

DESIGN OF THE SMALL HORIZONTAL AXIS WINDTURBINE BLADE WITH AND WITHOUT WINGLET

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ABSTRACT

In this paper computational studies are carried out to obtain the aerodynamic characteristics on with and without winglet added with small wind turbine rotor blades. To develop a small horizontal axis wind turbine rotor blade with and without winglet. 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. CREO software is used to design a small wind turbine blade with and without winglet. By using CFD software for Analysing of wind turbine blade with winglet.

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. Employing very small chord length can result in the winglets to be very ineffective as the drag increase due to the winglet stalling. It is also true the larger chord length will lead to poor performance of the winglets due to the excessive high loading at the tip. Choosing ideal chord length is not as straight forward as it may seem. Abdulkadir Ali reference [1] To investigate the aerodynamic characteristics of a small HAWT blade. Three different blade were designed, manufactured and tested under a range of wind speeds and yaw angles. The winglet has significant effect on the aerodynamic performance of the WT blade used for domestic scale wind generator. An increase of lift to drag ratio with upwind

winglet by around 26% and decrease the lift to drag ratio with downwind winglet by around 27%. M. Lydia [2] in her studies this paper presents an exhaustive overview on need for modeling of WT power curve and the different methodologies employed for the same. WT power curve shows the relation between the wind power and hub height. The drawbacks posed by the standard IEC power curve approach and the manufacturer provided power curve lay down the necessity for power curve modeling. Parametric and nonparametric techniques that have been employed for WTPC modeling. R.N. Sharma [3] studied a smart wind turbine concept with variable length bladed and an innovative hybrid mechanical- electrical power conversion system were analysed. The variable length blade concept uses the idea of extending blades when wind speeds fall below the rated level. Increasing a swept area and thus maintain a relatively high power output. Jeppe Johansen [4] studies carried out where four of the key parameters describing a winglet are varied and the various effects are analysed based on resulting mechanical power and thrust. In this result show that adding a winglet to an existing WT rotor increases produced power of around 1.0% to 2.8%. The additional increase in thrust is around 1.2% to 3.6%. Height of the winglet investigated. The largest winglet showed the largest increase in both power and thrust. Ali Salh Sawadi [5] The existing turbine blade compared with the modified blade having winglets for different angles for aerodynamic performance. Creoparametric2, Ansys fluent 14.5 software have been used to design blades. Naca4415 airfoil profile is considered for analysis of WT blade. The result obtained from the analysis program the best winglet angle is 45 deg. Thus was found less than the amount of force and pressure. A. Elfarra [6] studied the AD effects of blade tip tilting on power production of HAWT by using CFD. The effect of four tip configuration on the flow characteristics and the power production of the WT is investigated. Adding a winglet to the WT blade and tilting it toward the suction side of blade results in more power production compared to the other configuration. Not only increase the power with a winglet but also the axial thrust. Jeppe Johansen [7] Describes the numerical investigation of the aerodynamics around a WT blade with a winglet using CFD. Five winglets were investigated with different twist distribution. Results shows that adding a winglet to the existing blade increase the force distribution on the outer approx 14% of the blade leading to increased produced power of around 0.6% to 1.4% for wind speeds larger than 6m/s. Drew Gertz [8] A 3.3 m dia variable speed WT and rotor has been designed, fabricated and tested with exchangeable blade tip capability. The winglet was found to have a bell shaped power augmentation profile with a broad peak between 6.5m/s and 9.5m/s where power was increased by 5% to 8%. Monier A. Elfarra [9] TO aerodynamically design and optimize a winglet for a WT blade by using CFD and to investigate its effect on the power production. Multipoint optimization is carried out for three different operating wind speeds and a total of 24 CFD cases are run in the design. The final optimized winglet showed around 9% increase in the power production. P. Saravanan [10] studies the effects of changing the winglet configuration with the blade on the power performance of small WT rotor models were investigated experimentally. The blades with four

different configurations of winglet are fabricated using Glass Fiber Reinforced Plastic materials. The maximum power coefficient obtained for an effective winglet configuration is about 0.43. It is recommended that the smaller curvature radius with sufficient winglet height added to the WT rotor captures more wind energy in low wind speed region. M. Manikandan [11] To increase the reliability of WT blades through the development of the airfoil structure and also to reduce the noise produced during the running period of the WT blades. The WT blade is modeled and several section are created from root to tip with the variation from the standard design for improving the efficiency. The winglet is to be included at the tip of the blade which would help in increasing the efficiency and reducing the noise produced from the blades in working condition. Drew Gertz [12] A 3.3 dia WT rotor has been designed, fabricated and tested in large scale operated indoor wind facility. The rotor was custom designed for operation in the wind facility and allowed for exchangeable blade tips such that various tip designs can be tested for their effects on performance. The maximum power produced was 1.45kw at 11m/s. The peak C_p was found to be 0.42 at a tip speed ratio of 6.7. J. Johanson [13] A wind turbine rotor was designed for obtaining maximum C_p . Coefficient of power is further increased by adding winglets to reduce the induced drag from the tip vortices. Winglet is design using a Free Wake Lifting Line model combined with a numerical optimization method and CFD solver. M. Gokulraj [14] studies in order to increase the wind energy it is important to develop wind turbine rotor models with high rotation rates and C_p . This study aimed at manufacturing highly efficient WT rotor models using NACA profiles. The geometry is analyzed using the given Boundary conditions specified for FLUENT and the variation of flow parameters plotted and studied. D. Gertz [15] evaluate the winglet can apparently augment the power output. The rotor will produce a maximum of 1450w at 11.4m/s. The rotor peak power coefficient is predicted to be 0.50 at a tip speed ratio of 0.54.

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.

Table 1: Parameters of 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	0.1955	3.91	0.05	1.1702	5	0.2992	59.03	54.03
2	0.391	3.91	0.10	0.8736	5	0.2234	39.80	34.80

3	0.5865	3.91	0.15	0.6627	5	0.1694	29.05	24.05
4	0.782	3.91	0.20	0.5247	5	0.1341	22.61	17.61
5	0.9775	3.91	0.25	0.4314	5	0.1103	18.43	13.43
6	1.173	3.91	0.30	0.3651	5	0.0933	15.52	10.52
7	1.3685	3.91	0.35	0.3160	5	0.0808	13.39	8.39
8	1.564	3.91	0.40	0.2781	5	0.0711	11.76	6.76
9	1.7595	3.91	0.45	0.2484	5	0.0635	10.49	5.49
10	1.955	3.91	0.50	0.2243	5	0.0573	9.46	4.46
11	2.1505	3.91	0.55	0.2043	5	0.0522	8.61	3.61
12	2.346	3.91	0.60	0.1875	5	0.0479	7.90	2.90
13	2.5415	3.91	0.65	0.1734	5	0.0443	7.30	2.30
14	2.737	3.91	0.70	0.1611	5	0.0412	6.78	1.78
15	2.9325	3.91	0.75	0.1507	5	0.0385	6.34	1.34
16	3.128	3.91	0.80	0.1412	5	0.0361	5.94	0.94
17	3.3235	3.91	0.85	0.1329	5	0.0339	5.59	0.59
18	3.519	3.91	0.90	0.1258	5	0.0321	5.29	0.29
19	3.7145	3.91	0.95	0.1191	5	0.0304	5.01	0.01
20	3.91	3.91	1	0.1132	5	0.0289	4.76	-1.76

MATHEMATICAL MODELING

BLADE DESIGN

Velocity = 7 m/s

Power = 6 kW

Power of wind turbine:

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

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

Pitch angle:

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

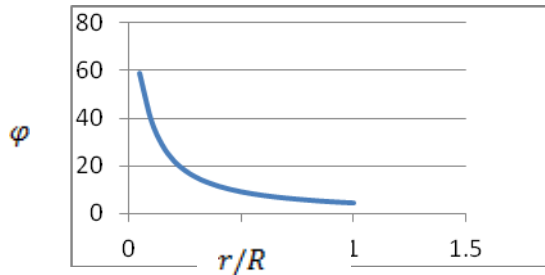
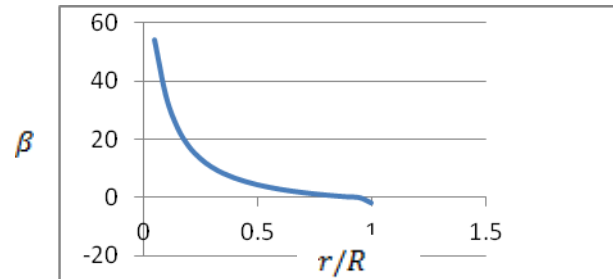
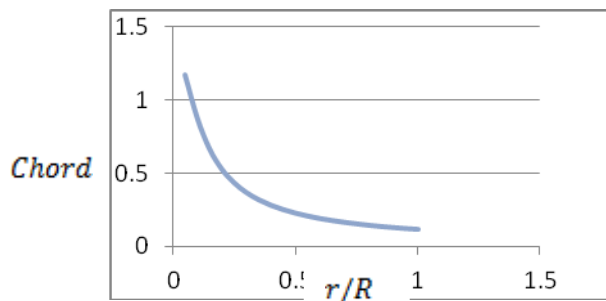
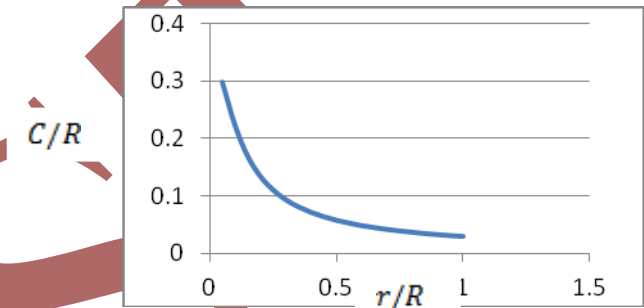
Chord:

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

Where, λ = Tip speed ratio ; B = Number of blade

Excel Graph for Blade Design

r/R vs Pitch angle Φ , Relative flow angle β , Chord c and C/R graph are plotted below by using excel.

Fig 1 r/R vs Φ Fig 2 r/R vs β Fig 3 r/R vs ChordFig 4 r/R vs C/R

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. Table 3 shows the configuration for a medium to large blade length recommended by NACA. 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

The location of the airfoil family along the length of the blade is described in table 3, where x is the position from root to tip of the blade and R is the radius of the blade (3.91m).

Table 3 Position of Airfoils along Length of the Blade

Airfoil	x/R	$X(m)$
63-215	0.0511	0.2
63-215(modified)	0.0895	0.35
63-415	0.1023	0.4

FINAL WINGLET PARAMETERS

Table 4 Final Winglet Design parameters

Height	0.16meters
Radius	0.01955meters
Cant angle	45,60,70,80,90 degrees

DESIGNING OF WIND TURBINE BLADE

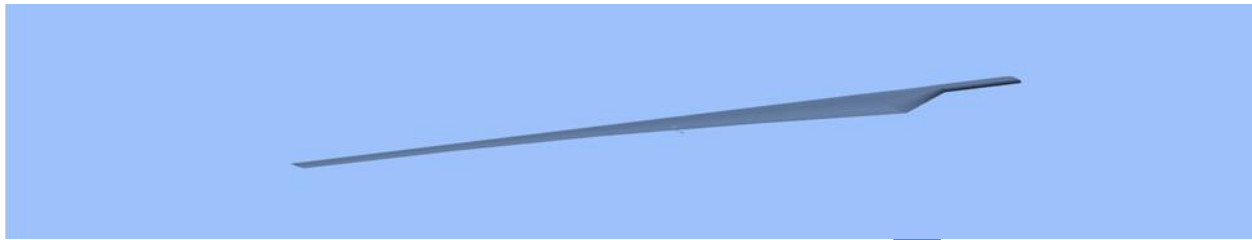


Fig 5. Blade Design Without Winglet

DESIGNING OF WIND TURBINE BLADE WITH VARIATION WINGLETS ANGLES



Fig.6 Blade design with 90 degree winglet

ISOMETRIC VIEW OF WIND TURBINE BLADE WITH VARIATION WINGLET ANGLES



Fig 7. Isometric view of Blade with 45 Degree Winglet

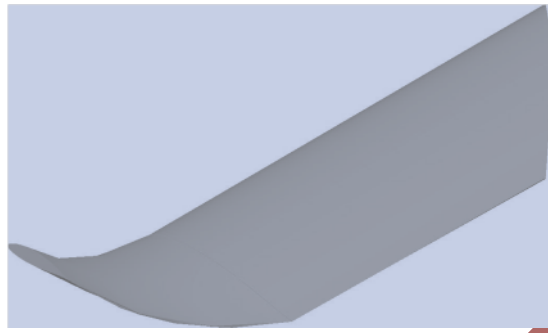


Fig 8. Isometric view of 45 Degree Winglet

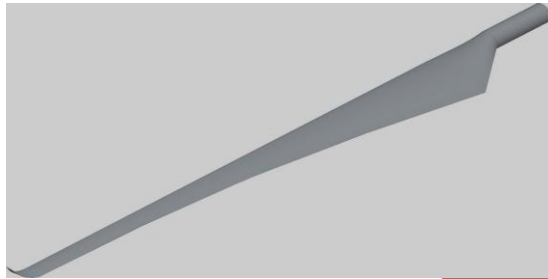


Fig 9. Isometric view of Blade with 60° Winglet

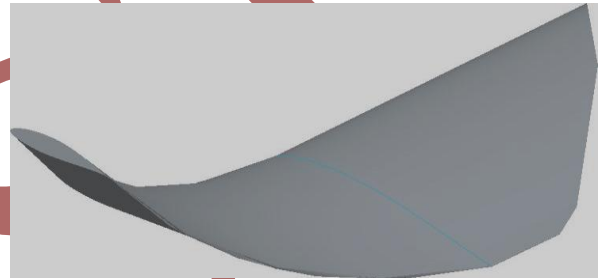
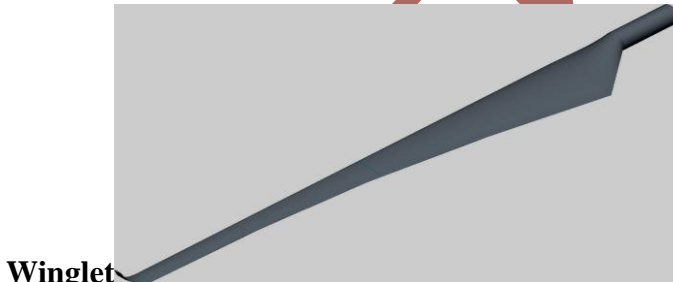
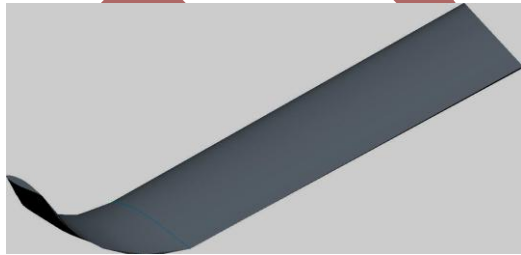


Fig 10. Isometric view of 60°



Winglet



70° Winglet Fig 12. Isometric view of 70° Winglet

Fig 11. Isometric view of Blade with

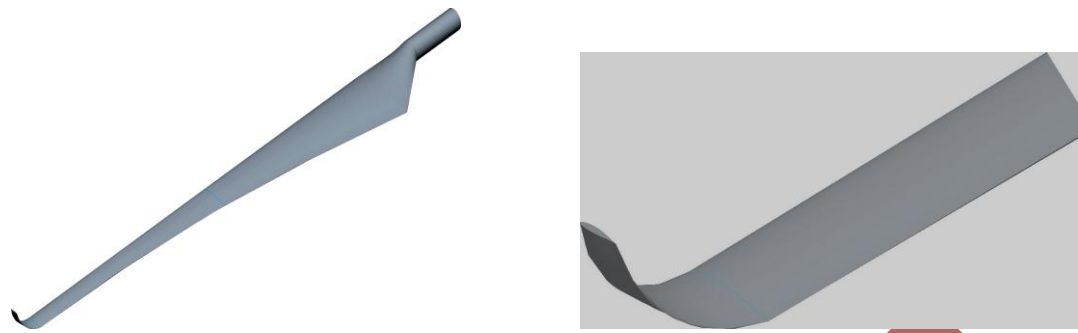


Fig 13. Isometric view of Blade with 80° Winglet **Fig 14. Isometric view of 80° Winglet**

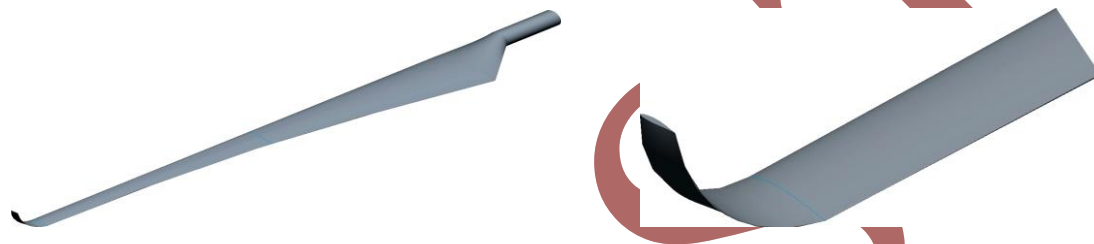


Fig 15. Isometric view of Blade with 90° Winglet **Fig 16. Isometric view of 90° Winglet**

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 all are describes in table4. It is used for increasing the power coefficient. By attaching winglets at the tip of the blade to improve the aerodynamic performance of turbine rotors and to make them less sensitive to wind gusts by reduce the pressure on the tip of blade and decrease the induced drag of the blade by changing the downwash distribution. 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. Ansys fluent 14.5 software is used for analyzing the rotor blade with and without winglet.

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