ADVANCE COMPOSITE MATERIALS USED IN WIND TURBINE BLADES AND USE OF CARBON NANOTUBES TO ENHANCE ITS PROPERTIES

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ABSTRACT

As the world is growing the need for resources is also increasing with it. Conventional resources are on the verge of extinction and the situation is critical for them. As a result the demand is growing heavily for non conventional resources and how energy can be extracted from them; making them the hottest discussion among the researchers. One of the non conventional resources is WIND ENERGY. Research is widely going on for production of energy using wind energy. The present review article enlightens the advancement in composite materials used in manufacture of wind turbine blade. It specifically throws light on use of carbon Nanotubes composites in wind turbine blades.

Keywords: Wind Turbine, Turbine blades, Carbon nanotubes, Advance Materials, Fibers

I. INTRODUCTION

Global demand for energy has increased concern about greenhouse effects caused by fossil incineration and fuel consumption. This has resulted in global heating and melting of the ice caps and has necessitated the increasing use of the sustainable energy resources provided by biomass, sun, wave and wind. Over the last 35 years, wind energy has become a prominent part of the solution to these problems, and the development, manufacture and operation of wind energy harvesters is no longer carried out on a small-scale, experimental basis but has grown into a fully modern and mature industrial sector.

Wind energy power generation is expected to continue the enormous growth it has enjoyed during recent decades, see Fig. 1.1 [1] .It is expected that wind power will deliver 2.5% of the world's electricity in 2013. Predictions indicate that wind power will be able to meet 8% of the world's consumption of electricity by 2021, only eight years from now. The average annual growth rate for new installations seems to have slowed down due to the economic recession, and it is expected that for 2013 it will be only 10%, although economic and political predictions indicate that the growth rate will increase and once again reach the rates seen 5–8 years ago.[3]

As per T.K Jacobsen [2] the cost of energy can be approximately calculated as:

$$\frac{cost\ of\ turbine + cost\ of\ installation + cost\ of\ maintainance}{power\ produced}$$

This implies that cost of energy increases as the cost of turbine increases. Thus it can be inferred that if cost of turbine can be somehow reduced then cost of energy can be reduced and hence its efficiency. The cost of turbine can be reduced by using highly advanced composite materials which are light, strong and cheap. The materials are discussed in the next section.

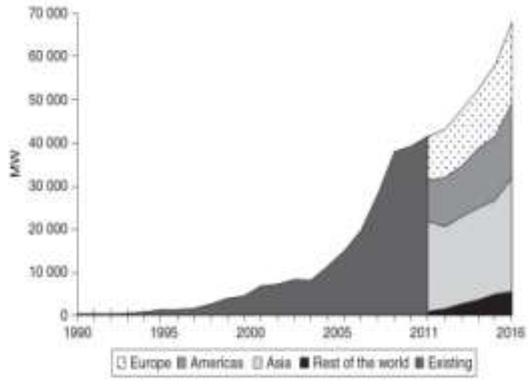

Figure 1.1- Development of Installed Wind Power During The Period 1990-2011 And Forecast Up To 2016.[4]

It has been discussed in later sections about a material carbon Nanotubes which is lighter than any material used till now and even stronger. It has been attracting researchers a lot for its incredible mechanical properties.

II. WIND TURBINE ROTOR BLADES

The wind turbine rotor has some important parts namely(blades,hubs,gearbox,generators,nacelle,tower etc). The part which provides weather protection is nacelle. These are low weight, strength and corrosion resistant. Typically nacelles are made of glass fiber composites.

Wind turbine rotor blades are the most important composite based part of a wind turbine. These rotor blades determine the lifetime and performance of the wind turbine. As stated by Mohamed and Wetzel in 2006 , the rotor blades are the costliest part of a wind turbine. Still the failure rates of rotor blades are of the order of 20% as stated by Richardson in 2010.

Wind turbines rotor blades are subjected to external loading which include flap wise and edgewise bending loads, gravitational loads, inertia forces, loads due to acceleration and torsional bending. Wind pressure causes flap wise loading whereas gravitational and torque load causes edgewise bending.

The wind turbine rotor blades are also subjected to cyclic loadings caused by wind vibrations, wind turbulence and wind shear.

The different parts of a wind turbine has its specific functions.

The wind blades are made with multiaxial fabrics. Often +/- 45^0 laminates are used in blade skin and shear web. In the root area triaxial fabrics are used which are +/- $45/90^0$ [3]. In unsupported parts of wind shell, sandwich composites are used.

The core of the sandwich bears shear load while the composite skin resists the bending stresses[4].The sandwich structures ensure much higher stiffness than monolithic composites.

The main requirements of wind turbine blades are :

1. High strength(To withstand high speed wind)
2. High fatigue resistance and reliability(For stable functioning and approx lifetime of 10^8 cycles)
3. Low weight(To reduce load on the tower)
4. High stiffness(To ensure stability of aerodynamic shape under extreme conditions)

The development in Wind turbine blades in recent times is shown in figure below.

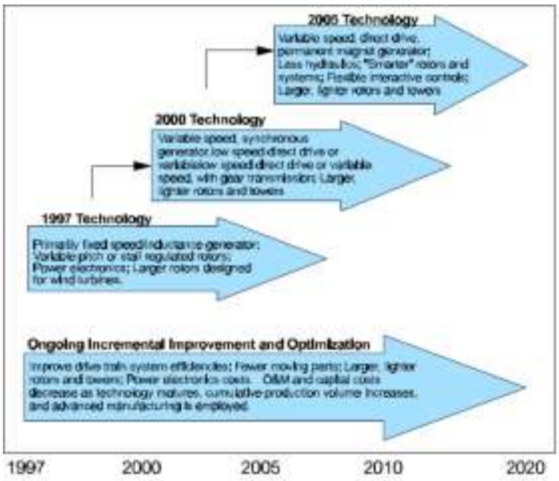

Fig 2.1- Development in Wind turbine blades[2]

In order to have a good durable, reliable and safe rotor blade of a wind turbine long carbon fibers based composites are used. These composites are discussed below.

2.1 Fibers

The stiffness of composites is determined by the stiffness of fibers and their volume content. Most often, E-glass (i.e., borosilicate glass called "electric glass" or "E-glass" for its high electric resistance) fibers are used as main reinforcement in the composites. The main properties of E-glass fibers are as follows: Young modulus E 70…77 GPa, density 2.55…2.64 kg/m3, diameter 8…15 µm, failure strain 4.5…4.9%.

With increasing the volume content of fibers in UD composites, the stiffness, tensile and compression strength increase proportionally, yet, at high volume content of fibers (after 65%), there might be dry areas without resin between fibers and the fatigue strength of the composite reduces. Typically, the glass/epoxy composites for wind

blades contain up to 75 weight % glass.

2.1.1 S-glass

(High strength glass, S means "Strength" here) developed in the 1960s for military applications, has 40% higher tensile and flexural strengths, and 10...20% higher compressive strength and flexural modulus, than the E glass. The main properties of Sglass are: Young modulus E 86-90 GPa, density 2.46…2.49 kg/m3, failure strain 5.4…5.8%. Still, the S-glass is much more expensive than E-glass. **S2 glass** was developed in the 1968 by Owens Corning company as a commercial, non-military version of S-glass. S glass and S2 glass fibers have the same composition (magnesium alumino-silicate). The main differences are in sizing and certification procedure. The price of S2-glass is around 10 times of that of E-glass. **R-Glass** fibers, introduced by Vetrotex in 1968, are produced with a calcium aluminosilicate glass with less silica and added oxides. The main properties of R-glass are: Young modulus E 84-86 GPa, density 2.55 kg/m3, failure strain 4.8 % (Fecko, 2006). Some other special glasses developed by Owens Corning are ECRGLAS (in 1980) and Advantex (in 1997). Relatively recently, in 2006, Owens Corning company developed **WindStrandTM** glass fibers, which have 15 percent higher stiffness and up to 30 percent higher strength when compared to traditional glass fiber reinforcements, and show very good fatigue properties under both tension and compression loading (Ashwill, 2009).

2.2. Carbon Fibers/Carbon Nanotubes

It attracted large interest of industry and research community as a very promising alternative to the glass fibers. Carbon fibers have much higher stiffness and lower density than the glass fibers (Young modulus *E* = 220-240GPa, density 1.7-1.8 kg/m3; failure strain 0.7%), thus, allowing the thinner blade profile as well as stiffer and lighter blades. However, they have relatively low damage tolerance, compressive strength and ultimate strain, and are much more expensive than the E glass fibers (7...20 times, see Grande, 2008). Furthermore, carbon fiber reinforced composites are very sensitive to the fiber misalignment and waviness: even small misalignments lead to the strong reduction of compressive and fatigue strength. In some cases, the problem of efficient wetting carbon fibers in vacuum infusion has been observed, thus, leading to the use of more expensive prepreg technology for the producing carbon fiber based composites.

2.3. Matrix

Due to the low weight requirement to the wind blades, polymers are the main choice as the matrix material for the wind blade composites. As noted above, matrix of composite controls fracture toughness, delamination strength and out-of-plane strength and stiffness of the composite, and influences the fatigue life of the composites. Typically, thermosets (epoxies, polyesters, vinylesthers) or (more seldom) thermoplastics are used as matrixes in wind blade composites.

2.4 Thermosets

It is based composites represent around 80% of the market of reinforced polymers (Nijssen, 2007, Joncas, 2019). The advantages of thermosets are the possibility of room or low temperature cure, and lower viscosity (thus, allowing better impregnation and adhesion). Initially, polyester resins were used for composite blades. With the development of large and extra-large wind turbines, epoxy resins replaced polyester and are now used most often as matrixes of wind blade composites. While polyester is less expensive and easier to process (needs no post-curing), epoxy systems are stronger (high tensile and flexural strength) and more durable as compared with polyester resins. Epoxy matrixes ensure better fatigue properties of the composites. The production of epoxy based composites is more environmentally friendly. Still, recent studies (e.g., by Swiss company DSM Composite Resins) support arguments for the return to unsaturated polyester resins, among them, faster cycle time and improved energy efficiency in the production, stating that the newly developed polyesters meet all the strength and durability requirements for large wind blades.

2.5 Thermoplastics

It represents an interesting alternative to the thermoset matrixes. The important advantage of thermoplastic composites is their recyclability. Their disadvantages are the necessity of high processing temperatures (causing the increased energy consumption and possibly influencing fiber properties) and, difficulties to manufacture large (over 2 m) and thick (over 5 mm) parts, due to the much higher viscosity. The melt viscosity of thermoplastic matrices is of the order 102-103 Pax s, while that for thermosetting matrix is around 0.1-10 Pax s. Thermoplastics (as differed from thermosets) have melting temperatures lower than their decomposition temperatures, and, thus, can be reshaped upon melting. While the fracture toughness of thermoplastics is higher than that of thermosets, fatigue behavior of thermoplastics is generally not as good as thermosets, both with carbon or glass fibers (Nijjssen, 2007). Other advantages of thermoplastics include the larger elongation at fracture, possibilityof automatic processing, and unlimited shell life of raw materials (Lystrup et al, 1998).

III. CONCLUSION

It was observed above that the wind turbine blades are needed to be made light and strong so that they can resist maximum bending torque and are cheap.

For the above purpose it was seen that glass fibers, composite matrices and thermosets and thermoplastics plays an important role. But above all carbon fibers and carbon nanotubes plays the most vital role.

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