

CFD ANALYSIS OF THE SMALL HORIZONTAL AXIS WIND TURBINE BLADE WITH AND WITHOUT WINGLETS

***P.Premalatha, **S.Rajakumar,**

**PG student, ** Assistant Professor,*

Department of Mechanical Engineering,

Regional centre, Anna university Tirunelveli Region, Tirunelveli, India

ABSTRACT

In this paper computational studies are carried out to obtain the aerodynamic characteristics of winglets added with small horizontal axis wind turbine rotor blades. To develop a small horizontal axis wind turbine rotor blade with and without winglets. Usages of small wind turbines are limited due to their limitations in self starting, low wind speed conditions and efficiency. The winglets added with small wind turbines, is to reduce the self-starting requirement and to improve the power coefficient of wind turbine system. NACA airfoil profile is considered for analysis of wind turbine blade. NACA 63215 airfoil profile used in the root section modified NACA 63(2)215 airfoil used in the mid section and NACA 63415 airfoil used in the tip section of the rotor blade. In this paper focuses on winglet height, cant angle and curvature radius which effects on small horizontal axis wind turbine in order to improve the coefficient of power. Five rotor models are designed. Among five rotor models one of the model without winglet and four of the models with variation in height, cant angle and radius of curvature. Wind turbine blade having winglets for different angle for aerodynamic performances. CREO software is used to design a small wind turbine blade with and without winglet. By using Ansys fluent 14.5 CFD software used for Analysing of wind turbine blade with and without winglets.

Keywords: Small Horizontal Axis Wind Turbine (HAWT), Winglet, Wind Turbine Rotor Blade

INTRODUCTION

In the past work the winglets added with small HAWT is to reduced the self starting requirements and to improved the efficiency and reduced the noise produced from the blades in working condition. Existing models of adding winglets at tip of the blade and modified blades for decrease the total drag force, decrease the generation of pressure and decrease the vortex created at the tip of the blade. The winglets were optimized to minimize the induced drag from the blade by changing the downwash distribution. The idea is to add a winglet which is able to carry aerodynamic loads so that the vortex caused by the winglet spreads out the effect of the tip vortex which results in decreasing the downwash and reducing the induced drag.

CALCULATION OF BLADE DESIGN

The blade was designed by following tabulation. It was calculated from the blade design formulas. First wind turbine power formula is used to find the radius of the small wind turbine blade. Blade was divided into various section of element. After using the formula to calculate the chord, angle of rotation and relative flow angle. These values are useful to design a small wind turbine blade.

MATHEMATICAL MODELING

BLADE DESIGN

Velocity = 7 m/s

Power = 6 kW

Power of wind turbine:

$$P_w = C_p \cdot \frac{1}{2} \cdot \rho \cdot A \cdot V^3 ; 6000 = 0.593 \cdot \frac{1}{2} \cdot 1.225 \cdot \pi \cdot 7^3$$

$$R = 3.91 \text{ m}$$

Pitch angle:

$$\tan \Phi = 2R/3r$$

Chord:

$$C = 8 \cdot R \sin \Phi / 3 \lambda B$$

Where,

λ = Tip speed ratio ; B = Number of blade

Table 1: Parameters of scale ratio blade design

Elements	Sectional radius r(m)	Radius of blade R(m)	r/R	Chord m	AOA	C/R	Pitch angle Φ	Relative flow angle β
1	0.01	0.2	0.05	0.5986	5	0.2992	59.03	54.03
2	0.02	0.2	0.10	0.4468	5	0.2234	39.80	34.80
3	0.03	0.2	0.15	0.3389	5	0.1694	29.05	24.05
4	0.04	0.2	0.20	0.2684	5	0.1341	22.61	17.61
5	0.05	0.2	0.25	0.2207	5	0.1103	18.43	13.43
6	0.06	0.2	0.30	0.1868	5	0.0933	15.52	10.52
7	0.07	0.2	0.35	0.1616	5	0.0808	13.39	8.39
8	0.08	0.2	0.40	0.1422	5	0.0711	11.76	6.76
9	0.09	0.2	0.45	0.1271	5	0.0635	10.49	5.49
10	0.10	0.2	0.50	0.1147	5	0.0573	9.46	4.46
11	0.11	0.2	0.55	0.1045	5	0.0522	8.61	3.61
12	0.12	0.2	0.60	0.0959	5	0.0479	7.90	2.90
13	0.13	0.2	0.65	0.0887	5	0.0443	7.30	2.30
14	0.14	0.2	0.70	0.0824	5	0.0412	6.78	1.78
15	0.15	0.2	0.75	0.0771	5	0.0385	6.34	1.34
16	0.16	0.2	0.80	0.0722	5	0.0361	5.94	0.94
17	0.17	0.2	0.85	0.0680	5	0.0339	5.59	0.59

18	0.18	0.2	0.90	0.0643	5	0.0321	5.29	0.29
19	0.19	0.2	0.95	0.0609	5	0.0304	5.01	0.01
20	0.2	0.2	1	0.0579	5	0.0289	4.76	-1.76

PROPOSED INITIAL DESIGN

CREO parametric2, have been used to design blades. The objective functions of this project are to maximize the power output while minimizing the blade volume and structural stress. The chosen blade radius is 3.91 m, and in the airfoil used is 63 series especially 63-215, 63215(modified), 63-415. In order to have an original blade design, the following NACA airfoil family was used for the blade geometry. Unlike typical airfoils used in aeronautics, these airfoils have been specially designed for wind turbines. The camber in these airfoils is higher than others, it can be observed that the thickness of the blade is higher at its root, and decreases along its length, until the thinnest airfoil is used at the tip.

Table 2 Airfoil for blade design

Blade length (m)	Generator (kW)	Thickness	Airfoil family (root to tip)		
3.91	6	15-21	63-215	63-215 (modified)	63-415

DESIGNING OF WIND TURBINE BLADE WITH AND WITHOUT WINGLETS



Fig 3. Blade Design Without Winglet

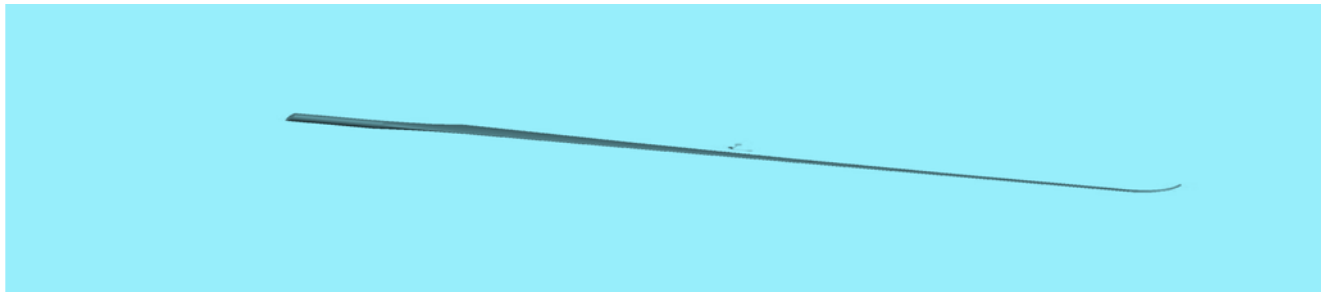
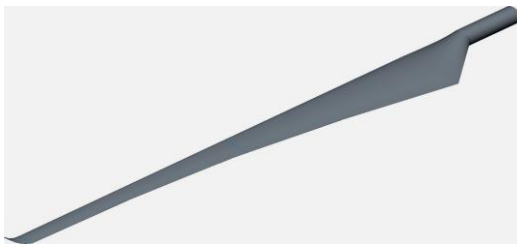


Fig 4. Blade design with 90 degree winglet



Isometric view of 45 Degree Winglet

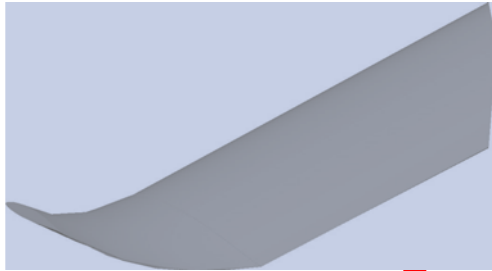


Fig 5. Isometric view of Blade with 45 Degree Winglet

Fig 6.

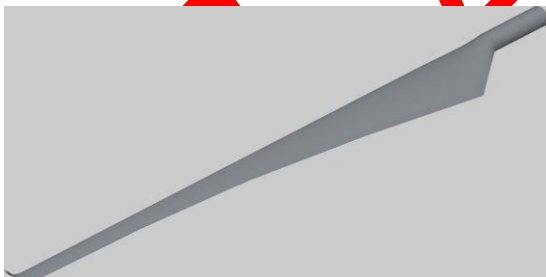


Fig 7. Isometric view of Blade with 60 Degree Winglet

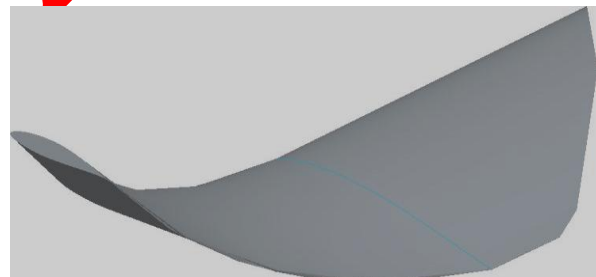


Fig 8. Isometric view of 60 Degree Winglet

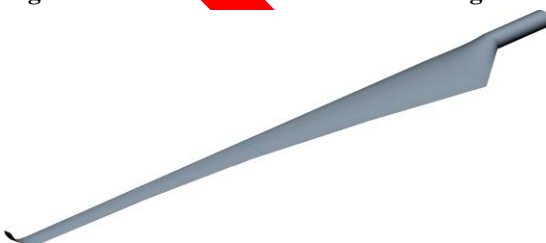


Fig 9. Isometric view of Blade with 80 Degree Winglet

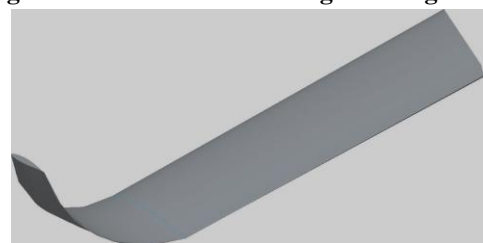


Fig 10. Isometric view of 80 Degree Winglet

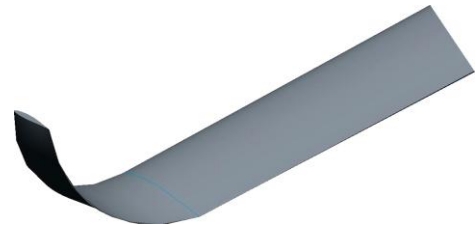
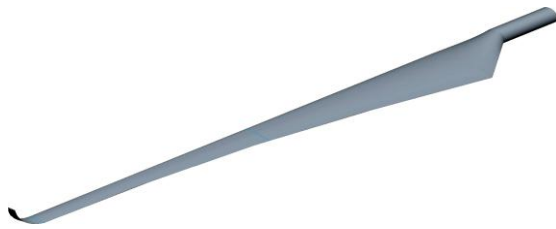


Fig 11. Isometric view of Blade with 90 Degree Winglet Fig12. Isometric view of 90 Degree Winglet

ANALYSIS OF WIND TURBINE BLADE

Anslys fluent 15.0 software have been used to analysis the wind turbine blades. The HAWT rotor was imported from the creo parametric 2 then create a Boolean condition. After completing the geometry the model is meshed. The inlet boundary conditions for the wind speed were set as inlet velocity of 7m/s , air temperature 288.16k, density 1.225kg/m³ and the reference pressure is 0pas. The background of the cylindrical model is considered as fixed walls around the rotors.

MESHING

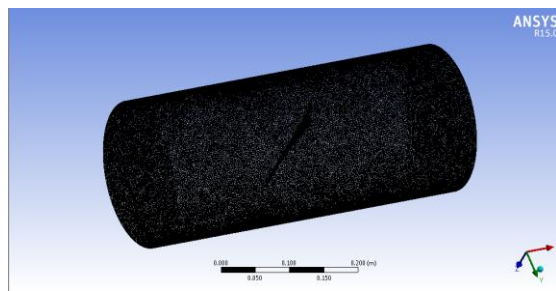


Fig 13. Meshing of cylindrical domain



Fig 14. Meshing of blade with winglet

RESULTS AND ANALYSIS

After the simulation of the 3d wind turbine blade was successfully completed, the results were compared in terms of pressure and velocity contours are primary indicators of aerodynamic performances. A comparison was made between the different types of blades configurations(45,60,80,90) angles.

PRESSURE COUNTOUR

The figures shows the pressure contour plots around the aerofoil for 7m/s of inlet air velocity. It can be observed the low pressure on the leading edge of the aerofoil and high pressure on the trailing edge of the aerofoil where most of the lift is produced. The maximum pressure for various winglets (45,60,80,90) is (21.967, 22.582, 21.479, 22.135) pa respectively.

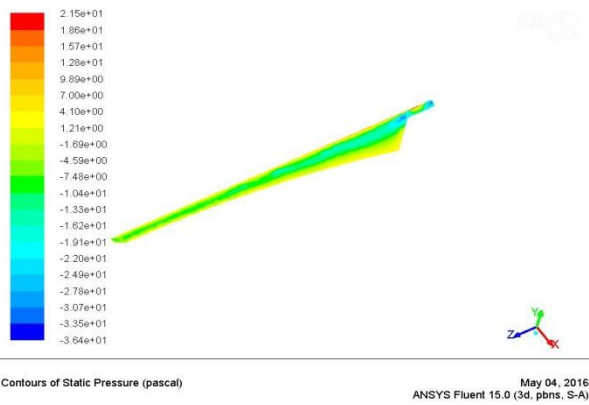
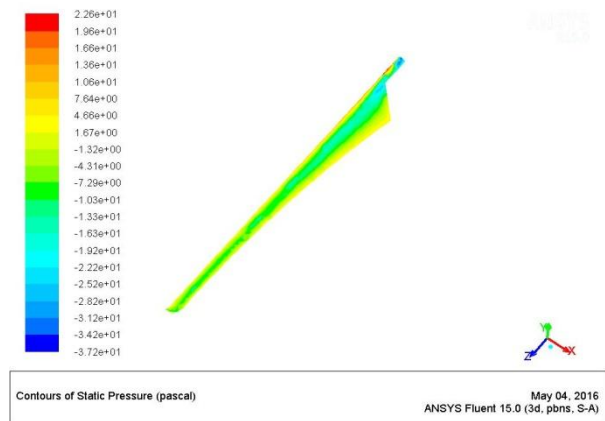
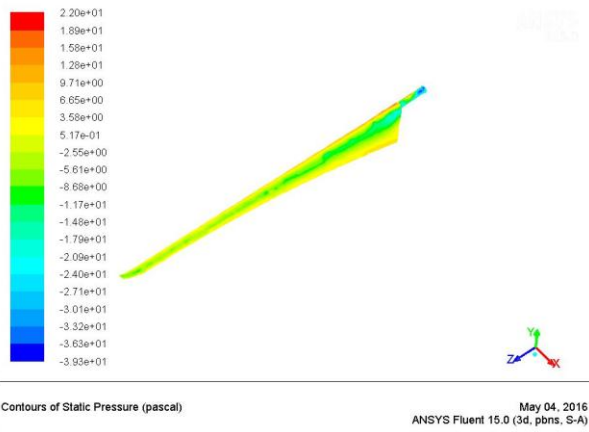


Fig 15. Pressure contour (winglet 45deg)

Fig 16. pressure contour (winglet 60deg)

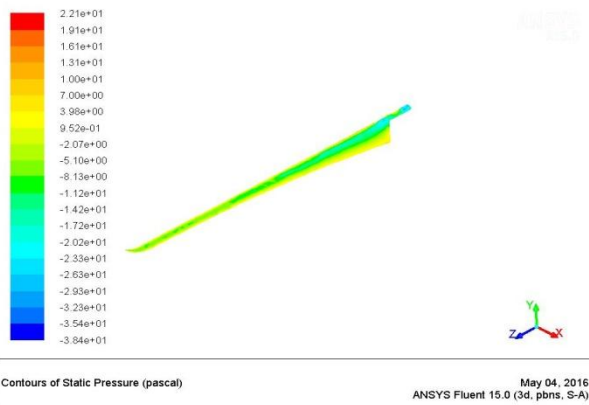


Fig 17. Pressure contour (winglet 80deg)

Fig 18. Pressure contour (winglet 90deg)

VELOCITY CONTOUR

The figure shows the velocity contour on rotor for 7m/s of inlet air velocity where the velocity on the blades is increasing from root to tip of the blade because of many reasons like reducing of chord length and difference of the radius radius from the root to tip. The maximum velocity for various winglet (45,60,80,90) is (10.258,10.249,10.409,9.869) m/s respectively.

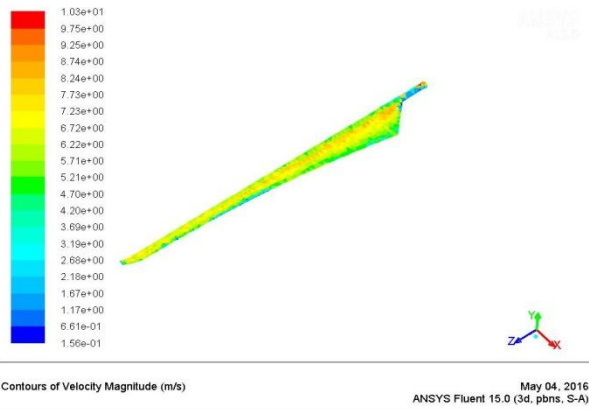


Fig 19. Velocity contour (winglet 45deg)

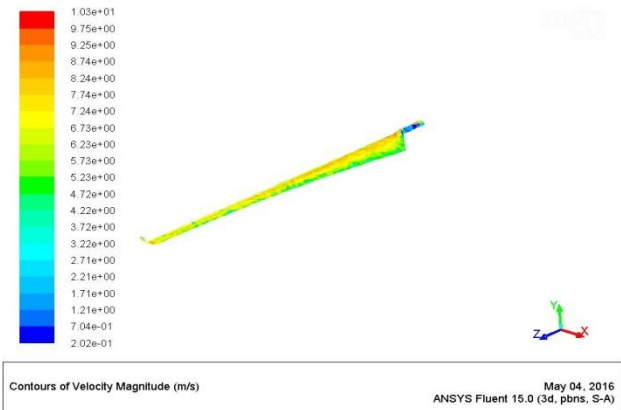


Fig 20. Velocity contour (winglet 60deg)

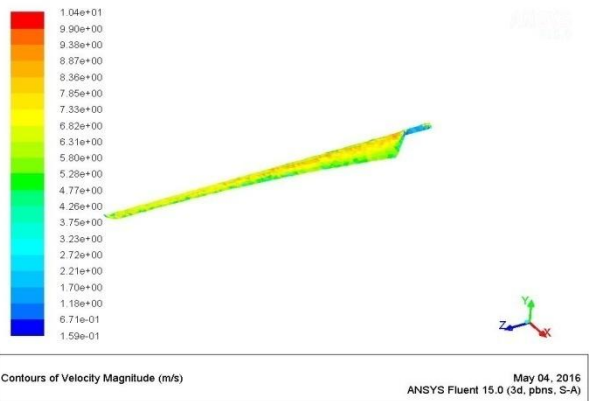


Fig 21. Velocity contour (winglet 80deg)

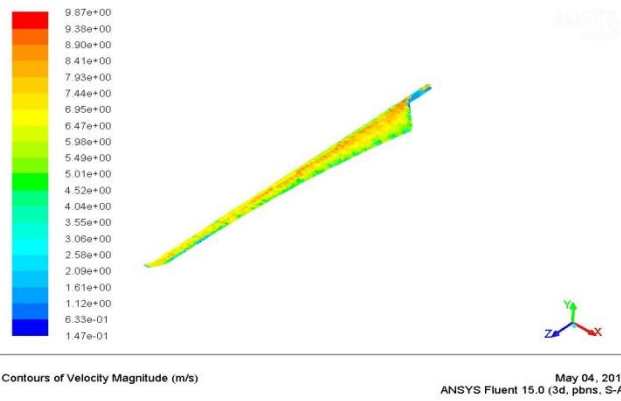


Fig 22. Velocity contour (winglet 90deg)

RPM ON THE BLADE WITH WINGLETS

N

N=489.78rpm (winglet 45deg)

N=489.35rpm (winglet 60deg)

N=496.99rpm (winglet 80deg)

N=471.21rpm (winglet 90deg)

FORCES ON THE BLADES AND THRUST ON TURBINE

Torque becomes

T =

T = 13.498 N-m (winglet 45deg)

T = 13.475 N-m (winglet 60deg)

T = 13.899 N-m (winglet 80deg)

T = 12.494 N-m (winglet 90deg)

Axial force becomes

7.199 N

7.186 N

7.412 N

6.663 N

CONCLUSION

Small horizontal axis wind turbine blade designed with various angle of winglets by using Creo parametric2 software. Winglets are used to increase the aerodynamic characteristics. Smaller curvature radius with sufficient height of winglet added to the wind turbine rotor captures more energy in low wind speed region as against plain wind turbine rotors without the provision of winglet. So I choose to design the wind turbine blade with winglet increasing winglet height and also decreasing curvature radius with different angles. The calculation shows when using blades with and without winglet at air velocity 7m/s it was observed that, the maximum pressure are (21.967,22.582,21.479,22.135)pa, velocity contour are (10.258,10.249,10.409,9.869) m/s, torque on the blade when winglet at various angles are (13.498,13.475,13.899,12.494)N-m and axial forces acts on the blade with various winglets are (7.199,7.186,7.412,6.663)N. According to the results obtained from the analysis program, the best winglet angle is 80 degree because the pressure around this winglet is less whereas velocity is high.

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