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FATIGUE LIFE ESTIMATION OF LOW COST WIND TURBINE BLADES USING FRACTURE MECHANICS

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ABSTRACT

Airfoil is a two dimensional section shape of aircraft wing or wind turbine blade. When an airfoil-shaped body is moved through a fluid it produces a system aerodynamic forces. The component of this force perpendicular to the direction of motion is called lift. The component parallel to the direction of motion is called drag. Subsonic flight airfoils have a characteristic shape with a rounded leading edge, followed by a sharp trailing edge, often with a symmetric curvature of upper and lower surfaces.

Airfoil plays a vital role in the behavior of a wind turbine as it is one of the major component. It is made up of different light weight composites. Here a low cost airfoil made up of aluminum alloy is used for analysis. Wind turbine blades are subjected usually to cyclic load, as forces are reversed in every revolution. A small macro crack induced due to any small accidents such as stone hit or bird hit events may drastically reduce the fatigue life of blades. In this work, a fatigue analysis of a wind turbine blade has been carried out with different crack length, and different thickness of the blade [1]. A relation between crack lengths, number of cycle (N), and thickness of blades has been studied using ANSYS. The study is expected to be of use in estimation of reserved life of a low cost wind turbine blades.

Keywords: Fatigue life, Fracture mechanics, Crack length, Goodman theory, Wind turbine blades

I. INTRODUCTION

Under service, a wind turbine blade is under tension along with bending when the turbine tip is below the hub center and is under compression and bending when it is above the center of the hub. Thus for half cycle of rotation, the wind turbine blades are under tension, shear and bending, while for another half cycle, the blade is under compression, shear and bending[6]. Thus, the blades are under constant fatigue load and the materials used in construction of the airfoil are light weight and has less fatigue strength as compared to the structural steel. So a micro or macro level crack will affect the fatigue life of the wind turbine blade [5]. Therefore it has been selected for fatigue analysis. Thus we must design and constantly keep inspecting for damage on the blade so that we can take appropriate measures before it fails. In this paper fatigue analysis is carried out with FEM based computational software ANSYS and Goodman theory. Variation between crack length, number of cycle (N), and thickness of the airfoil. Maximum von misses stress, strain, fatigue life, and the total deformation are also determined.Airfoil used for the analysis is the NACA 0012 Airfoil and the material used is the aluminum alloy.

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II. ANYLYSIS OF BLADE

NACA 0012 airfoil is used for analysis

Table.1 Dimension are as follows

Root(mm)	Mid span(mm)	Tip (mm)	Chord(mm)	Radius(mm)
100	450	50	8	60
100	450	50	10	60
100	450	50	12	60

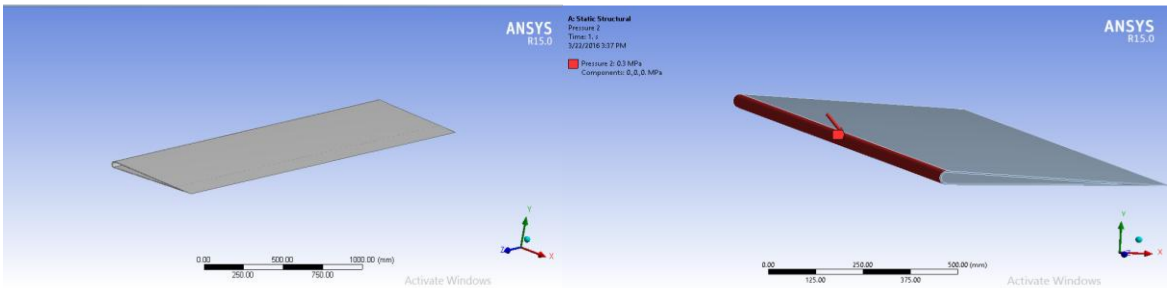

Fig.2(a):schematic of low cost Wind turbine blade **Fig.2(b):loads applied**

2.1 Determining Location of Crack

To determine the location of the crack preliminary analysis has been carried out and location of maximum equivalent Von-mises stress is determined which gives us the location of the crack. The co-ordinates of the anticipated crack were [0,10, 65]. The orientation of the crack was determined from principal stress direction and was found to be 60*

2.2 Crack Inputs

A crack of 1,2,3,4 mmwas introduced at a co-ordinate of [0, 10, 65] and inclination of 60*. A semi elliptical crack was used with maximum radius 4mm and minimum radius be 0.5 mm. Crack was meshed with fine 10 nodded tetrahedron elements.

2.3 Fatigue Inputs

A totally reversed load case is considered with the fatigue inputs value of mild steel and Goodman theory was used to determine the damage and the remaining life of blade in terms of number of load cycles.And the number of days were found out.

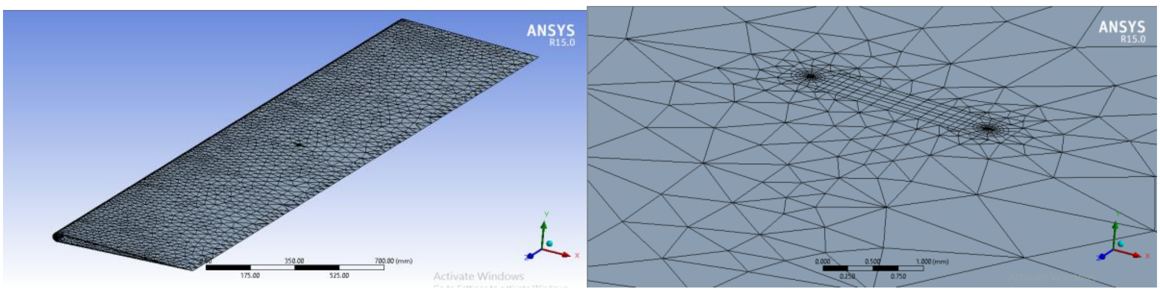

Fig. 2(a): MeshingFig. 2(b): Meshing on crack

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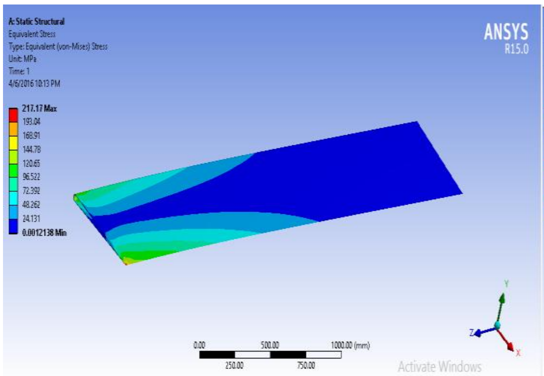
III. RESULTS

The Von-mises stress over the blade were determined and has been shown in fig.. 3.1. Equivalent strain, total deformation and fatigue life are shown in fig.. 3.2, 3.3 and 3.4 respectively. As stress &strain were observed maximum at the crack tip and the fatigue life was minimum at the crack tip. Graphs were plotted between the crack length, number of cycle reserved and different thickness of plate. Results shown are of 10 mm thick airfoil with 3 mm crack length.



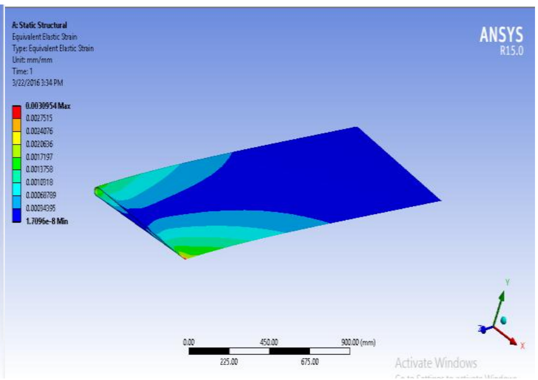
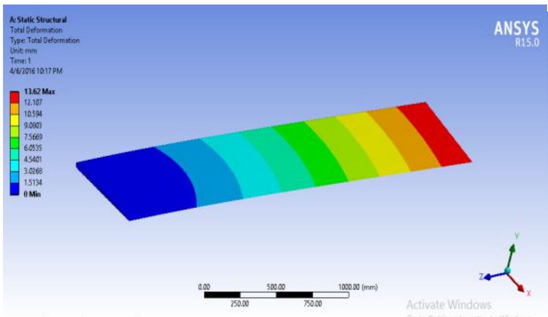


Fig.3(A): EQUIVALENT VON-MISES Stressfig.3(B):EQUIVALENT STRAIN:



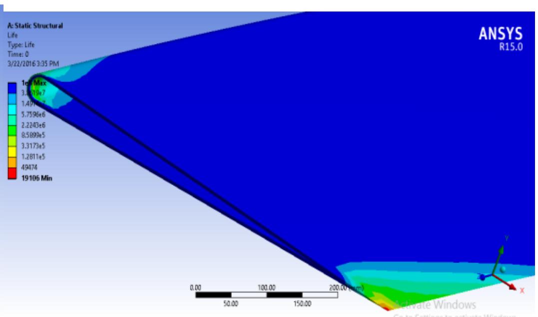


Fig.3(C): TOTAL Deformationfig. 3(D): FATIGUE LIFE

Table.2: Different crack length studied in wind turbine blades are as follows:

Maximum radius (mm)	Minimum radius (mm)
1	0.5
2	1
3	1
4	1

Table.3: Estimated fatigue life of wind turbine blade with different thickness and different crack lengths are as follows:

Crack length	8 mm (thk)	10 mm (thk)	12 mm (thk)
1	224080	580000	828070
2	98159	254500	385560
3	53662	133200	206570
4	25444	73521	109260

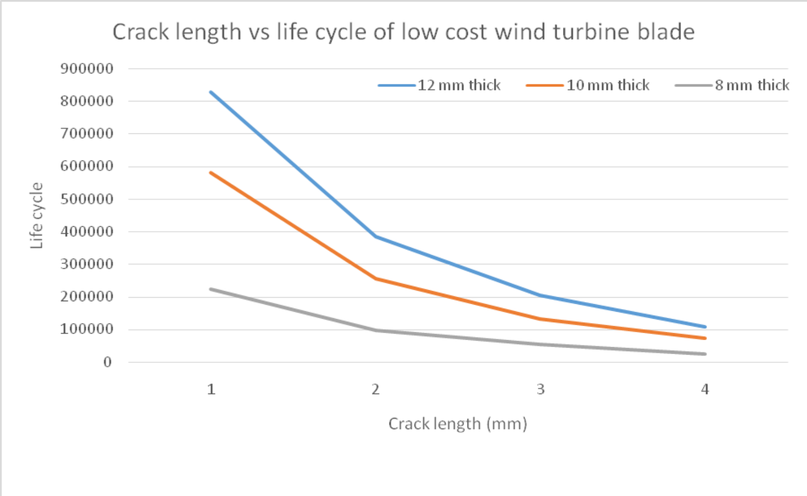


Fig. 3(e): CRACK LENGTH VS LIFE CYCLE

IV. CONCLUSION

Finite element based fatigue analysis has been carried out here and the relation of crack length, fatigue life of wind turbine blade with different thickness has been studied using ANSYS. This results will be useful in designing the wind turbine blade. The fatigue life has been determined as a function of the thickness and initial crack length. Fracture mechanics based analysis should be adopted in the design procedure for clearer description of crack propagation and estimation of life of the wind turbine blade.

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