# A Basic Design and Model of Wind Energy Using Additive Manufacture

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***Abstract :Wind energy is one of the fastest-growing electrical energy sources. Wind turbines work by converting the kinetic energy in the wind first into rotational kinetic energy in the turbine and then electrical energy that can be supplied. This paper is an insight into the design aspects of a wind turbine, like turbine blade design, blade manufacturing using additive methods. Therefore, this discussion will only be sufficient to allow comparison with processes that are candidates for future blade manufacturing. Current processes will be discussed in two categories, manual and mechanized. The small and medium blades in the field now are largely made by manual processes, basically wet lay-up. Large blades have been made by filament and tape winding in glass-reinforced plastic, hand-laminated wood/epoxy, aluminum, and steel. The following is a brief discussion of the current methods for manufacturing composite blades in order that the relation of material choice, design, and manufacturing method to fatigue life may be presented.***
***Keywords: Wind Energy, blades, Additive Manufacture, turbines***

## I.INTRODUCTION

The energy that can be extracted from the wind is directly proportional to the cube of the wind speed, so an understanding of the characteristics of the wind (velocity, direction, variation) is critical to all aspects of wind energy generation, from the identification of suitable sites to predictions of the economic viability of wind farm projects to the design of wind turbines themselves, all is dependent on characteristic of wind. The most striking characteristic of the wind is its stochastic nature or randomness. The wind is highly variable, both geographically and temporally. Moreover this variability exists over a very wide range of scales, both in space and time. This is important because extractable energy from wind varies with the cube of wind velocity. This variability is due to different climatic conditions in the world also the tilt of earth on its axis and its own spinning results in different wind distributions across the world. Also within any climatic region, there is a great deal of variation on a smaller scale, which is dictated by several factors such as ratio of land and water, presence of mountains etc. The type of vegetation also affects wind distribution through absorption of moisture, temperature moderation and reflection of sun's energy. Generally more wind is witnessed on the tops of hills and mountains than in low level areas. Even more locally, wind velocities are altered by obstacles such as trees or buildings. For any location there is variation of wind pattern, wind speed may wind speed may vary from year to year, also wind distribution will change from decade to decade.

Wind energy provides nearly 5% of the nation's total electricity generation. In 2015 alone, the wind industry generated enough electricity to power 17.5 million average U.S. homes and saved the equivalent of 131.7 metric tons of carbon dioxide. With an increase in generation, the wind industry must meet the challenges of a growing sector. Larger wind turbine blades and more e-cient wind farm configurations set the stage for industrial innovation and advancements. Collaboration between the public and private sectors provide a forum for addressing these challenges and opportunities for the future of wind power.

**Source: Wind area Technology**

The blade mold was built by the Big Area Additive Manufacturing machine (BAAM). BAAM is not only faster than traditional manufacturing methods, but it is also 500 to 1,000 times faster than other industrial additive machines. The new innovative wind blade mold will be used to create four research wind blades. Three blades will be flown on a test turbine at the Scaled Wind Farm Technology (SWIFT) facility at Texas Tech University, while a fourth blade will be utilized for static testing at the National Renewable Energy Laboratory (NREL) with results expected in late summer 2016.

## II. LITERATURE REVIEW

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### 2.1 Blade Manufacturing Processes

The structural design of a blade is closely linked to the manufacturing method as both have to be considered to enable the production of a cost effective and reliable blade. In the section on structural design two common approaches to blade design were discussed, namely the structural shell with shear webs and the box spar with shell fairings. As with the structural design there are two main approaches to manufacturing blades, Prepreg and Infusion. Although either manufacturing method can be used to make the two common structural designs, prepreg is currently almost exclusively used to build the box spar design [2].

### 2.2 Drivers for Composites in the Wind Industry

- Wind blade molding cycle time
- Labor content
- Material costs
- Lightweighting of wind turbine components
- Recyclability

**Source data: Wind Technology Area**

Blades represents the most important composite based part of a wind turbine, whose properties quite often determine the performances and lifetime of the turbine. In fact, a rotor is the highest cost component of a wind turbine. Still, the failure rates of wind turbine blades are of the order of 20% within three years, and this is surely too much. Increasing the reliability and lifetime of wind blades is an important problem for the developers of wind turbines[3].

Composite materials are the combination of two materials which results in new material having better properties than individual materials. Composites are the materials made up of two materials at microscopic scale having two different phases. One has to clearly understand the difference between alloys and composites. In alloys the materials used conserve their mechanical, physical and chemical properties. Reinforcement and matrix are main parts of composite. Reinforcements are generally fibers which add many new properties in the material [4].

The wind energy is an indirect form of the solar energy, since they are the temperature differences and the pressure-induced in the atmosphere by absorbing solar radiation, which set in motion the winds. The rotor mission in a wind turbine is transforming this kinetic energy of wind to mechanic energy. In this paper the design of the blades is based on the blade element moment theory. For the design and manufacturing CAD/CAM was developed a general methodology [5].

### 2.3 Reinforcement Forms for wind Blade Manufacturing

- Preimpregnated versus "Dry" reinforcement forms

  **Processing**

  - Consolidation of Prepregs.

- Vacuum resin Infusion (VARTM, SCRIMP, etc).
- Hand Layup/Vacuum Assisted Hand Layup
- Automation(Prepreg tape and "Tow-Pregs")

**Woven Fabrics**

- Most often used in tooling applications and Preimpregnated forms
- Higher cost, less applicable as structural components for blades.
- Specialized use in areas of high 3D stress fields (resist peel)[6].

## III.DESIGNING AND MANUFACTURING THE MODEL WIND TURBINE

### 3.1 Manufacturing considerations

The FDM technology can produce accurate shapes in the two-dimensional horizontal layers (slices), but in the vertical direction the part produced is discredited into layers of finite thickness, and ridges appear at the edges of the layers (known as stair-stepping). If a blade is built laid horizontally, it will have ridges running along the length of the blade, perpendicular to the air flow, and this is likely to compromise the performance of the aerofoil [4]. If the blade is built standing vertically, the ridges will be parallel to the air flow, which should be more acceptable[7]. Furthermore, a blade built in the vertical orientation requires less support structure (required to support overhanging structures or geometric features) than one built horizontally. However, the horizontally-built blade will have greater strength in the longitudinal direction, which is the direction of the bending stresses. Figure 1 shows blades as they come from the FDM machine, with the support structure still in place.

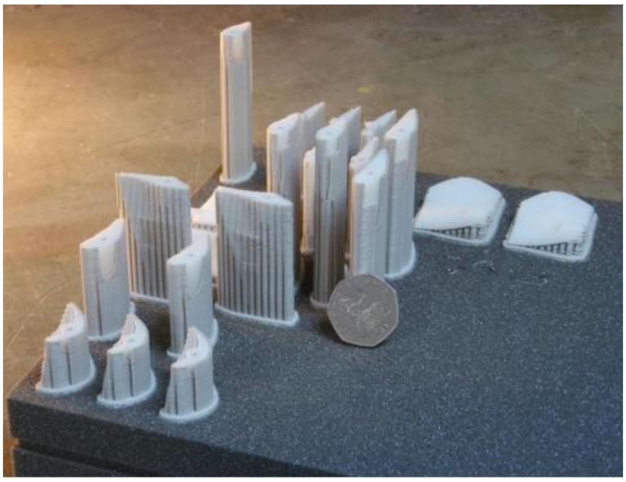

Figure 1. A bank of just-built model turbine blades on their platen, with the support structure still in place

### 3.2 Finishing and balancing

To achieve a smooth surface on the blades and hence low drag, the students are recommended to fill the surface with a two-part car-body filler, before sanding it to a smooth finish. The students have to take care not to sand too vigorously, in order to preserve the geometry of the aerofoil. Before testing the rotor in the wind tunnel, it must be static balanced, using a dummy shaft and knife-edges. For the purposes of manufacturing the geometries required in this project, the AM process is generally accurately repeatable, so usually the rotors are very nearly in balance, and all

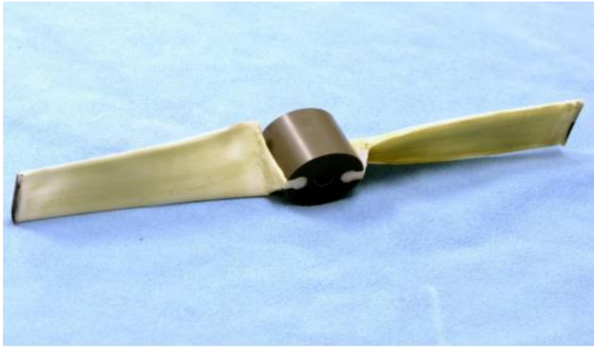

Figure 2. A finished model wind turbine ready for testing

### 3.3 Testing and reporting

For testing, the model rotor is mounted on a dynamometer in a small wind tunnel. Torque is applied by a simple Prony (friction) brake. The rotor speed is measured using a non-contact instrument such as an optical tachometer or a Hall Effect sensor.

### 3.4 Determining design parameters

The mission of a wind turbine rotor is to transform kinetic energy of wind into mechanical energy. The blades of the rotors have some form in cross section allowing them to make the most of wind energy. These forms are known as airfoils. Wind flow which impinges on the airfoil surface distribution of force occurs. The net effect of the distributions of pressure and shear on the aerodynamic profile is a resultant force **R** and moment **M**. The resultant force **R** is divided into two vector components, that is the lift **L** is the vertical component of **R** perpendicular to the flow rate or flow velocity $\mathbf{V}_{\alpha}$ free, and **D** is the drag, is the horizontal component of **R** parallel to the flow velocity $\mathbf{V}_{\alpha}$. Other important concepts in the nomenclature are airfoils; chord **C**, which is the connecting line between the leading edge of the profile with the trailing edge, the angle of attack is the angle between the cord and the free stream velocity $\mathbf{V}_{\alpha}$.

In the design of the horizontal axis turbines need to be considered besides the flow velocity, flows velocity due to the rotation of the blade, which will be greater as the distance from axis. This means that the aerodynamic forces will depend on the free stream velocity and the distance of the segment analyzed with respect to the axis.

In the blade design is its scale becomes necessary discretizar throughout, to thus specify in each discredited points, among other things, the length of the cord and the angle of attack.

Another important concept to define is the resultant moment due to aerodynamic, which is obtained from the expression:

$$M = \int_0^c x(P_l - P_U)dx$$

Calculating the cord at each discretized point where the blade is performed using the simplified theory.

$$C_L Bc = \frac{16}{9}\frac{R}{\lambda\sqrt{\frac{r^2}{R^2}\lambda^2+\frac{4}{9}}}$$

**Wind speed**

The design speed usually has average values the wind speed at the location for the installation of wind turbines. All turbines requires a minimum wind speed for its starting and another to keep it within its operating range, this is the rate for which the turbine is designed.

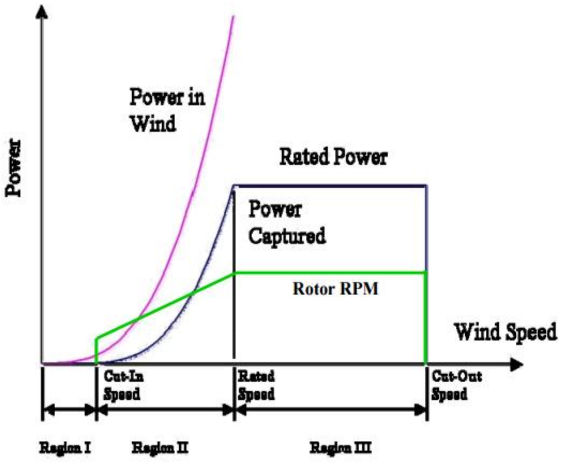


Figure:3. A typical power output versus wind speed curve.

**Power required in the production of electrical energy**

The power required is a function of the energy amount that requires the system to which it is desired to supply electric power. A previous study determined system to supply this parameter. Airfoil selection is enhanced depending on the intentions aerodynamic manufacturing and the specific speed ( λ ). Also to be Considered other design parameters: such as efficiencies of components (generator, gearbox, etc.), and determine the power coefficient $\mathbf{C_p}$.

IV.MATERIAL CHOICE

Materials are the primary drivers in system Performance and production costs:

- Structural Composite Materials
  Reinforcements
  **Glass:** Low-cost high specific strength, modest specific stiffness.
  **Carbon:** High cost but with high specific strength AND stiffness.
  **Others:** Aramids, Basalt etc.
- Resins
  - Epoxies
  - Vinyl/Poly-ester
  - Toughened Resins
    - ETBN/CTBN Reactive Liquid Polymers
    - Core Shell Rubber
    - Nano-technologies
- Thermoplastics

Table:1 Material Specification

| Sr. No. | Materials and its Composition (samples) | Size of spherical shaped Crystal (in µm) |
|---|---|---|
| 1 | Boron Carbide, composition- amorphous boron & technical Carbon | 100 |
| 2 | Silicon Carbide | 80 |
| 3 | Zirconium Diboride | 100 |
| 4 | Mullite like oxide crystals | Diameter 2-8 , length 80-200 |
| 5 | Basalt Powder | 100 |
| 6 | Diluvium Powder | 60 |

**Evolution of commercial Wind Technology**

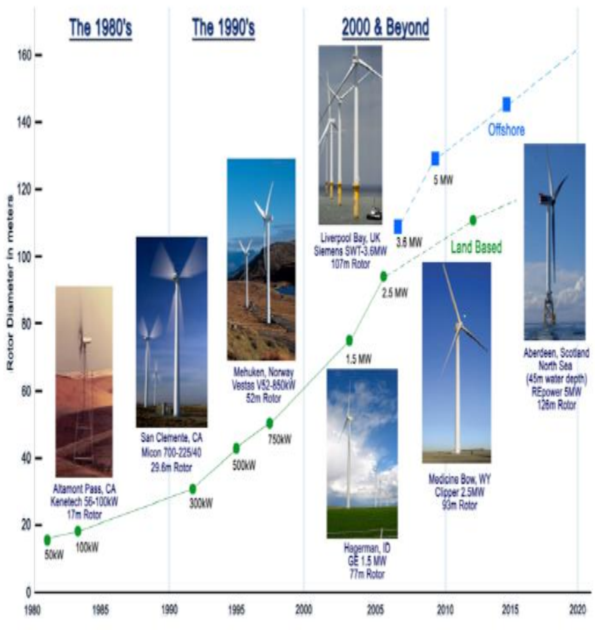


Figure:4 Evolution of commercial Wind Technology

**Next-Generation Wind Technology**

Innovation in the design and manufacturing of wind power generation components continues to be critical to achieving our national renewable energy goals. As a result of this challenge, the U.S. Department of Energy's Wind Program and Advanced Manufacturing Office are partnering with public and private organizations to apply additive manufacturing, commonly known as 3D printing, to the production of wind turbine blade molds.



Source Data: https://energy.gov/eere/next-generation-wind-technology

The Wind Program works with industry partners to increase the performance and reliability of next-generation wind technologies while lowering the cost of wind energy. The program's research efforts have helped to increase the average capacity factor (a measure of power plant productivity) from 22% for wind turbines installed before 1998 to an average of 33% today, up from 30% in 2000. Wind energy costs have been reduced from over 55 cents (current dollars) per kilowatt-hour (kWh) in 1980 to an average of 2.35 cents in the United States today[8].

To ensure future industry growth, the technology must continue to evolve, building on earlier successes to further improve reliability, increase capacity factors, and reduce costs. This page describes the goal of the program's large wind technology research efforts and highlights some of its recent projects.
The newest inventions coming out of the DOE Wind Program can also be found on the Energy Innovation Portal, which houses all technologies available for licensing funded by the DOE's Office of Energy Efficiency and Renewable Energy.

## V.CONCLUSION

Power production from wind technology has evolved very rapidly over the past decade. Capital costs have plummeted, reliability has improved, and efficiency has dramatically increased, resulting in robust commercial market product that is competitive with conventional power generation. High-quality products are provided by every major turbine manufacturer. Complete wind generation plants are now being engineered to seamlessly interconnect with the grid infrastructure to provide utilities with 0a dependable energy supply, free of the risks of future fuel price escalation inherent in conventional generation. No major technical breakthroughs in land-based technology are needed for a broad geographic penetration of wind power on the electric grid. Advancement requires a systems development and integration approach, reflecting the high level of engineering already incorporated into modern machines.

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