Aerodynamic Design, Fabrication and Testing of Wind Turbine Rotor Blades

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Abstract- The need for use of renewable source of energy for green electricity production is increasing day by day. Wind turbine blade must be designed aerodynamically to achieve optimum performance in both design and off design conditions. In present study eight different study eight different blades for 700 watts scaled radio of 4 we are fabricated. The sections of wind turbine blade are selected from NACA series. The blades are tested in wind tunnel and their lift and drag at various angle of attacks were observed. From the test results, power for various blades were calculated and compared to get the optimum blade for 700 watts wind turbine. For a small scale wind tunnel experimental work can be carried out to find out the optimized rotor blade for the selected configurations.

Keywords – Wind turbine blade, wind tunnel, Inlet wind velocity, Angle of attack, and Maximum power.

I. INTRODUCTION

Wind tunnels are devices which provide air streams flowing under controlled conditions so that models of interest can be tested using them. Wind turbine blades work by generating lift due to their shape. The more curved side creates low air pressures while high pressure air pushes on the other side of the aerofoil. The net result is found that lift force is perpendicular to the direction of flow of the air.

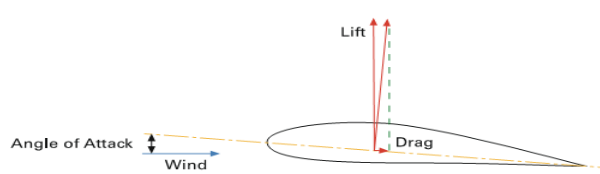

Figure 1. Lift & Drag Vectors

The lift force increases as the blade is turned at a greater angle to the wind. This is called the angle of attack. At very large angles of attack the blade, lift decreases again. This is due to stalling of rotor blade which results in an optimum angle of attack which in turn increases the lift.

Figure 2. Blade at Low, Medium & High Angles Of Attack

II. DESIGN AND FABRICATION OF AEROFOIL BLADE PROFILE

Wind turbine blades were fabricated for eight NACA series airfoils with the dimensions shown in Figure 3.The blade profile is then carved out of red cedar wood which has a density of 465 kg/m^3 and has good strength weight ratio.

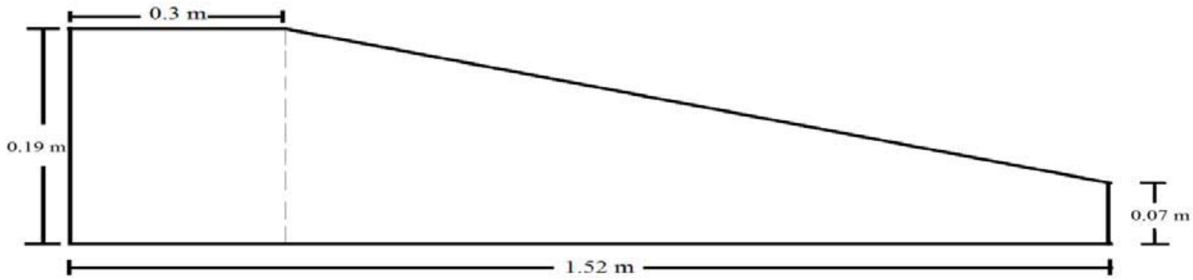

Figure 3.Front view of blade with dimensions

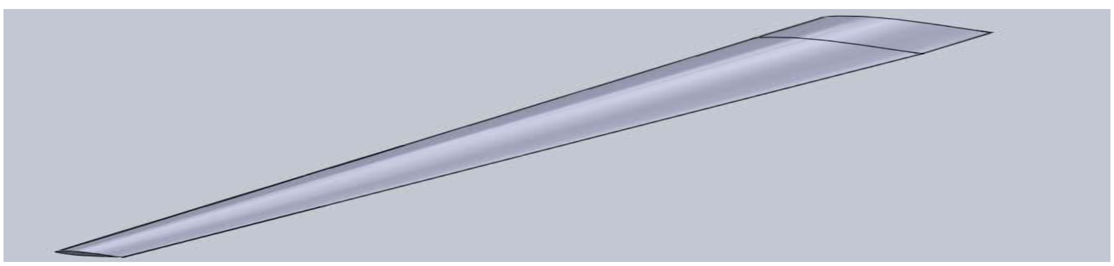

Figure 4.Three dimensional view of the blade (I.V)

Figure 5. Fabricated NACA 0010,4412,4415,4418 aerofoil profiles blades (F.V)

Figure 6. Fabricated NACA 0010,4412,4415,4418 aerofoil profiles blades (S.V)

Figure 7. Fabricated NACA 23012,23015,23018,63218 aerofoil profiles blades (F.V)

Figure 8. Fabricated NACA 23012,23015,23018,63218 aerofoil profiles blades (S.V)

III. METHOD OF EXPERIMENTATION

The experiments have been conducted on a wind tunnel and the specification of the test wind tunnel is shown in Table 1. The model is mounted on the wind tunnel test-section using suitable fixtures. The fixtures are designed in a way that the angle of attack of the blade can be adjusted. The fixtures are designed in a way that the angle of attack of the blade can be adjusted flow velocity is increased from 3 m/s to 11 m/s .Pressure at various locations are noted and lift and drag values are calculated from the pressure values.

Table -1 Specification of the wind tunnel

Test section	0.45 m x 0.45 m
Type	Open circuit low subsonic, suction type
Max Rpm	1500 rpm
Max Velocity	15 m/s

Blade velocity triangle showing lift and drag forces on blade element are shown in Figure 9.

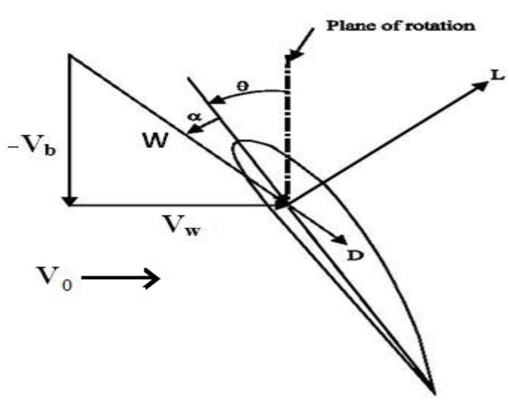

Figure 9. Blade element force velocity diagram

Figure 10. Wind tunnel testing

Lift and drag coefficients (C_L & C_D) for the fabricated blades are been calculated at various inlet velocities (ranging from 3 m/s to 11 m/s) and at various angle of attack (-5deg to 15 deg).The coefficient of performance which will not exceed 0.59 which is the betz limit.

MODEL CALCULATION

For NACA 23015 AEROFOIL,

$\alpha = 10^{o}$

$V_0 = 9\ m/s$

$N = 57$

$V = r.\omega$

$= r.2.\pi.N/60$

$V = 9.0921\ m/s$

$V_r = (V^2 + V_0^2)^{0.5}$

$= 12.79\ m/s$

From wind tunnel testing we get values of,

$C_L = 0.584$

$C_D = 0.02476$

Lift force $= 0.5 \times \rho \times V_r^2 \times C_L$

$F_L = 58.54\ N$

Drag force $= 0.5 \times \rho \times V_r^2 \times C_D$

$F_D = 2.48\ N$

$F_R = (F_D^2 + F_L^2)^{0.5}$

$F_R = 58.59$

Power = Torque $\times\ \omega = F_R \times V$

$= 58.59 \times 9.0921$

= 532.7 watts

$$POWER = 0.5 \times \rho \times A \times V_0^3 \times CP$$

CP = 0.16

IV. RESULTS AND DISCUSSIONS

The variation of power with inlet velocity and angle of attack for various aerofoil configurations is shown in Figure 11-18.

NACA 0010 aerofoil profile blade can generate maximum power of 313 W, at an angle of attack of 10^{o} and at an air velocity of 10 m/s.

NACA 4412 aerofoil profile blade can generate maximum power of 308 W, at angle of attack 10^{o} and at air velocity of air 10 m/s.

NACA 4415 aerofoil profile blade can generate maximum power of 199 W, at angle of attack 10^{o} and at velocity of air 10 m/s.

NACA 4415 aerofoil profile blade can generate maximum power of 308 W, at angle of attack 10^{o} and at velocity of air 10 m/s.

NACA 23012 aerofoil profile blade can generate maximum power of 374 W, at angle of attack 10^{o} and at velocity of air 10 m/s.

NACA 23015 aerofoil profile blade can generate maximum power of 675 W, at angle of attack 10^{o} and at velocity of air 10 m/s.

NACA 230118 aerofoil profile blade can generate maximum power of 193 W, at angle of attack 10^{o} and at velocity of air 10 m/s.

NACA 63218 aerofoil profile blade can generate maximum power of 168 W, at angle of attack 10^{o} and at velocity of air 10 m/s

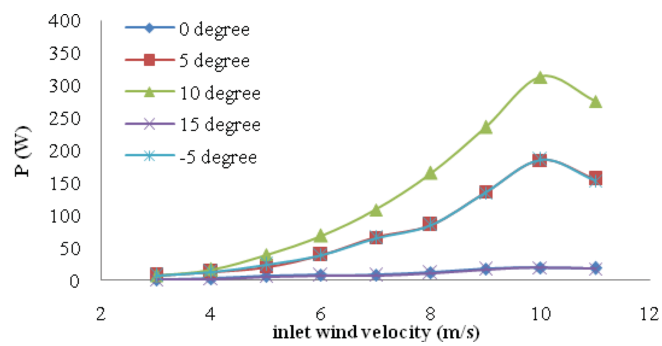

Figure 11. Comparison of inlet wind velocity and Power for NACA 0010

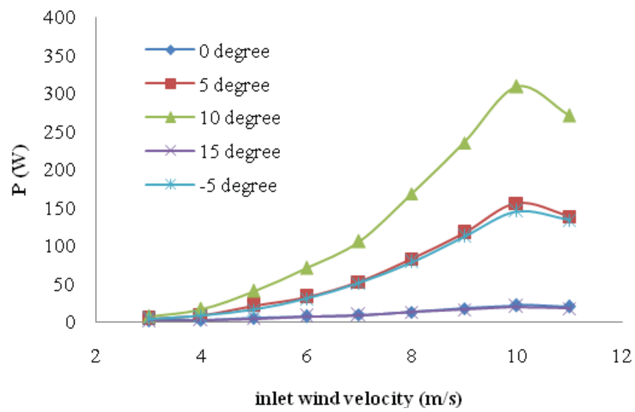

Figure 12. Comparison of inlet wind velocity and Power for NACA 4412

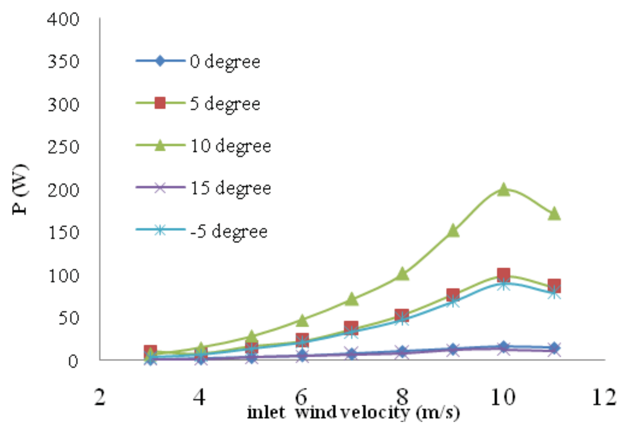

Figure 13. Comparison of inlet wind velocity and Power for NACA 4415

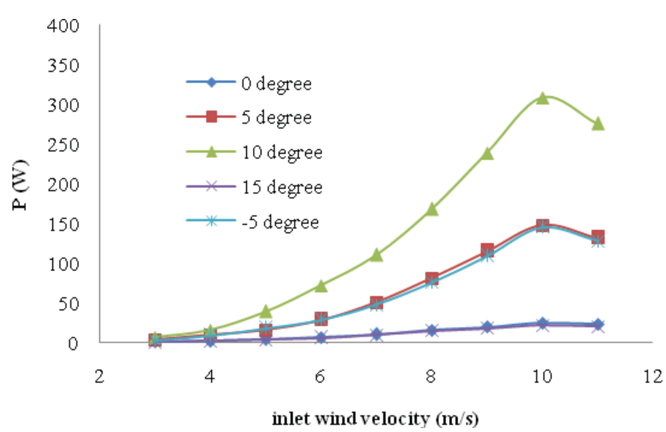

Figure 14. Comparison of inlet wind velocity and Power for NACA 4418

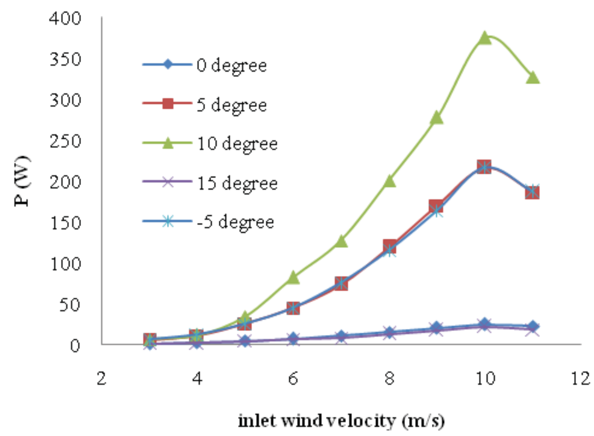

Figure 15. Comparison of inlet wind velocity and Power for NACA 23012

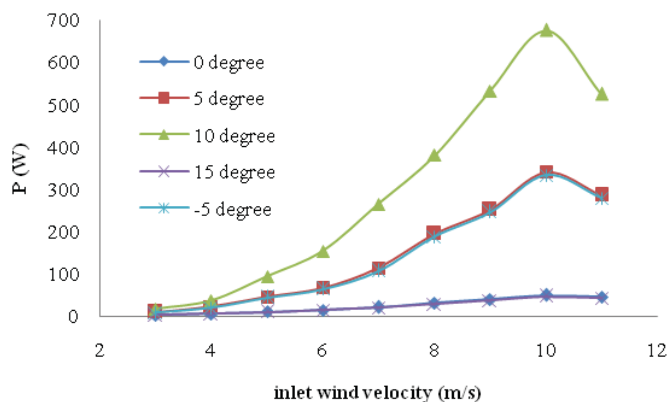

Figure 16. Comparison of inlet wind velocity and Power for NACA 23015

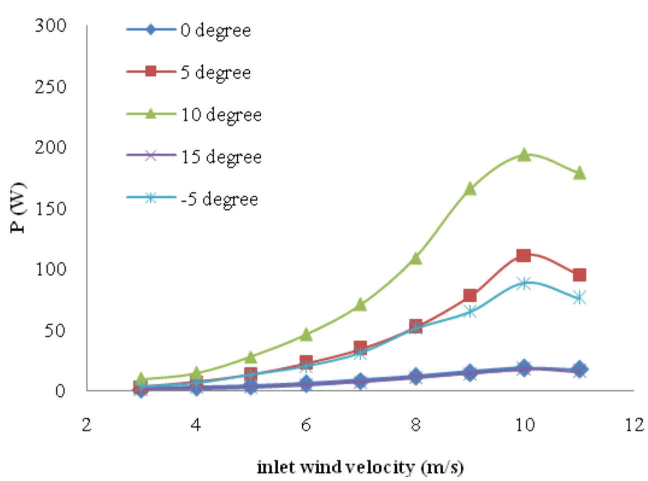

Figure 17. Comparison of inlet wind velocity and Power for NACA 23118

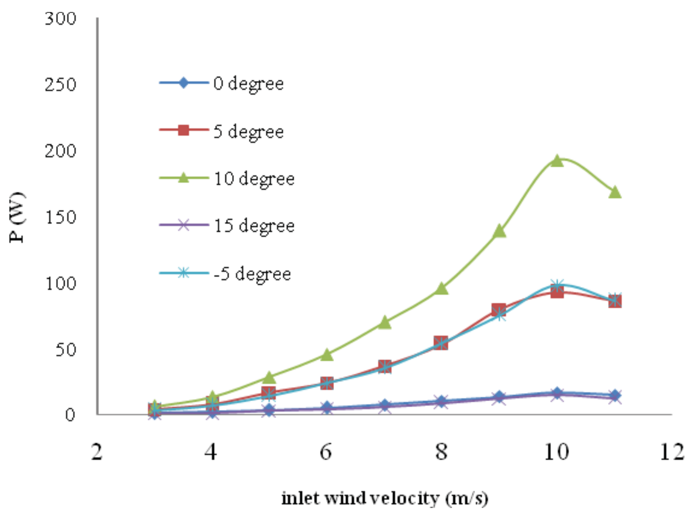

Figure 18. Comparison of inlet wind velocity and Power for NACA 63218

V. CONCLUSION

The following conclusions are made from this experimental investigation.

1. It was observed that the power increases with the angle of attack up to 10° and after that it reduces. Hence, the critical angle of attack is 10°.
2. The power increases with the air velocity from 3 m/s to 10 m/s and after that the power decreases.
3. Among all blades, NACA 23015 shows a maximum power of 675 Watts at an air velocity10 m/sec and at 10° angle of attack.

   In the future wind turbine blades varying with pith twist are to be experimented to get the best design for the requirement.

REFERENCES

[1] Ferhat Kurtulms and Nazmi Izli, ‘Aerodynamic analyses of different wind Turbine blade profiles’, Journal of applied sciences vol 5,pp 663-670,2007.
[2] V. Mahawadiwar & D.Dhopte, ‘Cfd Analysis Of Wind Turbine blade’, Vol 2, pp 3188-3194, 2012.
[3] Christoph Burger and Roy Hartfield9, ‘Wind turbine airfoil performance Optimization using the vortex lattice method and a genetic algorithm’AIAA 2006-4051, 2006.
[4] Deng viju & Dunan zhuoyi, ‘Aerodynamic Optimization Of multi element Airfoils by genetic algorithms’ West-East High Speed Flow Field Conference, 2007.
[5] Chalothorn Thumthae & Tawit Chitsomboon ‘Optimal angle of attack for untwisted blade wind turbine’, Renewable Energy 34 (2009) 1279–1284, 2008.
[6] Kamoun Badreddinne & Helali Ali, ‘Optimum project for horizontal Axis wind turbines ‘OPHWT’’, Renewable Energy vol 3,pp 2019–2043, 2005.
[7] Andrew Kusiak & Haiyang Zheng, ‘Power optimization of wind turbines with data mining and evolutionary computation’, Renewable Energy vol 3, pp 695-702,2010.