Bird impact analysis of a composite wind turbine blade

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Abstract - *Wind turbines are located at open fields to generate the electricity by using natural power of wind. Turbine blades have aero foil shapes they must tolerable against the bird impacts. We discussed here a methodology for damage valuation. Structural response of the blade is evaluated through implicit / explicit finite element simulations addressing its static and dynamic behavior focusing on deformation, stresses, damage mechanisms, and energy absorption. Impactor geometry is considered as cylindrical rigid body proportional mass of 2 kg, along with velocity 9.5 m/s which represents the bird. Stresses and deflections for impact loading were found to be around 90 MPa near the hub root fillet, and 70 Mpa in the laminate blade profile. Hub and Blade both are well within the limits. The structural response at different time shows the impact force on the blade is transmitted through the lateral and longitudinal stiffeners. Displacements are found to be around 16 mm, which follow the expected pattern and are within acceptable limits.*

***Key Words*: Wind turbine blade, solid works, impact analysis, Impactor geometry, aero foil, lateral and longitudinal stiffeners.**

1. INTRODUCTION

Wind turbines convey power by using the distinctive energy of the wind to drive a generator. The wind is a spotless and practical energy source, it doesn't make pollution and it will not ever run out as it is repeatedly recharged by vitality from the sun. From several points of view, wind turbines are the characteristic development of predictable windmills, yet now normally have three cutting edges, which pivot around an even center at the peak point of a steel tower. Most of the wind turbines begin producing power at twist velocities of about 3-4 meters for each second (m/s), (8 miles for each hour); create extreme "appraised" control at about 15 m/s (30mph); and secure down to avoid storm damage at 25 m/s or over (50mph). It is simple to generate power from wind: Turning force which is exerted by wind as it passes over the blades. As blades rotates which rotates the shaft, where at the end it is connected to gearbox and generator housing inside the nacelle. Shaft speed ratio is increased by gearbox to the generator which converts mechanical energy into electrical energy. The figure below shows a typical wind turbine.

Figure -1: wind turbine

1.1 Catastrophic failures of wind turbine

To obtain the dependable, safe and useful action of wind turbines which requires number of safety features, when compared to the any other engineered components, wind turbines required number of safety features. If we identified the possible failures of wind turbines like under extreme weather conditions, hazardous nature, which makes the turbines to the future safer turbine, designs.

During rainy seasons wind turbines are hit directly or nearby lightning, if a lightning strike directly on to the wind turbine causes fire. It is necessary to protect the structure from lightning.

Tubular structures of wind turbines having circular cross section at the bottom, here the risk is more, whose radius is equal to the radius of disc formed by turbine blades & height of the tower.

Ice peeling is one of the common problems encountered in wind turbines, few turbines are outfitted with icing prevention system. Due to the formation of ice on turbine blades would slow down speed of turbine.

If any critical components of turbine fails, turbine need to shut down immediately, if not which leads to over speed along with successive failure and even breakdown.

Probably the main reason for over speed and breakdown of wind turbine is generator, if the generator is at critical temperature or cut off from the main grid.

1.2 Problem definition

Wind turbines are located at open fields to generate the electricity by using natural power of wind. Generally where there is a continuous flow of wind minimum of 4-5 meter/second, certain type of wind turbines started to generate the electricity at this speed. Maximum power generated at the wind speed of 15 meter/second, but at the speed of 25 meter/second wind farms are stopped to avoid the damage happened to the turbine blades and to the structure. Turbine blades have aero foil shapes they must tolerable against the bird impacts. For such type of damages caused by bird impact on wind turbine blades, we discussed here a methodology for damage valuation.

Structural response of the blade is evaluated through implicit / explicit finite element simulations addressing its static and dynamic behavior focusing on deformation, stresses, damage mechanisms, and energy absorption.

2. METHODOLOGY

The basic step is to create a geometric model of wind turbine blade using SOLID WORKS modeling tool and it is imported into ABAQUS (mesh) for messing. The finite element model is prepared by meshing it with appropriate elements like quadrilateral, hexahedral or tetrahedral, contact elements and constraining the model by applying material properties and boundary conditions. This finite element model is imported to ABAQUS to evaluating the structural response of the blade and dynamic behavior of structure.

Following are the basic steps

Step 1: Creating 3D model of the small composite wind turbine blade by using solid works modeling tool and meshed by using free quad mesh in ABAQUS/ CAE.
Step 2: Bird is assumed to be a rigid cylindrical mass with appropriate properties.
Step 3: Composite material properties applied to wind turbine blade and bird configuration will be considered as load which is hitting on rotating wind turbine blade.
Step 4: Explicit dynamic analysis is performed for this assembly using ABAQUS / EXPLICIT Solver.
Step 5: Results are validated Employing appropriate multi axial failure criteria.

2.1 Primary design-power calculations

The primary design calculation involves calculating the peak Power estimate for a specific rotor/blade diameter and the available site wind velocities. The equation is defined as below.

$$P = \frac{1}{2}\rho \pi R^2 U^3 C_P \eta$$

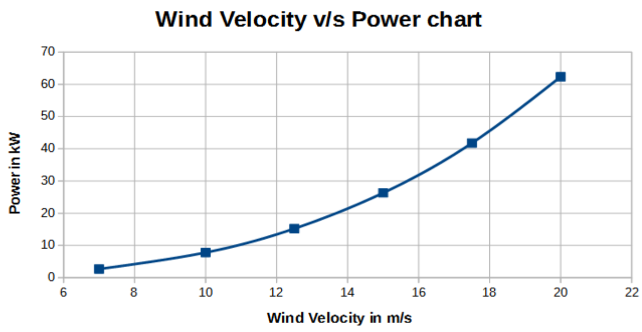


Chart -1: Velocity of wind v/s power chart

2.2 Geometric modeling

Figure 2 shows the geometric model of wind turbine in half symmetry showing one blade, solid wood hub with a layer of aluminium 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.

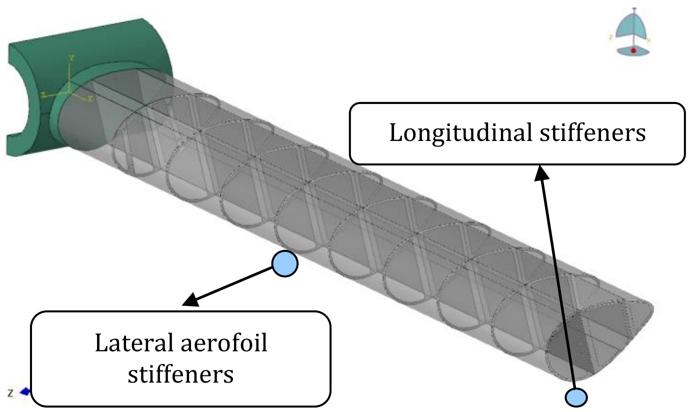


Figure -2: Half symmetry, showing one blade

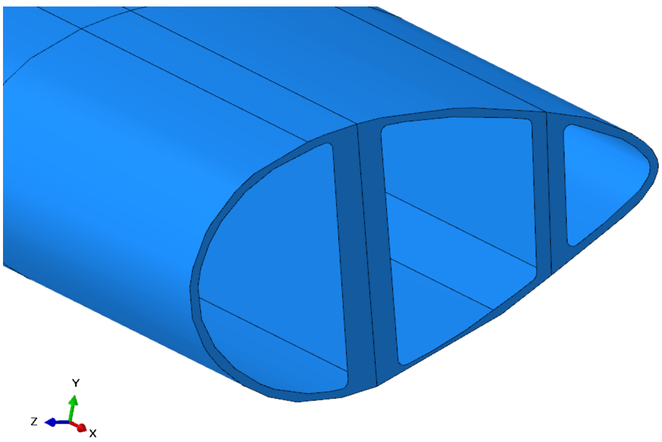


Figure -3: Composite shell section

Aerodynamic forces generated on the rotor blades, which is used to extract the energy from the wind. Turbine blades designed to an aero foil shape, productivity of the blade in abstracting the energy from wind is a function of aerodynamic characteristics.

Knowledge about boundary properties, relation between pressure circulation and geometry are the initials for the aero foil design procedure. The aim of an aero foil design differs. Low drag is produced in some types of aero foil designs, in which normally there is no need of lift. In other section the given quantity of lift is produced along with low drag. Where maximum lift has been generated in some types of aero foil designs, here drag in neglected. Restrictions on breadth or unusual restrictions are included in the performance which is required to achieve by these sections.

2.3 Meshing

Created 3D model of wind turbine blade using modeling tool solid works is imported into the Abaqus for free quad mesh. Figure 4 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 interpolation at the integration point.

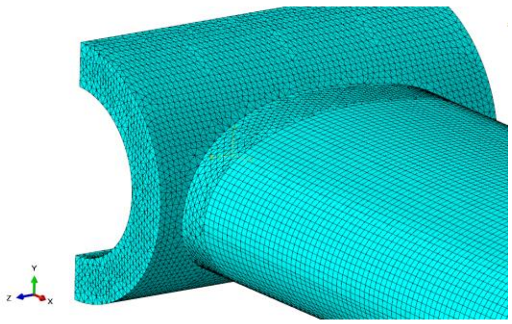


Figure -4: Mesh model of wind turbine blade

2.4 Loads and boundary condition

Impactor geometry is considered as cylindrical rigid body proportional mass of 2 kg, which represents the bird. This is considered for the application of load on to the wind turbine blade.

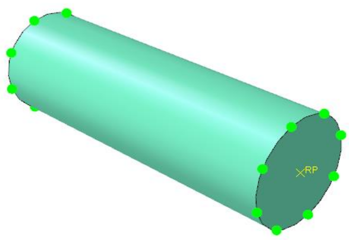


Figure -5: Bird geometry

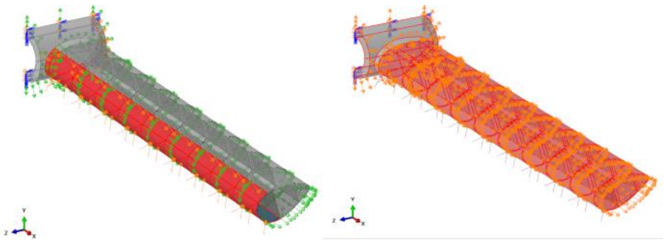


Figure -6: Wind pressure and Centrifugal load

Wind velocity at located sites is typically 20 m/s, which excerts pressure on turbine blade, and due to the rotational speed of 1500 rpm centrifugal load is also acted on the aero foil section of turbine blade can be seen from the above figure 6.

3. RESULTS AND DISCUSSION

The FE model of wind turbine blade with loads and boundary conditions was run for analysis in ABAQUS/EXPLICIT solver. The following figures give the results of bird impact analysis on composite wind turbine blade. For impact analysis displacements and stresses are obtained.

3.1 Static results

From the figure 7 it can see that the Static analysis results at the root and shell show a higher stress which is included as predefined fields in the impact analysis.

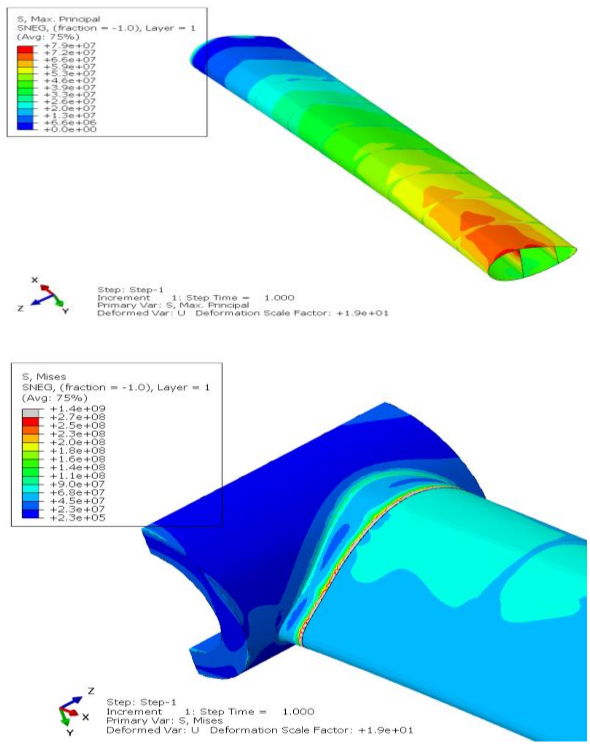


Figure -7: Maximum & Von misses stress

3.2 Impact results

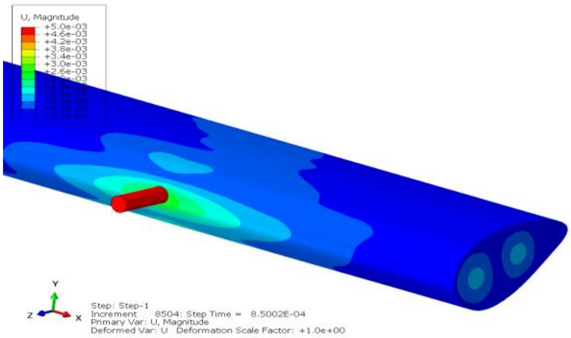


Figure -8: Displacement results at 0.85 milliseconds

Figure 8 & 9 shows Displacement results at 0.85 milliseconds and 2 milliseconds. The structural response at different time shows the impact force on the blade is transmitted through the lateral and longitudinal stiffeners. Displacements are found to be around **16 mm**, when a bird of mass 2Kg with velocity 9.5 m/s.

According to loads and boundary condition, blade is fixed at the hub and bird represented by gelatin material as load at the tip of the blade. Which follow the expected pattern and are within acceptable limits.

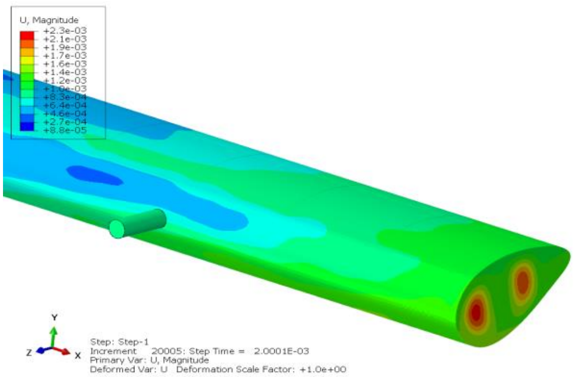
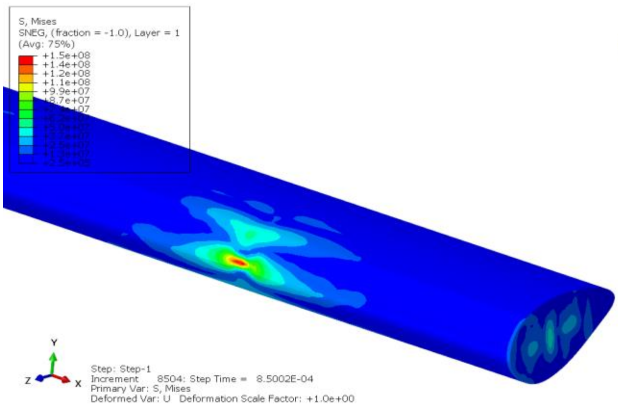


Figure -9: Displacement results at 2 milliseconds



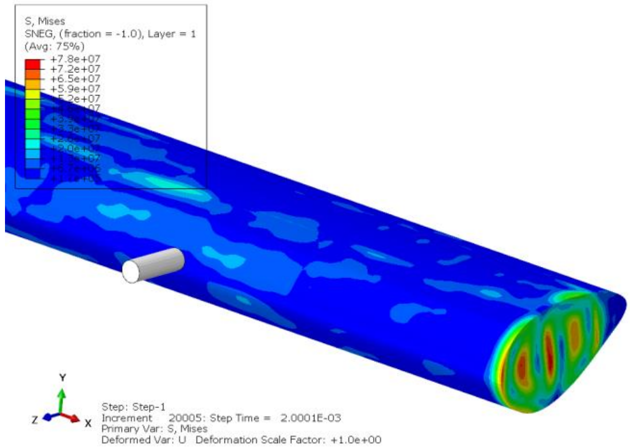


Figure -10: Displacement results at 0.85 & 2 milliseconds

The structural response at different time shows the local stress on the blade is absorbed and the stress response is shown at the end cap.

The maximum stress in the small wind turbine blade and hub is found to be around **90 MPa** near the hub root fillet, and **70 Mpa** in the laminate blade profile. Hub and Blade both are well within the limits.

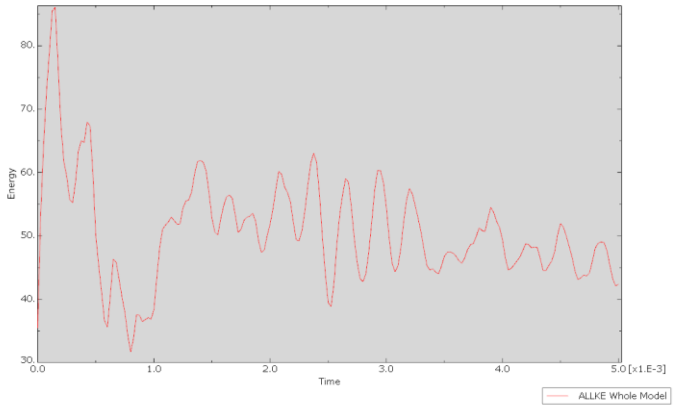


Chart -2: Kinetic energy v/s time

The above graph shows that the variation of internal energy when a bird with mass 2Kg with a velocity 9.5 m/s is hits at a time interval of 0.85 to 2 milliseconds. The whole kinetic energy is converted into potential energy as shown in the form of waves in the above graph.

4. CONCLUSION

- The static analysis is performed for the two blade wind turbine and followed by impact analysis due to an external body impact. The model is pre stressed in the impact analysis.
- The maximum stress in the wind turbine blade and hub is found to be around 90 MPa near the hub root

fillet, and 70 Mpa in the laminate blade profile. Hub and Blade both are well within the limits.

- Displacements are found to be around 16 mm, which follow the expected pattern and are within acceptable limits.
- Wind turbine design passes all the loading conditions such as wind load, gravity load and centrifugal loads due to the rotations.
- Impact analysis results show the local stress during the initial impact time and soon it transmits the energy into the structure. Graph plot shows all the energy absorbed.

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