International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 1, Issue 1, September 2014

Analysis and Performance of Small Wind Turbine Blades

Satheesh Kumar S[1]
Assistant Professor, Department of Electrical and Electronics Engineering, Karunya University[1]
Email:satheesh@karunya.edu[#]

Abstract: The objective of this project is to design, model and analyze a 750W wind turbine blade. The blade profile chosen is NACA 4412 series. Here two types of blade materials, fiber material and teak wood are considered. The blade profile is designed using Pro-E considering the blade length, 1.2m. An analysis is done using Ansys v.12. In the structural analysis module of Ansys the stress intensity and displacement for different lengths of the blade are noted. From the value twist at which the stress levels for the both the type of materials are minimum, noted using the structural analysis module of Ansys. From the comparative study the best material for the wind turbine blade is selected. The theoretical output is compared with that of the experimental output from the fabricated blades.

Keywords: Glass fiber, Teak wood, stress intensity, displacement, power output.

I. INTRODUCTION

The increasing concern for the environment and the oil price shock provides an impetus for clean resources of energy, such as wind power. Wind energy had become the leading developing direction in electric power in the last 20 years. Micro-generation, or small- scale embedded generation, has a significant part to play in the future. Small-scale embedded generation includes solar photovoltaics, small-scale wind turbines, micro-hydro generators, micro-combined heat and power along with hydrogen fuel cell and bio-energy. Such small-scale embedded generators are generally connected to mains at 230 V, single phase, with currents limited to below 16A that is maximum power rating of about 3kW.This paper is concerned with small-scale wind turbines, typically, > 2kW, for design and analyze purpose here we chosen NACA 4412 series. The design of blade for NACA 4412 is imported from DESIGNFOIL software and the dimensions are adjusted as our requirement.

TABLE NO. 1
PARAMETERS REQUIRED

Parameters	Values
Blade Length	1.2m
Chord Length at route & tip	150mm & 60mm

For our analysis, we chosen our blade twist 0º, 4º, 6º, 8º, 10º, 12º and PRO-E model for 4º twist blade as follows.

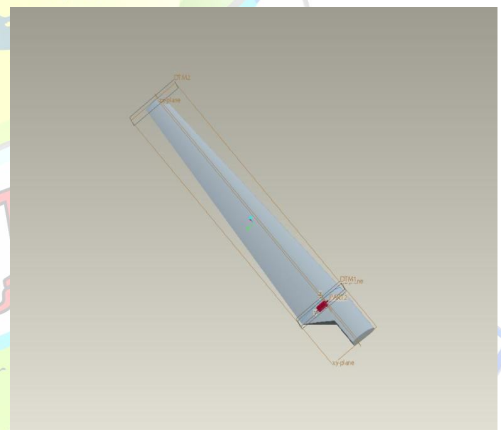

Fig.1.Wind blade for 4º twist.

II. STRUCTURAL ANALYSIS

In this paper, in structural analysis, mainly we focused to stress intensity and displacement of blade at different blade twist for both materials such as glass fiber and teak wood.

TABLE NO.2
PROPERTIES OF GLASS FIBER

Parameters	Values
Young's modulus	73000Mpa
Density	1850Kg/m^3
Poisson ratio	0.28

For analysis purpose, we need pressure value for wind velocity at the side of blade. The pressure to be calculated by using following formula (1).

Pressure= Force/Area (1)

Force= $(\pi/9)*\rho*D^2*V_i^2$ (2)

Where, ρ= density of air in Kg/m^3

D=Rotor diameter in m

V_i= Velocity of incoming air in m/s

For simple analysis, here we showed stress intensity (Fig.2) and displacement (Fig.3) for fiber blade with twist of 4º at wind velocity 6m/s.

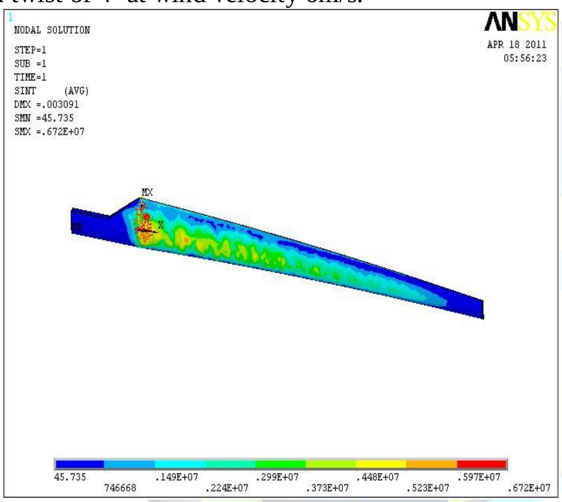

Fig.2 Stress intensity for glass fiber with twist 4º at wind velocity 6m/s

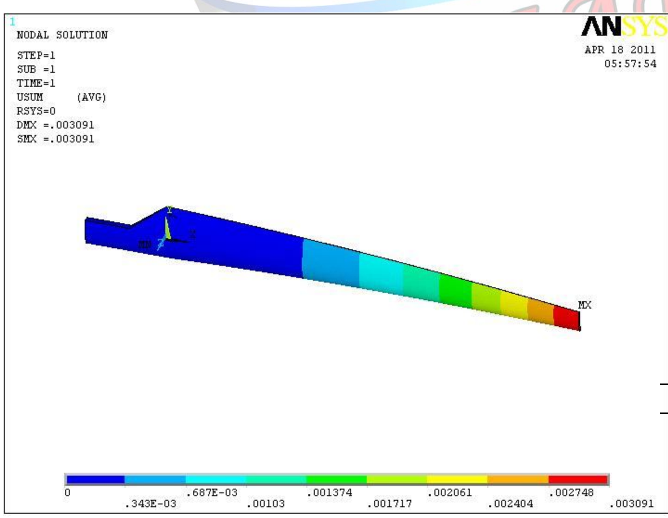

Fig.3 Displacement for glass fiber with twist 4º at wind velocity 6m/s

Similarly, for different blade twist angle we calculated stress intensity (Fig.4) and displacement (Fig.5) for glass fiber wind blade and plotted in graph.

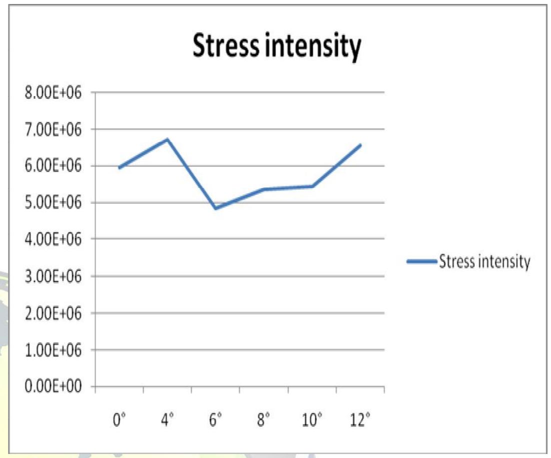

Fig.4 Stress intensity graph for glass fiber with different blade twist angle

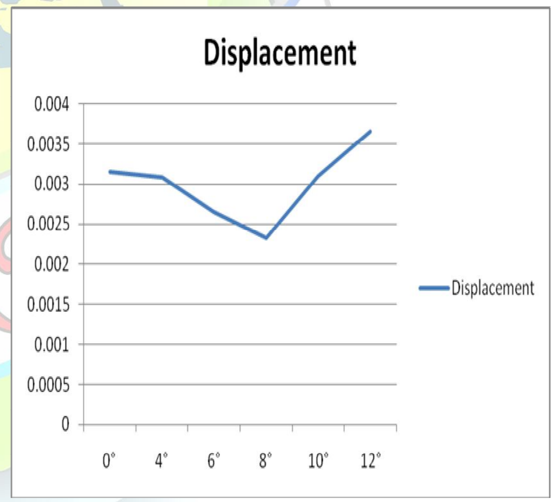

Fig.5 Displacement graph for glass fiber with different blade twist angle

Same procedure to be followed for calculating stress intensity and displacement for teak wood.

TABLE NO.3
PROPERTIES OF TEAK WOOD

Parameters	Values
Young's modulus	15600Mpa
Density	630Kg/m^3
Poisson ratio	0.02

International Journal of Advanced Research Trends in Engineering and Technology (IJARTET)
Vol. 1, Issue 1, September 2014

By using formula 1&2, we calculate pressure value at different velocity for teak wood.

Here also for simple analysis, we showed stress intensity (Fig.6) and displacement (Fig.7) for teak wood with the twist of 4º at wind velocity 6m/s.

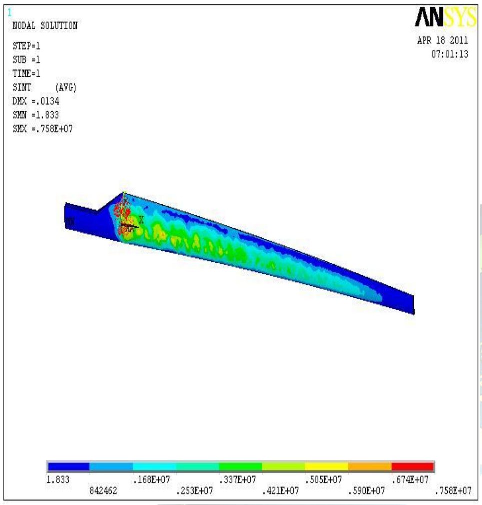

Fig.6 Stress intensity for teak wood with twist 4º at wind velocity 6m/s

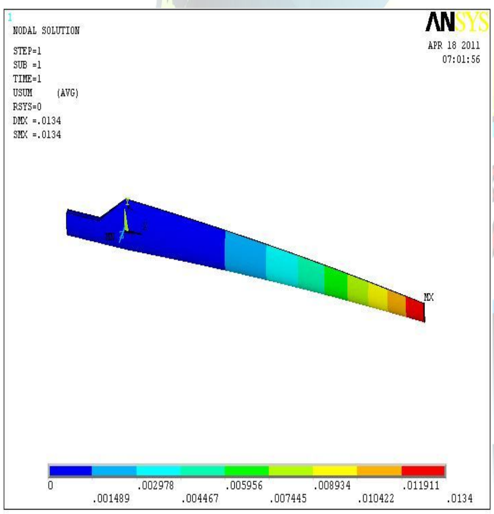

Fig.7 Displacement for teak wood with twist 4º at wind velocity 6m/s

Similarly, for different blade twist angle we calculated stress intensity (Fig.8) and displacement (Fig.9) for teak wood wind blade and plotted in graph.

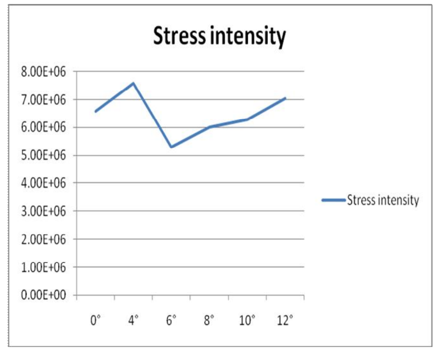

Fig.8 Stress intensity graph for teak wood with different blade twist angle

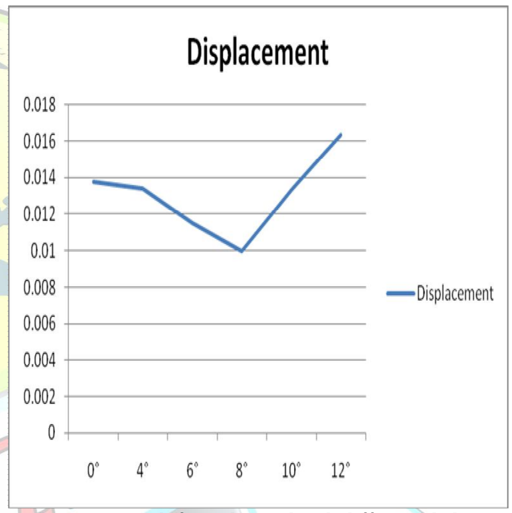

Fig.9 Displacement graph for teak wood with different blade twist angle

III. POWER OUTPUT

In this paper power output to be calculated by varying the twist angle for Angle of Attack (AOA). Here velocity also changes so that Cl and Cd also changes and we calculate Cp shown in table no. 4 and power output shown in table no.5 for different velocity.

TABLE NO.4
CP FOR DIFFERENT TWIST ANGLE FOR AOA 6

Velocity	twist30	twist 40	twist 50	twist 55	twist 60
6	1.3509	1.4821	1.5079	1.5021	1.4894
7	1.3509	1.4821	1.5079	1.5021	1.4894
8	1.3509	1.4821	1.5079	1.5021	1.4894

9	1.3509	1.4821	1.5079	1.5021	1.4893
10	1.3509	1.4821	1.5079	1.5021	1.4894
11	1.3588	1.4893	1.5143	1. 0814	1.4950
12	1.3674	1.4974	1.5217	1.5152	1.5017
13	1.3738	1.5033	1.5269	1.5200	1.5063
14	1.3802	1.5091	1.5321	1.5249	1.5108
15	1.3850	1.5135	1.5360	1.5285	1.5142

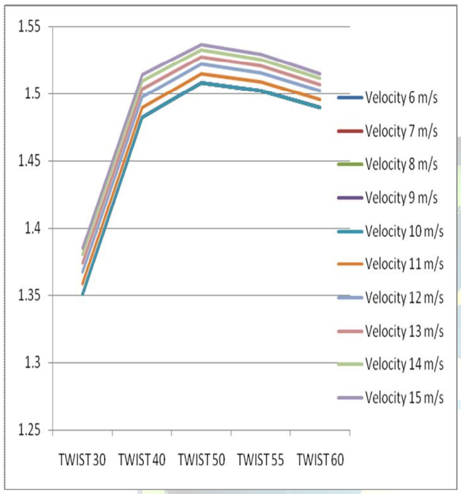

Fig. 10 Cp graph for different twist at various wind velocity for AOA 6

Now we calculate power output for different velocity.

TABLE NO.5

OUTPUT POWER FOR DIFFERENT TWIST ANGLE FOR AOA 6

Velocity	twist 30	twist 40	twist 50	twist 55	twist 60
6	851.0	933.6	949.9	946.2	938.2
7	1351.4	1482.6	1508.4	1502.6	1489.9
8	2017.2	2213	2251.6	2243	2224
9	2872.2	3151	3205.9	3193.6	3166.6
10	3940	4322.4	4397.7	4380.8	4343.8
11	5274.7	5781.2	5878.3	5854.2	5803.5
12	6891.5	7546.7	7669.1	7636.0	7568.4
13	8802.7	9632.3	9783.7	9739.6	9651.6
14	11045	12077	12261	12203	12091
15	13633	14897	15118.9	15045	14905

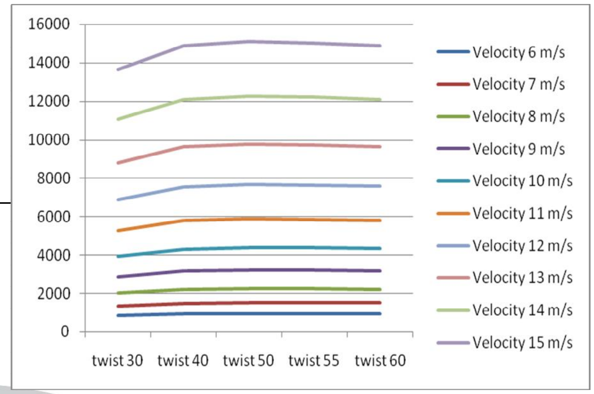

Fig.11 Power output for different twist at various velocity for AOA 6

TABLE NO.6

CP FOR DIFFERENT TWIST ANGLE FOR AOA 7

Velocity	twist 30	twist 40	twist 50	twist 55	twist 60
6	1.354	1.504	1.542	1.540	1.531
7	1.354	1.504	1.542	1.540	1.531
8	1.354	1.504	1.542	1.540	1.531
9	1.354	1.504	1.542	1.540	1.531
10	1.354	1.504	1.542	1.540	1.531
11	1.362	1.511	1.548	1.546	1.536
12	1.369	1.518	1.554	1.552	1.541
13	1.376	1.524	1.560	1.557	1.547
14	1.382	1.530	1.565	1.562	1.551
15	1.380	1.529	1.564	1.561	1.550

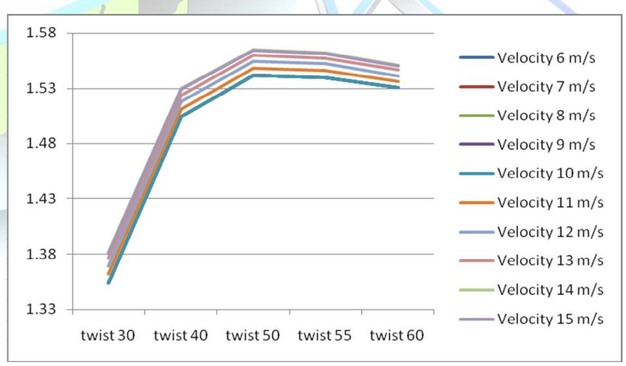

Fig.12 Cp graph for different twist at various wind velocity for AOA 7

TABLE NO.7
POWER OUTPUT FOR DIFFERENT TWIST ANGLE FOR AOA 7

Velocity	twist 30	twist 40	twist 50	twist 55	twist 60
6	853.5	947.9	971.5	970.4	964.4
7	1355	1505.3	1542.7	1541.0	1531
8	2023	2246.9	2302.9	2300.2	2286
9	2880	3199.3	3278.9	3275.2	3255
10	3951	4388.6	4497.9	4492.7	4465
11	5288	5867.8	6010.4	6002.1	5964
12	6903	7652.5	7834.0	7821.5	7770
13	8819	9770	9997.9	9980.3	9913
14	11062	12247	12526	12502	12416
15	13591	15049	15395	15365	15261

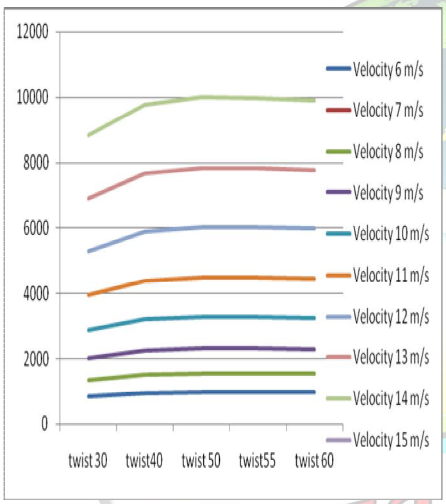

Fig.13 Power output graph for different twist at various wind velocity for AOA 7

IV. EXPERIMENTAL OUTPUT

After installation Fig.14, it is capable to run the 1 H.P motor at wind velocity of 16m/s in teak wood wind turbine blade.

Blade Material= Teak wood
Number of Blades = 3 blade
Voltage= 48V
Current=5.2A
Power output= 744watt
Braking system= Electrical Braking system
Tower height= 12m

Fig.14 Experimental output for 750W small wind plant

V. CONCLUSION

In this article, the design, model and analyze a 750W wind turbine blade is done for glass fiber material and teak wood and their results are shown in above graphs. Power for different AOA (AOA 6 and AOA 7) is analyzed theatrically and experimentally.

REFERENCES

[1] M. E. Bechly And P. D. Clausent, *Structural Design Of A Composite Wind Turbine Blade Using Finite Element Analysis*, Computers & Structures Vol. 63. No. 3, Pp. 639-616. 1997.

[2] Tony Burton, David Sharpe, Nick Jenkins, Ervin Bossanyi, *Wind Energy Handbook*, John Wiley & Sons, Ltd

[3] N. Stannard And J.R. Bumby, *Performance Aspects Of Mains Connected Small-Scale Wind Turbines*, Iet Gener. Transm. Distrib. Vol. 1, No. 2, March 2007.

[4] N.J. Stannard, J.R. Bumby, *Energy Yield And Cost Analysis Of Small Scale Wind Turbines*, Durham University, Uk.

[5] Rajesh Saiju, Abdel Tamzarti, Siegfried Heier, *Performance Analysis Of Small Wind Turbine Connected To A Grid Through Modeling And Simulation*, The 33rd Annual Conference Of The Ieee Industrial Electronics Society (Iecon) Nov. 5-8, 2007, Taipei, Taiwan.

[6] L. Mihet-Popal, V. Groza2, 0. Prostean' And I. Szeidert', *Modeling And Design Of A Grid Connection Control Mode For A Small Variable-Speed Wind Turbine System*, I2mtc 2008 - Ieee International Instrumentation And Measurement Technology Conference Victoria, Vancouver Island, Canada, May 12-15, 2008.

[7] N.M. El Chazly, *Static And Dynamic Analysis Of Wind Turbine Blades Using The Finite Element Method*, Renewable Energy Vol. 3. No. 6/7, Pp. 705-724, 1993.

[8] N. M. El Chazly, *Static And Dynamic Analysis Of Wind Turbine Blades Using The Finite Element Method*, Computers & Structures Vol. 48, No. 2. Pp. 273-290. 1993.

