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CFD ANALYSIS OF 5KW HORIZONTAL AXIS WIND TURBINE

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ABSTRACT

This paper reviews the design optimization of wind turbine blades through investigating the design methods and analyzing the performance of the blades. Blade geometric design addresses the design parameters, including airfoils and their aerodynamic coefficients, attack angles, design tip speed ratio, design and/or rated wind speed, rotor diameter, blade aerodynamic shape with chord length and twist distributions, so that the blade achieves an optimum power performance. Here, an s809 airfoil with different chord and root twist angle of 40 degree is designed for 3metere blade. Computational fluid dynamics (CFD) model has been used to calculate the aerodynamic effect on the blade airfoil at angle of attack of 0, 5, 10, 15 degree. Constant wind speed of 8m/s has been considered during analysis under turbulence model spallart-almaras. Power performance was predicted from the analysis results. The result indicate that the co efficient of power at higher angle of attach is high compared to lower angle of attack.

Keywords: Angle of attack; Horizontal axis wind turbine; ANSYS FLUENT; Aerodynamic behaviour; S809 airfoil.

INTRODUCTION

The wind is a free-flowing fluid stream. The energy extraction device is submersed into this stream and can convert only a certain amount from the total available energy in the fluid stream, not all of it. Energy conversion from free-flowing fluid streams is limited because energy extraction implies decrease of fluid velocity, which cannot fall down to zero; the stream should continue traveling and cannot stop entirely. In addition, the turbine is an obstruction to the fluid flow. Some fluid may not pass through the turbine and may simply flow around it. The most common type of lift-force wind turbines is the horizontal axis wind turbine - HAWT. The rotor axis lies horizontally, parallel to the airflow. The blades sweep a circular plane normal to the airflow, situated upwind or downwind. The main advantage of HAWTs is the good aerodynamic efficiency and versatility of applications. A wind turbine transforms the kinetic energy in the wind to mechanical energy in a shaft and finally into electrical energy in a generator. The maximum available energy, $P_{max,}$ is thus obtained if theoretically the wind speed could be reduced to zero: $P = 1/2mV_o^2 = 1/2\ \rho A V_o^3$ where m is the mass flow, V_o is the wind speed, ρ the density of the air and A the area where the wind speed has been reduced. The equation for the maximum available power is very important since it tells us that power increases with the cube of the wind speed and only linearly with density and area.

BLADE WITH TWIST

Using a mathematical model the performance of a wind turbine is evaluated with the following characteristics: Three-blade rotor, wind velocity of 8 m/s and blade external radius of 3m. The S809 aerodynamic cross-section profiles are considered for this proposed work. The chord, twist angle and in flow angle is shown from Fig.1.The twist angle given in the blade root is 40 degree.

Fig. 1. Twisted Blade Designed In CREO

SECTIONAL AIRFOIL:

The designed blade was divided into ten sections with different chord length from root to tip. Each airfoil has different twist angle from root to tip. The twist angle decreases from root to tip as chord length. For a 3m blade, the chord and twist angle is distributed as follows:

Table.1. BLADE GEOMETRY

SL.NO	SECTIONAL RADIUS, r	BLADE RADIUS,R	TWIST ANGLE	CHORD, C
1	0.3	3	40	0.67
2	0.6	3	22.619	0.402
3	0.9	3	15.524	0.28
4	1.2	3	11.768	0.213
5	1.5	3	9.462	0.172
6	1.8	3	7.907	0.144
7	2.1	3	6.788	0.123
8	2.4	3	5.946	0.108
9	2.7	3	5.29	0.096
10	3	3	4.763	0.086

COMPUTATIONAL FLOW ANALYSIS

The CFD analysis of airfoil S809 is performed for a velocity of 8 m/s at angles of attack of 0,5,10,15 degree. ANSYS is used to mesh the airfoil, which is designed in CREO and exported to FLUENT for analysis. Inlet velocity for the experiments and simulations is 8 m/sec and turbulence viscosity ratio is 10. A fully turbulent flow solution was used in ANSYS FLUENT, where Spalart Allmaras equation was used for turbulent viscosity. A simple solver was utilized and the operating pressure was set to zero. The meshing of ten sectional airfoil from a 3m blade as follows:

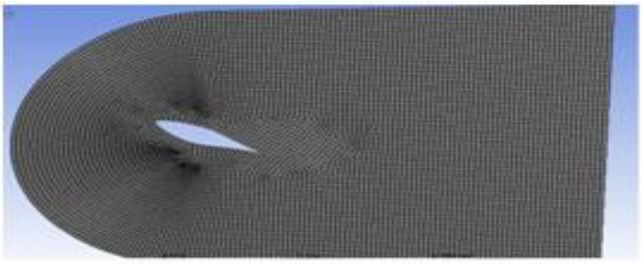


Fig. 2.Airfoil with chord 0.67

Fig. 3. Airfoil with chord 0.402

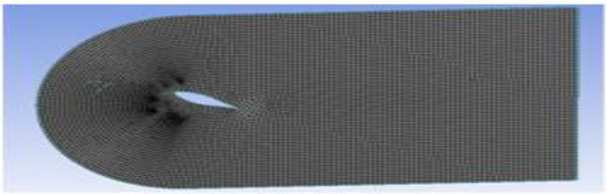


Fig. 4.Airfoil with chord 0.28

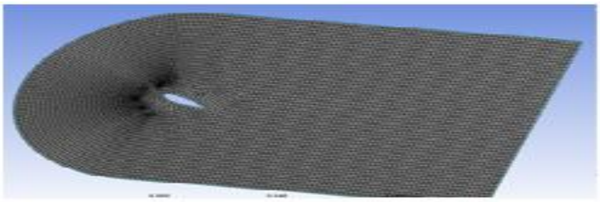


Fig. 5.Airfoil with chord 0.213

Fig. 6.Airfoil with chord 0.172

Fig. 7.Airfoil with chord 0.144

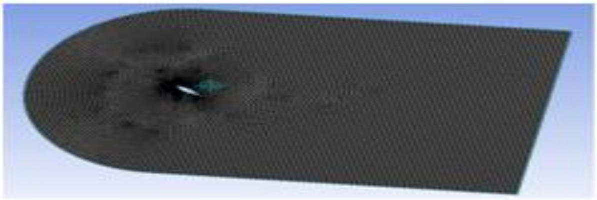


Fig. 8.Airfoil with chord 0.123

Fig. 9.Airfoil with chord 0.108

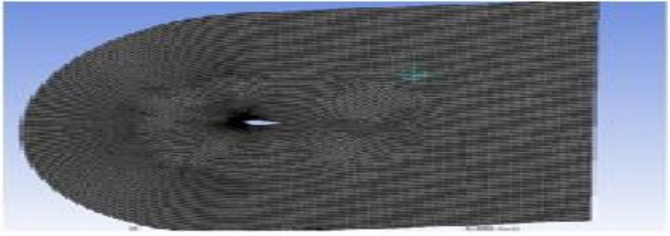


Fig. 10.Airfoil with chord 0.096

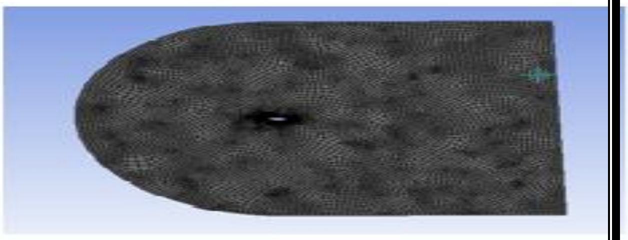
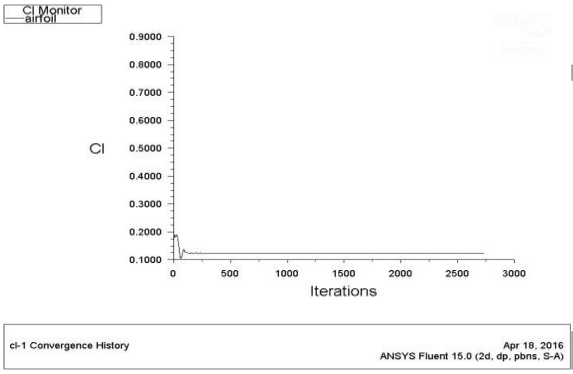


Fig. 11.Airfoil with chord 0.086

RESULTS AND DISCUSSION

It is observed that the results change based on airfoil geometry. Present results depict the lift and drag Coefficients are showing monotonic increase/decrease with respect to the angle of attack. The aim of the simulations has been to determine the flow field around the airfoil of the wind turbine responsible for the buildup of forces acting on the airfoil. In this investigation of flow around the simplified airfoil, shape that included different viscosity models at constant Reynolds number. The range of the results varies with respect to the viscosity models and with the function of angle of attack with different airfoil geometries. All the analysis was performed using turbulence models like Spalart-Allmaras and Viscous for the simulation S809 series airfoil at various angle of attacks (AOAs) starting from 0 to 15 degrees respectively. For quantitative validation, the experimental Wind Tunnel Profile Coefficients data was taken as a basis. The CFD analysis of the flow over an airfoil of a simplified section gave relatively good agreement with the experiments.

Performance curve at 0 degree



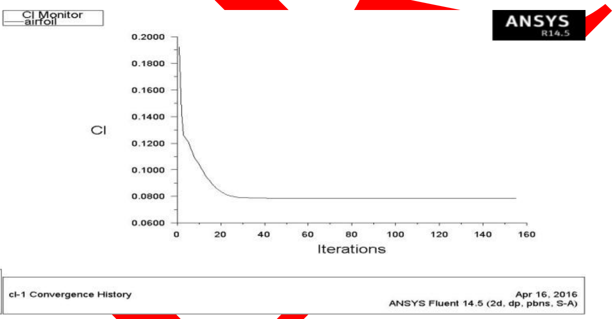
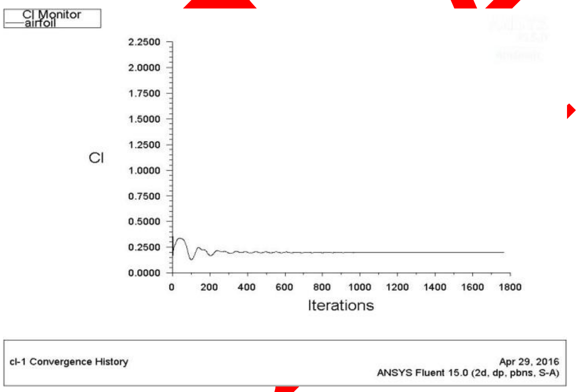


Fig. 12.Lift curve for chord 0.67 **Fig. 13. Lift curve for chord 0.402**

Performance curve at 5 degree



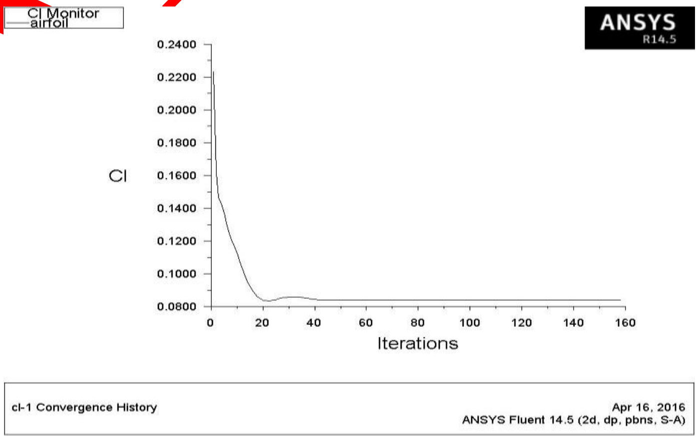


Fig. 14.Lift curve for chord 0.67 **Fig. 15.Lift curve for chord 0.402**

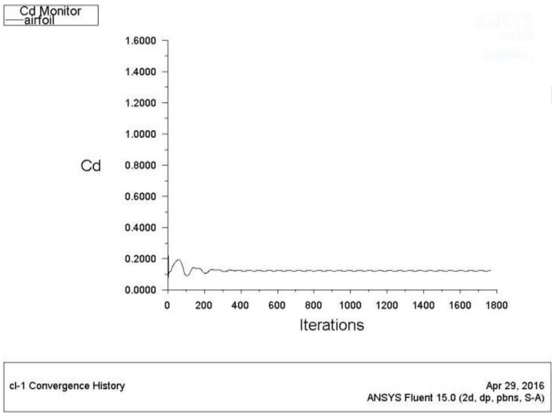


Fig. 16.Drag curve for chord 0.67

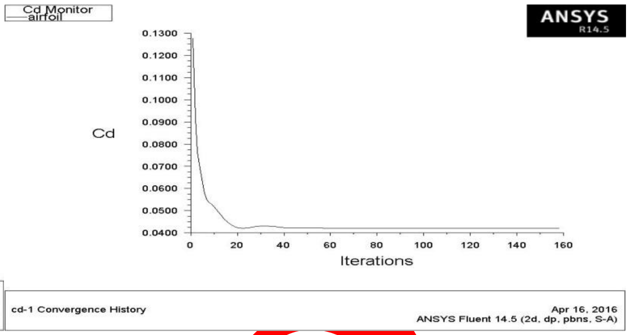


Fig. 17.Drag curve for chord 0.402

Performance curve at 10 degree

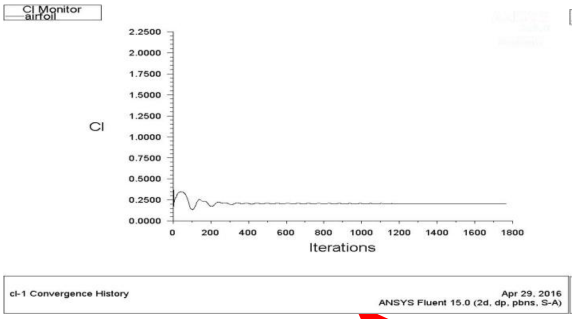


Fig. 18.Lift curve for chord 0.67

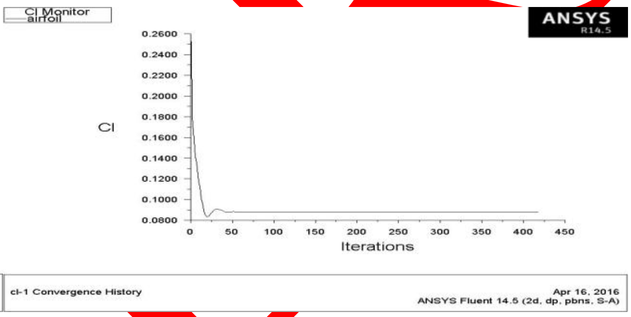


Fig. 19.Lift curve for chord 0.402

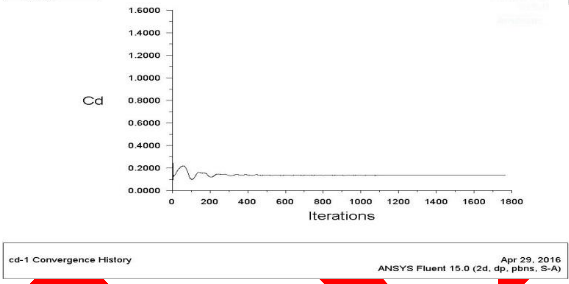


Fig. 20.Drag curve for chord 0.67

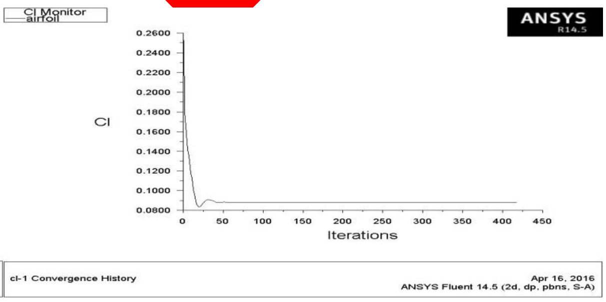


Fig. 21.Drag curve for chord 0.402

Performance curve at 15 degree

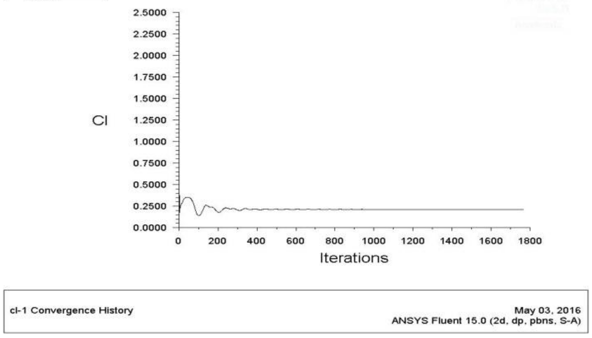


Fig. 22.Lift curve for chord 0.67

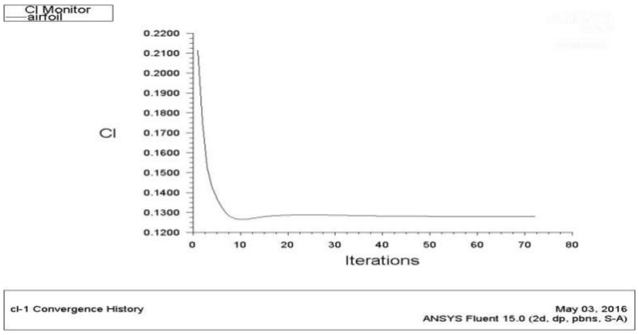


Fig. 23.Lift curve for chord 0.402

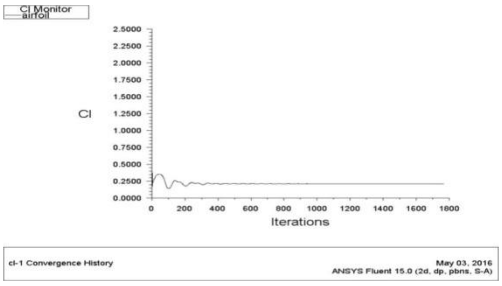


Fig. 24.Drag curve for chord 0.67

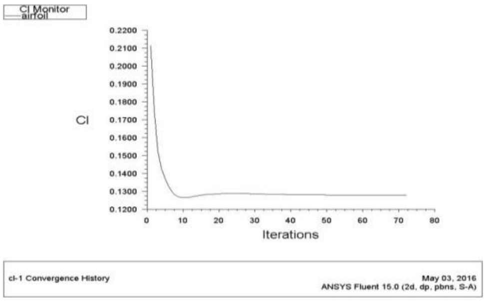


Fig. 25.Drag curve for chord 0.402

TABLE.2.LIFT TO DRAG RATIO

CHORD,C	CL/CD (0 deg)	CL/CD (5deg)	CL/CD (10 deg)	CL/CD (15 deg)
0.67	1.922	1.639	1.5	1.394
0.402	2.36	1.99	1.68	1.634
0.28	1.87	1.68	1.53	1.429
0.213	2.4	2.008	1.73	1.623
0.172	1.805	1.6	1.467	1.359
0.144	1.714	1.666	1.533	1.44
0.123	1.5	1.407	1.366	1.28
0.108	2	2	1.818	1.574
0.096	1.185	1.923	2.043	1.85
0.086	0.913	2.035	2.181	1.894

TABLE.3.POWER PERFORMANCES

At α=0 degree

Tip Speed Ratio	CO EFFICIENT OF POWER
5	0.0119
6	0.0124
7	0.0173
8	0.03

At α=5 degree

Tip Speed Ratio	CO EFFICIENT OF POWER
5	0.0095
6	0.0154
7	0.0267
8	0.041

At α=10 degree

Tip Speed Ratio	**CO EFFICIENT OF POWER**
5	0.0098
6	0.0187
7	0.0364
8	0.0571

At α=15 degree

Tip Speed Ratio	**CO EFFICIENT OF POWER**
5	0.0125
6	0.0242
7	0.0474
8	0.0764

CONCLUSIONS

In this project, for analyzing the power performance over a 5KW horizontal axis wind turbine, the S809 airfoil for the desired wind turbine has been selected and designed. The modification factor and models were also combined into the BEM theory to predict the blade performance and there is a good comparison of radius ratio and various angles in each section between the improved BEM theory and numerical simulation. Performance analysis has been carried out for a ten different chord length of a selected airfoil by predicting co efficient of lift, drag, velocity and pressure. A modeling approach using the Spalart-Allmaras in an attempt to describe the flow behavior of the respective ten airfoils. The power performance from the respective airfoil is predicted for different angle of attack from 0-15 degree. The result indicates that the co efficient power at lower angle of attack is less compared to higher angle of attack.

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