Analysis of Blade Design, Power Output and Efficiency of A Horizontal Axis Wind Turbine on A Working Model.

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Abstract— In this research a small wind turbine has been developed for experimenting the performance of a Horizontal axis wind turbine with varying wind speed. To improve the performance, the flow straighteners are provided at leading edge of the turbine blades. These flow straighteners give a stream line flow to the airflow circulating over the aero foil and reduces the drag. We notice an improved value of Betz limit. The blades are twisted from root to tip about 12 to 13 degree and rpm was noticed. In the present research we obtained an average mechanical efficiency of 39% also it was noticed that the mechanical efficiency increases with increase in wind speed.

Keywords-- Rotor blades, Flow straightener, rotor shaft, Nose cone.

I. INTRODUCTION

The demand for power is increasing day by day in India. We depend upon the traditional fuel for power production. We know that our traditional fuel resources are limited which is getting short day by day. In this condition wind power can be a very suitable replacement for power production. Particularly in rural India the domestic turbine or micro wind turbine can play an important role as it is cheaper than the other sources of power production. Secondly it is pollution free and requires low maintenance. The micro wind turbine produces low power even at lower wind speed. Therefore minimum requirement of power or lighting can be achieved by this wind turbine. The induction of LED light has given a momentum to this work as even at lower wind speed the lighting task can be achieved efficiently. The object of our project is to develop a wind turbine model with various lift augmentation arrangements to work at low air speed and produce power for domestic use.

II. LITERATURE SURVEY & REVIEW

In order to extract power from the wind, there are so many blade design of wind turbine, all work on the same principle of energy production. Rotors capture the energy of the wind, which give drive to the shaft which is connected to an electrical generator which creates electrical energy through induction. Higher the wind speed higher will be the RPM of the rotor and more energy would be extracted from the wind by the turbine rotor blades.

There are two general types of wind turbine designs. They are determined by the mounting of the rotor blades, which are either vertical or horizontal. Horizontal-Axis turbines main advantage is that there rotating shaft runs parallel with the ground. The advantage of having a horizontal axis is that one have a control on blade pitch giving the turbine blades he optimum angle in w.r.t to the wind. Mounting the wind turbine on tall towers enables them to have obstruction free high speed wind flow.

The other most important thing in a HAWT is the Betz limit. Betz limit limits the maximum power produced by a wind turbine to 59.3%. But all the experiment carried out by different researcher shows that the actual value of the betz limit ranges between 25%-45%. This is due to the fact that 33% of the air passing through the rotor do not do any work on to the rotor. This is possible only by doing design change in the rotor blade. Researchers have experimented on various blades at different angle of attack and various pitch angles. In the present work we have incorporated a flow straightener over the rotor blade to reduce the drag over the blade and giving a streamline flow to the air passing over the blade camber area is increased to 60%. The experimental result showed an increase in the value of Betz limit.

III. PROBLEM STATEMENTS

We know that the maximum theoretical power produced by a wind turbine is 59% as per theory of Betz Limit. But practically it ranges between 25%-40%. Most of the air passes the turbine blade without doing any work on the blade. Therefore the efficiency of wind turbine can be improved by reducing drag increasing device by incorporating some drag reducing device. Increased camber area and suitable camber position can also play a role in utilizing more and more air. In the current research we have added a flow straightener on the leading edge of the blade camber area is taken 60% of chord length and the camber position at the center of the aero foil section and experimented for the power output at given wind speed.
IV. RESEARCH METHODOLOGY

To study the power output in terms of rotational kinetic energy of a wind wheel, a typical model of wind turbine is prepared and the experiment is carried out on the model at various wind speed and the resulting RPM of the wind wheel is registered for further analysis.

V. SPECIFICATION WIND TURBINE

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of blade</td>
<td>0.6 m</td>
</tr>
<tr>
<td>Weight of the blade</td>
<td>0.5 kg each</td>
</tr>
<tr>
<td>Twist angle</td>
<td>12 degree</td>
</tr>
<tr>
<td>Chord length</td>
<td>6.5 cm</td>
</tr>
<tr>
<td>Blade thickness</td>
<td>0.7 cm</td>
</tr>
<tr>
<td>Camber</td>
<td>4.2 cm</td>
</tr>
<tr>
<td>Camber position</td>
<td>2.3 cms from leading edge</td>
</tr>
<tr>
<td>Blade twisting</td>
<td>13 degree</td>
</tr>
<tr>
<td>Blade nomenclature</td>
<td>NACA-6512</td>
</tr>
</tbody>
</table>

VI. MATHEMATICAL CALCULATION

\[
P = \text{Density of air (kg/m}^3\text{)}
\]
\[
\omega = \text{Angular velocity of rotor blade (rad/sec.)}
\]
\[
M = \text{Mass of the rotor blade (kg)}
\]
\[
I = \text{Moment of inertia of the rotor blade}
\]
\[
A = \text{Swept area of the rotor blade}
\]
\[
\psi_i = \text{Initial velocity of air}
\]
\[
\psi_e = \text{Exit velocity of blade}
\]
VII. ACTUAL POWER DEVELOPED

Rotational K.E developed in the rotor

\[
power_{\text{actual}} = \frac{1}{2} I \omega^2
\]

\[
\omega = \frac{2 \pi N}{60}
\]

\[
I = \frac{ML^2}{12} \quad \text{L=D, the rotor blade are assumed to be a cylindrical rod rotating about its center.}
\]

\[
power_{\text{theoretical}} = \frac{1}{2} \rho AV_l^3
\]

\[
c_p = \frac{power_{\text{actual}}}{power_{\text{theoretical}}}
\]

VIII. EXPERIMENTAL RESULTS

<table>
<thead>
<tr>
<th>Wind speed</th>
<th>RPM</th>
<th>Rotational K.E of the wind wheel</th>
<th>Theoretical power of the wind</th>
<th>Betz Limit</th>
<th>Mechanical efficiency of the wind wheel</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5 m/s</td>
<td>72</td>
<td>3.9</td>
<td>10.5</td>
<td>0.37</td>
<td>37%</td>
</tr>
<tr>
<td>2.2</td>
<td>60</td>
<td>2.3</td>
<td>7.2</td>
<td>0.32</td>
<td>32%</td>
</tr>
<tr>
<td>2.6</td>
<td>86</td>
<td>4.8</td>
<td>11.9</td>
<td>0.41</td>
<td>41%</td>
</tr>
<tr>
<td>3.1</td>
<td>116</td>
<td>8.8</td>
<td>20.2</td>
<td>0.43</td>
<td>43%</td>
</tr>
</tbody>
</table>

Average efficiency = 39%

IX. CONCLUSION

In a wind turbine there is change in the power output with the change in the value of Betz limit. If we add lift augmentation devices like flow straightener and nose cone and optimum camber area is taken the value of Betz can be increased. Angle of twisted also has a great impact on power output if the angle of twist range is kept within the optimized limit of change of angle of attack the turbine would be more sensitive to change in wind speed.

Future scope: Basically the efficiency of a wind turbine depends upon the exit velocity of the wind past the wind wheel. The efficiency increases with the decrease in exit wind speed. Therefore more experiments can be carried out with different camber area and blade twist angle incorporating various lift augmentation arrangements.

REFERENCES


