An analysis study of HAWT blades with Extender

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ABSTRACT

In this paper a theoretical study of wind turbine blade design has been carried out. For the said study the Horizontal Axis Wind Turbine of 1kW which was installed at SSSCE RKDF University Bhopal has been taken into consideration.1000W HAWT which is having 3 blades in number is used for the study. The wind turbine blade is a structure, comprising Polypropylene/Carbon Reinforced material, and an extender is provided with the blades to connect the blade with the rotor .The material of blade is SS 304. The wind turbine is certified with ISO 9001-2008, CE, IEC 61400. It has been observed that the wind velocity or pressure is converted into the load on the blade structure. Effect of extender with the blades has been observed.

Keywords: HAWT, Extender ,performance, Power coefficient, wind velocity

1.Introduction

Improvement and relevance of horizontal axis wind turbines and the interrelated issues like structural design, smooth aerodynamically design, and the selection of material as well as issues related with the manufacturing which includes failure due to fatigue load, power optimization, and stability for the aero elasticity have drawn the interest of various researchers, scientist and scholars '. Jureczko et al. [1] worked on the design and optimization of wind turbine blades and developed an ANSYS program and presented a model for the implementations of a modified genetic algorithm which optimizes of various objective functions which are subjective to various restraint likewise thicknesses and other dimensions of the blade model which is taken into considerations. Guo [2] considered wings of aircraft for the optimization of its weight, an analytical and numerical analysis has been carried out by the researchers and shown a comparison of the results with the experimental results. Veers et al. [3] carried out a detailed stress analysis of wind turbine blades by considering its design, manufacturing technology. Baumgart [4] compared the results of experimentation with the analytical data by preparing a mathematical model for an elastic wind turbine blades. Larsen and Nielsen [5] investigated a nonlinear rotor dynamic stimulation of wind turbine by parametric excitation of both linear and nonlinear terms caused by centrifugal and Coriolis forces.

Petrini et al. [6] worked with the offshore wind turbines and discussed its fundamental and the major aspects related to the design. They carried out a research for the evaluation of required performance related with the decomposition of the configuration systems, under the action of loads. By utilizing the active aerodynamic load control devices (trailing edge flaps),the load reduction of large wind turbine blades numerically investigated by Lee et al. [7]. Tenguria et al. [8] considered HAWT and NACA airfoils blade from root to tip for the study and design and analysis.

All structures acts specifically under the action of aerodynamic forces, structures can change its properties like structure constants, stiffness coefficient and natural frequencies under the influence of aerodynamic forces. So the structure becomes instable even the reliability of the design of the system is improved. Due to the instability of the system the system has been destructed by an amount of specific force this phenomenon of destruction due to the specific amount of forces which is created by the specific amount of relative velocity is called Flutter phenomenon. And the specific speed responsible for destruction is called the speed of fluttering [9]. For making the safety of the system once the flutter speed has been recognized then the safety of structure can be ensured. In structures like an aeroplane, flutter speed is considered as the limiting velocity. Limiting velocity is the velocity which must not be reached by an aircraft under any circumstances.

2.Theory

2.1Blade element momentum theory (BEM)

It is theory which includes the steady state load sing condition for calculating the thrust and power for various combinations of wind speed, angle and rotational speed.

For finding out the loading thrust the blades is divided into number of blade elements known as N sections of blades.

With the following assumptions which are as follows:

1. Every section is free from other section as the variation in ones will not affect the others.

2.Force can be determined separately by the drag and lift coeff.of the airfoil shape of the blades

2.2Aerofoil Behavior

Whenever we talk about the aerofoil behavior of the blades we need to know the Mach number and Reynolds number

Mach number is a ratio of speed of an object over sound and it is defined as:

$$\frac{v_s}{u_c} = \text{Ma} \qquad \textbf{(Eqn2.1)}$$

Where,

Ma- mach number,

v_s -object speed and

u_c - sound speed.

For

Ma- 1 ; Subsonic

Ma 2, transonic

Ma 3, supersonic

Ma 5 hypersonic.

Similarly The Reynolds number can be defined as it is a non-dimensional value, and it is a ratio of inertial force to viscous force, defined as:

$$Re = \frac{\rho V^2/L}{\mu V/L^2} = \frac{\rho V L}{\mu} \text{........(Eqn 2.2)}$$

Aerofoil behavior of blades can be described into following flow regimes:

- the attached flow regime,
- the high lift/stall development regime and

In attached flow regime, flow is considered at the upper surface of aerofoil, lift increases with the angle of attack.

In high lift/stall development regime, the lift coefficient peaks as the airfoil becomes increasingly stalled.

aerodynamic performances are different because of different geometry of aerofoil, and according to different aerofoils behavior, choosing an applicable aerofoil for wind turbine blade will improve the efficiency.

Blade specification

Item	Desc
1	SS Bl
2	SS Lo
3	SS H
4	Nose
5	SS Fl

Fig.2.1

Fig.2.2

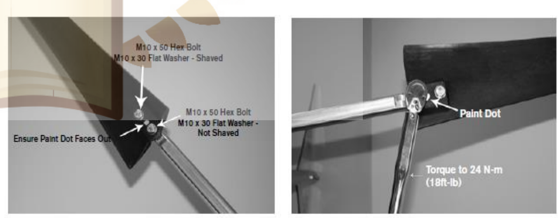

Fig.2.3

Fig2.4

3.Detailed Discussions

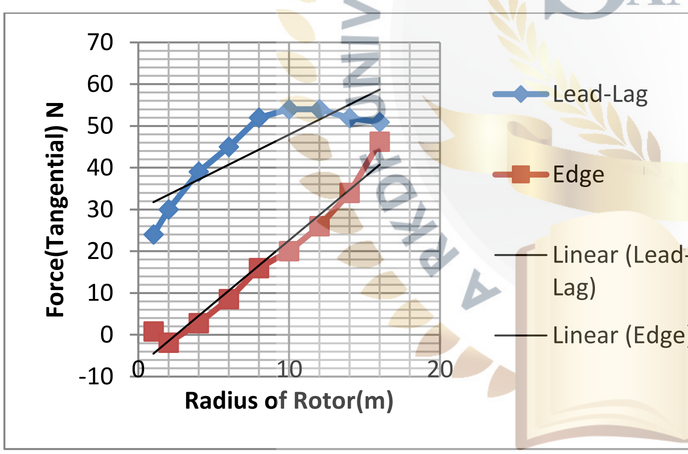

Fig.3.1

Blade of a rotor in our case a three blades rotor system acts as a cantilever beam which is twisted under the application of large amount of driving as well as tangential force. It is experienced that the large axial force is observed towards the exterior surface of the blade, which is most efficient aerodynamically and generate the leading lift forces, which produces a huge amount of bending moment at the core of the blade. It is graphed in the fig.3.2.

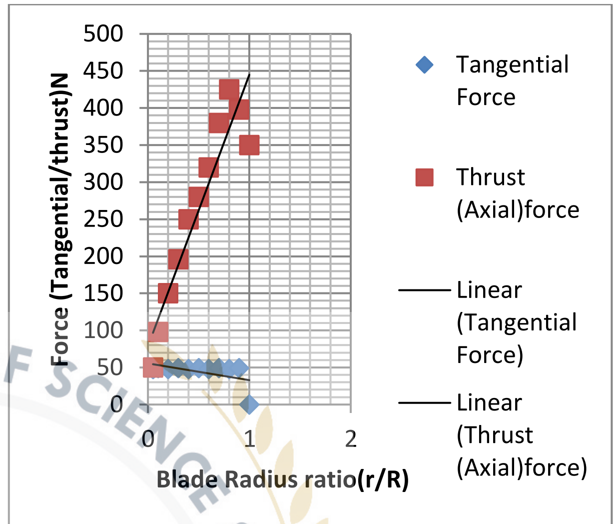

Fig.3.2

The effect of the alteration of forces between the blade root and the local blade reference systems may be seen in Figure 3.3 below.

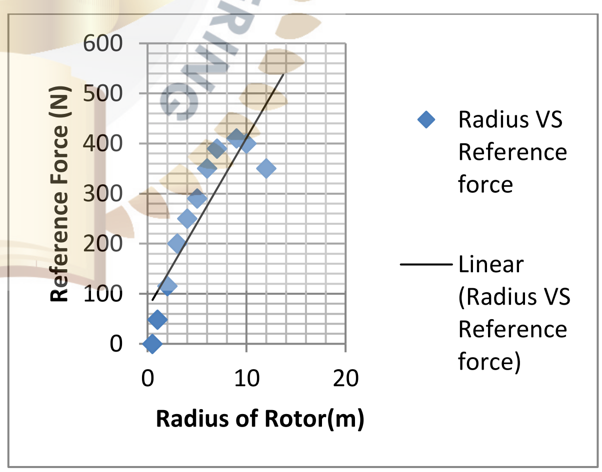

Fig.3.3

It can be seen that there is slight difference between the flap wise and flat wise forces near the blade root where the blade section twist angle is highest but these differences are shown to be insignificant when the flap wise and flat wise moments are compared as shown above in Figure 3.5.

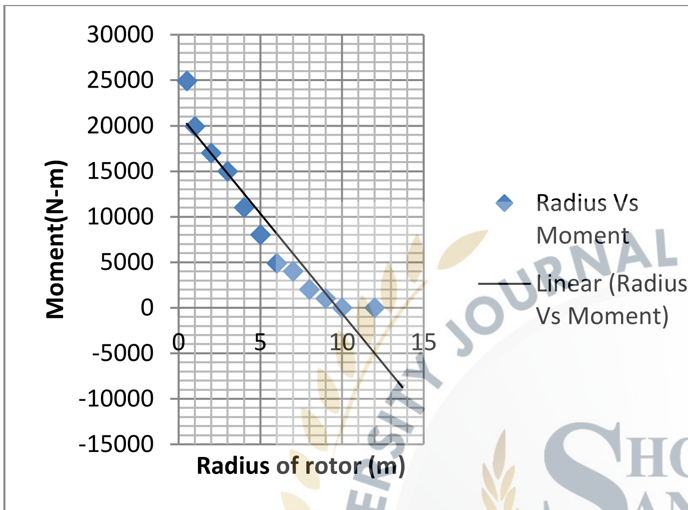

Fig.3.4

For comparison, the lead-lag and edge-wise forces and the tangential moments which are generated along the length of the blade are diagramed in Figure 3.5 below.

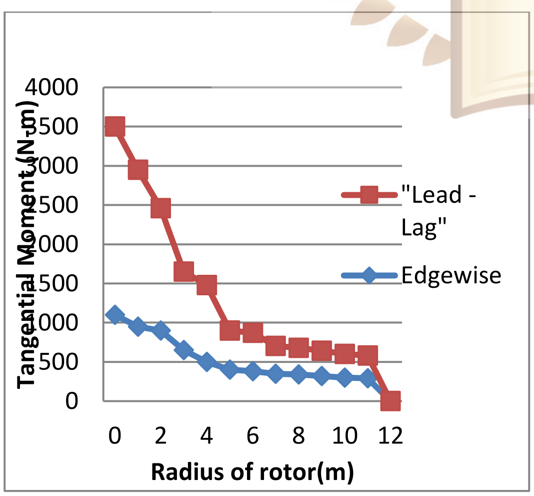

Fig.3.5

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In this study and analysis, the clockwise rotation speed of the wind blade was assumed at 12 m/sec, which is approximately nearer to the maximum designed wind speed of 18 m/s. The loading conditions are analyzed and discussed for the wind turbine blades.

The wind blades are subjected to the gravity force, the wind thrust, and tangential force. Figure 3.1,3.2 and 3.3 are showing various load and boundary conditions for the wind blade at the horizontal and vertical position and the gravity force is acting through the wind blade from its tip exterior position to the root (interior) end. The root end of the wind blade is fixed on the wind turbine hub, so the petiole degrees of freedom are all fixed.

4.Concluding Remark

The maximum tip displacements at three positions are 2.56 m, 2.37 m and 2.64 m, respectively. The deflection of wind blade is similar to that of a cantilever beam as shown in Figure 3.4 in the flapwise direction of wind blade. The maximum von Mises stresses and maximum tip displacements of 1000watts horizontal axis wind turbine blade at different angular position are shown in Table4.1.

Table 4..1 results of wind turbine blade at different angular position

S.No.	Value($\sigma_{von\ mises}$)MPa	Tip displacement(m)	Blade angular position

1.	87.11	2.56	0 º
2.	74.97	2.37	-120 º
3.	109.79	2.64	120 º

The Tsai-Hill failure criterion has been used to determine the failure of wind turbine blades. And one blade of a three rotor turbine has been taken into consideration and its taken as a reference blade and maximum time three most achieving position are considered. Among which blades angles 0 º , -120 º , 120 º are taken into consideration.

The maximum von Mises stresses, at 120º clockwise angular position in Table 4. 1, are summarized It can be seen from Table 5. 1, for the wind blade with fixed pitch angle, the wind blade with fixed pitch angle and if for certain case the the pitch angle is increased so it is an alternative way to prevent the wind blade from failure.

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