DESIGN AND ANALYSIS OF WIND TURBINE BLADE -STRUCTURAL ANALYSIS

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Abstract: A windmill is a mill that converts the energy of wind into rotational energy by means of vanes called sails or blades. The majority of modern windmills take the form of wind turbines used to generate electricity, or wind pumps used to pump water, either for land drainage or to extract groundwater. A wind turbine is a windmill-like structure specifically developed to generate electricity.The smallest turbines are used for applications such as battery charging for auxiliary power for boats or caravans or to power traffic warning signs. Slightly larger turbines can be used for making contributions to a domestic power supply while selling unused power back to the utility supplier via the electrical grid.In this project we are going to design a blade for small turbines using catiaV5 and analyse for a Epoxy material using ANSYS in order to give a good advantages of using that in a safe manner. Also,to initiate the advantages and disadvantages of the blades.So that the production time may also reduced.

***Index Terms* – EPOXY, CATIAV5, ANSYS etc…**

INTRODUCTION:

A wind turbine is a power generating device that is driven by the kinetic energy of the wind. Wind turbines general fall into one of two categories: Horizontal axis wind turbines (HAWTs) and vertical axis wind turbines (VAWTs). HAWTs, the more common type, consist of propeller-like rotors fixed around a central hub and facing into the wind, like a windmill. In a VAWT, blades surround the drive shaft of the turbine. The device resembles a giant push mower laid on its side and extending into the sky.

Both types use bladed rotors of various designs driving a shaft to a generator that uses electromagnetic induction to produce a voltage.

Among these two HAWT is more efficient than VAWT because,Comparing to horizontal-axis wind turbine (HAWT), stall control can only be used in VAWT as it is difficult to incorporate aerodynamics control such as variable pitch and aerodynamic brake, so the overall power efficiency is lower than HAWT.

Smallest turbines are used for applications such as battery charging for auxiliary power for boats or caravans or to power traffic warning signs. Slightly larger turbines can be used for making contributions to a domestic power supply while selling unused power back to the utility supplier via the electrical grid.

Today, small-scale Horizontal axis wind turbines for individual use generally have a maximum output of 400-1600 watts. In contrast, the largest industrial turbines might generate as much as 7.5 megawatts of wind power.

From small scale industries, they are looking for the turbine blades with more efficiency and should have more lifetime. In order to achieve that, we are going to design a blade by using PVC which is more economical in production and has good lifetime.

A. PARTS OF WIND TURBINE:

The principle behind wind turbines is very simple: the energy in the wind turns the blades around a rotor. The rotor is connected to the shaft, which spins a generator to create electricity. Wind turbines are mounted on a tower to capture the energy from the wind. The higher the blades are, the more they can take advantage of faster and less turbulent wind. A simple wind turbine consists of three main parts, the blades, shaft and generator.

Tower

A tower that supports the nacelle and rotor hub at its top. These are made from tubular steel, concrete, or steel lattice. Height of the tower is an important in design of HWAT. Because wind speed increases with height, taller towers enable turbines to capture more energy and generate more electricity. Generally output power of the wind system increase with increase in height and also reduces the turbulence in wind.

Blades

Wind turbine blades are used to extract the kinetic energy of wind and convert to mechanical energy. These blades are made up of fiber glass-reinforced polyester or wood-epoxy. Wind turbines have one or two or three or multiple blades based up on the construction. Most of the HAWT have three blades. These are connected to rotor hub. Multiple blade concept is used in earlier days for pumping water and grinding etc..

Hub

A rotor hub is provided for coupling a wind turbine rotor blade and a shaft. The hub assembly consists of hub, bolts, blade bearings, pitch system and internals . Rotor hubs are made with welded sheet steel, cast iron, forged steel.

Drive shaft

Drive shafts are a hollow or solid steel hardened shaft under very high stresses and considerable torque. Drive shafts are used to transfer rotational mechanical energy from blade hub to the generator to produce electricity.
A housing which contains all the components which is essential to operate the turbine efficiently is called a nacelle. It is fitted at the top of a tower and includes the gear box, low- and high-speed shafts, generator, controller, and brakes. A wind speed anemometer and a wind vane are mounted on the nacelle.

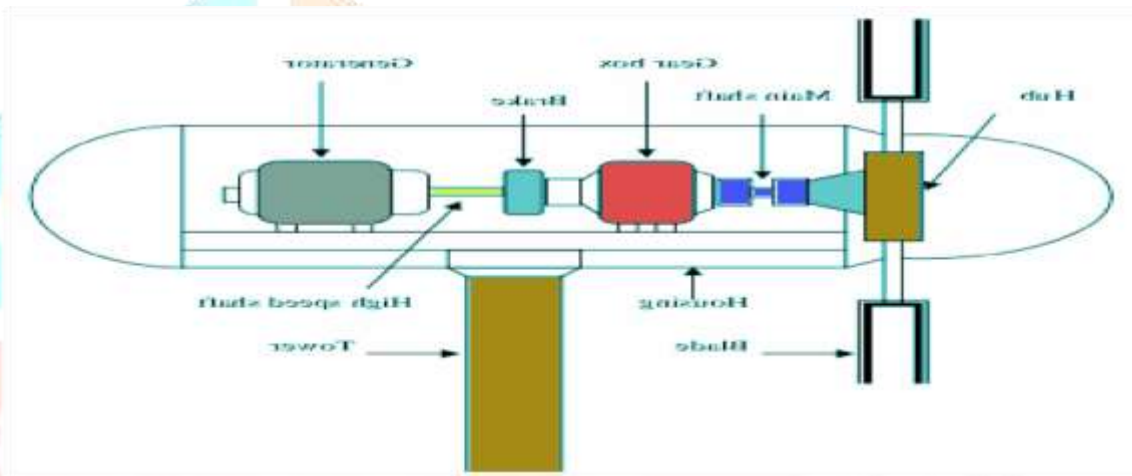

Fig.1

Generator

The output rotational mechanical energy of the gear box is connected to the generator through generator shaft. It works on the principle of 'Faraday's law of electromagnetic induction". It converts mechanical energy into electrical energy.

Wind vane

Wind vanes are used to measure the wind directions and communicates with the yaw system to orient the turbine properly with respective to wind directions, to extract maximum amount of power from wind. Wind turbines are oriented to upstream wind or down stream wind.

Anemometers

Wind speed is the most important factor for determining the power content in the wind.

B. DIMENSIONS OF BLADE DESIGN:

The blade is of various dimensions.According to the requirement of usage of wind turbines the blade will be designed.Here we used a small wind turbine blade at specific dimensions.It is as follows,

S.NO	PARAMETRES	DIMENSIONS
1	LENGTH	2meters
2	BREATH	1meter
3	DIAMETER	5meters
4	THICKNESS	200mm

PROPERTIES OF EPOXY MATERIAL:

Mechanical properties:

Glass transition temperature (Tg)	120 - 130 °C
Tensile strength	85 N/mm²
Tensile Modulus	10,500 N/mm²
Elongation at break	0.8%
Flexural strength	112 N/mm²
Flexural Modulus	10,000 N/mm²
Compressive Strength	190 N/mm²

PROPERTIES OF BLADE:

Material properties:

Modern wind turbines are designed to spin at varying speeds (a consequence of their generator design, see above). Use of aluminum and composite materials in their blades has contributed to low rotational inertia, which means that newer wind turbines can accelerate quickly if the winds pick up, keeping the tip speed ratio more nearly constant. Operating closer to their optimal tip speed ratio during energetic gusts of wind allows wind turbines to improve energy capture from sudden gusts that are typical in urban settings.

Force properties:

The blade experiencing two forces.Lift force and the drag force. The definition of these forces are,

1)Lift force:

Lift is the force used to overcome gravity and is defined to be perpendicular to direction of the oncoming airflow.This lift force should be maximum in rotation.

2)Drag force:

The drag force is defined as a force parallel to the direction of oncoming airflow. The drag force is due both to viscous friction forces at the surface of the aerofoil and to unequal pressure on the airfoil surfaces facing toward and away from the oncoming flow.

Dynamic properties:

The dynamic properties are other external forces,which also includes temperature at the outfield,pressure at the outfield,and other physical phenomenons.Speed is also a major factor determining the generation of energy.

Time and speed ratio:

The time and speed are different terminologies which controls the entire performance of every object.This two cofficents are discussed as follows,

Time co-efficient:

Time is more evaluatable one.Based on the time we can able to calculate the performance of the wind turbine.Based on the time of rotation we can able to calculate the speed.

Speed co-efficient:

We can able to calculate the efficiency only by the speed at which the wind mill is rotating.The amount of power generation is also can be identified by the use of speed ratio.

DESIGN:

A. DESIGN CALCULATION:

Tip Speed Ratio(TSR) :
TIP SPEED RATIO (TSR) = (tip speed of Blade)/(wind speed).

Power (W) = 0.6 x Cp x N x A x V

Revolutions (rpm) = V x TSR x 60 / (6.28 x R),
Cp = Rotor efficiency,
N = Efficiency of driven machinery,
A = Swept rotor area (m),
V = Wind speed (m/s)
TSR = Tip Speed Ratio ,
R = Radius of rotor ,
Rotor efficiency can go as high as Cp = 0.48, but Cp = 0.4 is often used in this type of calculations.
The width of the blade is also called the blade chord. A good formula for computing this is:

Blade Chord (m) = 5.6 x R2/ (i x Cl x r x TSR2),
R = Radius at tip,
r = radius at point of computation,
i = number of blades, Cl = Lift coefficient, TSR = Tip Speed Ratio.

DESIGN OF PISTON USING CATIAV5:

Fig.2

ANALYSIS RESULT OF EPOXY BLADE:

A.STRESS ANALYSIS:

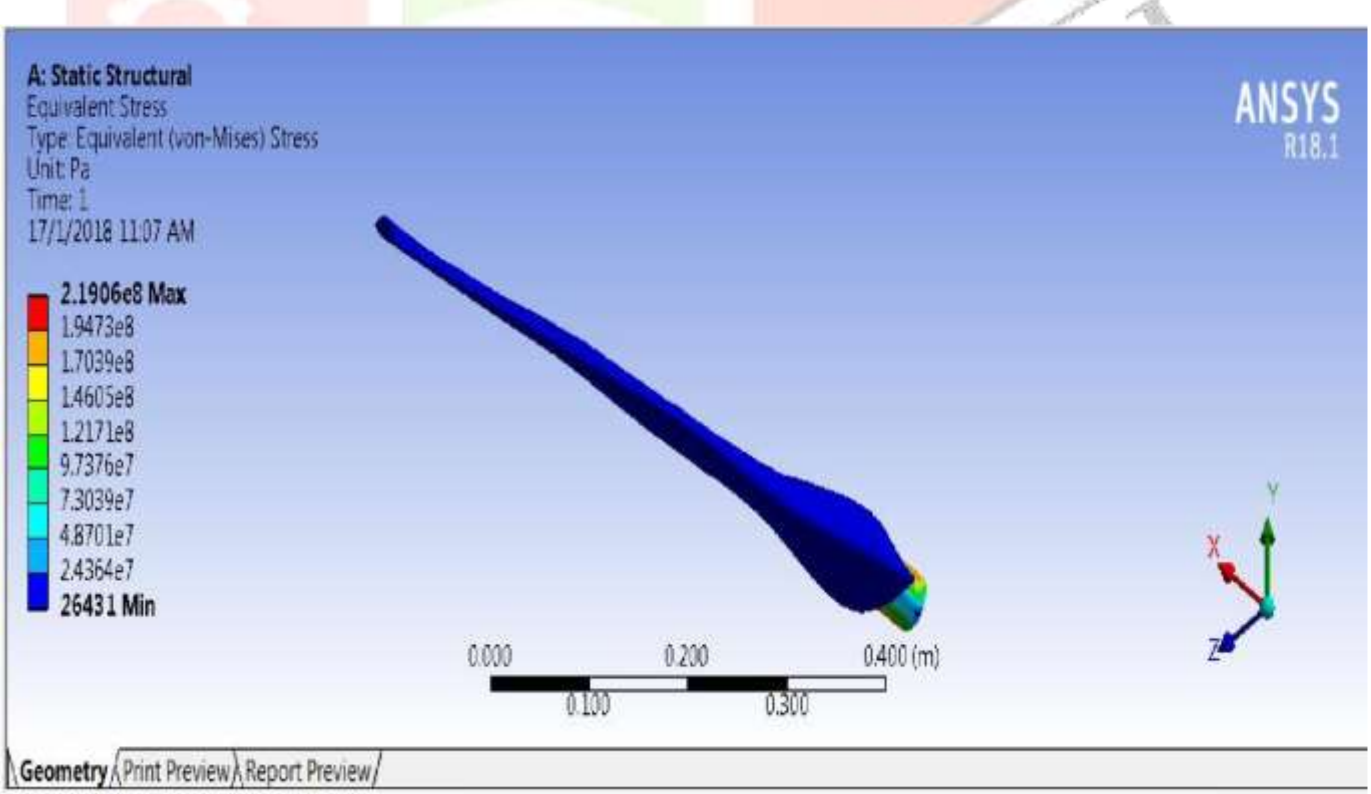

Fig.3

B.STRAIN ANALYSIS:

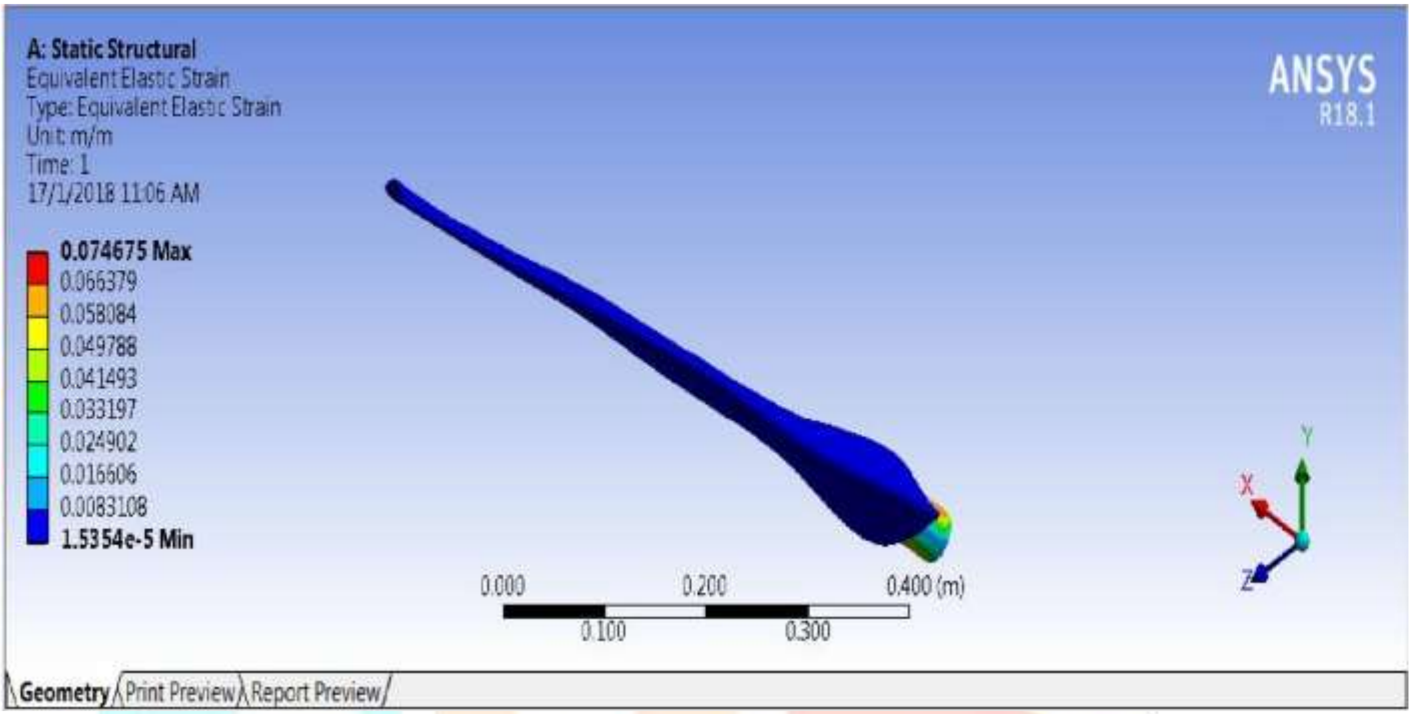

Fig.4

C.DEFORMATION ANALYSIS:

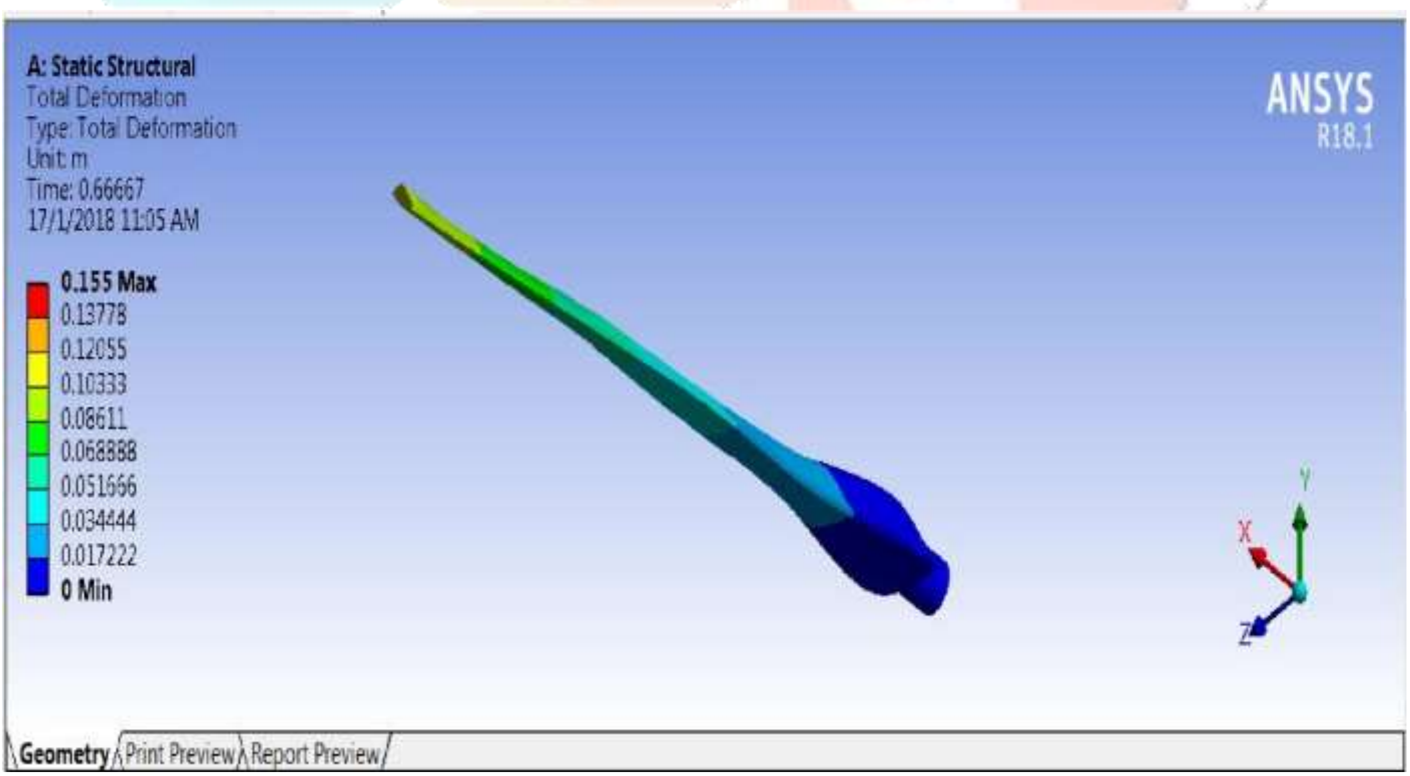

Fig.5

METHOD OF REINFORCING CARBON FIBRE:

Carbon fiber reinforced polymer, carbon fiber reinforced plastic or carbon fiber reinforced thermoplastic (CFRP, CRP, CFRTP or often simply carbon fiber, carbon composite or even carbon), is an extremely strong and light fiberreinforced plastic which contains carbon fibers. CFRPs can be expensive to produce but are commonly used wherever high strength-to-weight ratio and rigidity are required, such as aerospace, automotive, civil engineering, sports goods and an increasing number of other consumer and technical applications.

The properties of the final CFRP product can also be affected by the type of additives introduced to the binding matrix (the resin). The most frequent additive is silica, but other additives such as rubber and carbon nanotubes can be used. The material is also referred to as

graphite-reinforced polymer or graphite fiber-reinforced polymer (*GFRP* is less common, as it clashes with glass-(fiber)-reinforced polymer). The two different equations governing the net elastic modulus of composite materials using the properties of the carbon fibers and the polymer matrix can also be applied to carbon fiber reinforced plastics.

$$E_c = V_m E_m + V_f E_f$$

Where,

E_c = Total composite modulus

V_m = Volume fraction of matrix

V_f = Volume fraction of fibre

E_m = Elastic moduli of matrix

CONCLUSION:

Thus,we concluded that when the epoxy is reinforced with carbon fibre,the material will become so hard,stiffness and has good properties which is very much good for manufacturing the wind turbine blade.In this work, an optimised horizontal axis wind turbine rotor blade is modelled by using the airfoil geometries created at various sections along the span of the blade. The obtained geometry is then transferred to finite element modelling environment and the material properties are assigned. For the investigation of both the dynamic and static behaviour of the blade, various analyses are performed regarding the finite element mesh independency check, for diversity of boundary conditions and layer orientations configuration.

Regarding the effect of the layer orientation both on modal and static analyses, the original configuration could be made stiffer by applying all layers in the degree direction. Some changes are observed in the order of appearance of the normal modes regarding the new layer orientations (i.e. 0 and 90 degrees) with respect to that of the original one.

The obtained analysis results of this particular research study show that the normal modes are highly coupled and needed to be investigated in details. This requires an experimental modal testing which is an ongoing process. This study proposed the proper structural test method to be applied to the full scale prototype through the sub scale model structural test.

Thus our project is successfully completed and the results are successfully analysed and verified.The results obtained are checked and our project is very much able to furnish for further developments in the future.

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