Optimum and Reliable Material for Wind Turbine Blade

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***Abstract*— Over Centuries overall world has been depend on non-renewable energy resources like fuel, wood, natural gas, coal, uranium etc. All these energy resources are limited and create pollution. Due to above stated problem the world has lid to focus on renewable energy resources like solar energy, hydropower, wind energy, tidal energy. Which provide optimized use of energy ecofriendly and minimizing pollution. Wind energy is preferable and provide fuel solution to global energy problem. The wind energy is utilized by using wind turbine. The blade of turbine is plays important role. The blade efficiency of wind turbine is depend on shape of blade, size of blade, strength, density of blade material. To increase efficiency of wind turbine blade material plays very vital role. The material of turbine blade should have above stated key properties like low density, high strength, and long fatigue life. Also material should have to face large aerodynamic inertia, fatigue load as well as being design to sustain environmental effect such as accumulation of dust particle, moisture ingredients. Due to all this issues it is necessary to select material which will sustain above environmental condition and required mechanical properties.**

Keywords— Wind Turbine Blade, Polyester resign, Thermoset Composite, Polypropylene Plastic, Aramid fiber, Carbon fiber.

I. INTRODUCTION

There is an increasing concern about the population of the world due to supplied energy over the centuries like wood coal etc. which leads to concentrate on a reasonable energy supply which intends less amount of use of energy, minimized population and completely reduction in energy consumption. The most developed types today are wind energy and biomass because they are short time stored energy resources. A converter is required to turn kinetic wind energy into operational energy ex. electricity and heat. And the converter is based on a rotor driven by the wind while the rotor need a type of device ex. a wing or rotor blade to be able to rotate. In this the rotor is simply placed on the tower conversion calling it a turbine. The development of a wind turbine is responsible for the positive contribution to the human achievement and technology advancement throughout past. Current wind turbine design being increasing efficient, cost effective and reliable. The important role in the wind turbine design is the selection of a material of a turbine blade. Today an ever increasing is available each having characteristics, applications, advantages and limitations. We should have a clear understanding functional requirements for each separate component while choosing material for engineering design. Technological consideration of a material properties and characteristics are important while selecting material for an application. Availability, cost of raw material, cost of manufacturing are equally important in selecting material on economic aspects. [1]

In the wind turbine the turbine blades plays a major role to generate the maximum torque to drive the generators blades are required to preserve an optimum cross section for aerodynamic efficiency. The efficiency of wind turbine depends up the material, shape and angle of the blade. Therefore in wind turbine the material of the turbine blade plays a vital role. The material of the blade should have high stiffness, low density and long fatigue life features.

SELECTION OF A MATERIAL

The factors affecting material selection are properties of materials, performance requirements, materials reliability, safety, physical attributes, environmental conditions, availability, disposability, recyclability and finally economic factors.

In these properties;

1. Mechanical, thermal, chemical etc. are the important properties of a material while one of the most important factors affecting selection of materials of engineering design in the properties of the materials.
2. The part composed of a material should be capable of performing its functions without any failure.
3. The material must be reliable in a given application.
4. The material should perform its functions safely.
5. Configuration, size, weight and appearance also sometimes serve functional requirements like physical attributes can be used.
6. The product should give a significant service performance in the environment in which it operates strongly.
7. For the intended use the material should be easily available in a large enough quantity.
8. The development and manufacturing of the product should be decent in its material cost and processing cost making it a sound economical choice of material.

Following are some major process in material selection:

1. Reasoning of a material functions issues.

2. Conversion of a materials application requirements to materials property values.
3. Choosing a suitable material.

Following requirements are focused while any material selection:

1. To maintain required shape of performance high material firmness is necessary.
2. To reduce gravity forces low density is needed.
3. To lower material demotion long fatigue life is required.

Today it's difficult and multifaceted task and requires a development in properties, performance and economy to make a best design of a rotor blade. [1]

II. COMMONLY USED MATERIALS IN WIND BLADES

Cellulose and lignin are composed together to form a wood hence it has been the common construction material for many engineering application. Woods have low stiffness which makes it a difficult to limit the bending for very large rotor blades but are potentially interesting because of their low density. Woods are difficult to obtain in reproducible and high quantity which is the requirement for stable and economical manufacturing of rotor blades and are natural material being an environmental attractive wind energy. [2]

Development of wood by thin sheets not galvanized steel became popular thoroughly. This set up a vast research and understanding of metal behavior for wind turbine application. Alloy steel abandoned undue to its high weight and low fatigue level once was thought to be the perfect choice for blade fabrication. However excessive weight of steel brought up various problems therefore aluminum is introduced but it too has issues due to low fatigue resistance and high cost. Then it was type of PMC (FRP) fiber reinforced plastic turn the most popular and widely used material for wind turbine blade manufacture which is used till date. For structural application the most commonly used fiber and its matrix is E-Fiber and polyester resins. Depending upon the manufacturing methods followed, the amount of fiber FVF in the resins determines the strength of the composite. Composites mechanical properties began to suffer on adding certain amount of fiber because there is not enough resins too transfer exerted load to the fiber. FVF of around 30-35% can be achieved by normal hand layup technique while sophisticated techniques like SCRIMP and vacuum infusion using prep lugs can give FVF of up to 70%. The extent of air inclusion can be determine by manufacturing techniques also thus voids in the composite reducing its strength. [2]

A. POLYESTER RESIN

Polyester having better water resistance ability is composed of two types that is orthopthalic resin and isopthalic resin. The storage life of polyester is limited. Generally it requires other additives when used for molding (i.e. catalyst, accelerator and additives) if not added by manufacturer. It becomes brittle when shock loading is applied because of its chemically resistant property thus it suits for small scale wind turbine blades. However it is strongly competed by other resins for larger wind turbine blade. The load is not that effectively transmitted to the fiber because of poor adhesion of fiber to polyester. Transverse micro cracking is when a wind turbine blade loading reaches a certain level before the ultimate tensile strength cracks start to appear in the resins. The wind blade designer never exceed the limit to ensure adequate life because it's very crucial.

B. THERMOSET COMPOSITE

1. Epoxies
2. Polyurethanes
3. Phenolic and Amino Resins
4. Bismaleimides (BMI, Polyimides)
5. Polyamides

Epoxy compounds are also known as glycidyl compounds. Including glycidyl esters, diglycidyl esters and glycidyl amines are other types of epoxy compounds which are reactive diluents and are sometimes added to basic resins to modify performance characteristics. To form a wide variety of resin products the epoxy molecule can also be expanded or cross linked with the molecules. These resins range from low-viscosity liquids to high-molecular weight solids. But basically they are high viscosity liquids. In the wind blade manufacturing industry these thermo sets resins are the most widely used resin type, mostly because of their superior properties in terms of their load carry ability, resistance to environmental degradation and adhesiveness it has tensile strength of 85Mpa and Young's modulus of 10.5Gpa. Epoxy resins has low viscosity which is essential in different blade manufacturing methods. It maintains good dimensional tolerance during curing due to its other counterpart. [4]

Another group of resins used in advance composite process is polyurethane. By reaching a poly component with an isocyanate these compounds are formed. Typically toluene diisocyanate (TDI), methylene diisocyanate (MDI), hexamethylene diisocayanate (HDI) are also used widely. The isocayanate can represent a positive respiratory hazard because polys are relatively innocuous. Another groups of PMC resins are phenolic and amino resins. The well-known hazards of both phenol and formaldehyde mostly protected with respect to the phenol and formaldehyde resins. In addition to traces of the formaldehyde contact with these resins in the uncured state is to be avoided because they may also contain free phenol. Urea and melamine-formaldehyde resins present similar hazards. Free formaldehyde can irritate the mucous membrane due to presence of trace amount may be liberated when their resins are processed. [3]

Using thermo set technologies such as glass or carbon fibers reinforces with thermo set polymers wind industries producing turbine blades. Styrene emissions while processing and cost epoxy issues with epoxy resins and the drawback with current thermo set blades repairing or joining or thermo set composites which is possible only with special adhesives are another disadvantages. Nowadays in wind industry selection of polymer for blade manufacturing has become an important economical factor. Industry needs to find a polymer which give similar process ability like thermo set polymers as well as perform better than current blade material in critical situation like increasing length and cost of blade. On offering higher strength to weight properties thermoplastic material is better than thermo sets, so leading to lighter aero foils which can lead to cheaper transport cost and reduced turret weights. [3]

Table 1 Thermo composite properties

	Epoxy	Polyester	Polypropylene
Tensile Strength	73 MPa	40 MPa	42 MPa
Young's Modulus	5 GPa	3.3 GPa	2.9 GPa
Elongation at Break	4 %	1 %	1.5 %
Density	1.16 Kg/m^3	1.09 Kg/m^3	0.9 Kg/m^3

C. ARAMID

Aramid has a high specific strength. Has a vast range of properties making it quiet reasonable of diverse range of uses like boat manufacturing. Its comprehensive strength is similar to E-glass fibers but shows high resistance to impact. Disadvantages of aramid is it's susceptibility to water ingress UV erosion and insect collision due to possession of good resistance to impact. It is also high enough to make a strong wind blade material because of its fatigue resistance capacity. [1]

Table 2 Aramid (Kevlar) fiber properties

	Kevlar 29 High toughness	Kevlar 49 High Modulus	Kevlar 149 Ultrahigh modulus Tensile
Tensile Strength	3.6 Gpa	3.6-4.1 Gpa	3.4 Gpa
Young's Modulus	83 Gpa	131 Gpa	179 Gpa
Elongation at break	4%	2.8%	2%

[2]

D. CARBON FIBER

High strength (HS), Intermediate modulus (IM), High modulus (HM) and Ultra high modulus (UHM) are the different types of carbon fibers. It can pose very high resistance to fatigue, creep and erosion due to its highest strength in tension and comprehension. For large wind turbine blades carbon fiber has become the material of choice. By the controlled burning of oxygen, nitrogen and other non-carbon parts of precursor fiber, leaving only carbon in the fiber. By burning off step the fibers are run through a furnace to produce carbon or graphite fiber. Furnace temperature for carbon is 1000°C to 2000°C while for graphite its 2000°C to 3000°C in which carbon atoms in the fibers are rearranged to impact the required characteristics to the finished fiber. High-modulus reinforcement material carbon fiber is actually predated by boron fibers with replacement with carbon fiber cost of boron has seen its demise. Though their tensile strength do not differ from glass fiber, their modulus can be five times than that of glass. The significant advantage is that the objective of reinforcement is to stiffer. [2]

Table 3 Carbon fiber properties

	Standard modulus	Intermediate modulus	High modulus
Tensile Strength	3450-4830 MPa	3450-6200 MPa	3450-5520 MPa
Young's Modulus	220-241 GPa	290-297 GPa	345-448 GPa
Elongation at break	1.5-2.2%	1.3-2.0%	0.7-1.0%

[2]

E. HYBRID FABRICS

Hybrid fiber is used in such a case where the desire application requires two different properties specific to a particular fiber type. Two different fiber sheets are woven together to form one thinner sheet calling it a hybrid fabric having lesser weight. Most engineering structures these days are using hybrid fabrics prep lug in epoxy resins due to stringent weight limitations and enduring excessive loading similar to wind blade. Translation of higher carbon fiber properties into accountable composite properties is the best challenge with hybrid fabrics. If the reinforcements layer of carbon and glass fibers have suitable and compatible fiber treatment with the polymer resin used for infusion process then only it's possible. [4]

CONCLUSION

For future wind turbine blade development this article presents a critical review of various material system. Various fiber reinforcements, thermo sets composites, thermoplastic composites, natural fiber composites and hybrid composites are the materials considered in the study. To give good insight for materials selection for both large and small turbine blades its advantages, disadvantages and limitations are explained. In order to considered the material for blade design the processing challenges for various materials system needs to resolve first. The ultimate strength must be sufficient to withstand the excessive loads and the fatigue strength must be sufficient to withstand the time-varying loads throughout the intended life of blade for that it must be strong enough to withstand the applied loads without failure. To prevent collision with the tower under extreme conditions the blades must also be stiffed enough for preventing buckling of those parts of the blade that experience comprehensive stresses stiffness is also important. The blades construction needs to be as light as possible to minimize the cost of the power generator which is done by optimizing the structural arrangement and dimensions in accordance with the material selection. To ensure that the end product is always compatible with the design assumptions and calculations the production process used for manufacturing the blades must be sufficient consistent and reliable.

ACKNOWLEDGMENT

The authors would like to present their sincere gratitude towards the faculty of Department of Mechanical Engineering, Sinhgad Institute of Technology and Science, Narhe, Pune, 411041.

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