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Design and Analysis of Horizontal Axis Windmill Turbine Blade

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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. Centuries ago, windmills usually were used to mill grain, pump water, or both they often used gristmills, wind pumps, or both. Daniel Halladay was the first to design windmills in New England. The majority of modern windmills take the form of wind turbines used to generate electricity. Wind turbines also include a utility box, which converts the wind energy into electricity and which is located at the base of the tower.
In these days, composite materials are widely used in varieties of Engineering Application due to its superior Mechanical Properties which have high Strength to Weight ratio, high stiffness, high fracture toughness, high Corrosion resistance and low thermal conductivity and many more.
The wind turbine blade sustains various kinds of loadings during the operation and parking state. Most of the composite blades are made of glass fibers composites while carbon fibers are also employed in recent years.
In this investigation, wind mill turbine blade was modeled using pro-E (creo-5.0) and static analysis was carried out using ANSYS software package. In this investigation four different composite materials were considered namely, carbon/Epoxy, E-Glass/Epoxy, Carbon-Sic/Epoxy and Al-Sic/Epoxy.
The design constraints considered in this investigation were stresses and deformations. The induced stresses and deformations have been compared with the permissible limits of material selected.
Finally a comparison is made among the different composite materials considered in this investigation in terms of stresses, deformations, stiffness and percentage weight saving. From the experimental results it is confirmed that Al-Sic/Epoxy exhibited better results among the other materials.

1. Introduction

1.1. 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).

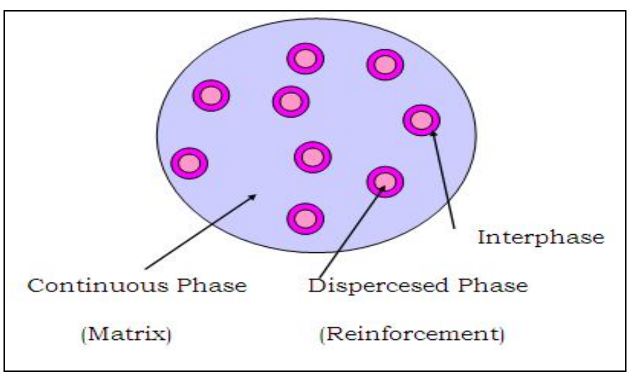

Figure 1: Composite Constituents

Reinforcement provides strength and rigidity, helping to support structural load. The matrix or binder (organic or inorganic) maintains the position and orientation of the reinforcement. The reinforcement may be platelets, particles or fibers and are usually added to improve mechanical properties such as stiffness, strength and toughness of the matrix material. Long fibers that are oriented in the direction of loading offer the most efficient load transfer. This is because the stress transfer zone extends only over a small part of the fiber-matrix interface and perturbation effects at fiber ends may be neglected. In other words, the ineffective fiber length is small. Popular fibers available as continuous filaments for use in high performance composites are glass, carbon and 8 fibers.

1.2. Characteristics of Composites

The composites characteristics that have made them useful and unique are:

1.2.1. Strength

One of the most important characteristics of the composites is their strength. As they are very hard and rigid they provide the required strength for all structures that they are used for such as buildings, ships in combination with low weight. Tensile strength, which is the capacity to bear stress, is four to six times greater than that of aluminum etc. Structures made of composites are 30-40% lighter than similar ones made of aluminum. The high strength, low weight and excellent design flexibility allows them to be easily molded into structures that have such requirements.

The strength of composites may be hindered as a result of different environmental interaction. As recent study shows that the tensile and recent study shows that the tensile transverse strength of composite resins demonstrate lower values after storage and test in water as compared to dry condition due to its water absorption.

1.2.2. The Reinforcement may be Platelets, Particles or Fibers and are Usually Added to Improve Mechanical Structures

This is the reason that fiber composites have various structural applications. The stiffness can be tailor made and usually depends on the spatial configuration of the reinforcements. It also depends on the type of fiber used, as the synthetic fiber composites are stiffer than the natural fiber ones.

1.2.3. Expense

A lot of composites are manufactured at a lower cost as compared to other material such as steel, concrete etc.

1.2.4. Environmental Sustainability and Sustainability of Composites

A lot of research is being conducted in order to see which plants can provide raw material for composites and how to make them more environmental friendly. The use of composites have reduced the impacts on the environment as it has reduced the use of various toxic compounds and increased that of environment friendly products. It helps in various natural disasters such as earthquakes. Houses may be built in earthquake zones using lightweight composites and therefore may help in reducing the impact on human life when disaster strikes. Indeed most earthquake related deaths occur due to the fact that people are being buried under heavy concrete and metal beams. Lightweight structures have increased fuel efficiency in cars, buses, ships, etc., thus saving on fuel consumption and increased payload.

1.3. Types of Composite

For the sake of simplicity, however, composites can be grouped into categories based on the nature of the matrix each type possesses. Methods of fabrication also vary according to physical and chemical properties of the matrices and reinforcing fibers.

1.3.1. Blends

A blend is a mixture of two or more substances. These materials can be polymers, metals, or other components. There is no chemical bonding between the components in the blends rather links are created as a result of intermolecular forces that do occur. This blend can be quite homogenous in some cases. Some blends are mixed on the order of 1 millionth of a meter (molecular) while some are just homogenous to the naked eye.

1.3.2. Nano composites

Composites in which the fiber reinforcement is on the extremely small Nano scale (1x10-9 meters) are known as Nano composites. Clay particles are a common Nano component in composites that offers a selection of applications not seen in other large fiber composites.

1.3.3. 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.

1.3.4. Ceramic Matrix Composites (CMCs)
Ceramic matrix composites have ceramic matrix such as alumina, calcium, alumina silicate reinforced by silicon carbide. The advantages of CMC include high strength, hardness, high service temperature limits for ceramics, chemical inertness and low density. Naturally resistant to high temperature, ceramic materials have a tendency to become brittle and to fracture. Composites successfully made with ceramic matrices are reinforced with silicon carbide fibers. These composites offer the same high temperature tolerance of super alloys but without such a high density. The brittle nature of ceramics makes composite fabrication difficult. Usually most CMC production procedures involve starting materials in powder form. There are four classes of ceramics matrices: glass (easy to fabricate because of low softening temperatures, include borosilicate and alumina silicates), conventional ceramics (silicon carbide, silicon nitride, aluminum oxide and zirconium oxide are fully crystalline), cement and concreted carbon components.

1.3.5. Polymer Matrix Composites (PMCs)
The most common advanced composites are polymer matrix composites. These composites consist of a polymer thermoplastic or thermosetting reinforced by fiber (natural carbon or boron). These materials can be fashioned into a variety of shapes and sizes. They provide great strength and stiffness along with resistance to corrosion. The reason for these being most common is their low cost, high strength and simple manufacturing principles. Due to the low density of the constituents the polymer composites often show excellent specific properties.

1.4. Structural Composites
Common structural composite types are

1.4.1. Laminar
Laminar is composed of two-dimensional sheets or panels that have a preferred high strength direction such as found in wood and continuous and aligned fiber-reinforced plastics. The layers are stacked and cemented together such that the orientation of the high-strength direction varies with each successive layer. The arrangement of laminas in a laminate is shown in figure 2.

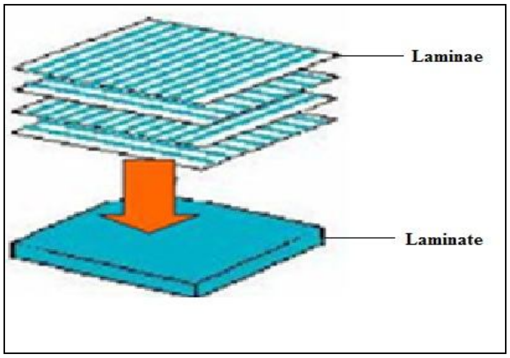

Figure 2: Lamina and Laminate

1.4.2. Sandwich Structures
A sandwich-structured composite is a special construction that is fabricated by attaching two thin but stiff skins to a lightweight but thick core. The core material is normally low strength material, but its higher thickness provides the sandwich composite with high bending stiffness with overall low density.
Open and closed cell structured foam, balsa wood and syntactic foam, and composite honeycomb are commonly used core materials. Glass or carbon fiber reinforced laminates are widely used as skin materials. Sheet metal is also used as skin materials in some cases. They are commonly being used in ship construction, building, bridges, trains, car doors, panels etc. In construction new green sandwich structures are also being introduced where the core is usually made from the natural materials (wood) and the skin is made from earth (clay) instead of cement.

1.4.3. 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.

1.5. Constituents of Composites
The constituents or materials that make up the composites are resins, fillers, additives and reinforcements (e.g. fibers).

1.5.1. Resin Systems

The resin is an important constituent in composites. The two classes of resins are the thermoplastics and thermo sets. A thermoplastic resin remains a solid at room temperature. It melts when heated and solidifies when cooled. The long-chain polymers do not form strong covalent bond. That is why they do not harden permanently and are undesirable for structural application. Conversely, a thermo set resin will harden permanently by irreversible cross-linking at elevated temperatures. This characteristic makes the thermo set resin composites very desirable for structural applications. The most common resins used in composites are the unsaturated polyesters, epoxies, and vinyl esters; the least common ones are the polyurethanes and phenolics.

1.5.2. Epoxies

The epoxies used in composites are mainly the glycidyl ethers and amines. The material properties and cure (hardening) rates can be formulated to meet the required performance. Epoxies are generally found in aeronautical, marine, automotive and electrical device applications. Although epoxies can be expensive, it may be worth the cost when high performance is required. It also has some disadvantages, which are its toxicity and complex processing requirements. Most of the epoxy hardeners cause various diseases.

1.5.3. Vinyl Esters

The vinyl ester resins were developed to take advantage of both the workability of the epoxy resins and the fast curing of the polyesters. The vinyl ester has better physical properties than polyesters but costs less than epoxies. A composite product containing a vinyl ester resin can withstand high toughness demand and offer excellent corrosion resistance. Its properties are considered the best and it can adhere to reinforcements very well.

1.5.4. Polyurethanes

Polyurethanes are mainly used without reinforcements or in some case with fiber reinforcement. They are desired due their low cost, low viscosity and rapid hardening. They have less mechanical and less temperature tolerance as compared to the above mentioned thermo set resins. Polyurethanes are also related with resin toxicity. Most of their applications are in the car industry.

1.5.5. Phenolics

The phenolics resins are made from phenols and formaldehyde, and they are divided into resole (prepared under basic conditions) and novolac resins (prepared under acidic conditions). The phenolics are praised for their good resistance to high temperature, good thermal stability, and low smoke generation. They have a disadvantage due to their brittleness and inability to be colored until now.

1.5.6. Unsaturated Polyesters

The unsaturated polyester amounts to about 75% of all polyester resins used in USA. The advantages of the unsaturated polyester are its dimensional stability and affordable cost as well as the ease of handling, processing, and fabricating. Some of their special properties are high corrosion resistance and fire retardants. These resins are probably of the highest value for they have a balance between performance and structural capabilities. They have low cost and have good properties such as low viscosity. One disadvantage of unsaturated polyesters it has an impact of light and UV light. In this study the LCA that has been conducted uses polyester as a resin that, forms glass reinforced composite skins of the balsawood core and PVC foam sandwich structures.

1.5.7. Fillers

Since resins are very expensive, it will not be cost effective to fill up the voids in a composite matrix purely with resins. Fillers are added to the resin matrix for controlling material cost and improving its mechanical and chemical properties. Some composites that are rich in resins can be subject to high shrinkage and low tensile strength. Although these properties may be undesirable for structural applications, there may be a place for their use.

The three major types of fillers used in the composite industry are the calcium carbonate, kaolin, and alumina trihydrate. Other common fillers include mica, feldspar, Wollastonite, silica, talc, and glasses. When one or more fillers are added to a properly formulated composite system, the improved performance Strength to bear stress includes fire and chemical resistance, high mechanical strength, and low shrinkage. Other improvements include toughness as well as high fatigue and creep resistance. Some fillers cause composites to have lower thermal expansion. Wollastonite filler improves the composites toughness for resistance to impact loading. Aluminum trihydrate improves on the fire resistance or flammability ratings. Some high strength formulations may not contain any filler because it increases the viscosity of the resin paste.

1.5.8. Additives

A variety of additives are used in the composites to improve the material properties, aesthetics, manufacturing process, and performance. The additives can be divided into three groups catalysts, promoters, and inhibitors; coloring dyes; and, releasing agents. The additives can alter the processing ability, mechanical properties, electrical properties shrinkage, environmental resistance, crystallization, fire tolerance and cost.

1.5.9. Reinforcements

It is the reinforcements that are the solid part of the composites, which are reinforced in to the matrix. They determine the strength and stiffness of the composites. Most common reinforcements are fibers, particles and whiskers. Fiber reinforcements are found in both natural and synthetic forms. Fiber composite was the very first form of composites, using natural fiber such as straw was reinforced in clay to make bricks that were used for building. Particle reinforcements are cheaper and are usually used to reduce the cost of isotropic material. Whiskers are pure single crystals manufactured through chemical vapor deposition and are randomly arranged in the matrix. They are also isotropic but this type of reinforcement is very expensive. Among these reinforcements the long glass fiber (12 to 50 mm) are the ones most commonly used. There four kinds of fiber reinforcements, which are:

1.6. 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 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.

1.7. 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.

1.8. Application of Fiber Composites

Today with all the advancement in life, growing population and its increasing needs we have to consider how to meet those needs by producing the best and making it available for all. Fiber reinforced composites are helping to fulfill the needs of this growing population. They have been and are being studied in order to maximize their utilities in different fields. This part of the chapter will look into the various fields that fiber reinforced composites are being used and what are their environmental impacts.

Application of fiber composites are represented by the following groups which are 70% of the total market value: automotive (23%), building and public works (21%), aeronautics (17%) and sports (11%). North America represents 40% of the composites industry's total market value, with 35% for Europe, 22% for the Asia-Pacific region and 3% for the rest of the world.

1.9. Fiber Composites in Construction

The very first known application of fiber composites was in construction. Straw reinforced clay bricks were used by the Egyptian Pharaohs, Israelites and Chinese centuries ago. Nowadays the construction is the field of greatest application of fiber composites. The property of composites of being strong and resistant to environmental impacts makes them good building material. Its weight helps only in case of transportation of this material as they are lightweight and can easily be transported. Its light structure may help in earthquake prone region. The fiber composites being lightweight and strong and has an ability to absorb and reduce seismic wave unlike heavy stones, bricks, mortar, granite etc. Being lightweight and fixed with nuts and bolts help in lateral movement and in case of collapse reduces threats to human life. In Gujarat India such fiber composite houses have been installed in an earthquake prone region in order to reduce the impacts of future earthquakes. Flexible concrete is also made using fiber reinforcements that can withstand earthquakes. Foldable structures have been introduced and are available due to the fiber composites otherwise making of foldable structures out of cement and a bricks is a difficult task. As mentioned earlier, the first application of glass fiber reinforced composites was in a dome structure in Benghazi in 1968. Today glass fiber reinforced composites are used in footbridges as well as Highway Bridge in Bulgaria. The first fully instrumented all-composite two-lane vehicle bridge, with an extensive health-monitoring system, was installed in US. Nearly four-year long continuous monitoring was carried out to demonstrate the performance of the bridge. Field monitored information was studied to evaluate the behavior and durability of composites in the harsh infrastructure environment. This evaluation showed the level of confidence in the long-term field benefits of composite materials and technology. Since the early 1990s, there has been an increase in the use of small protruded structural shapes for the construction of industrial platforms, pedestrian bridges, latticed transmission towers, and for other applications. Application of composites in construction in the civil engineering applications which is shown in figure 3.

Figure 3: Application of composites in construction

As mentioned before, the quality of fiber composites of being light weight and strong has been put into use in the aircraft, rockets, and other equipments used in aerospace. A new low cost resin system has been used to produce a composite elevator. It is widely used because of stiffness to density ratio and exceptional strength. The use of fiber composites in the transport has provided 15-30% weight saving thus increasing fuel efficiency and lowering maintenance and operation costs. Fiber composites are easier to shape according to aerodynamic rules and are therefore being widely used in rockets and spaceships. First passenger carrying spaceship was made used fiber composites it has 24.8 m wingspan.

Ballistic composites are materials with superior properties being lightweight and durable under environmental conditions, (water and chemicals) with high performance (high strength, impact and ballistic resistance, damage tolerance). Lightweight ballistic composites are used in a wide range of lightweight vehicles, watercraft and aircraft armor giving high performance and lightweight protection against bullets and fragments. They also have exceptional insulating properties in high temperature environments. They are being used in missiles, tanks, fighter planes and retractable bridges. They can receive and send radar signals. And they are not magnetic thus help in wars from being easily targeted. Application of composites in Aerospace and Military is shown in figure 4.

Figure 4: Application of composites in Aerospace and Military

1.10. Fiber Composites in Transportation

Fiber composites are being used is car industry. The reason for their increasing demand in this industry is because the strength and stiffness in combination with low weight decreases the fuel consumption. It is said to save up to 27% of the weight in most of the structures. All vehicles from train to cars as well as bicycles are now using fiber composites. They are not only being used in the exterior but a lot of car parts are also being made from composites which include radiators, ignition components, spoilers, door panels, hoods, hatchbacks, roof panels, bonnets, wing mirrors, rear light units, brake linings, Internal parts and trim where they are the solution to lightness, freedom of shape, freedom of design, matching internal decor and providing thermal and sound insulation. They are used to mold interior components for buses, seat squabs and bases, car door liners, back panel of seats, parcel shelves.

Composite materials are increasingly being used in the train industry, which has resulted in high performance and lower costs. Weight savings of up to 50% for structural and 75% for non-structural applications brings associated benefits of high-speed, reduced power consumption, lower inertia, less track wear and the ability to carry greater pay-loads. Application of composites in transportation (Ex: Mercedes Benz E-Class) is shown in figure 5.

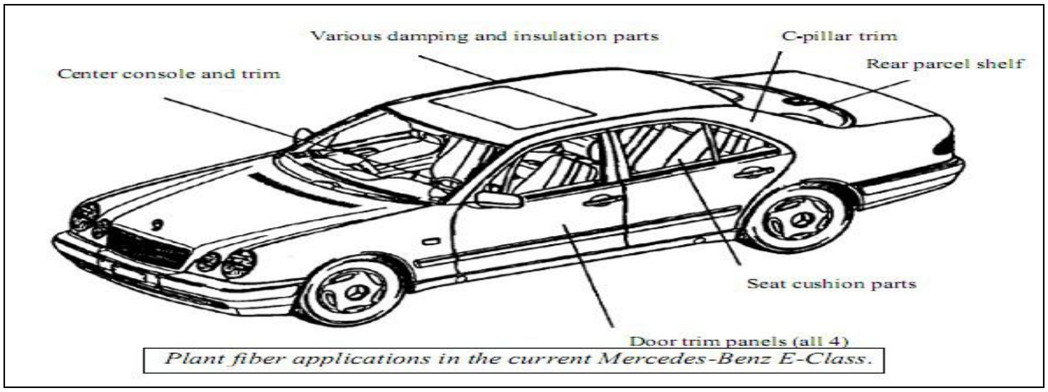

Figure 5: Application of composites in Mercedes Benz E-Class

Composites also provide greater versatility in train design and optimization of train performance (e.g. lowering the centre of gravity to enhance stability). High stiffness from structural materials reduces (even eliminates) supporting framework, increases passenger room, carries fittings readily. The construction of composites (interchangeable panels) is easy to handle and install and offers rapid fitting. Due to fire resistant characteristics, it also allows full safety to the entire system. Components of 25 coaches are generally made of glass fiber reinforced with polyesters/epoxies phenolic resins. Fiber composites are being used in Formula 1 cars as new and improved materials are being introduced that are fireproof.

1.11. Fiber Composites in Sports Goods

Another application of fiber composites is in sports goods. Nowadays wooden racquets and fishing rods are almost history. Wood is rarely being used for sports goods. In sports where the time and strength is what is required fiber composites are playing a great role. When designing sport equipment most important things to consider are strength, ductility, density, fatigue resistance, toughness and cost. With introduction of new materials in sports new records have be set. Initially bamboo stem was used for pole vaulting then came the aluminum and now sophisticated fiber composites are being used. These have layers of different fibers, which optimize the performance with an outer layer of high-strength carbon fiber providing high stiffness and an intermediate webbing of fibers together with an inner layer of wound-glass fiber building resistance to twisting.

Cycling is not limited to the Olympics or sports but has become one of the modes of transportation. China manufactures 10 million cycles per year. Since the first cycle that was built in 1817 a lot of advancements have taken place in the bicycle. The most important of these changes are that made in the frame and tires. Application of fiber composites in sports goods is shown in figure 6.

Figure 6: Application Of composites in Sports goods

In addition to the carbon-fiber-reinforced composite frames, frames have recently been produced from magnesium, aluminum, titanium, and metal-matrix composites.

1.12. Fiber Composites in Household Products

Fiber Composites have also made their way in to our homes on the basis of their useful properties. Manufacturing of the fireproof core of fire resistant doors and screens, insulating and fire-resistant materials with different characteristics are being used, including a large number of materials comprised of insulators based on different silica compounds, e.g. fly ashes, which can be reinforced by fibers and produce fire resistant products with good thermal stability at high temperatures.

Furniture is now being produced which is made of fiber composites. They are being used because they can easily be shaped into various beautiful and fashionable shapes. With the help of additives they can easily be colored according to our taste. Being lightweight it is preferred over heavy wooden and steel furniture.

Various appliances in our homes are made from fiber composites such as vacuum cleaners, food processor etc. Bathtub swimming pools and other toiletries are also made from fiber composites. Children swings, joyride, water slide are another application of fiber composites.

The application of fiber composites in household products is shown in figure 7.

Figure 7: Application of composites in Household Products

1.13. Classification of Wind Turbine

The Wind mill turbines are of two types
1) Horizontal Axis wind Turbine
2) Vertical Axis Wind Turbine

Based on the axis of the Windmill turbine these are divided and placed on the top of the Windmill turbine. Both the turbines have different efficiency and power generating capacity and relative parameters also changes. The Schematic diagram of the wind turbines are shown in the below sketches Figure 8 and Figure 9.

Depending on the place and direction and velocity of wind in that particular area this different turbines are manufactured as shown below. Both the turbines are used for the similar purpose that is for the power generation due to the wind.

Figure 8: Horizontal axis wind turbine

Figure 9: Vertical axis wind turbine

1.14. Based on size

- Small scale (up to 2KW).
- Medium size machine (2 – 100 KW).
- Large scale or Large size (100 KW and above).

1.15. Based on the type of output
- DC output.
- AC output.

1.16. Based on the rotation speed
- Constant speed – with variable pitch blades.
- Nearly constant speed – with fixed pitch blades.
- Variable speed with fixed pitch blades.

1.17. Based on the utilization of output
- Battery storage.
- Direct connection to an electromagnetic energy converter.
- Other forms of storage.
- Interconnection with conventional electric utility grids.

1.18. Based on the yaw control
- Yaw – fixed.
- Yaw – active.

1.19. Based on the direction of wind

Based on the force or pressure acting on the blades of the wind turbine it is divided into two types and they are

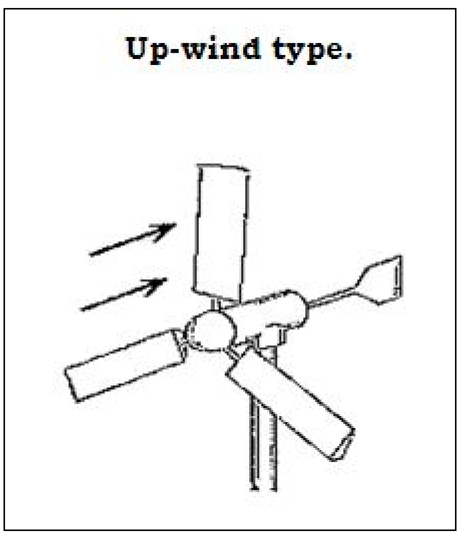

Figure 10: Up-Wind type

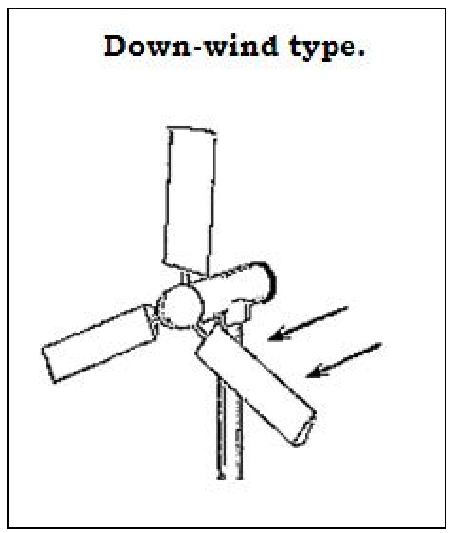

Figure 11: Down-wind type

1.20. Parts of a Horizontal Axis Wind Turbine

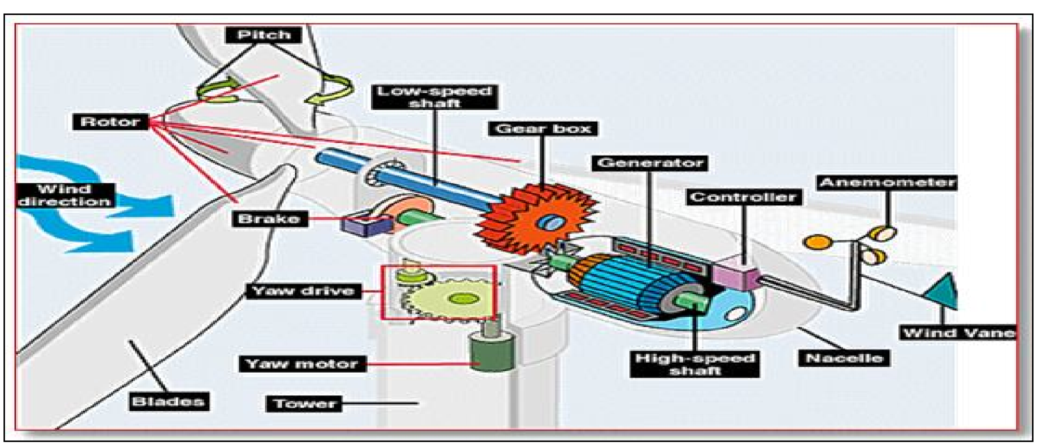

Figure 12: Wind Mill parts

The main components of a horizontal axis Wind turbine includes,

1. Tower.
2. Nacelle.
3. Rotor
4. Shaft.
5. Brake.
6. Gear box.
7. Generator.
8. Wind Vane.
9. Anemometer.
10. Yaw Mechanism.
11. Controller Unit.

1.21. Tower

The tower of the wind turbine carries the whole weight of the rotor and the nacelle. Hence it has to withstand heavy forces and should be made of material with a high strength. It must be a hollow one. It can be of two types namely lattice type and tubular type.

Figure 13: Lattice type

Figure 14: Tubular type

1.22. Nacelle

Nacelle is the part of the wind turbine which encloses the shaft, brake systems, generator and the gear boxes. This unit is kept on the top of the tower.

1.23. Rotor

The rotor is the main part of the wind turbine which converts the kinetic energy of the wind into mechanical energy. The rotor may be single bladed, two bladed or three bladed**.**

1.24. Shaft

The Rotor is bolted to a very strong disc on the main shaft of a wind turbine. It is important that the rotor is firmly secured by a lot of bolts. The gear box is placed at the other end of the main shaft.

The Rotor is bolted to a very strong disc on the main shaft of a wind turbine. It is important that the rotor is firmly secured by a lot of bolts. The gear box is placed at the other end of the main shaft.

Figure 15: Main Shaft

1.25. Brake

There are two types of brakes namely,

- Aerodynamic brakes.
- Mechanical brakes.

1.26. Mechanical Brake

This brake is achieved with the help of a brake disc coupled with the main shaft. When the mechanical brake alone is applied, the speed is suddenly reduced to 0 r.p.m. So the bearings and the gears may fail. To avoid the damage of the gears, aerodynamic brakes are applied first followed by the mechanical brake.

1.27. Aerodynamic Brake

The aerodynamic brake consists of a turn-able blade tip pivoted on a stainless steel shaft which is embedded in the blade beam along the main axis. During normal operating conditions, the blade tip is kept in place and aligned with the main blade by a hydraulic pressure in the blade cylinder which in turn pulls the wire to the blade tip tight.

1.28. Gear Box

The rotor turns with approximately 22 revolutions per minute (RPM). But the generator has to turn 1500 revolutions per minute. The gearbox converts the 22 revolutions to 1500 revolutions

1.29. Generator

The output from the gear box is given to the generator. The generator generates electricity based on the speed of output shaft. The output from the generator is given to the transformer through large electricity cables.

1.30. Wind Vane

The wind makes the wind vane turn. The wind vane gives a signal to the controller regarding the direction of the wind. The controller then gives a signal to the yaw motor to yaw (turn) the rotor up against the wind.

1.31. Anemometer

The anemometer measures the wind speed. It sends information about the wind speed to the controller all the time.

1.32. Yaw mechanism

The large cam wheel is mounted onto the tower.
The cam wheel of the yaw motor engages the large cam wheel and turns the nacelle with the rotor into the wind.

Figure 16: Yaw Mechanism

1.33. Controller Unit

The wind turbine controller is a computer that controls many parts of wind turbine. The controller turns the nacelle against the wind and allows the wind turbine rotor to start when the anemometer tells it that there is enough wind.

<u>1.33.1. Blade Element/Wake Momentum Met</u>

The Blade Element Momentum Met (BEM) is computational method which is widely used for performance predictions of rotating wings: marine aircraft propellers, helicopter rotors and wind turbine blades. Its general premise is quite simple, and involves modeling the blade propeller in questions as span – wise series of “extruded” two dimensional aerofoil sections.
Leon Mishnaevsky [1] describes the current research efforts of Sandi's Wind energy department which are primarily aimed at developing large rotors.
Benkwith [2] has demonstrated overview of resin infusion technology for composite manufacturing.
Bian [3] In several work, the possibilities of improvement of composite properties by adding Nano-reinforcement in matrix were demonstrated. Addition of small amount (at the level of 0.5 weight %) of nano reinforcement (carbon nanotubes or nanoclay) in the polymer matrix of composites.
Brohsted, et. al. [4] demonstrated wind power for the composite materials of turbine blades providing overview of manufacturing. The turbine was already produced by the company SEES at the Gendser Coast. The connections between the success of wind energy generation technology and development of the composites for turbine parts the turbine built with steel failed but the turbine with the

composite materials worked for many years.
Gamstedt et.al [7] demonstrated the Fatigue Degradation and failure of Rotating Composite Structures-Materials Characterizations and underlying mechanisms and report the reviews the damage mechanisms in rotating Structures.
From the literature review as well as to the author's knowledge no comprehensive work was carried out in the analysis of Horizontal axis wind mill turbine. Hence in the present work, an attempt is made to replace the existing Glass/Epoxy with a Composite Materials made of three different materials viz.,, Carbon/Epoxy, C-Sic /Epoxy & Al-Sic/Epoxy. During the static analysis the physical dimensions of the Composite Wind Mill blade are considered same as that of E Glass/Epoxy.

2. Materials and Blade Design Terminology

2.1. Introduction

First non-oxide CMCs, based on carbon /carbon composites, were developed in the 1970s as lightweight structures for aerospace applications. They had to be designed as limited life structures as the environment conditions were highly aggressive and the long term behavior of these composites was still unknown. Typical representatives for components were rocket nozzles, engine flaps, and leading edges of spacecraft and brake disks of aircraft. Their lifetime comprises several minutes to some few under highest thermo mechanical requirements which cannot be fulfilled by any other structural material.
In order to improve the oxidation resistance and thus the application lifetimes of these composites, research has been exerted on using ceramics instead of carbon as the matrix material. Silicon carbide is particularly suitable as a matrix material due to its high oxidation resistance, its superior temperature and thermal shock stability and its high creep resistance. Practically, similar manufacturing techniques can be used for the silicon carbide matrix formation of C/Sic composites as for the manufacture of carbon/carbon composites. Generally, ceramic matrix composites have been developed to combine the advantageous properties of monolithic with a high damage tolerance, which is known for example from the reinforcing of fiber reinforcement polymers. However, the mechanism which causes high damage tolerance are completely different for both classes of material. polymers are reinforced with strong and stiff fibers, whereas the matrix is weak and of low strength, stiffness as well as thermal stability. A strong bonding between matrix and fiber is desired as a result of high fiber surface reactions. Based on the differences of stiffness between fibers and polymer, the matrix itself is stressed only slightly and the energy release rate of a matrix crack is low because of the modest matrix strength. Therefore, the highly loaded fibers are able to stop cracks without being damaged.
Ceramic matrix composites are characterized by the fact that the stiffness of both, fibers and matrix, are in the same order of magnitude. High fiber/matrix bonding result in stresses which are similar for the matrix as well as for fibers and the damage tolerance is comparable low to monolithic ceramics. The opposite case with extremely low fiber/matrix bondings leads to a nearly stress-free matrix and a high fracture toughness. However, as the deboning and shear properties mainly depend on frictional effects, such kinds of composites are usually not suitable as a structural material.
Similar to polymer and metal matrix composites, the CMC's fracture behavior and properties are dominated by the reinforcing fibers. But to an even higher degree the fibers must show a high stiffness and extreme thermal stability. Carbon fibers fulfill these requirements in an outstanding way. They are commercially available to various modifications, wearable to performs and carbon fibers show a very high thermal stability well above 2000 C. however, their main disadvantage is the degradation in an oxidation atmospheres beyond 450C,resulting in the need for an external oxidation protecting. It is known from oxidation kinetics that increasing the final heat treatment temperature results in an improved oxidation resistance of the C-fiber. Therefore the oxidation resistance is also improved by reinforcements with high modulus or ultra modulus carbon fibers in comparison to high tenacity fibers.

2.2. Ceramics

Ceramics are non-metallic in nature and refer to the carbide, boride, nitride and oxides of Aluminum, silica, zirconium, etc. However, the ceramics possess excellent resistance to thermal and chemical corrosion and wear resistant. Ceramics are also good thermal and electrical insulators.

2.3. Ceramic Matrix Materials

Ceramics can be described as solid materials which exhibit very strong ionic bonding in general and in few cases covalent bonding. High melting points, good corrosion resistance, stability at elevated temperatures and high compressive strength, render ceramic-based matrix materials a favorite for applications requiring a structural material that doesn't give way at temperatures above 1500ºC. Naturally, ceramic matrices are the obvious choice for high temperature applications. High modulus of elasticity and low tensile strain, which most ceramics posses, have combined to cause the failure of attempts to add reinforcements to obtain strength improvement. This is because at the stress levels at which ceramics rupture, there is insufficient elongation of the matrix which keeps composite from transferring an effective quantum of load to the reinforcement and the composite may fail unless the percentage of fiber volume is high enough. A material is reinforcement to utilize the higher tensile strength of the fiber, to produce an increase in load bearing capacity of the matrix. Addition of high-strength fiber to a weaker ceramic has not always been successful and often the resultant composite has proved to be weaker.
The use of reinforcement with high modulus of elasticity may take care of the problem to some extent and presents pre-stressing of the fiber in the ceramic matrix is being increasingly resorted to as an option. When ceramics have a higher thermal expansion coefficient than reinforcement materials, the resultant composite is unlikely to have a superior level of strength. In that case, the composite will

develop strength within ceramic at the time of cooling resulting in micro cracks extending from fiber to fiber within the matrix. Micro cracking can result in a composite with tensile strength lower than that of the matrix.

2.4. Silicon Carbide Fibers

Silicon carbide can be coated over a few metals and their room temperature tensile strengths and tensile modules are like those boron-tungsten. The advantages of silicon carbide-tungsten are several and are more desirable than uncoated boron tungsten fibers. Elevated temperature performance and the fact that they reported only a 35% loss of strength at 1350ºC are their best qualities. Silicon carbide-tungsten and silicon carbide-carbon have both been seen to have very high stress-rupture strength at 1100ºC and 1300ºC. Uncoated boron-tungsten fibers do not react with molten aluminum, unlike uncoated boron and they also withstand high temperatures used in hot-press titanium matrices.

However, Silicon carbide-tungsten fibers are dense compared to boron tungsten fibers of the same diameters. They are prone to surface damage and need careful, delicate handling, especially during fabrication of the composite. Further, above 930ºC weakening reactions occur between tungsten and silicon carbide, making it different to maintain balance in high-temperature matrix formations.

Silicon carbide on carbon substrates have several advantages, viz. no reaction at high temperature, being lighter than silicon carbide tungsten and possessing tensile strengths and modulus that is are often better than those of silicon carbide-tungsten and boron fibers.

2.5. Innovative Materials

A composite material that combines carbon fibers within a ceramic matrix to maximize material properties. Carbon fiber reinforced silicon carbide C-Sic is manufactured at SGL Carbon GmbH by infiltrating carbon fiber-reinforced with silicon carbide. The fiber-reinforcing materials used are short and long carbon fibers, woven carbon fabrics, felts, etc. Outstanding features are:

- High fracture toughness
- Low density
- Low wear rates
- Good corrosion resistance
- Exceptional hardness
- High thermal stability

2.6. Applications

Because of the high stability against tear and wear, the high mechanical strength, the impressive temperature and thermal shock stability and the low coefficient of thermal expansion SIGRASIC is an excellent alternative to conventional materials.

They are suitable for industrial applications such as:

- Structural components shaped to close geometric tolerances
- Components for high-temperature applications
- Components for chemical process equipment
- Structural components for aerospace technology
- Components for semiconductor technology

Oxidation and the thermal shock resistant of the components for the glass fiber is processing in industry.

2.7. Calculation of All the Parameters

From all the values of specifications and considered parameters like wind speed, profile diameter, the calculations like Force, Pressure, Edge Wise area, Flap wise area, stiffness are calculated below

Force $F = \pi/9*\rho*V^2*D^2$

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

Edgewise Area = 46.9619 m². It is area of the blade taking edge wise

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

Flap wise Pressure P=220532.67/79.9634=2758 N/m².(Pressure acting on the flap of blade)

Edgewise Pressure P = 220532.67/46.9619 = 4696 (Pressure acting on the flap of the blade)

- For the 50% 0f glass fiber and 50% Epoxy the deflection of blade is 286.64 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=Force/Deformation

Stiffness acting on the windmill Blade= 220.532/86.52

=2548 N/mm

- For the 50% 0f Carbon fiber and 50% Epoxy the deflection of blade is 76.47 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=Force/Deformation
Stiffness acting on the windmill Blade= 220.532/76.47
=2883.9 N/mm

- For the 25% of carbon and 25% Silicon Carbide/50% Epoxy the deflection of the blade is 120.87 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=Force/Deformation
Stiffness acting on the windmill Blade=220.532/120.87
=1824.53 N/mm

- For the 25% 0f Aluminum 25% of Silicon Carbide/50%

Epoxy the deflection of the blade is 57.37 and the mass of the entire blade is 82 kg.
Force acting on the blade is 220.532 K-N
Stiffness acting on the Windmill Blade=Force/Deformation
Stiffness acting on the windmill Blade= 220.532/57.37
=3844 N/mm

2.8. Blade Design Terminology of Composite Materials

2.8.1. Angle of Attack (α)
It is the angle between the direction of the resulting wind velocity on the blade and the chord line of the blade airfoil section

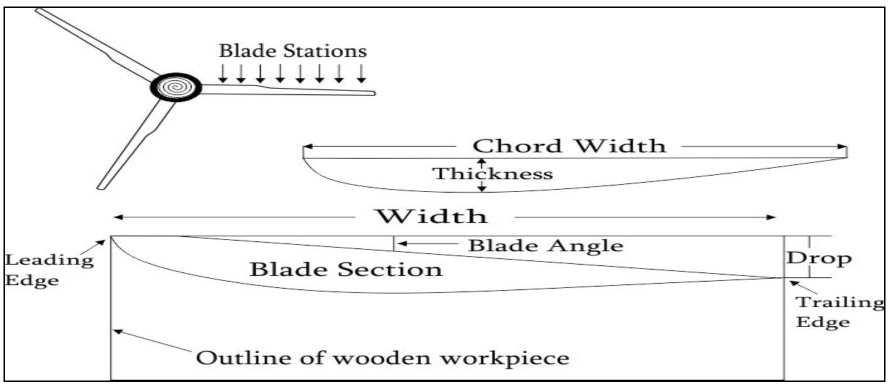

Figure 17: Wind Mill Blade

2.8.2. Blade Angle (θ)
Angle between the plane of the rotor and the local chord line of the blade profile.

2.8.3. Camber-Line
A blade section of infinitesimal thickness is a curved line known as " camber line". This forms a backbone line of a blade of
A blade section of infinitesimal thickness is a curved line known as " camber line". This forms a backbone line of a blade of finite thickness.

2.8.4. Chord Line
It is a straight line connecting an airfoil's leading and trailing edges.

2.8.5. Cut in Wind Speed (V_{in})
It is the lowest mean wind speed at hub height at which the wind turbine starts to produce power.

2.8.6. Cut Out speed (V_{out})
It is the highest mean wind speed at hub height at which the wind turbine is designed to produce power.

2.8.7. Drag Force (F_D)
It is the force acting on the wind turbine blade parallel to the direction of relative wind velocity

2.8.8. Hub Height
It is the height of the centre of the rotor above the terrain surface

2.8.9. Lift Force (F_L)
It is the force acting on the wind turbine blade perpendicular to the direction of relative wind velocity

2.9. Power-Coefficient(C_P)

The power coefficient C_P is the ratio of the power output from the wind turbine to the power available in the wind

2.9.1. Projected Area (A)

Area covered at any instant by the rotor blades, as seen from the direction of wind velocity. (Area solidly covered by the blades as opposed to the swept area).

2.9.2. Rated Speed

It is the specified wind speed at which a wind turbines rated power is achieved

2.9.3. Rotar Diameter (D)

It is the diameter of the circular swept area of the rotor and blade assembly for a HAWT.

2.9.4. Rotar Speed:

It is the rotational speed of a wind turbine rotor about its axis

2.9.5 Solidity (S)

It is the ratio of rotor projected area to the swept area of the rotor.

2.9.6. Survival Wind Speed

It is the maximum wind speed that a wind turbine has been designed to sustain without damage to structural components or loss of ability to function normally.

2.9.7. Swept Area (A)

It is the projected area perpendicular to the wind direction that a rotor will describe during one complete rotation.

2.9.8 Tip-Speed (V_{tip})

It is the linear speed of a blade tip.

$V_{tip} = r*\omega$ (r - rotor radius, ω -angular speed

2.9.9. Tip-Speed Ratio (λ)

The ratio of the speed of the rotor tip to the speed of the wind is known as tip – speed ratio.

2.9.10. Twist

It is the span wise variation in angle of the chord lines of blade cross-sections.

2.10. Upwards

It denotes the direction opposite to the main wind dir

2.10.1. Wind Vane

It is the device for indicating or recording wind direction.

2.10.2. Wind Velocity

It is vector describing the speed and the direction of wind.

2.10.3. Yaw Rate

It is the rate of change of nacelle yaw position

The structure of the airfoil is shown in the Fig 18 which consists of Shear Web, Shear Cap and also the skin of the airfoil

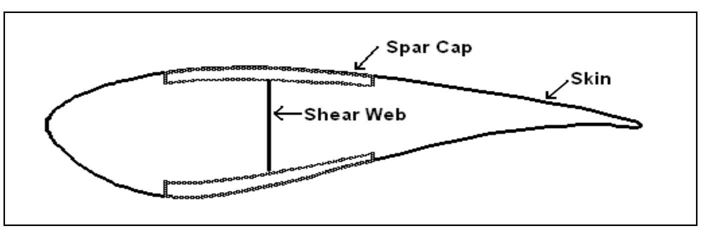

Figure 18: Structural cross section of an airfoil

3. Modeling and Analysis

3.1. Introduction of Modelling

Model is a Representation of an object, a system, or an idea in some form other than that of the entity itself. Modeling is the process of producing a model; a model is a representation of the construction and working of some system of interest. A model is similar to but simpler than the system it represents. One purpose of a model is to enable the analyst to predict the effect of changes to the system. On the one hand, a model should be a close approximation to the real system and incorporate most of its salient features. On the other hand, it should not be so complex that it is impossible to understand and experiment with it. A good model is a judicious tradeoff between realism and simplicity. Simulation practitioners recommend increasing the complexity of a model iteratively. An important issue in modeling is model validity. Model validation techniques include simulating the model under known input conditions and comparing model output with system output. Generally, a model intended for a simulation study is a mathematical model developed with the help of simulation software.

3.2. Solid Works

Solid modelling is the first step for doing any 3D analysis and testing. It also gives 3D physical picture for new products. FE models can be easily created from solid works by the process of meshing. Solid models can be prepared as testing models by giving this in ".stl" format to rapid prototyping machines. Rapid prototyping models give opportunity to show the model or assembly in presentation before it is manufactured.

FE models can be manually prepared for simple cases only, But if the model is of complex form (or) shape then, the only way for preparing FE model is "Meshing the Solid Model" using a suitable computer program.

Commercially available solid modelling packages are

I-DEAS

PRO-E

UNIGRAPHICS

In the present work Pro-E 5.0 software is used for modelling the Windmill turbine blade for different composite materials.

3.3. CAD/CAM

Computer aided design or CAD has very broad meaning and can be defined as the use of computers in creation, modification, analysis and optimization of a design. CAE (Computer Aided Engineering) is referred to computers in engineering analysis like stress/strain, heat transfer, and flow analysis. CAD/CAE is said to have more potential to radically increase productivity than any development since electricity. CAD/CAE builds quality form concept to final product. Instead of bringing in quality control during the final inspection it helps to develop a process in which quality is there through the life cycle of the product. CAD/CAE can eliminate the need for prototypes. But it required prototypes can be used to confirm rather predict performance and other characteristics. CAD/CAE is employed in numerous industries like manufacturing, automotive, aerospace, casting, mold making, plastic, electronics and other general-purpose industries. CAD/CAE systems can be broadly divided into low end, mid end and high-end systems.

Low-end systems are those systems which do only 2D modelling and with only little 3D modelling capabilities. According to industry static's 70-80% of all mechanical designers still uses 2D CAD applications. This may be mainly due to the high cost of high-end systems and a lack of expertise. Mid-end systems are actually similar high-end systems with all their design capabilities with the difference that they are offered at much lower prices. 3D sold modelling on the PC is burgeoning because of many reasons like affordable and powerful hardware, strong sound software that offers windows case of use shortened design and production cycles and smooth integration with downstream application. More and more designers and engineers are shifting to mid end system.

High-end CAD/CAE software's are for the complete modelling, analysis and manufacturing of products. High-end systems can be visualized as the brain of concurrent engineering. The design and development of products, which took years in the past to complete, is now made in days with the help of high-end CAD/CAE systems and concurrent engineering.

3.4. Creo

CreoElements/Pro(formerlyPro/ENGINEER), PTC's parametric, integrated 3D CAD/CAM/CAE solution, is used by discrete manufacturers for mechanical engineering, design and manufacturing. Created by Dr. Samuel P. Geisberg in the mid-1980s, Pro/ENGINEER was the industry's first successful rule-based constraint (sometimes called "parametric" or "variation") 3D CAD modelling system. The parametric modelling approach uses parameters, dimensions, features, and relationships to capture intended product behaviour and create a recipe which enables design automation and the optimization of design and product development processes. This design approach is used by companies whose product strategy is family-based or platform-driven, where a prescriptive design strategy is fundamental to the success of the design process by embedding engineering constraints and relationships to quickly optimize the design, or where the resulting geometry may be complex or based upon equations. Creo Elements/Pro-E provides a complete set of design, analysis and manufacturing capabilities on one, integral, scalable platform. These required capabilities include Solid Modelling, Surfacing, Rendering, Data Interoperability, Routed Systems Design, Simulation, Tolerance Analysis, and NC and Tooling Design. Like any software it is continually being developed to include new functionality. The details below aim to outline the scope of capabilities to give an overview rather than giving specific details on the individual functionality of the product.

Creo Elements/Pro-E is a software application within the CAD/CAM/CAE category, along with other similar products currently on the market. Creo Elements/Pro is a parametric, feature-based modelling architecture incorporated into a single database philosophy with advanced rule-based design capabilities. It provides in-depth control of complex geometry, as exemplified by the as per parameter. The capabilities of the product can be split into the three main headings of Engineering Design, Analysis and Manufacturing.

3.5. Engineering Design

Creo Elements/Pro-E offers a range of tools to enable the generation of a complete digital representation of the product being designed. In addition to the general geometry tools there is also the ability to generate geometry of other integrated design disciplines such as industrial and standard pipe work and complete wiring definitions. Tools are also available to support collaborative development.

A number of concept design tools that provide up-front Industrial Design concepts can then be used in the downstream process of engineering the product. These range from conceptual Industrial design sketches, reverse engineering with point cloud data and comprehensive free-form surface tools

3.6. Different Modulus in Creo

1. PART DESIGN
2. ASSEMBLY
3. DRAWING
4. SHEETMETAL

The Modeling of the Windmill blade is done below by using the pro-E (Creo/parametric Elements) software 5.0 which is a 2D view as shown in the figure 19.And the 3D view of the same blade is also shown in the figure 20.

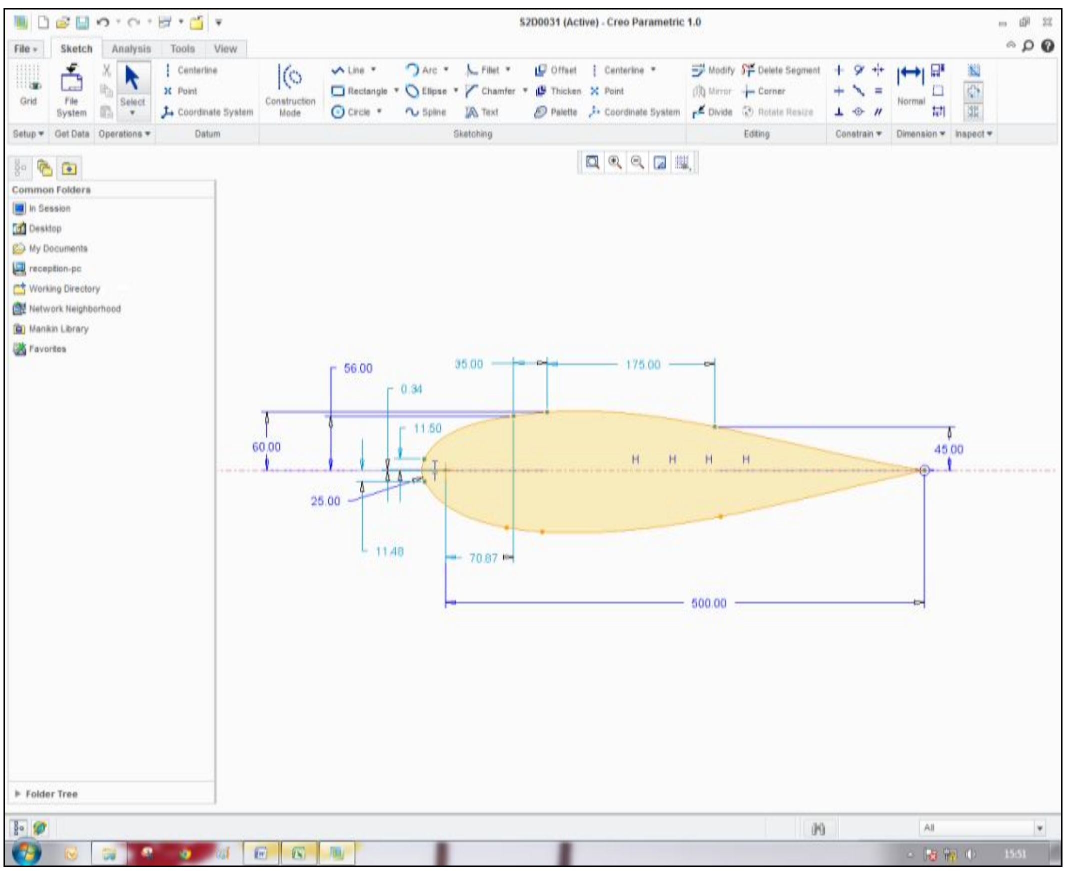

Figure 19: These 2D view design of Blade

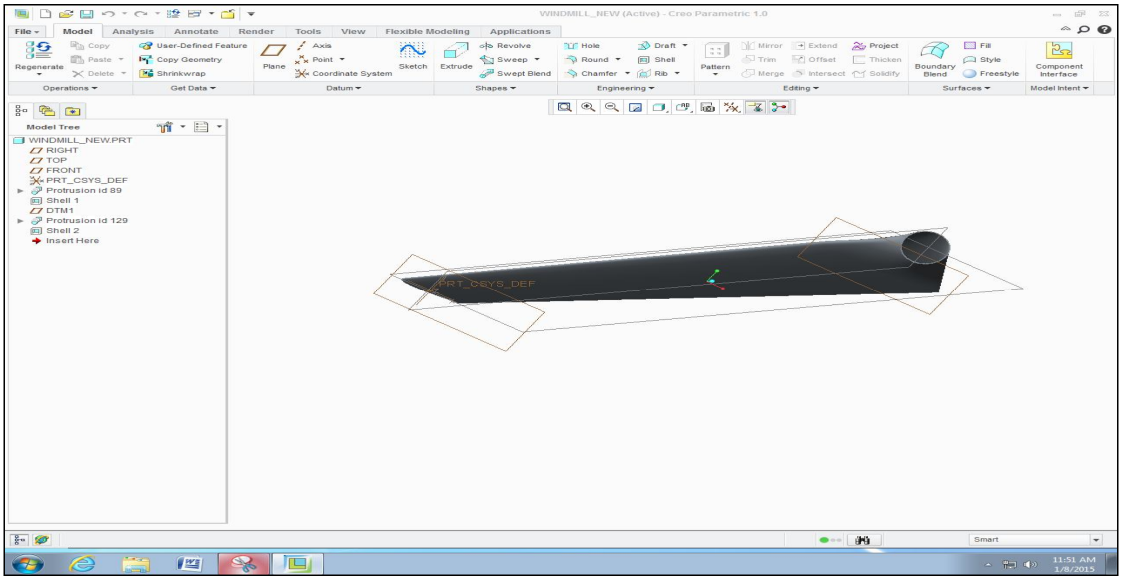

Figure 20: These 3D view Design Blade

3.6.1. Meshing Using ANSYS

In preparing the model for analysis, Ansys subdivides the model into many small tetrahedral pieces called elements that share common points called nodes. The Meshing of the blade is done as shown in figure 21

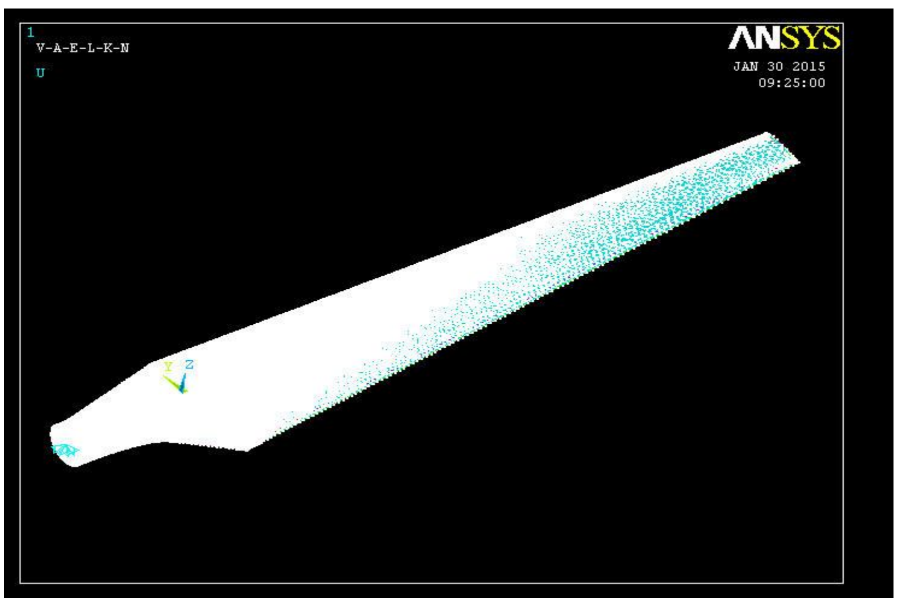

Figure 21: Meshed blade with different Nodal points

The Blade choosen for the analysis of composite material is E Glass/Epoxy, which is a Horizontal Wind Mill Axis turbine Blade which is used for the generation of power present at the heights like mountains, hills etc. The Analysis of different materials are carried out for viz., Carbon/Epoxy, C-Sic/Epoxy,Al-Sic/Epoxy.

3.6.2. Boundary Conditions

The displacement of the Blade is constrained along all directions and at the middle constrained along X and Z directions. Figure 22 shows the meshed model of Horizontal wind Mill blade with boundary conditions.

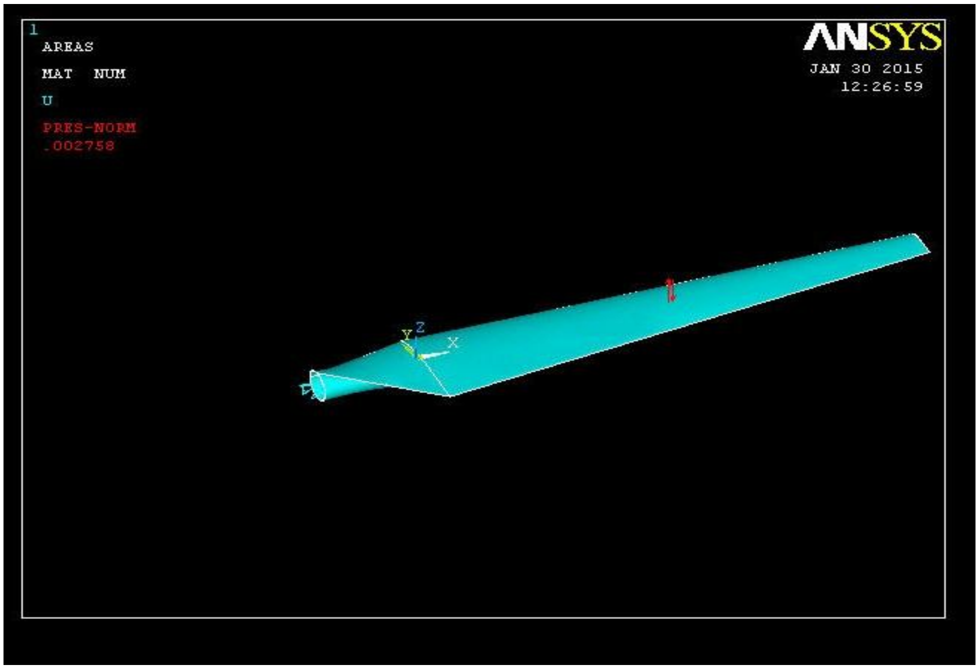

Figure 22: Boundary conditions of Turbine Blade

The Blade choosen for the analysis of composite material is E Glass/Epoxy, which is a Horizontal Wind Mill Axis turbine Blade which is used for the generation of power which are located at very high altitudes like mountains, hills etc. The Analysis of different materials are carried out for viz., Carbon/Epoxy, C-Sic/Epoxy,Al-Sic/Epoxy in this investigation.

3.6.3. Stress Analysis

FE analysis is carried out using ANSYS 15.0 software to determine stresses and deflections. The displacement is constrained along X and Y directions in the middle of the turbine blade and along all directions. The resultant Strain due to the Vonmisses Stress applied on the horizontal axis wind turbine blade asshown in figure 22

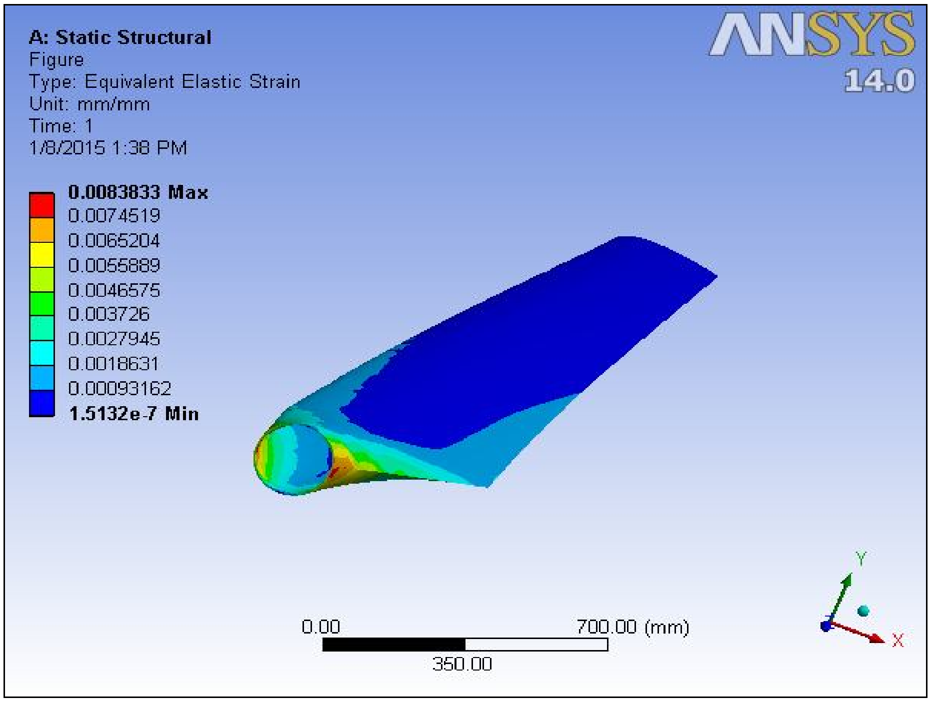

Figure 23: Strains due to applied Stress on turbine blade

4. Results and Discussions

4.1. Introduction

This chapter discusses the results of Static and Modal analysis of HORIZONTAL WIND MILL BLADE made with the four other Composite Materials (viz., E-glass/Epoxy, Carbon/Epoxy, C-Sic/Epoxy and Al-Sic/Epoxy).

Static analysis of Turbine blade was performed using ANSYS analysis software, by considering the pre-determined conditions (necessary boundary conditions and loads) to achieve the results within the allowable limits. By considering a four Composite materials including E Glass/Epoxy which was initially used in the manufacturing of blades.

From the static analysis, Deflection and Von-misses stresses of turbine blade are 86.64 mm and 329.92 MPa for E-glass/Epoxy, 76.48 mm Deflection and 327.56 MPa Von-misses stresses for the Carbon/Epoxy,120.81 mm Deflection 348.07 Von-misses stresses for C-Sic/Epoxy and Deflection of 57.37 mm and 326.52 Von-misses stresses for Al-Sic/Epoxy have obtained from ANSYS software are shown from figures 5.0 to 5.2.

The masses and Stiffness calculated for all the considered composite materials in this investigation (viz., E-glass / epoxy, Carbon/ epoxy, C-Sic / epoxy and Al-Sic/Epoxy) are values of masses are 50.94 kg, 45.28, 48.11 and 82 respectively and for the stiffness values are 2548.8 N/mm, 2883.9 N/mm, 1824 N/mm and 3884.58 N/mm. These values are obtained from the mathematical calculations by taking the extreme values and blade designed for the E Glass/Epoxy.

Modal analysis has been carried out to determine the natural frequencies for all the composite materials used for designing the turbine blade. The fundamental Frequency for the E-glass /Epoxy, Carbon/Epoxy, C-Sic /Epoxy and Al-Sic/Epoxy are 0.143056 Hz, 0.132907 Hz, 0.102481 Hz, and 0.363072 Hz.

4.2. Glass/Epoxy Composite Windmill Turbine Composite Blade

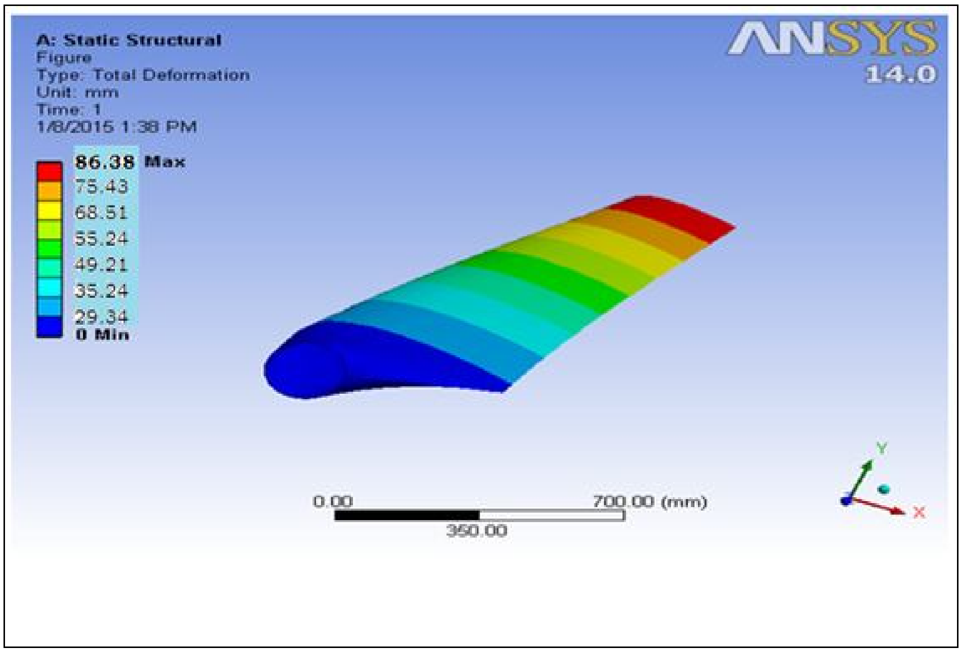

Figure 24: Total Deformation of the E Glass/Epoxy blade

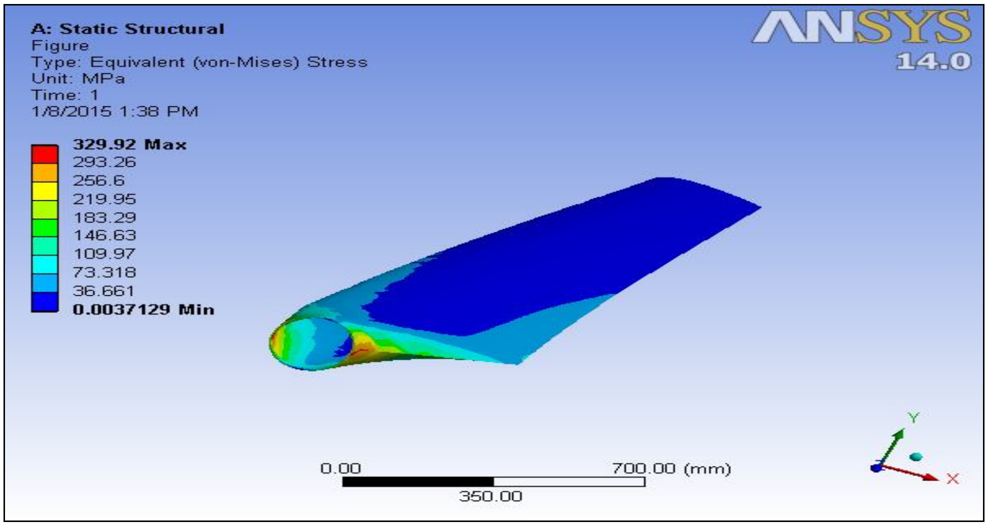

Figure 25: Equivalent Stress Distribution of the

4.3. E Glass/Epoxy Blade

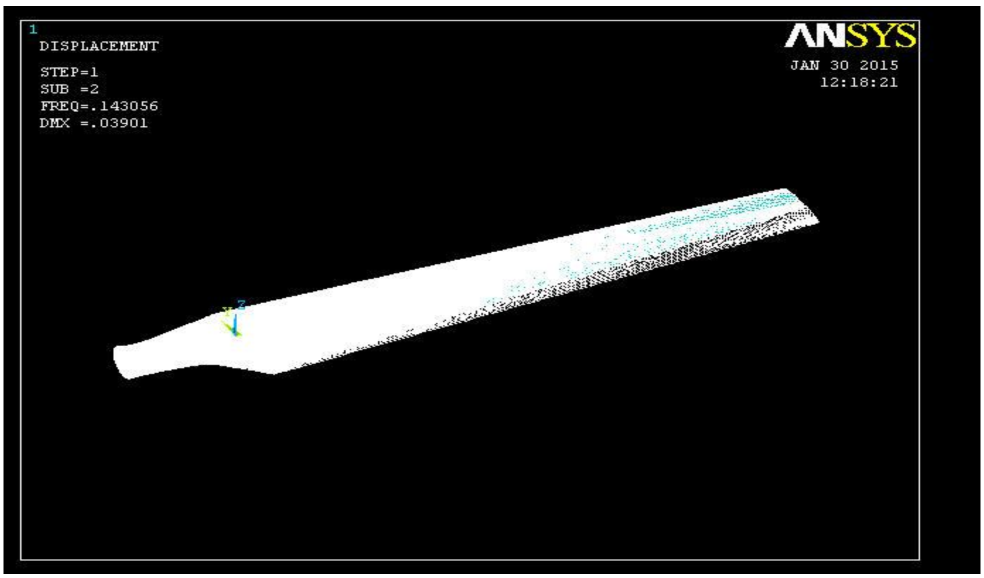

Figure 26: Modal Analysis o Glass/Epoxy of blade

4.4. Carbon/Epoxy Composite Windmill Turbine Composite Blade

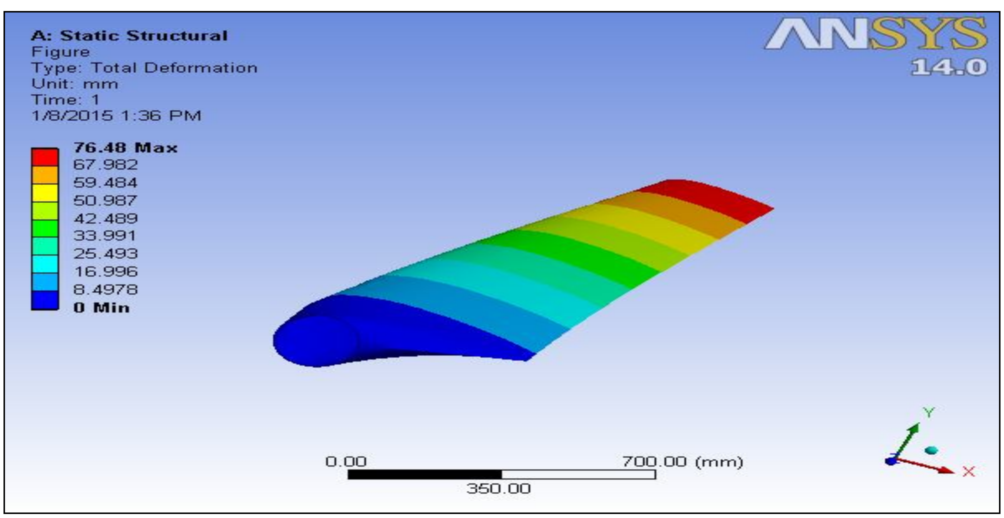

Figure 27: Total Deformation of Carbon /Epoxy blade

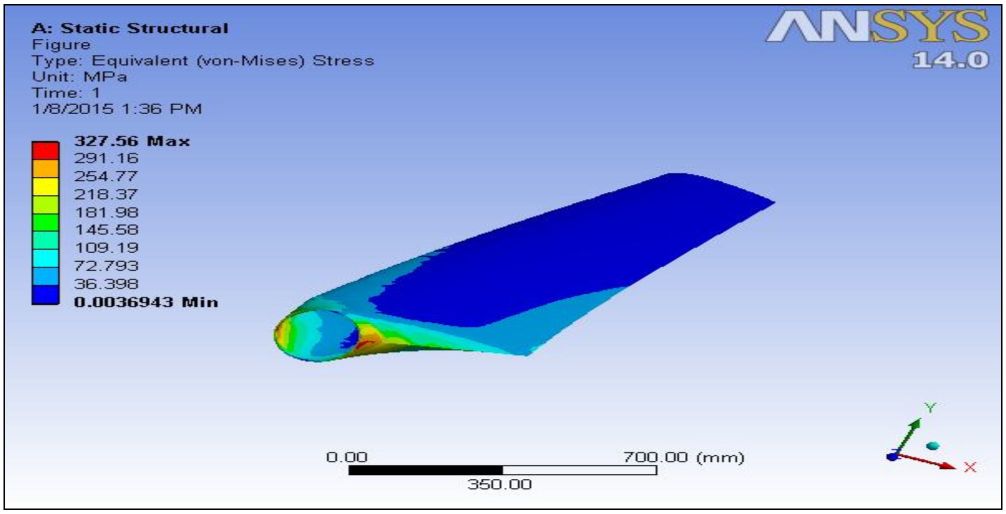

Figure 28: Equivalent Stress Distribution of Carbon/Epoxy blade

Figure 29 : Modal Analysis of the Carbon/Epoxy of blade

4.5. C-Sic/Epoxy Windmill Composite Blade

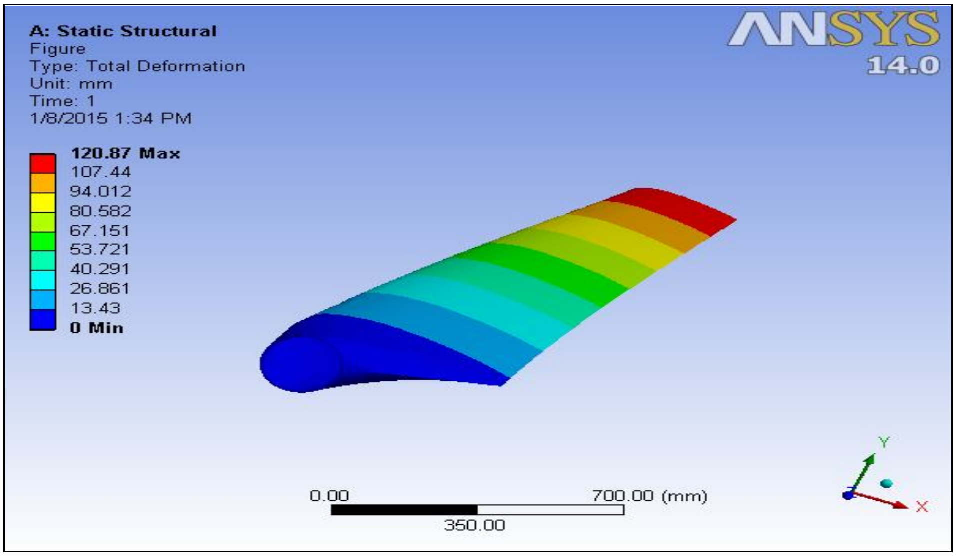

Figure 30: Total Deformation of C-Sic/Epoxy blade

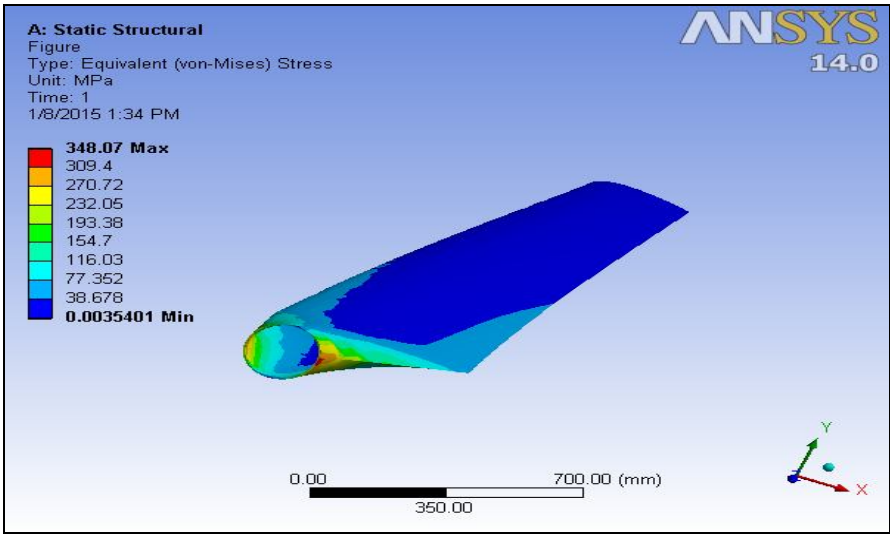

Figure 31: Equivalent Stress Distribution of C-Sic/Epoxy blade

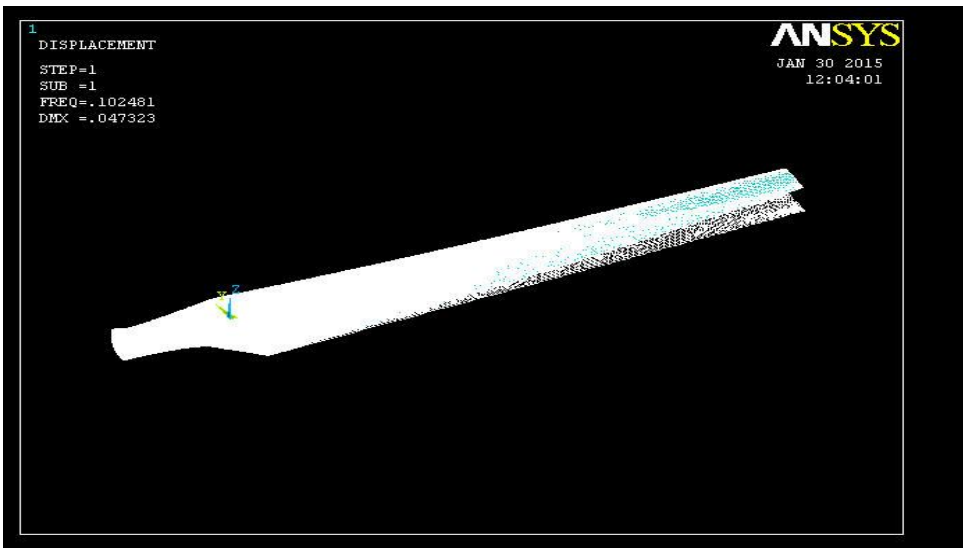

Figure 32: Modal Analysis of the C-Sic/Epoxy of blade

4.6. Al-Sic/Epoxy Windmill Composite Blade

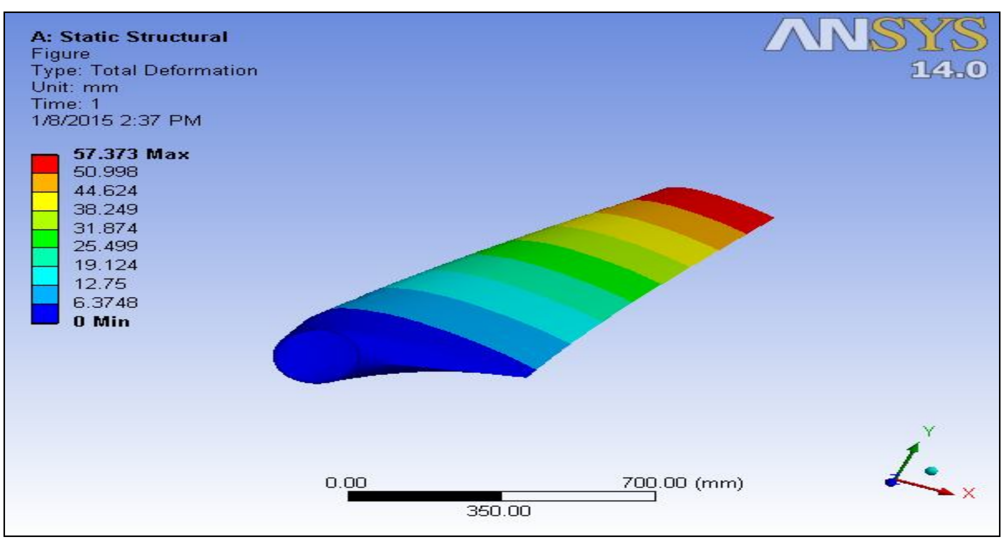

Figure 33: Total Deformation of Al-Sic/Epoxy blade

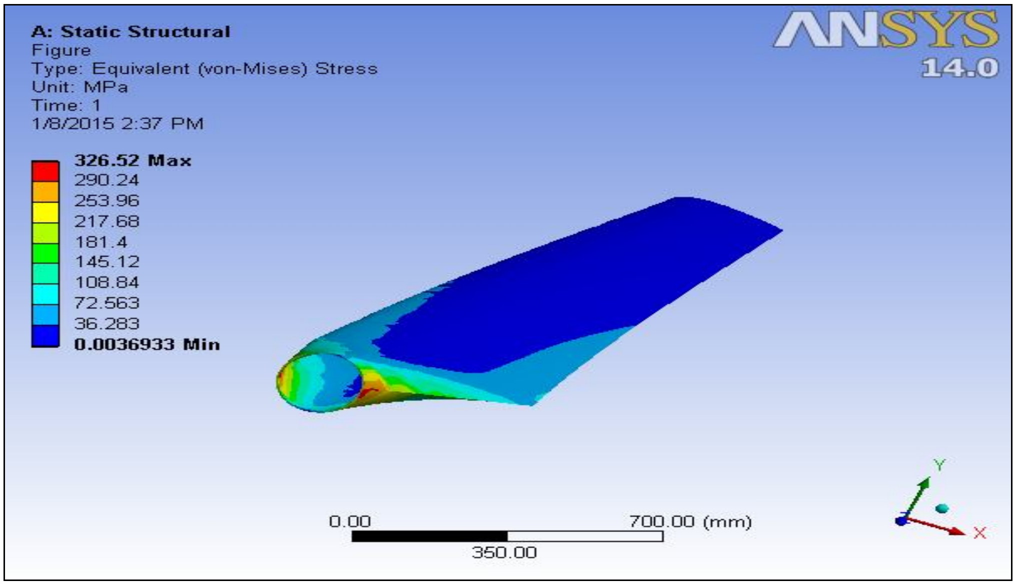

Figure 34: Equivalent Stress Distribution Al-Sic/Epoxy blade

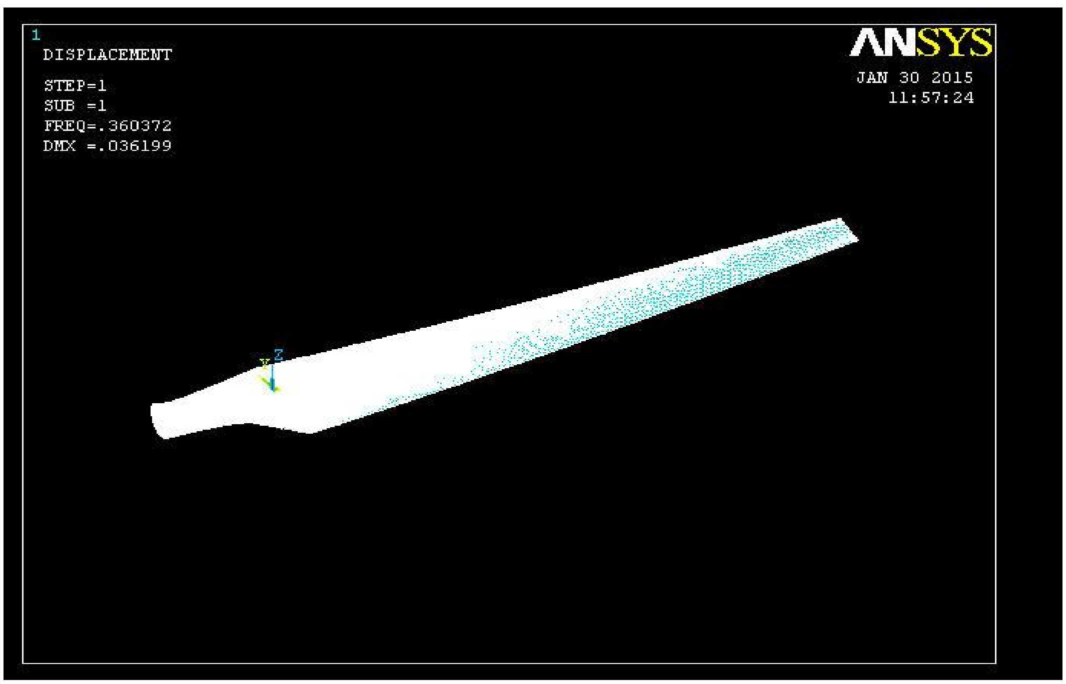

Figure 35 : Modal Analysis of the Al-Sic/Epoxy of the blade

Finite Element Analysis was carried out on all the four types of wind mill blades made with different Composite materials at pre defined boundary conditions. The designed constrains are the total deformation, Von-Misses stresses, Stiffness and Mass are considered in this investigation. In this investigation, a relative comparison was made among the designed constrains and on the basis of the results, the best composite material was recommended for the wind mill turbine blade. All the figures show the total deformation, Stresses and fundamental frequency in different composite materials considered. All the properties that are obtained from the Static, Modal and Mathematical calculations are tabulated below in the table 2. And from the values which are mentioned below in the table are taken and graphs have plotted for all the constrains like Deformations (mm), Von-Misses Stress (Mpa), Mass(Kg) and Stiffness (N/mm) and best material is considered for the Horizontal Axis Wind Mill Turbine.

4.7. Results From Ansys:

The Results which are obtained from the ansys software are tabulated like Deformation, Von-Misses Stress, Mass and Stiffness are mentioned in the table, which are mathematically calculated in the table 1.

Material	Deformation (mm)	Von-Misses Stress (Mpa)	Mass (kg)	Stiffness N/mm
GLASS AND EPOXY	86.64	329.92	50.94	2548.8
CARBON AND EPOXY	76.48	327.56	45.28	2883.9
C-SiC/Epoxy	120.87	348.07	48.11	1824.53
Al-SiC/Epoxy	57.37	326.52	82	3844.58

Table 1: Table Results of all the Composite Materials

4.8. Variation of Different Composite Materials with Respect to Total Deflection

After getting all the results obtained from the software Ansys the graph for the Total Deformation is plotted for all the Materials that are considered in these investigations.

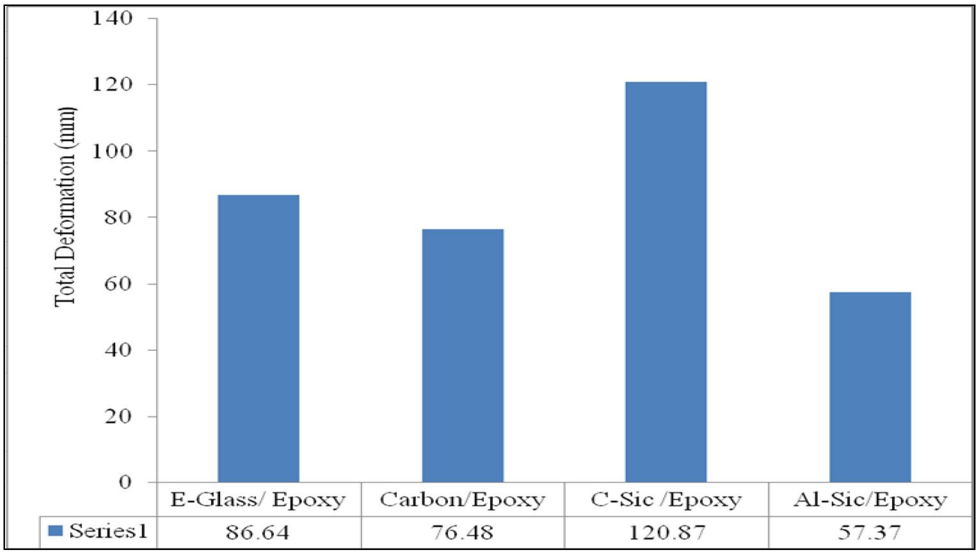

Figure 36: Total deformation in different Composites Materials

From the figure it is observed that, Carbon-SiC/Epoxy composite material undergoes a maximum deformation of 120.87mm and minimum deformation of 57.37mm was observed for Al-SiC/ Epoxy composite material.

4.9. Variation of Different Composite Materials with Respect to Von-Misses Stress

The composite Materials considered for the manufacturing of the windmill blade viz., E Glass/Epoxy, Carbon/Epoxy, C-Sic/Epoxy and Al-Sic/Epoxy a graph is plotted for them taking Stress acting on the blade showing the variations of different materials.

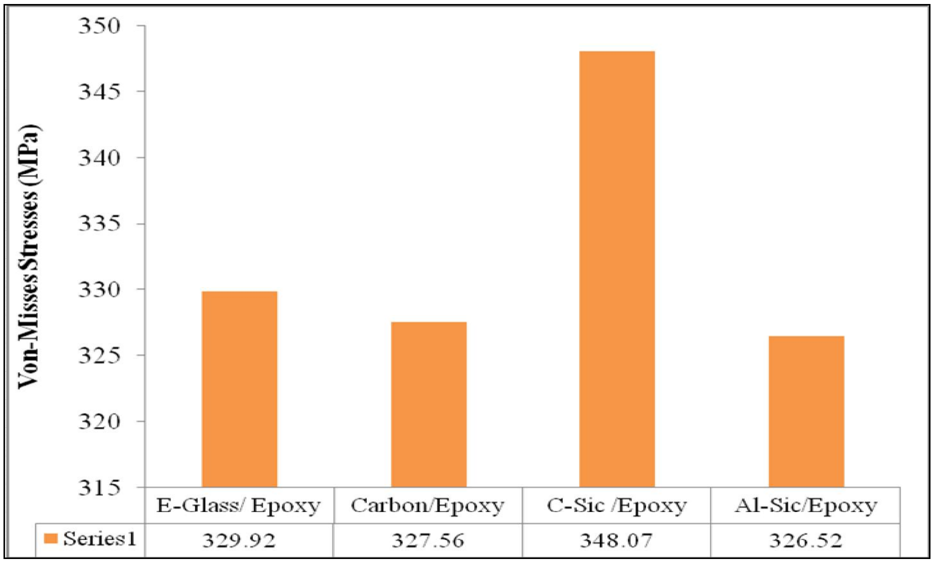

Figure 37: Von-misses Stress in different Composites Materials

From the above Figure it is seen that Von-misses Stress of the carbon silicon carbide is having high stresses 348.07 Mpa where as the Aluminum Silicon carbide is having very less 326.52 Mpa which is a very good property for the composite materials which are considered in this investigation and it is preferable for the manufacturing the Wind mill Blade.

4.10. Variation of Different Composite Materials with Respect to Mass.

In the same way the graph is drawn for all the composite materials showing there variations with the Mass of each windmill blade with different materials in the table.

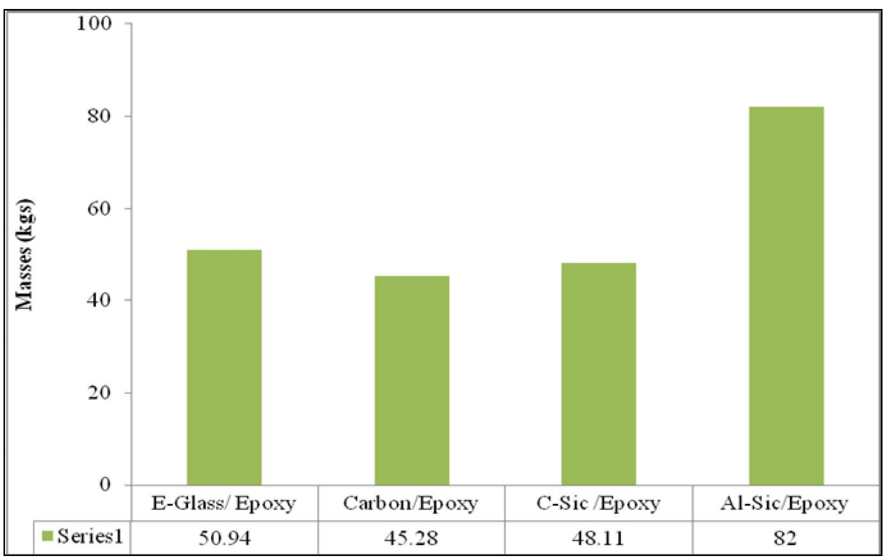

Figure 38: Masses of different Composites Materials]

In the Figure the composite materials considered in the research have been plotted from it is clear that Al-Sic/Epoxy is having very high weight i.e.,82 kg and carbon/Epoxy is having less weight which is a good property for preparation of the Wind mill Blade.

4.11. Variation of Different Composite Materials with Respect to Stiffness

From the Stiffness obtained from the Deformation and the force the would act on the windmill turbine Stiffness of the blade is which are used in this investigation and variation of them obtained Calculated and it is plotted against the different Composite materials

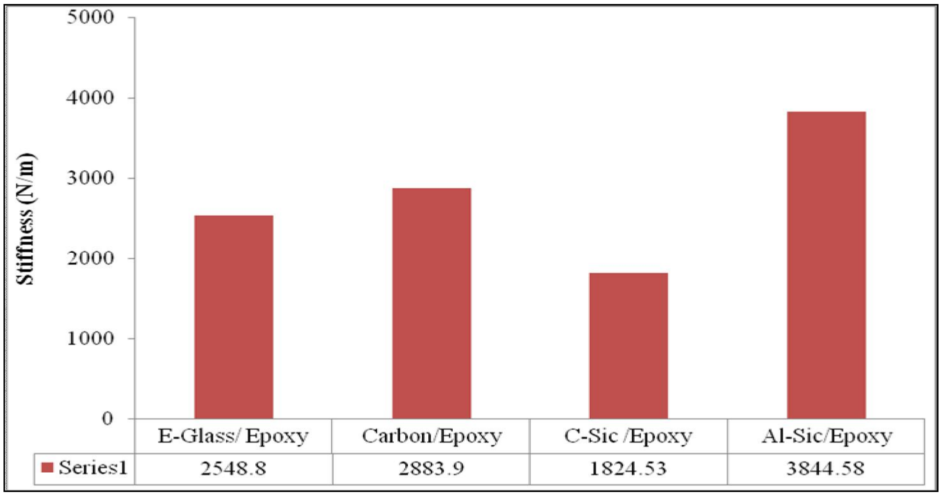

Figure 39: Stiffness of different Composites Materials

From the figure,Stiffness have been viewed from the above figure and Al-Sic/Epoxy 3844.58 Mpa has the highest stiffness and C-Sic/Epoxy is having the lowest stiffness 1824.53 Mpa. So the stiffness with highest value is preferred over the other materials. In this investigation it is Al-Sic/Epoxy inferred for manufacturing the wind mill turbine blade

4.12. Results From Modal Analysis:

Modal analysis was carried out all the composite materials considered in this investigation. The fundamental frequency (H_z) for which Composite material is higher is generally taken for manufacturing the Windmill Blade. The fundamental frequency values along with critical speeds for all composite materials obtained are shown in table

Composite Materials	Fundamental Frequency (Hz)	Critical Speed (rpm)
E-Glass /Epoxy	0.143056	8.58
Carbon /Epoxy	0.132907	7.98
C-Sic/Epoxy	0.102481	6.12
Al-Sic/Epoxy	0.363072	21.28

Table 2: Fundamental Frequency and Critical Speed

Based on the Modal analysis, the Al-Sic/Epoxy Composite Material is having the higher Critical Speed in comparing with all the other materials, hence it is preferred for manufacturing the wind mill turbine blade.

Based on the experimental results, It is inferred that Al-Sic/ Epoxy composites shown best results in terms of strength, stiffness, deformation and also shown higher fundamental frequency as compared to the other composite materials considered in this investigation.

5. Conclusions

5.1. Introduction

In this project work, Creo parameter 1.0 (Pro/e wildfire) software was used for designing and modeling of the horizontal axis Wind turbine blades. Wind turbine blade profile NACA 4412 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-Sic/Epoxy composite material under goes the minimum deformation of 57.37 mm as compared to the other composite materials, and the maximum deformation of 120.87mm was observed in C-Sic/ Epoxy composite.
2. The Minimum Von-misses Stress of 326.52 Mpa was observed in Al-Sic/Epoxy compsoite material as compared to the other materials. It is observed that C-Sic/ Epoxy composite material experiencing huge stress of 348.07MPa.
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 Al-Sic/ Epoxy composite materials performing better than the other composite materials considered in this work.
5. The natural frequency of Al-Sic/ Epoxy composite material is 0.360372Hz, which is higher than the other composite materials considered in this work.
6. Based on the experimental observations in terms of strength, stiffness Al-Sic/ Epoxy Composite material is recommended.

5.2. Future Scope

1. Similar analysis can be replicated by changing the materials for the wind mill blade like Metal matrix composites (MMCs).
2. Dynamic analysis of wind turbine blades can also be performed.
3. Temperature effect on the properties of the wind mill blade can also be performed.

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