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Development of the Performance of Small Horizontal Axis Wind Turbine Blade by Optimizing its Chord Using QBlade Software

Mr. Akash Mohokar[1], Mr. N. W. Kale[2]

[1]Scholar M.E (Thermal), Dept. of mechanical Engineering, PRMIT & R Badnera. Amravati, Maharashtra, India.
[2]professor, dept. of mechanical Engineering, PRMIT &R Badnera. Amravati, Maharashta, India.

Abstract:- *In order to optimally explore and utilize wind energy, we have to obtain the optimum design of turbine blade. A lot of study has been carried out 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, For this study we have used the QBlade software. The QBlade software is based on blade element momentum theory. Which gives the whole knowledge about the effects of angle of twist on the performance of small horizontal axis wind turbine blade. We have experimented different blade designs in this study by changing the chord of wind turbine blade. It ranges from 30 to 120 mm and results are observed critically and it was found that at 90 mm chord the performance of blade is optimum it gives maximum power output.

Keywords: *Wind Turbine, QBlade, Chord, 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.

There are two main types of wind turbines which are used to extract energy in the form of electricity from wind, one is horizontal axis wind turbine and another one is vertical axis wind turbine.

Comparatively the horizontal axis wind turbine is more useful than the vertical axis wind turbine because height of the horizontal axis wind turbine is high than the vertical axis wind turbine.

The power output produced is completely depends upon the size of the blade and the design of blade and the velocity of the wind striking on the rotor. To obtain maximum power output from the wind it is very important 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. if we want to design the optimum blade we have to study the complete effects of these parameters on the performance of wind turbine blade.

In order to study the effects of chord 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 unified into XFOIL, analysis tool and an airfoil design. The objective of this software is to design and aerodynamic simulation of the wind turbine blades. It was started in 2010 in the field 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 module of airfoil design we can design airfoils with the help of splines, also we can import airfoil from a NACA airfoil generator or can import from a point distribution. To use these functions we have to use the Foil menu. this module has been implemented from the XFLR5 software. In this paper we have used the NACA 5518 airfoil.

First of all go to the airfoil design button and press it then go to the Foil in that select NACA foils and having selected the NACA foils enter the 4 or 5 digits of series in the window given and then press ok and you will get your desired airfoil.

Fig.2 Selection of airfoil

B. Direct Airfoil Analysis

In the module of direct analysis we can create polars with the help of XFOIL algorithms. I n this module to define a polar first of all we have to select the airfoil in the airfoil combo box which is given inside the modules toolbar, now press the define Xfoil polar which is given inside the right dock window. After defining the polar we have to press the analyse button which is given in the dock window and we get the value of coefficient of lift Cl and coefficient of drag Cd.

In this way the values of cl, cd and cl/cd can be seen clearly.From the fig3.

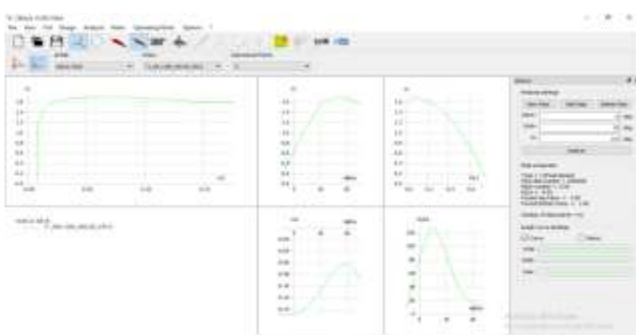


Fig.3 *Direct Airfoil Analysis*

C .Polar 360° Extrapolation

In the module of 360° Extrapolation the polars that were created inside the module of direct analysis can be further extrapolated to the 360° angle of attack. In order to extrapolate a polar, first of all we have to select the polar to extrapolate in the polar combo box which is given inside the modules toolbar, then select the method of extrapolation from the dock window and then press the new button, and after that in order to save the 360° polar we have to click the save buton.

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

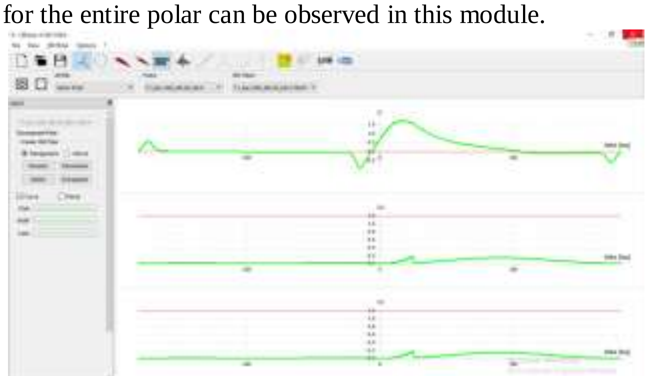


Fig.4 Selection of airfoil

D. Blade Design

In the module of blade design we can design blades with the help of previously defined data such as airfoil and 360 degree polars. To design a blade at least one 360 degree polar has to be present in the database. To design a blade first of all press the HAWT rotor blade design button then click on new blade and then enter the blade data or create your own blade using the scale, chord and angle of twist have to be specified to design the blade. We can adjust the values of chord and angle of twist according to our requirements. And press the save button. For this research purpose 11 differet designs of blade were experimented using the same module.

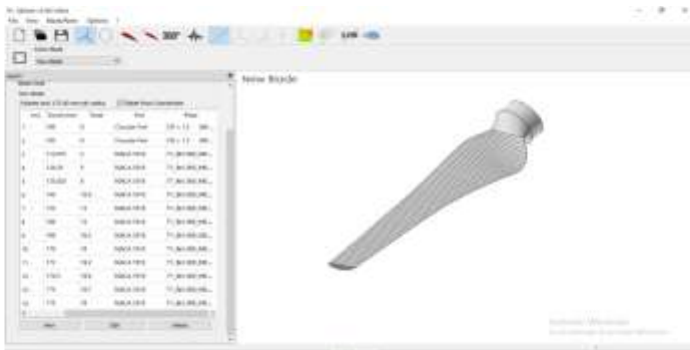


Fig.5 *Blade Design*

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

The module of Rotor/ Turbine blade momentum simulation plays a very important role in the simulation of rotor and achieving optimum blade design. This module works on blade element momentum theory. In this module the designed rotor can be simulated completely and results can be observed. In order to go through this module first of all we have to press the rotor BEM simulation button, then we have to define the wind velocity and tip speed ratio range and then press the start simulation button.

In the rotor BEM simulation the value of Chord was defined for the different blade designs ranging from 30 to 120 mm. 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.

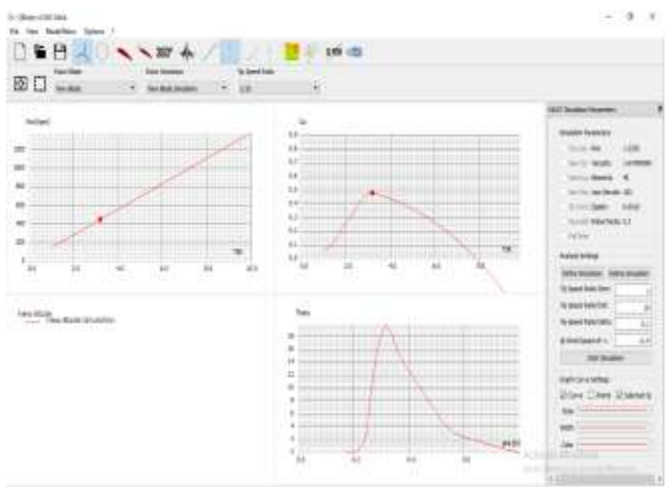


Fig.6 Rotor / Turbine Blade Element Momentum (BEM) Simulation

F. Multi Parameter Simulation

In this module various parametrical relations can be studied. In order to proceed in this module first of all we have to press the multi parameter BEM simulation button then we have to specify the range of wind speed, rotational speed and pitch. After defining all the values we have to press the start simulation button to see the simulation results.

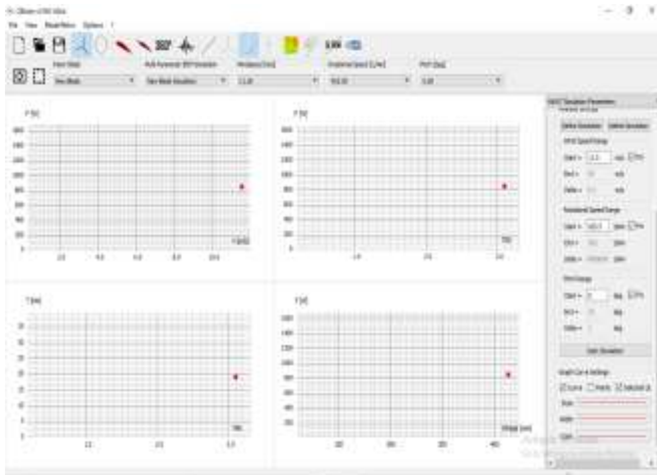


Fig 7. Multi Parameter Simulation

The main variables and free parameters can be set in the graphs context menu by right clicking. 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.

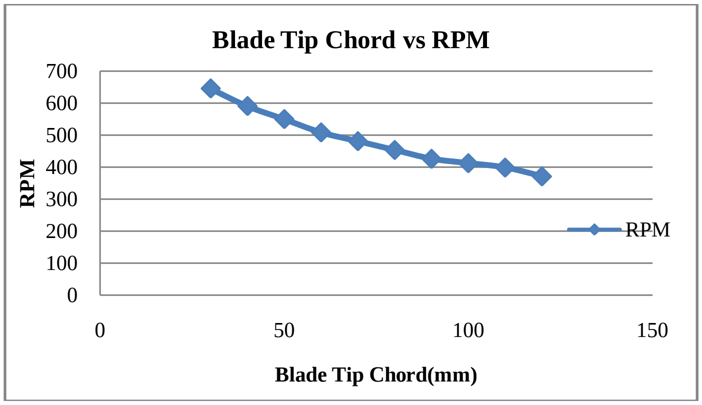
III. RESULTS

Table1:. Results

Sr. No.	Blade Tip Chord	RPM	TSR	CP	P(w)	T(Nm)	Thrust (N)
1	30	645.2	4.7	0.397	743.8	11.1	98.8
2	40	590.3	4.2	0.42	784.9	12.7	105.8
3	50	549.5	4	0.433	809.9	14.1	111.9
4	60	508	3.7	0.441	825.5	15.55	115.4
5	70	480.5	3.5	0.446	834.5	16.6	119.6
6	80	453	3.3	0.448	839.5	17.7	122.4
7	90	425.5	3.1	0.449	840	18.9	123.7
8	100	411.8	3.0	0.448	839.6	19.5	127.7
9	110	398.2	2.9	0.447	837	20.1	130.9
10	120	370.7	2.7	0.445	833.2	21.5	129.1

The analysis is done by QBlade for different blades viz. Chord length 30, 40, 50, 60, 70, 80, 90, 100, 110 and 120 mm considering NACA 5518 airfoil for entire blade span and keeping angle of twist 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 90 mm chord length and can be selected for small wind turbine rotor blade design.

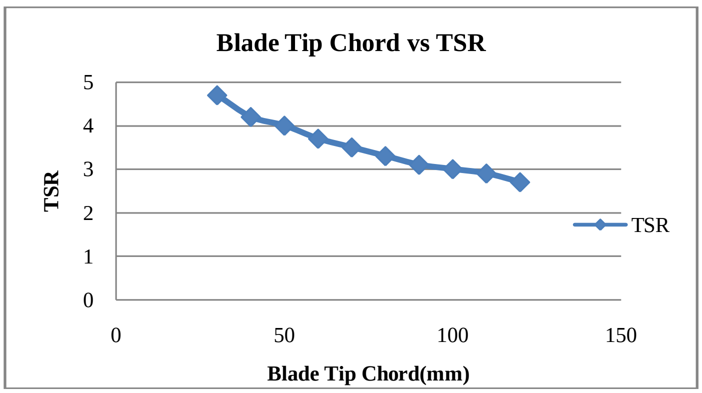
1.Blade Tip Chord Vs RPM



Graph1. Blade Tip Chord Vs RPM

In this graph we can take a look at the relationship between chord and rpm, and it can be seen that as the chord of the blade is increased the rpm decreases. At 30 mm chord we can see the maximum rpm and minimum at 120 mm. but the optimum performance of blade is not only depends upon the speed of blade but also the other factors. So let us look at the other factors as well in further graphs.

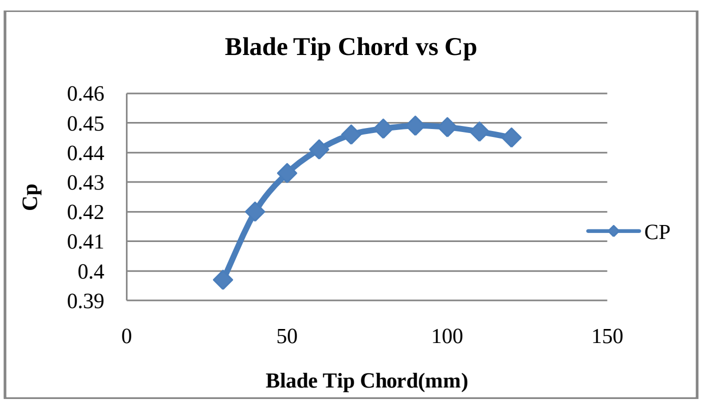
2. Blade Tip Chord Vs TSR



Graph2. Blade Tip Chord Vs TSR

This graph shows the effect of chord length on tip speed ratio, as the chord is increased tip speed ratio decreases as we can see in the graph the value of tip speed ratio is maximum at 30 mm chord and minimum at 120 mm chord. Because increment in chord length also increases the weight of the blade therefore it is very necessary to chose optimum chord to get optimum tip speed ratio. For that purpose we have to check the power coefficient of blade.

3. Blade Tip Chord Vs Cp

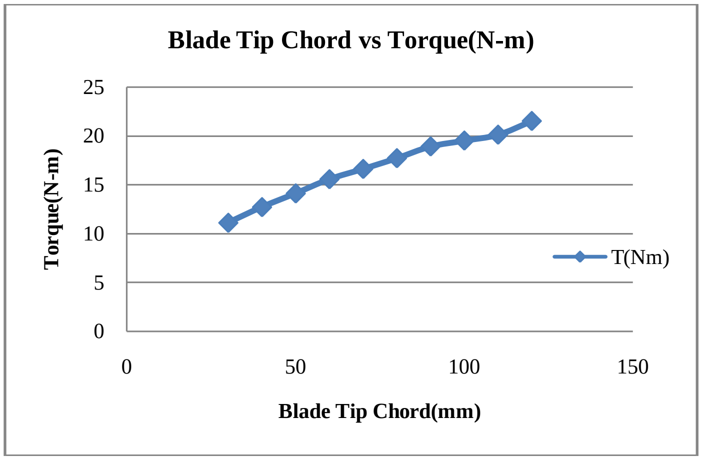


Graph3. Blade Tip Chord Vs Cp

In this graph we can see the relation between blade tip chord and coefficient of power, blade tip chord 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 chord 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 90 mm chord length.

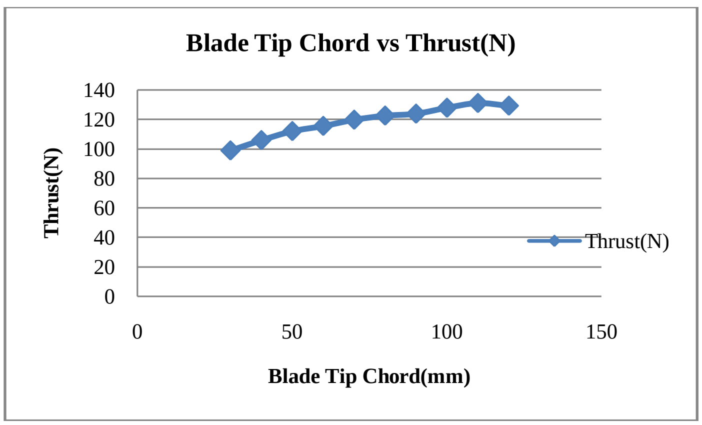
4. Blade Tip Chord Vs Torque

This graph shows the effect of chord on the torque produced, chord is plotted along the X-axis and torque is plotted along the Y-axis and results are observed. It was observed that as the chord is increased the torque increases. It means that torque is directly proportional to the blade size. But for high torque blade requires high speed wind which may not available all the time and also it increases cut in speed. So to avoid such kind of problems we need optimum design which can give maximum amount of power output and also fulfill other requirements.



Graph4. Blade Tip Chord Vs Torque

5. Blade Tip Chord Vs Thrust.



Graph5. Blade Tip Chord Vs Thrust

The effect of chord on the thrust can be seen in this graph, the chord is plotted along the X-axis and thrust is plotted along the Y-axis. As the chord is increased the value of thrust increases, at 30 mm chord the value of thrust is minimum. This parameter can give the insight to the structural integrity of the wind turbine blade. How much force is going to act on the turbine blade can be seen in this graph.

IV. CONCLUSION

All the experiments are carried out with the aid of QBlade software, it is convenient to use. After studying and observing all the results, we have reached to the conclusion that the chord is an important parameter of the blade design.

Having experimented 10 blade designs at different chord length ranges from 30 to 120 mm at fixed wind velocity 11.5 m/s. And it is found that the blade having 90 mm chord length gives the maximum power coefficient thus we can get maximum power output.

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