular to the direction of motion is called lift. The component parallel to the direction of motion is called drag. Subsonic flight airfoils have a characteristic shape with a rounded leading edge, followed by a sharp trailing edge, often with a symmetric camber. The lift on an airfoil is primarily the result of its angle of attack and shape. When oriented at a suitable angle, the airfoil deflects the oncoming air, resulting in a force on the airfoil in the direction opposite to the deflection. This force is known as aerodynamic force and can be resolved into two components: Lift and drag. Most foil shapes require a positive angle of attack to generate lift, but cambered airfoils can generate lift at zero angle of attack.

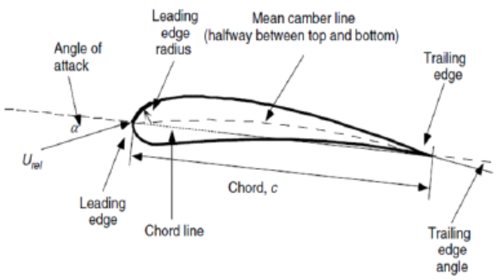

Fig-3: Airfoil nomenclature

BLADE DESIGN PROCEDURE

Determine the rotor diameter required from site conditions and $P=Cp\eta(1/2)\rho\pi R^2V^3$

Where:

P is the power output

$Cp$is the expect coefficient of performance (0.4 for a modern three bladed wind turbine)

η is the expected electrical and mechanical efficiencies (0.9 would be a suitable value)

R is the tip radius

V is the expected wind velocity

2. According to the type of application, choose a tip speed ratio For a water-pumping windmill, for which greater torque is needed, use 1<<3. For electrical power generation, use 4<<10. The higher speed machines use less material in the blades and have smaller gearboxes, but require more sophisticated airfoils.

3. Choose the number of blades, B, from Table-1. Note: if fewer than three blades are selected, there are a number of structural dynamic problems that must be considered in the hub design.

4. Select an airfoil. If <3 curved plates can be used. If > 3 use a more aerodynamic shape.

5. Obtain and examine lift and drag coefficient curves for the airfoil in question. Note that different airfoils may be used at different spans of the blade; a thick airfoil may be selected for the hub to give greater strength.

6. Choose the design aerodynamic conditions for each airfoil. Typically select 80% of the maximum lift value, this choice effectively fixes the blade twist .On long blades a very large degree of twist is required to obtain 80% of the maximum lift near the hub. This is not necessarily desirable as the hub produces only a small amount of the power output, a compromise is to accept that the airfoils will have very large angles of attack at the hub.

7. Choose a chord distribution of the airfoil. There is no easily physically accessible way of doing this but a simplification of an ideal blade is given by:

$$C = \frac{8\pi r \cos\beta}{3B\lambda_r} \quad (7)$$

This gives a moderately complex shape and a linear distribution of chord may be considerably easier to make.

8. Divide the blade into N elements. Typically 10 to 20 elements would be used.

9. As a first guess for the flow solution use the following equations. These are based on an ideal blade shape derived with wake rotation, zero drag and zero tip losses.

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Note that these equations provide an initial guess only. The equations are given as follows:

$$\beta = 90° - \frac{2}{3}tan^{-1}\left(\frac{1}{\lambda_r}\right)(8)$$

$$a = \left(1 + \frac{4\,cos^2\beta}{\sigma' C_L \sin\beta}\right)^{-1} \quad (9)$$

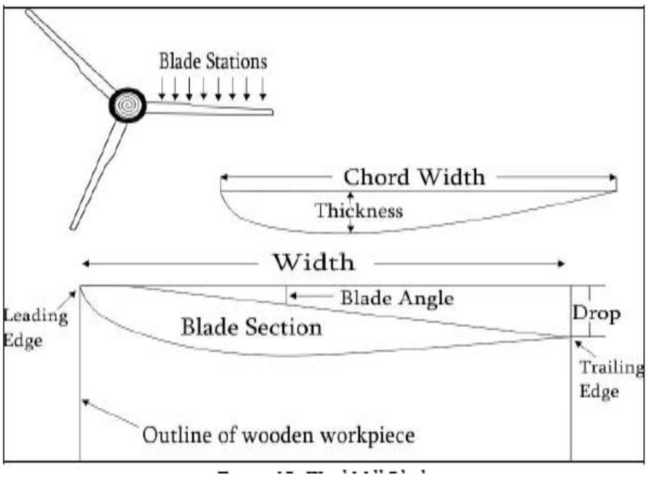
$$a' = \frac{1-3a}{4a-1}(10)$$

10. Calculate rotor performance and then modify the design as necessary. This is an iterative process

PROBLEM STATMENT

Design profile of wind mill blade as per analytical approach. Calculate stress, Deformation & strain as per design profile. Take basic material and change material like composite and check the optimization of material with less density. Validation will done using Analytical and numerical.

BLADE DESIGN CALCULATIONS



CALACULATION

Calculation of All the Parameters:

From all the values of specifications and considered parameters like wind speed, profile diameter, the calculations like Force and pressure acting

Pressure, Edge Wise area, Flap wise area, stiffness are calculated below

Force F = $\frac{\pi}{9 \times \rho \times V^2 \times D^2}$

Pressure P = $\frac{F}{A}$

Here Force is the one that is acting on parameter

Where ρ- density of air = 1.29 kg/m³ (density of air)

V- Velocity of wind = 10 m/s. (Velocity of air)

D- Diameter of the profile = 70 m.

Pressure P = Force/Area

Angle of blade is 15 degrees

Flap wise Area = 79.9634 m². It is area of the blade taking edge wise

Flap wise Pressure P=$\frac{220532.67}{79.9634}$ =17580 N/m². (Press acting on the flap of blade)=0.1 MPA

For the aluminium Alloy the deflection of blade is 2.2 mm and the mass of the entire blade is 50.94 kg.

Force acting on the blade is 220.532 K-N

Stiffness acting on the Windmill Blade = $\frac{\text{Force}}{\text{Deformation}}$

Stiffness acting on the windmill Blade= 220.532/2.2 =100.24 N/mm

Stress = $\frac{E \times l}{\delta l}$ = 365.05 MPA

For the Carbon Epoxy the deflection of blade is 1.02 mm and the mass of the entire blade is 45.27 kg.

Force acting on the blade is 220.532 K-N

Stiffness acting on the Windmill Blade = $\frac{\text{Force}}{\text{Deformation}}$

Stiffness acting on the windmill Blade = $\frac{220.532}{1.02}$

=216.20 N/mm

Stress = $\frac{E \times l}{\delta l}$ = 215.37 MPA

For the E-Glass Epoxy the deflection of the blade is 1.1 mm and the mass of entire

Blade is 48.11 kg

Force acting on the blade is 220.532 K-N

Stiffness acting on the Windmill Blade = $\frac{\text{Force}}{\text{Deformation}}$

Stiffness acting on the windmill Blade = $\frac{220.532}{1.1}$

=200.48 N/mm

Stress =$\frac{E \times l}{\delta l}$ = 116.52 MPA

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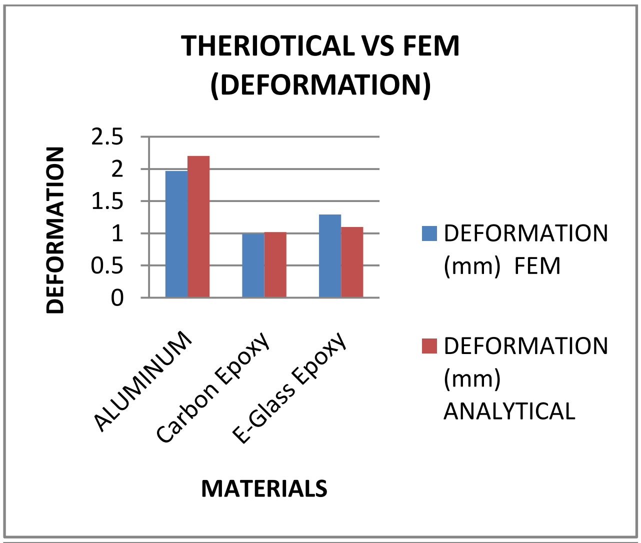
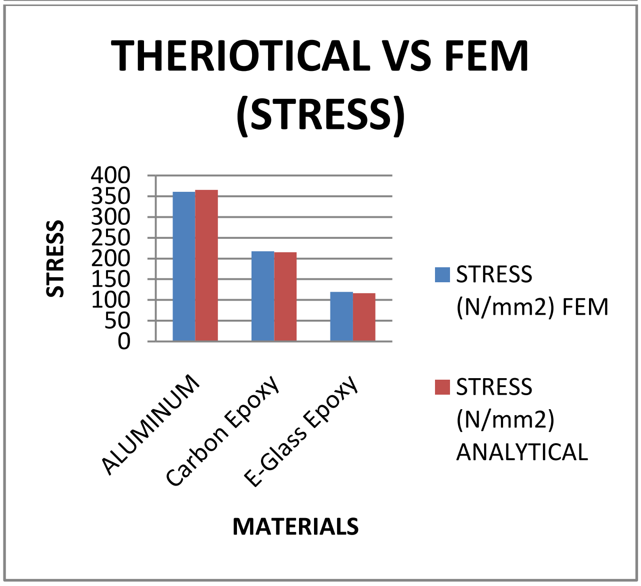
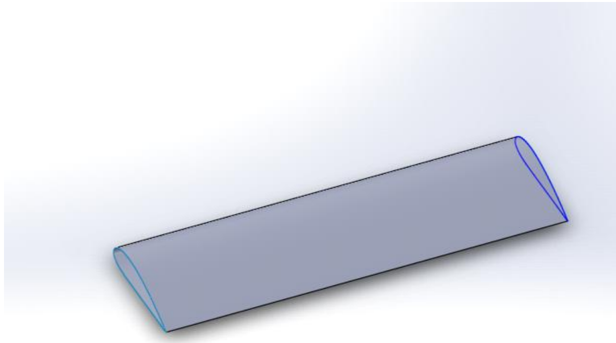
RESULTS TABLE

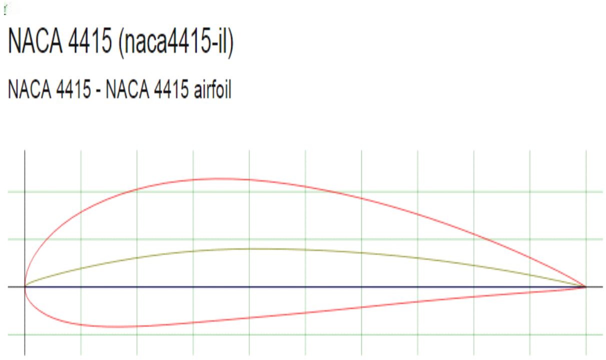
S.NO.	MATERIALS	DEFORMATION (mm) FEM	DEFORMATION (mm) ANALYTICAL	STRESS (N/mm2) FEM	STRESS (N/mm2) ANALYTICAL	STRAIN
1	ALUMINUM	1.97	2.2	361.02	365.05	0.0051
2	Carbon Epoxy	0.99	1.02	217.18	215.37	0.008
3	E-Glass Epoxy	1.29	1.1	119.82	116.52	0.0065





SOLIDWORKS MODEL

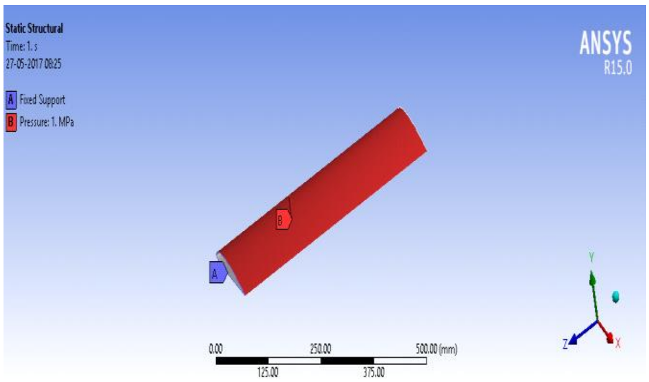




ANALYSIS OF WINDMILL BLADE

Sl. no.	Properties	Units	ALUMINUM ALLOY	Carbon Epoxy	E-Glass Epoxy
1	Young's Modulus E11	N/m^2	2.068×10^{11}	1.34×10^{11}	50×10^9
2	Young's Modulus E22	N/m^2	2.068×10^{11}	7×10^9	12×10^9
3	Density	kg/m^3	7830	1600	2000
4	Poisson Ratio	-	0.3	0.3	0.3
5	Shear Modulus G	N/m^2	-	5.8×10^9	5.6×10^9

BOUNDRY CONDITIONS



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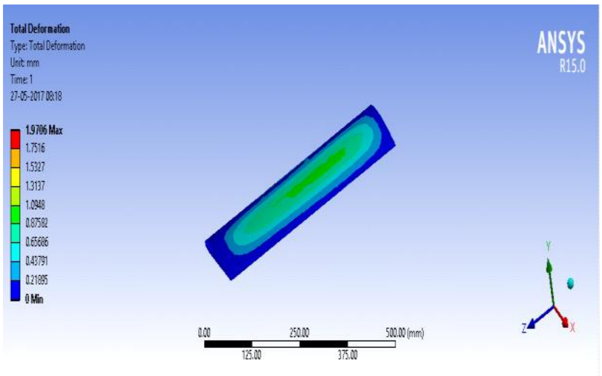
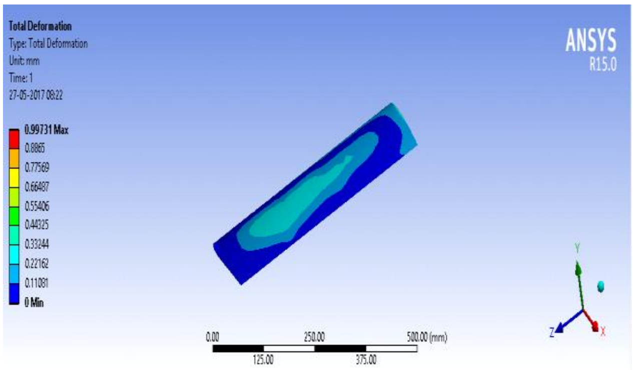
CASE 1: MATERIAL ALUMINUM USED FOR BLADE



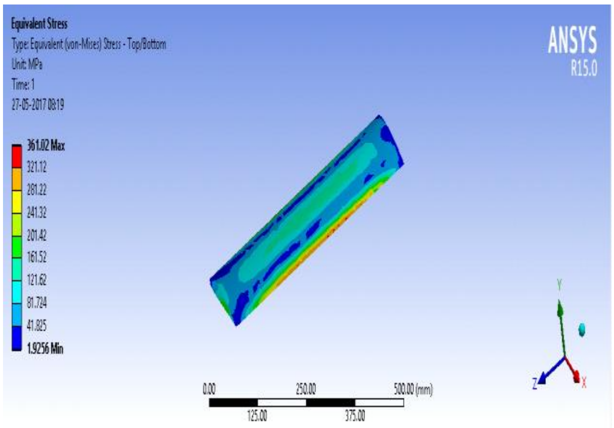
DEFORAMTION OF ALUMINUM WITH MAXIMUM DEFORMATION 1.97 mm

CASE 2: MATERIAL CARBON EPOXY USED FOR BLADE



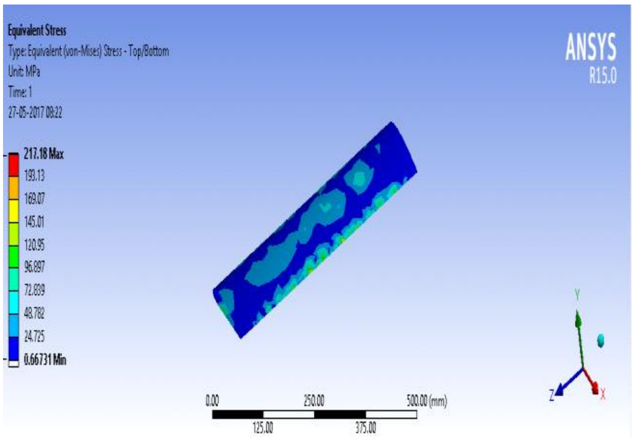
DEFORAMTION OF CARBON EPOXY WITH MAXIMUM DEFORMATION 0.99 mm

EQUIVALENT STRESS



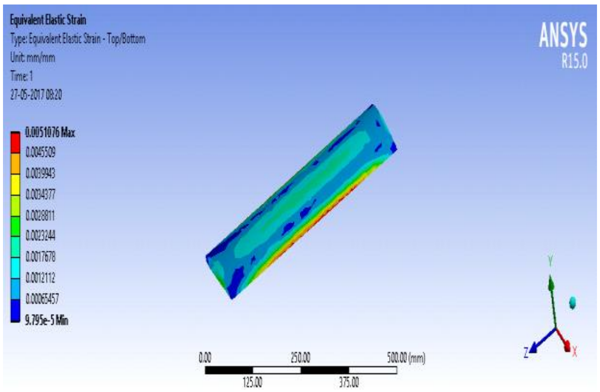
STRESS DISTRIBUTION ON BLADE WITH MAXIMUM 361.02 MPA

EQUIVALENT STRESS



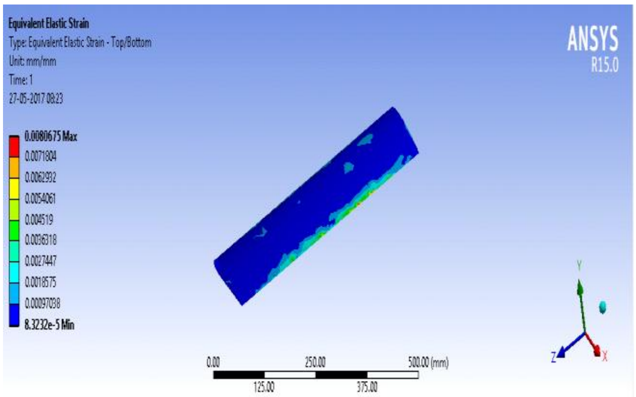
STRESS DISTRIBUTION ON BLADE WITH MAXIMUM 217.18 MPA

EQUIVALENT ELASTIC STRAIN



STRAIN DISTRIBUTION ON BLADE WITH MAXIMUM 0.0051

EQUIVALENT ELASTIC STRAIN



STRAIN DISTRIBUTION ON BLADE WITH MAXIMUM 0.00806

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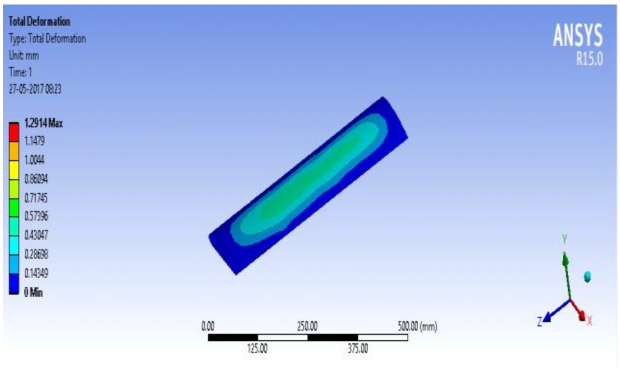
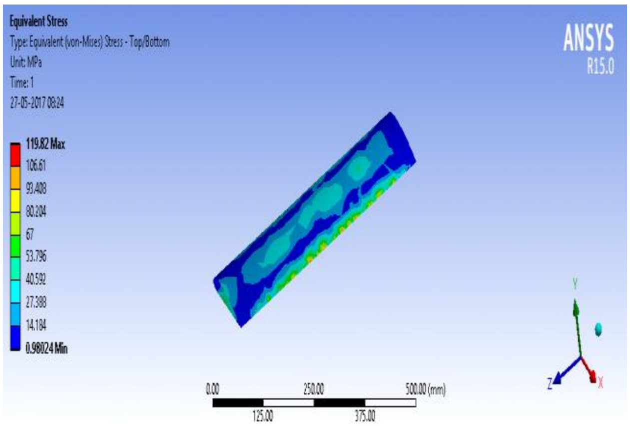
CASE 3: MATERIAL E-GLASS EPOXY USED FOR BLADE



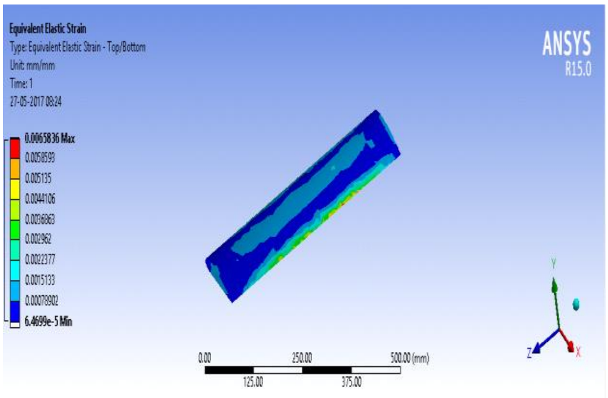
DEFORAMTION OF E-GLASS EPOXY WITH MAXIMUM DEFORMATION 1.29 mm

EQUIVALENT STRESS



STRESS DISTRIBUTION ON BLADE WITH MAXIMUM 119.82 MPA

EQUIVALENT ELASTIC STRAIN



STRAIN DISTRIBUTION ON BLADE WITH MAXIMUM 0.0065

RESULT TABLE

S.NO.	MATERIALS	DEFORMATION (mm)	STRESS (N/mm²)	STRAIN
1	ALUMINUM	1.97	361.02	0.0051
2	Carbon Epoxy	0.99	217.18	0.008
3	E-Glass Epoxy	1.29	119.82	0.0065

CONCLUSION

In this project work, Solid works 2014 software was used for designing and modelling of the horizontal axis Wind turbine blades. Wind turbine blade profile NACA 4415 with twist angles of 15º in which the chord length both tip and root was given and then analyzed. The Analysis work is carried out by Ansys workbench software.

1. The Static Analysis results indicates that, Al-alloy/ E-GLASS Epoxy composite material under goes the minimum deformation of 1.97 mm as compared to the other composite materials, and the maximum deformation of 1.29mm was observed in Carbon- Epoxy / E-GLASS Epoxy composite.

2. The Minimum Von-misses Stress of 361.02 M pa/119.82 was observed in Al-alloy/ E-GLASS Epoxy composite material as compared to the other materials. It is observed that Carbon- Epoxy / E-GLASS Epoxy composite material experiencing huge stress of 217.18/119.82 MPa.

3. Stiffness of Al-Sic /Epoxy composite material is higher as compared to the stiffness of other materials considered in this investigation.

4. From strength and stiffness point of view Carbon-Epoxy / E-GLASS Epoxy composite materials performing better than the other composite materials considered in this work.

REFERENCES

1. Navin Prasad E1, Janakiram S2, Prabu T3,Sivasubramaniam S4 DESIGN AND DEVELOPMENT OF HORIZONTAL SMALL WIND

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International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

TURBINE BLADE FOR LOW WIND SPEEDS, IJESAT Volume-4, Issue-1, 075-084

2. Cooper P, Kosasih PB, Ledo L. Roof mounting site analysis for micro-wind turbines. Renewable Energy 2010;36:1379-91.

3. Hirahara H, Hossain MZ, Nonomura Y. Testing basic performance of a very small wind turbine designed for multiepurposes. Renewable Energy 2005;30: 1279-97.

4. Fasel HF, Gross A. Numerical investigation of different wind turbine airfoils. Tucson, Orlando, Florida: The University of Arizona; 2011.

5. Ozgener O, Ozgener L. Exergy and reliability analysis of wind turbine systems: a case study. Renewable and Sustainable Energy Reviews 2007;11:1811-26.

6. Wang F, Bai L, Fletcher J, Whiteford J, Cullen D. The methodology for aerodynamic study on a small domestic wind turbine with scoop. Wind Engineering and Industrial Aerodynamics 2008;96:1-24.

7. Mayer C, Bechly ME, Hampsey M, Wood DH. The starting behaviour of a small horizontal-axis wind turbine. Renewable Energy 2001;22:411-7.

8. Clausen PD, Wood DH. Research and development issues for small wind turbines. Renewable Energy 1999;16:922-7.

9. Peacock AD, Jenkins D, Ahadzi M, Berry A, TuranS. Micro wind turbines in theUKdomestic sector, energy and buildings. Renewable Energy 2008;40:1324-33.

10. Grant Ingram, (October 18, 2011), Version 1.1, Wind Turbine Blade Analysis using the Blade Element Momentum Method.

11. A.K. Wright and D.H. Wood, September 2004 "The starting and low wind speed behaviour of a small horizontal axis wind turbine", Journal of Wind Engineering and Industrial Aerodynamics.

12. P.R. Ebert, D.H. Wood, Observations of the starting behaviour of a small horizontal-axis wind turbine, Renew. Energy 12 (3) (1997) 245–257.

13. Giguere P, Selig MS. Low reynolds number airfoils for small horizontal axiswind turbines. Wind Engineering 1997;21:379.

14. Singh RK, Ahmed MR, Zullah MA, Lee YH. Design and testing of a low Reynolds number airfoil for small horizontal axis wind turbines. Renewable Energy 2012;42:66-76.

15. Anderson, John, D (2007). Fundamentals of Aero dynamics.McGraw-Hill.

Author Details

V.Maheswararao
M.Tech.[Cad/Cam] Student
Department of Mechanical Engineering
Avanthi Institute of Engineering and Technology Cherukupally, Bhogapuram Mandal, Vizianagarm.

M.Lakshmi Sramika Was Born In Andhra Pradesh, India. She Is Working As HoD And Associative Professor In Avanthi Institute of Engineering and Technology Cherukupally, Bhogapuram Mandal, Vizianagarm.

P.Purushotama Anil Kumar
Assistant Professor
Department of Mechanical Engineering
Avanthi Institute of Engineering and Technology Cherukupally, Bhogapuram Mandal, Vizianagarm.

G.Ramu
Assistant Professor
Department of Mechanical Engineering
Avanthi Institute of Engineering and Technology Cherukupally, Bhogapuram Mandal, Vizianagarm.