Effect of Angle of Twist on Small Horizontal Axis Wind Turbine Blade

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Abstract— In order to optimally explore and utilize wind energy, an optimal design of wind turbine rotor blades needs to be obtained. A lot of work has been done for the optimization of wind turbine blade. There are many factors which are important to take into consideration while designing the turbine blade. Therefore, for that purpose, QBlade software based on the Blade Element Momentum (BEM) theory is used in the present study. Which gives a brief insight of effects of angle of twist on the performance of small horizontal axis wind turbine. Different blade designs are experimented in this study by changing the angle of twist of wind turbine blade. It ranges from zero to fifty degree angle of twist and results are observed critically and it was found that at 20 degree angle of twist the performance of blade is optimum it gives maximum power output.

Key words: Wind Turbine, QBlade, Agle of Twist, Airfoil, BEM Theory

I. Introduction

Wind energy has been a source of energy for several decades and the most important thing is that it is a renewable form of energy which means it doesn't cause any effect on nature. Wind is used for many purposes, and harnessing electricity is one of them.

To harness the power from wind two basic types of wind turbines are used, which are vertical axis wind turbines and horizontal axis wind turbines, some of these turbines are located on land, usually in areas that receive heavy wind, while others are located offshore, positioned to catch winds that run across lakes and seas.

The vertical axis wind turbines use a series of rotor blades that move in a circle around a central axis. Horizontal axis turbines, which are far more common than vertical axis, have their blades arranged in the shape of a propeller and mounted on a tower. Turbines and generators produce electricity.

How much energy is produced depends on the size and design of the turbine and the speed of the wind going through the rotor. To get maximum power from the wind it is necessary to design optimum blade by performing various experiment. There are various parameters on which blade performance depends such as blade chord, blade size, blade twist, airfoil, wind velocity etc. Without studying the effects of these parameters on the performance of wind turbine it is difficult to design optimum blade.

So to study the effects of angle of twist on the performance of wind turbine this research paper has been carried out.

II. QBlade

The designing of the blade was done in software called QBlade. It is an open source wind turbine designing software. The software is seamlessly integrated into XFOIL, an airfoil design and analysis tool. The purpose of this software is the design and aerodynamic simulation of wind turbine blades. It was started in 2010 at the chair of Fluid Dynamics of the TU Berlin. In order to encourage the research on wind turbine all over the world.

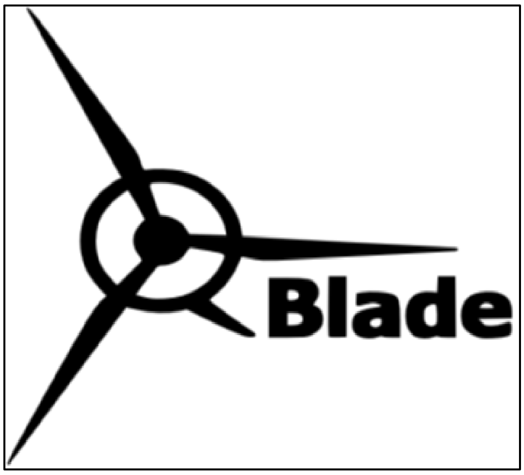


Fig. 1: QBlade Logo

A. *Selection of Airfoil*

In the Airfoil Design module airfoils can be designed via splines, a NACA airfoil generator or imported from a point distribution. These functions are accessed from the Foil menu. This module is implemented from the XFLR5 software. In this paper NACA 5518 airfoil has been selected.

1) NACA generator: Foil - NACA Foils
2) Circular airfoil : Foil - Generate a Circular Foil
3) Import airfoil : Foil - Import Foil
4) Store Spline Airfoil : Splines - Store Splines as Foil

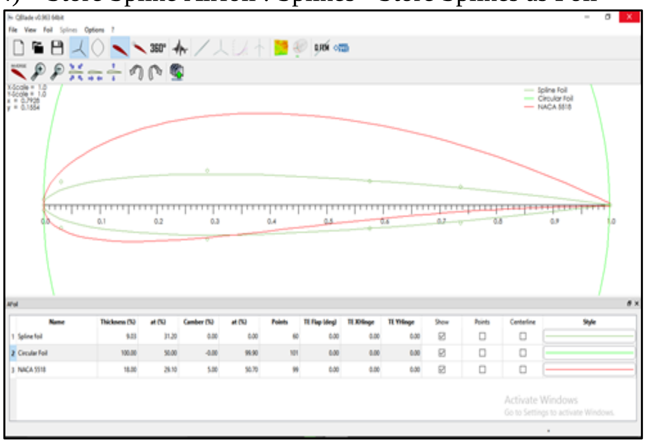


Fig. 2: Selection of airfoil

B. *Direct Airfoil Analysis*

In the Direct Analysis module polars can be created using the XFOIL algorithms. To define a polar select the airfoil in the airfoil combobox inside the modules toolbar and click on Define XFOIL Polar inside the right dock window. When a polar has been defined the lift and drag coefficients can be computed by pressing the Analyze button in the dock window. Polars can be imported / exported from the Polars menu at the top. This module is also an implementation from the XFLR5 software.

In this window the values of cl, cd and cl/cd can be seen clearly.From the above fig. it was found that the value of cl varies along the angle of attack so does cd, cm and cl/cd as well.

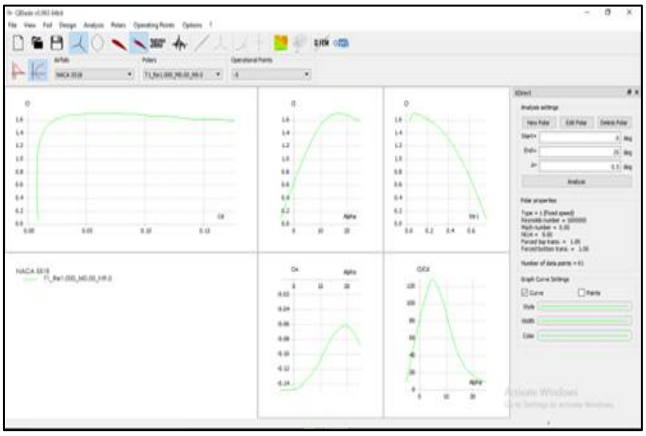


Fig. 3: Direct Airfoil Analysis

C. Polar 360° Extrapolation

In the 360° Polar Extrapolation module the polars that have been previously created inside the Direct Analysis module can be extrapolated to 360° angle of attack. To extrapolate a polar, select the polar to extrapolate in the polar combobox inside the modules toolbar, select the method of extrapolation (Montgomerie or Viterna) from the dock window and click the new button. You can tune the polar shape using the A+, B+, A- and B- sliders and the CD90 (drag at 90° AoA) or AR (Aspect Ratio) number edits. To save a 360° polar click the Save button. 360 Polars can be imported / exported from the 360 Polar menu.

The values of cl and cd for the entire polar can be observed in this module.

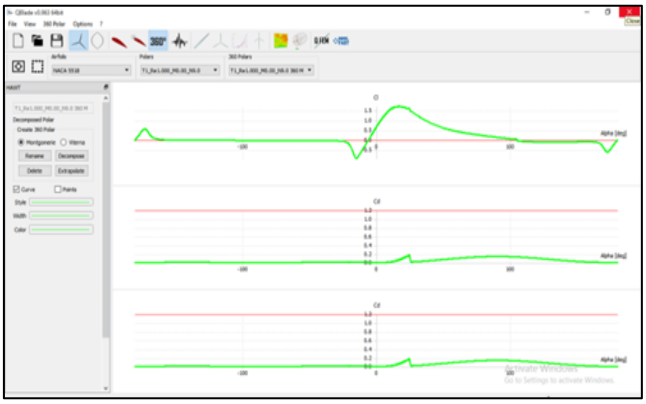


Fig. 4: Selection of airfoil

D. Blade Design

Inside the Blade Design module blades can be designed from airfoils and 360° polars. A blade can only be created if at least one 360° polar is present in the database. To start a blade design press the HAWT Rotor blade Design button then press New Blade then enter the blade data or configure your own blade using the Scale, and chord and angle of twist are adjusted according to requrement and press save. For this research purpose 11 differet designs of blade were experimented using the same module.

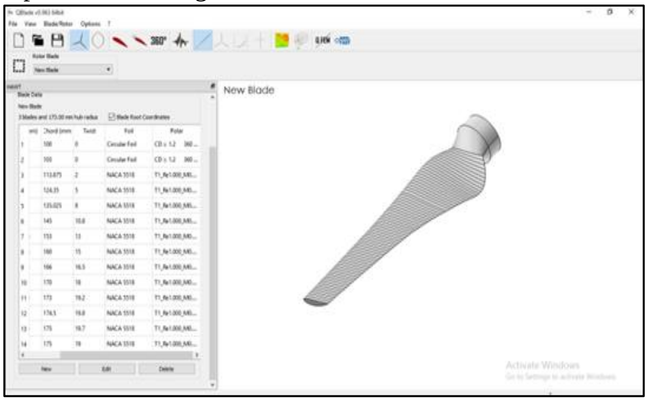


Fig.5: Blade Design

E. Rotor / Turbine Blade Element Momentum (BEM) Simulation

The Rotor / Turbine Simulation modules perform a Blade Element Momentum Method simulation of a rotor or a turbine. All rotors in the database can be simulated in the HAWT rotor simulation sub module. Whenever a rotor simulation is defined, all simulation parameters need to be specified. Then, the dimensionless simulation is conducted over the desired range of tip speed ratios. The three graphs show the simulation results. By double-clicking on a graph, the user may change the plotted variables. By right clicking on a graph, the graph type to display local or global variables can be set in the graph's context menu, the user may isolate the highlighted curve and then compare it to the local curves of other rotor simulations at the same tips peed ratio in a rotor graph.

In the rotor BEM simulation the value of angle of twist was defined for the different blade designs ranging from 0 degree to 50 degree. And the results of all the blades were compared. All the results were carried out at the constant speed of 11.5 m/s. Software showed the three graphs of different variables, from that graphs the RPM, TSR, Cp and Theta along the radial length of the blade were observed.

In the turbine BEM simulation the value of RPM from the rotor BEM simulation was defined and values of cut in speed and cut out speed were given and found out the results for the corresponding blade. In this simulation power output and Thrust were observed.

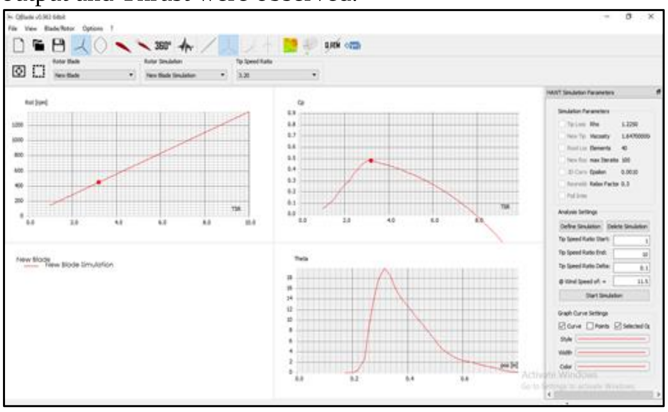


Fig. 6: Rotor / Turbine Blade Element Momentum (BEM) Simulation

F. Multi Parameter Simulation

A multi parameter simulation is a simulation over a range of wind speeds, rotational speeds and pitch angles. Before a simulation is defined the range for each parameter should be set, parameters can also be selected as fixed for a simulation. The simulation is defined and started using the dock buttons. Each graph in this module can plot curves over one main variable and one free parameter.

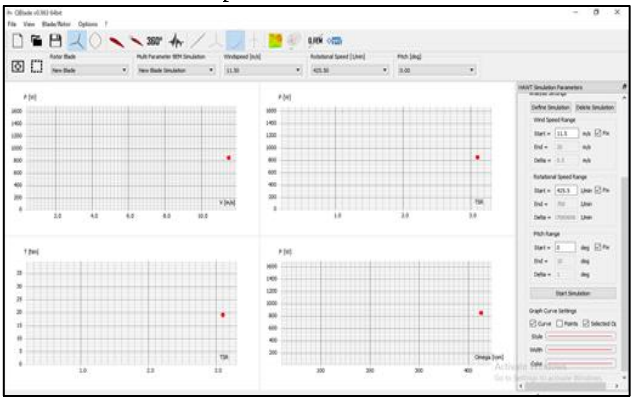


Fig. 7: Multi Parameter Simulation

The main variable and free parameter can be set in the graphs context menu (right click). The fixed parameter of each graph has the value that is selected in the according combobox from the toolbar (windspeed, rotational speed, pitch angle). In the multi parameter simulation for the angle of twist optimization the fixed values of RPM and wind speed were defined from the previous rotor and turbine BEM simulations and results were carried out at the fixed pitch angle. With the aid of this simulation method the value of power output over the range of wind speed was found out and likewise the value of torque produce over the range of TSR and power output over the range of rotation of the blade were observed.

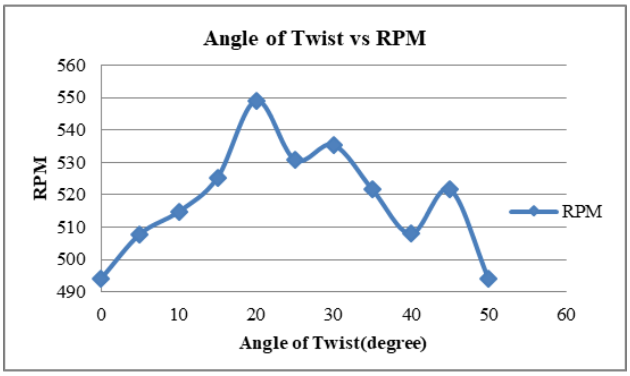
III. RESULTS

Sr. No.	Angle of Twist	RPM	TSR	CP	P(w)	T(Nm)	Thrust(N)
1	0	494.2	3.6	0.449	840	16.3	131
2	5	507.9	3.7	0.46	861.5	16.2	135.7
3	10	514.8	3.75	0.471	881.5	16.4	136.1
4	15	525.3	3.86	0.476	884	16.2	135.7
5	20	549.1	4	0.488	913.5	15.94	135.7
6	25	530.8	3.67	0.481	900.9	16.22	129.25
7	30	535.4	3.9	0.481	878.4	15.7	126.7
8	35	521.7	3.8	0.459	858.5	15.65	121.8
9	40	508	3.7	0.441	825.5	15.55	115.4
10	45	521.7	3.8	0.405	575.6	13.87	102.8
11	50	494.2	3.6	0.35	655.2	12.65	83.1

Table 1; Results

The analysis is done by QBlade for different blades viz. Angle of twist 0, 5, 10, 15, 20, 25, 30, 35, 40, 45 and 50 degree considering NACA 5518 airfoil for entire blade span and keeping chord constant for each blade and results are plotted for optimum power output which can be seen in table below. From obtained data the maximum power output was found at 20 degree angle of twist and can be selected for small wind turbine rotor blade design.

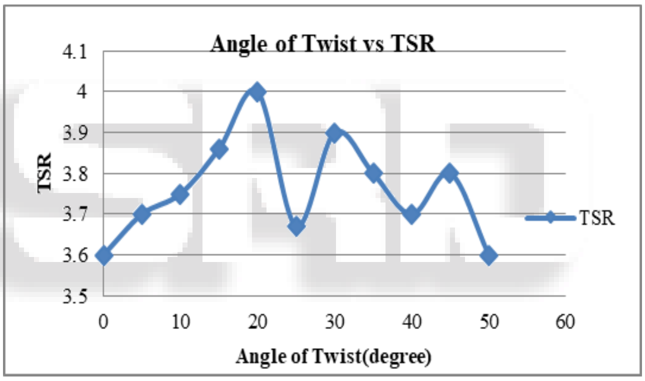
A. Angle of Twist Vs RPM



Graph 1: Angle of Twist Vs RPM

In this graph we can take a look at the relationship between angle of twist and rpm, but it can be seen that there is no certain fashion in this relationship as the angle of twist ranges from 0 to 50 degree. At 20 degree angle of twist we can see the maximum rpm and minimum at 0 and 50 degree. The lift generated by an airfoil is a function of the angle of twist to the inflowing air stream. The inflow angle of the air stream is dependent on the rotational speed and wind velocity at a specified radius.

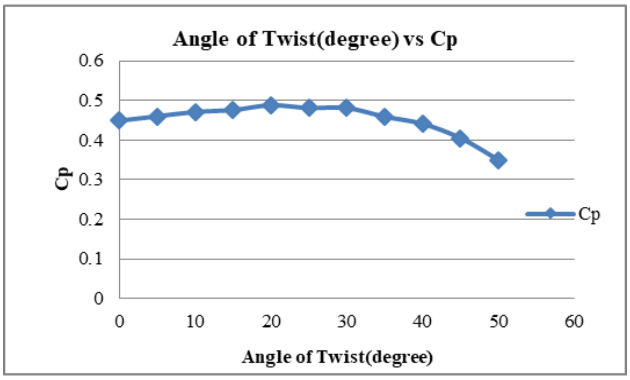
B. Angle of Twist Vs TSR



Graph 2: Direct Airfoil Analysis

This graph shows the effect of angle of twist on tip speed ratio, as the angle of twist is increased tip speed ratio varies in uncertain fashion as we can see in the graph it increases up to 4 at 20 degree and falls down at 25 degree and again increases at 30 degree after that it decreases up to 40 degree and the minimum tip speed ratio can be seen at 0 and 50 degree. The TSR required is dependent upon angle of twist, airfoil and angle of attack.

C. Angle of Twist Vs Cp

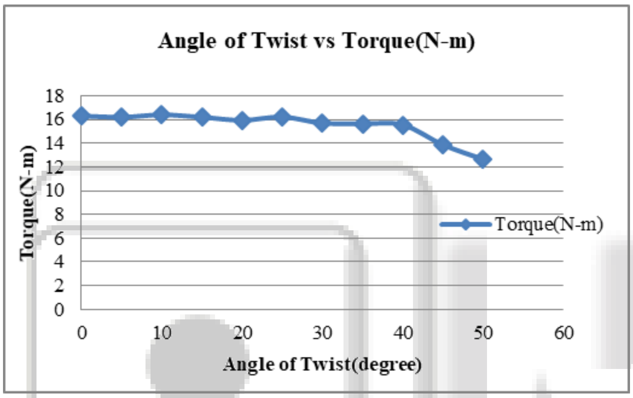


Graph 3: Angle of Twist Vs Cp

In this graph we can see the relation between angle of twist and coefficient of power, angle of twist is plotted on X-axis and coefficient of power is plotted on Y-axis. Different designs of blade were experimented to find out the effect of angle of twist on the coefficient of power of the turbine because coefficient of power is directly proportional to the power output. For any blade design we have to choose a blade which can give the maximum power output. From the graph it can be seen that the maximum coefficient of power is available at 20 degree angle of twist.

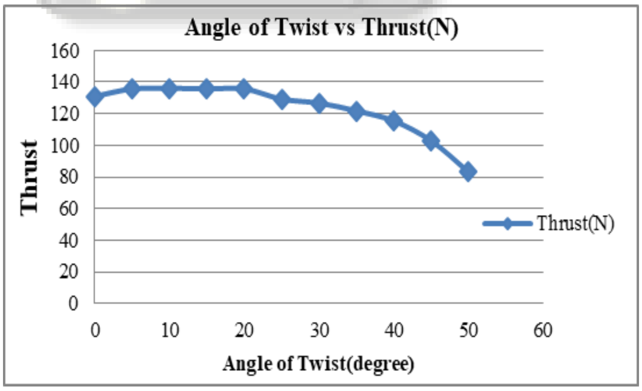
D. Angle of Twist Vs Torque

This graph shows the effect of angle of twist on the torque produced, angle of twist is plotted along the X-axis and torque is plotted along the Y-axis and results are observed. It was observed that there is no such kind of proportional relation between the angle of twist and the torque. Many variations in torque were found out over the range of angle of twist, the range of angle of twist starts from 0 to 50 degree. With the increment of 5 degree 11 blades were designed and examined.



Graph 4: Angle of Twist Vs Torque

E. Angle of Twist Vs Thrust



Graph 5: Angle of Twist Vs Thrust

The effect of angle of twist on the thrust can be seen in this graph, the angle of twist is plotted along the X-axis and thrust is plotted along the Y-axis. As the angle of twist is increased the value of thrust decreases, at 50 degree the value of thrust is minimum. There is no direct significance of thrust on the power output but it can help to improve the structural integrity of the blade. How much force is applied by wind on the blade can be seen in this graph

IV. CONCLUSION

All the experiments are carried out with the aid of QBlade software, it is easy to handle. After studying and observing all the results, we have reached to the conclusion that the angle of twist is an important parameter of the blade design. Having experimented 11 blade designs at different angle of twist ranges from 0 to 50 degree at fixed wind velocity 11.5 m/s. And it is found that the blade having 20 degree angle of twist gives the maximum power coefficient thus we can get maximum power output.

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