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# Design & Structural Analysis of a Small Wind Turbine Blade for Operation at Low Wind Speed

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**Abstract-** *A small wind turbine blade was designed and optimized in this research paper. The blade plays an important role, because it is the most important part of the energy absorption system. Consequently, the blade has to be designed carefully to enable to absorb energy with its greatest efficiency. The main objective of this paper is to optimized blade number and selection of tip speed ratio corresponding to the solidity. The power performance of small horizontal axis wind turbines was simulated in detail using blade element momentum methods (BEM).In this paper for wind blade design various factors such as tip loss, hub loss, drag coefficient, and wake were considered. The design process includes the selection of the wind turbine type and the determination of the blade aerofoil, twist angle distribution along the radius, and chord length distribution along the radius. A parametric study that will determine if the optimized values of blade twist angle and chord length create the most efficient blade geometry.*

***Keywords— Small wind turbine;static analysis;Catia V5; ABAQUS.***

## INTRODUCTION

Nowadays electricity is the major problem in this world. In the present era of steadily rising fuel costs, wind energy is becoming an increasingly attractive component of future energy systems. The wind potential of India is very high. The wind turbines have been installed and wind energy is being harvested, predominantly in the high wind velocity areas. However, due to the restriction of space, the comparatively lower wind areas are beginning to populate with similar wind turbines. In order to ensure the extraction of maximum wind potential even at lower wind speeds, these turbine blades have to be designed and analyzed to suit the low wind areas. At present India stands fifth in the world of wind power generation. Taking into consideration that a large portion of the Indian land will not be viable for the use of traditional windmills due to low wind speeds, a generator which would produce the energy even at low wind speed is required. Also the transmission losses in India are very high. Hence, to reduce the losses due to transmission the turbine could be placed near the place of consumption. Most of the leading wind turbine manufacturers consider blades as their key components of wind turbine system and have concentrated their efforts on developing their own blade design and increasing the supply through in-house production facility.

## SMALL WIND TURBINES

Developing attention to rising levels of nursery gasses [1], an Earth-wide temperature boost and expanding costs of non-renewable energy sources have prompted a move towards putting into minimal effort little breeze turbines. Basic organized, reduced in outline, versatile and low clamor [2], the little breeze turbines are presently fundamental breeze control removing gadgets in the rustic, rural and even in the populated city territories where establishment of vast scale wind turbines would not be acknowledged because of space limitations and age of commotion. Little breeze turbines accomplish control coefficients of 0.25 or more noteworthy in contrast with vast turbines which have $CP$ values around 0.45 [3]. Little breeze turbines have been coordinated on household house rooftop tops, ranches, remote groups and pontoons [4]. As opposed to bigger flat pivot wind turbines (HAWTs) that are situated in territories managed by ideal breeze conditions, little breeze turbines are required to create control without essentially the best of wind conditions [4-6]. A little breeze turbine is one that depends on streamlined powers to fire up and has a tail vane for uninvolved yawing. Little breeze turbines are ordered as small scale (1 kW), mid-go (5 kW) and smaller than expected breeze turbines (20 kW+) [7]. A more itemized portrayal of smaller scale wind turbines is given by Cooper as being appraised under 2.5 kW and industrially delivers control in the scope of 0.4 kW-1.5 kW at 12.5 m/s wind speed [8].

**Figure 1.1:** wind turbine

## Material

### A. BALSA WOOD

It is called as "miracle material" for this interesting world. When compared with the available material, whose strength to weight ratio is at its best. Along with its strength & low density, it can be easily, formed, fastened, and coated. It is also recyclable, non-toxic, and it's also absorbs vibrations and shocks. Balsa wood is used to build the wind turbine blade; longitudinal stringers are made up of balsa wood, Because of its adaptability and strength. Material properties of Balsa wood is given in the table 2.1.

| Material | Density | Young's modulus | Poisson's ratio |
|---|---|---|---|
| Balsa wood | 155 kg/m3 | 4.1 Gpa | 0.38 |

**Table 2.1: Material properties**

### B. GLASS FIBER

The skin of the turbine blade is made up of Glass fiber composite , where the glass are in the form of fibers, because of its multipurpose utility, one of the most widely used industrial material. Glass fibers are the resulting from configuration comprising Silica. They show bulk properties such as stability, rigidity, and transparency also the desired properties like flexibility, strength and stiffness. The following table shows the properties of glass fiber.

### C. Aluminium

| Material | Density | Young's modulus | Poisson's ratio |
|---|---|---|---|
| Aluminium | 2700 kg/m3 | 69 GPa | 0.34 |

## Problem Definition

Now a days Small wind turbines are failing due to structural instability to overcome the failure, we have analyzed that the stability of small wind turbine under the wind speed and centrifugal load. The analysis results is validated and improvements are implemented for safe operating conditions. Analysis is carried out using ABAQUS.

## Methodology

1. A geometric model of small wind turbine was modelled by using Catia V5.
2. The finite element model is prepared by meshing it with appropriate by linear quadrilateral element, triangular element, tetrahedral quadrilateral element.
3. The loads and boundary conditions were calculated and applied on the FE Model. And assigned material property.
4. This finite element model is imported to ABAQUS to carry out Static analysis.

## Geometric Modeling

The geometric model of small wind turbine in half symmetry showing one blade, solid wood hub with a layer of aluminum sheet, and it also shows composite shell section. The modeling has been done using modeling software, solid works. The dimensions of wind turbine are considers from the literature survey. It consists of blade which is coupled to the hub and having a Lateral aerofoil stiffener, longitudinal stiffeners as shown in the figure.

## Dimensions as follows

Hub diameter = 0.36 meters
Blade tip diameter = 5.86 meters
Chord dimension = 0.4 meters
No. of blades =2
No. of lateral aerofoil sections =10
Longitudinal stiffness sections =2
Aerofoil Thickness ratio= 1.5

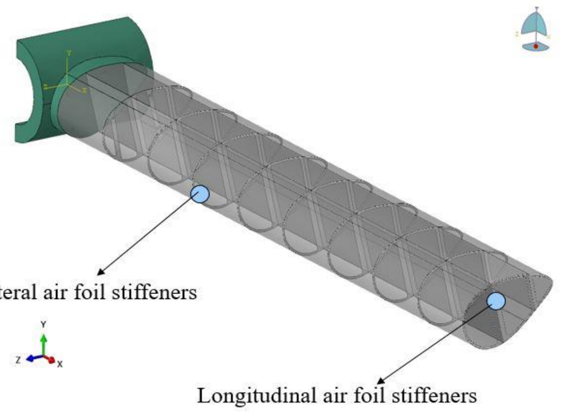


**Figure 4.1:** Geometric Model of small Wind turbine blade

## Meshing

**Figure 4.2:** Meshed model of the bracket

Using modeling tool solid works is imported into the ABAQUS for free quad mesh. Figure 4.2 shows the Finite Element mesh generated for the geometric model of the wind turbine structure using linear quadrilateral elements (S4R) and linear triangular elements (S3). These elements are selected because the quadratic result interpretation at the integration point.

**Table 4.1:** Elements and nodes count

| | |
|---|---|
| **Element Types** | linear quadrilateral elements (S4R) and linear triangular elements (S3) |
| Number Of Elements | 40181 |
| Number Of Nodes | 77575 |

## Loads and Boundary Conditions

### 1. Wind pressure Due to velocity

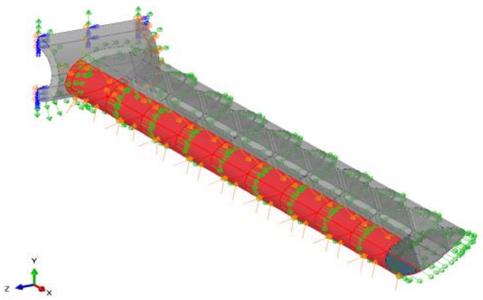

**Figure 4.3:** Wind pressure Due to velocity

Wind velocity at located sites is typically 7 m/s, which excerts pressure on turbine blade, and due to the rotational speed of 850 rpm centrifugal load is also acted on the aero foil section of turbine blade can be seen from the above figure

### 2. Centrifugal load Due to 850 RPM

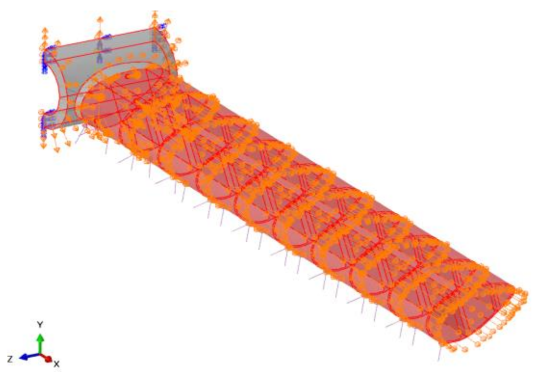

**Figure 4.4:** Centrifugal load

The rotational speed of 850 rpm centrifugal load is also acted on the aero foil section of turbine blade can be seen from the above figure.

## Results & Discussion

The FE model of wind turbine blade with loads and boundary conditions was run for analysis in ABAQUS. The following figures give the results of static analysis on composite wind turbine blade.

### 5.1 Results due to Wind pressure

### Stress contour

From the figure 5.1 above it can see that the static result shows the maximum von misses stress plot for the given loading condition, at the root is **80 Mpa** and at the tip is **25 Mpa.** That show an obtained stresses in small wind are well within the safer limit of the material.

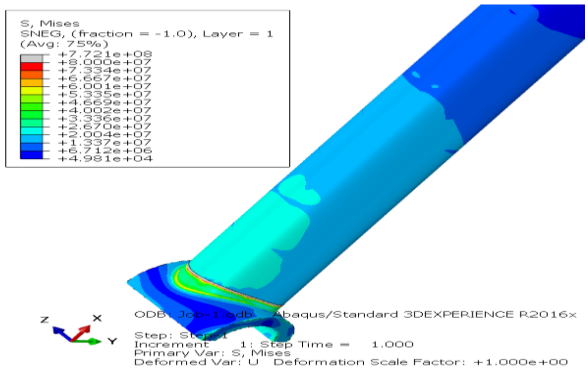


**Figure 5.1** Stress contour of the blade at the Root

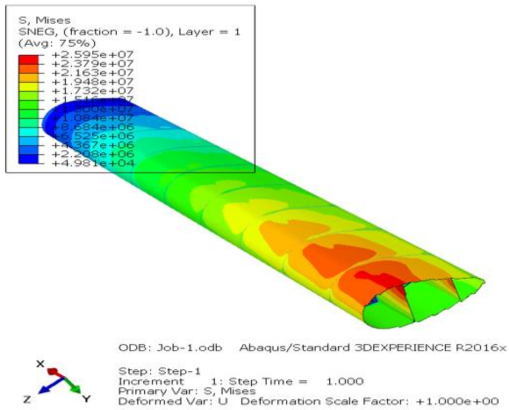


**Figure 5.2** Stress contour of the blade at the tip

### Displacement contour

From the figure 5.3 above it can see that the static analysis result shows the displacement of small wind turbine blade for the given loading conditions. It is clear from the above figure the maximum displacement occurs on tip end is 5.5 mm.

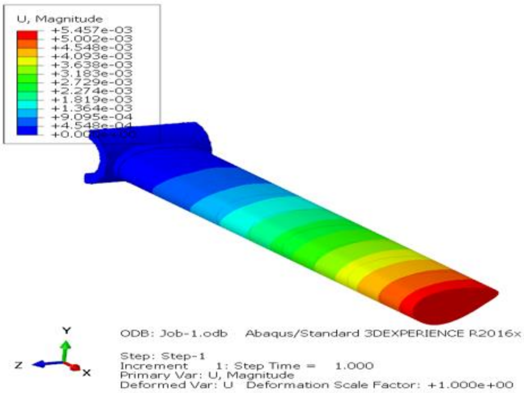


**Figure 5.3** Displacement at root of the blade

## CONCLUSION

- The maximum stress in the small wind turbine blade and hub is found to be around 80 MPa near the hub root fillet, and 26 MPa in the laminate blade profile. Hub and Blade both are well within the limits of the yield of the material.
- Displacements are found to be around 5.5 mm, which follow the expected pattern and are within acceptable limits in linear static analysis.
- Small wind turbine design pass all the loading conditions such as wind load, gravity load and centrifugal loads due to the rotations.

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