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Fatigue Failure Analysis of Small Wooden Wind Turbine Blade

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Abstract:
Advances in engineering technology in recent years have brought demands for reliable wind turbine blade which can operate at different climatic condition and speeds. When failures occur they are expensive, not only in terms of the cost of replacement or repair, but also the costs associated with the down-time of the system of which they are part. Reliability is thus a critical economic factor and for designers to produce wind turbine blade with a high reliability they need to be able to accurately predict the stresses experienced by the different load condition. A wooden 1.5m wind turbine blade was tested by means of a mechanically operated test rig for fatigue failure. The rig uses a crank eccentric mechanism by variable load for each load cycle. The stress distribution in fatigue critical areas of the blade during testing was found to be similar to the expected stress distribution under normal operational condition

Keywords: Wind turbine, blade, bending stresses, analysis, wood, fatigue.

1. Introduction

Wind power is a source of non-polluting, renewable energy. Using wind as an energy source is not a new technology as the first reliable source of the existence of windmills dates back to 644 A.D. and some have claimed to have found remains of windmills 3000 years old. From that time windmills were used to mill grain and later pump water. In the early 1900s, wind was first used to generate electricity. Today, wind turbines (WT) can generate megawatts of power and have rotor diameters that are on the order of 100 meters in diameter. Modern WT, like the one shown in Figure are nearly all horizontal-axis WT (HAWT) and have three rotor blades. The blades of modern WT are manufactured borrowing technology from the boat building industry, are made of both glass and wood composites, and have an airfoil shape adapted from aeronautical engineering. The blades have the ability to pitch in the rotor hub to maintain the optimal angle of attach given the conditions as well as to pitch far enough to stop the rotor in extreme conditions. Some turbines also have internal brakes to stop the rotor. Wind power is one of the fastest growing energy technologies in the world. Wind power has been the second largest source of new power generation in the country for the past two years second only to natural gas, but wind still only currently makes 1% of the country's total electric generation capacity . However, the wind resource is vast and relatively untapped in the United States and theoretically could supply all of the nation's energy. Wind as a sole power source is of course a hypothetical possibility, but the federal government has made a goal for 20% of the country's power to be supplied by wind . However, for this goal to become a reality, WT technology must be improved. The Department of Energy's Wind Energy Program works with the WT industry and research labs, like Sandia National Laboratories (SNL) and the National Renewable Energy Laboratory's (NREL) National Wind Technology Center (NWTC), to improve wind energy technology.

1.1 Wind turbine blades:

Following fig. 1.1 shows different types of failure of wind turbine blade. Wind turbine blade is only 7% still my main emphasis on wind turbine blade because of the following reason.

1) Cost of wind turbine blade is almost 30% cost of wind turbine. For composite blade.
2) Failure of wind turbine blade means total turbine failure for long period of time. Because replacement of blade takes long period of time.
3) Also replacement cost of wind turbine blade is too high. And it may be performed by skilled technical person with highly skilled crane operator.
4) Maintaining the inventory of wind turbine blade required huge capital.
5) Sudden failure or failure of wind turbine blade in running condition hamper the total wind turbine set ultimately 90% loss of total wind turbine cost.
6) Lastly if failure occur at the time when person working with near by it may loss of life to human being.
7) Table no. 1 shows the wind potential available in different states of INDIA.

Table no 1 : Wind power potential in INDIA [1]

Sr. no.	State	Gross potential (MW)	Technical potential (MW)
1	Andhra Pradesh	8275	1920
2	Gujarat	9675	1780
3	Karnataka	6620	1180
4	Kerala	875	605
5	Madhya Pradesh	5500	845
6	Maharashtra	3650	3040
7	Orissa	1700	780
8	Rajasthan	5400	910
9	Tamilnadu	3050	1880
10	West Bengal	450	450
	Total	45 195	13 390

In this work fatigue failure of small wooden wind turbine blade by bending strength is found out with the help of crank eccentric bending fatigue failure test rig. A wind turbine blade of 1500 mm length and angle of attack 12 degree for maximum wind speed 25 m/s and rated output for 5 Kw. The long-term goal is to develop general approaches and generic models for each possible failure modes, so that the material properties can be fully utilized and the structural design can be optimized. The new design methods will enable the wind turbine industry to improve their design details and their choice of materials.

Fig 1.1 Different types of failure of wind turbine due to failure of blade

2. Materials and Methods

2.1 Mechanical properties

Table 1 shows the mechanical properties of material used for the experimental investigation of fatigue failure analysis of . all wood wind turbine blade.

Table no 2. Mechanical properties of material [2]

Name of material (Botonical name)	Poisson ratio	Yield stress(Mpa)	Ultimate tensile stress (Mpa)	% Elongation	Modulus of elasticity (Mpa)	Density (Kg/m^3)
Pine (Pinus strobes)	0.328	11500	40	4.01	11500	470
Teak wood (Tectona grandis)	0.341	10830	95	3.88	9400	630
Spruce (picea glauca)	0.372	9800	88	3.50	8500	400

2.2 Material manufacturing

Material is purchase from 1) Gil timber mart, bazarpeth, sangamner. 2) Krushna saw mill, Opposite to bus stand, sangamner. 3) Electronic switches K-11, Ambad MIDC , nasik. 4) Composite mart, 161, 3-pancham ellite, vishvantwadi, airport road, pune.

Blade manufacturer Vitthal Date , Near navale fabrication, ghulewadi, sangamner.

2.3 Testing facilities

Crank eccentric type fatigue test rig with strain gauges and Load cell is use to measure the applied load.

Fig. 2.1 Test rig used for rotating bending fatigue. And test specimen of wood wind turbine blade.

2.4 Testing condition

Normal operating temperature condition at the time of testing is 35^0 C .

3. Result and Discussion

Wind turbine blade fatigue testing involves the automated cyclic loading of blades typically at resonant frequency and under closed-loop control, as a means of exciting the blade and achieving the desired strain rate. Cyclic loads are applied to blades at resonant frequency for flap-wise (20 Hz) evaluations. This constant-amplitude fatigue testing can be used to validate blade models, characterize design durability, confirm load profiles and track early failures, cracks and changes in properties. Because of practical limitations, laboratories cannot test a blade with such a large number of design-load cycles in a time period that is reasonable. The advantage of laboratory testing is that the load-amplitude may be increased to accelerate the level of damage per load cycle by as much as two orders of magnitude over the design condition in order to achieve the same total damage in a fraction of the time. The difficulty comes in knowing the properties of the structure well enough to predict where the high damage will occur.

Blade sample	Stress (N/mm^2)	Load (N)	No. of cycle
Pine sample 1	43	399	$4.578x10^4$
Pine sample 2	42	395	$4.547x10^4$
Teak sample 1	35	330	$1.447x10^6$
Teak sample 2	34	324	$1.486x10^6$
Spruce sample 1	24	268	$3.635x10^6$
Spruce sample 2	22	239	$4.005x10^6$

Table no.2 Test result of bending fatigue test

Table no 2 shows the test result of pine wood, teak wood which is commonly available in India. And spruce wood are tested for the different types of load at that time stress is calculated when blade is damage.

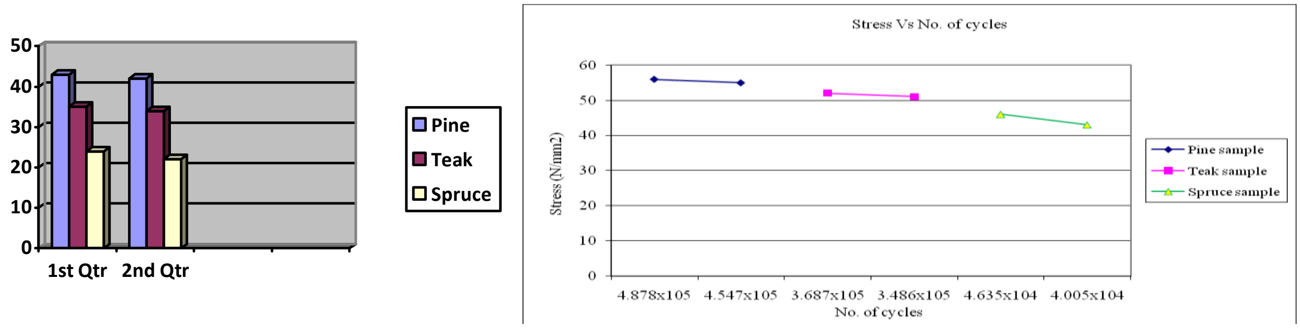

Fig 3.1 Fatigue life of different sample and stress level at that time.

From fig. 3.1 it identified that Teak wood sustain high stress with respect to number of cycle at the time of fatigue life of blade in comparison with the Pine wood and spruce wood also teak wood is very good solution for small types of blade.

4. Conclusions

A 1.2 m wooden wind turbine blade has been successfully tested and it is generally observed that failure of wind turbine blade is 7% as that of total component available in wind turbine generator (WTG). But in actual practice when the WTG blade is fail at running condition total WTG system is collapse and approximate 90% cost of WTG is going to be waste. So it is necessary to search a alternative material for WTG. In the present work 1.2 m wood wind turbine blade has been tested for fatigue test. Following are the advantages of Teak wood, Pine wood, Spruce wood which has been successfully test in this study.

- Easily availability of material.
- Cost of material is low.
- Non pollutant to environment.
- Weight is low.
- High strength for small WTG blade.

Limitation.

- It is difficult to form a aerodynamic shape of blade.
- High length knot free wood is difficult to search.
- Cost of making a blade is equal to cost of material.

Still it is concluded that for the use of micro and mini size wind turbine blade wood is the best material for wind turbine blade.

1) Approximate cost of wood wind turbine blade (each) is Rs 1000/- for a 5 years of reliability and for 15 years of reliability Rs 3000/- while it compare to composite material each blade is to be 12000 Rs/- for 15 years of reliability. It means cost shaving in blade material and down time cost due to failure of blade is to be avoided.
2) Fatigue life is also considerable for 5 years of life of wind turbine.

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