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ANALYSIS OF BLADE DESIGN HORIZONTAL AXIS WIND TURBINE

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Abstract

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. Computers are used to perform the calculations required to simulate the interaction of liquids and gases with surfaces defined by boundary condition. In this paper, CFD analysis of wind turbine blade, a complete drawing, and details of sub-system are carried out. 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.

***Keywords**:* Wind energy, CFD, Blade geometry.

1. INTRODUCTION

Wind turbines are machines that generate electricity from the kinetic energy of the wind. In history, they were more frequently used as a mechanical device that turned hennery.Today, Turbines can be used to generate large amounts of electrical energy in wind farms both onshore and offshore Nowadays electricity is the major problem in this world especially in Tamil Nadu, India. In the present area of steadily rising fuel costs, wind energy is becoming an increasingly attractive component of future energy systems. The wind potential of India is very high. The wind turbines have been installed and wind energy is being harvested, predominantly in the high wind velocity areas. However, due to the restriction of space, the comparatively lower wind areas are beginning to populate with similar wind turbines. In order to ensure the extraction of maximum wind potential even at lower wind speeds, these turbine blades have to be designed and analyzed to suit the low wind areas. At present India stands fifth in the world of wind power generation. Taking into consideration that large portion of the Indian land will not be available for the use of traditional windmills due to low wind speeds; a generator which would produce the energy even at low wind speed is required. Also the transmission losses in India are very high. Hence, to reduce the losses due to transmission the turbine could be placed near the place of consumption.

2. LITERATURE 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 bets 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.

3. PROBLEM STATEMENT

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.

This study simulates air flow around inclined NACA0018 airfoil. Lift, drag coefficient, lift to drag ratio and power coefficient around the airfoil were calculated and compared with different velocity. With the increasing of wind velocity, lift and drag coefficient increases and maximum lift to drag ratio starts to increase then degreases again. Maximum lift to drag ratio is reached around 4 degree. Power coefficients were calculated at the speed of 10 m/s and graph was plotted. With the increasing angle of attack pressure difference between upper and lower surface increases.

4. AIRFOILS

Major features of such an airfoil are shown in Figure 3.For the efficient energy extraction; blades of modern wind turbine are made with airfoil sections. The airfoils used for the earlier day's wind turbines were the aviation airfoils under the NACA (National Advisory Committee for Aeronautics) series. NACA specifies the features of the airfoil by numbers. For example, in a four digit specification, the first number denotes the maximum camber of the airfoil at the chord line (in per cent of chord), the second number gives the location of the point of maximum camber from the leading edge (in tenth of the chord) and the third and fourth numbers indicate the maximum thickness (in per cent of the chord). Thus a NACA 2415 air foil have maximum camber of 2 per cent, located at 0.4 times the chord length from the leading edge and the maximum thickness is 15 per cent of the chord.

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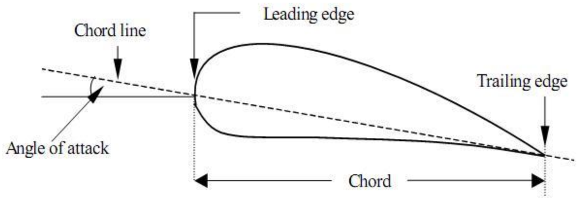


Figure: 1 Important parameter of an Airfoil

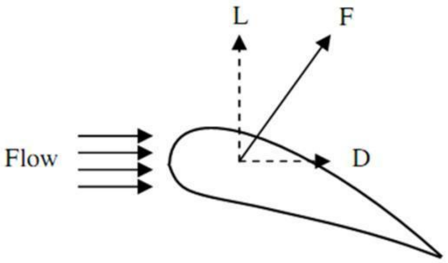


Figure: 2 Airfoil lift and drag

When an airfoil is placed in a wind stream, air passes through both upper and lower surfaces of the blade. Due to the typical curvature of the blade, air passing over the upper side has to travel more distance per unit time than that passing through the lower side. Thus the air particles at the upper layer move faster. According to the Bernoulli's theorem, this should create a low-pressure region at the top of the airfoil. This pressure difference between the upper and lower surfaces of the airfoil will result in a force F. The component of this force perpendicular to the direction of the undisturbed flow is called the lift force L. The force in the direction of the undisturbed flow is called the drag force D.

$$FL = \frac{1}{2}\rho.Vr^2\ CL\ (N)$$

And the drag force (D) by

$$FD=\frac{1}{2}\rho.Vr^2\ CD\ (N)$$

Where CL and CD are the lift and drag coefficients respectively.

Resultant force is given by

$$F_R = (F_D^2 + F_L^2)^{½}\ (N)$$

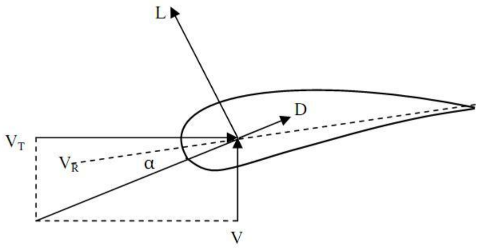


Figure: 3 Section of rotating blade

And power is given by

$P = FR \times r \times \omega$

Angular velocity is given by

$\omega = 2\pi N/60$

Consider the cross section of the rotating blade of a wind turbine as in Figgure3. Apart from the wind velocity „V‟, a point at the section is subjected to a velocity V_T due to rotation of rotor as shown in figure. Thus the velocity V_R experienced at this point of is the resultant of V and $V_{T.}$ V_R will have lift and drag component as shown in figure. Under this condition, the angle of attack V_R and the chord line of the airfoil. For the same rotational speed, V_T at different section of the blade varies with the distance from the hub. Hence, the angle at which the resultant velocity approaches the rotor would also be different along the blade section, being steeper at the root of the blade. As we have seen, the C_D/C_L ratio for an airfoil is minimum at particular angle of attack. To maintain this optimum attack angle throughout the blade sections, the blade may be twisted along its length.

5. MODELING, MESHING

The First task in CFD analysis is preparation of geometry. First, the type of airfoil is used is decided. Then find out the airfoil co-ordinate for drawing the airfoil shape. Here NACA 0018 selected for the analysis. Here the maximum thickness is 18% which indicate the maximum thickness (in per cent of the chord).In this analysis, the geometry is prepared in the pro-e software package and then after it is saved in IGES format. Then import this geometry in the Ansys 12.0

Dimensions of the blade:

Chord length C= 240mm

Length of blade =500mm

Chord length at the 500mm distance= 40 mm

Airfoil	NACA0018
Simulation type	Steady Simulation
Fluid material	Air
Temperature	288K
Kinematic viscosity	$1.4\times10^{-5}m^2/s$
Density	$1.225kg/m^3$
Pressure	101325Pa
Wind speed	3-11m/sec
Boundary condition	Velocity inlet & pressure outlet

Table: 1 Computational condition

The blade is made in the pro-e software. In pro-e software this is possible by using the blend tool.

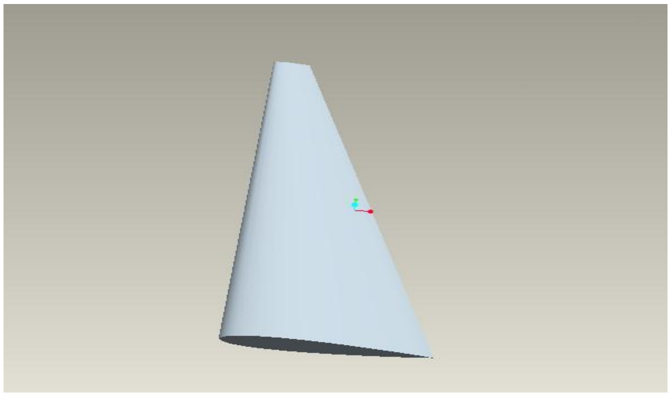


Figure: 4 Blade design in Pro-E

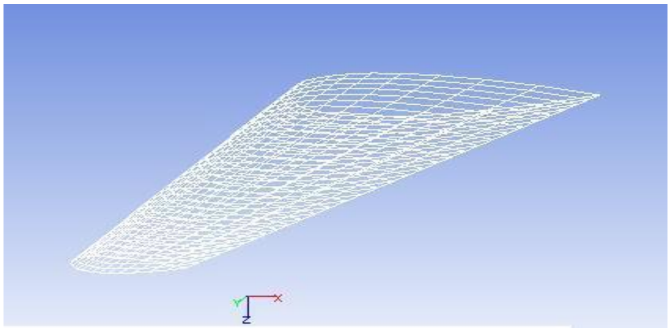


Figure: 5 Meshed blade in Ansys

6. RESULT AND CALCULATION

Calculations: The following procedure is used to calculate the numerical power developed by the wind turbine

$\alpha = 6^0$; $V_0 = 8$ m/s : N = 51rpm; r =1.2m; $\rho = 1.225kg/m^3$

$V_T = r \times \omega = 1.2x\ 2.\pi.\ 51/60 = 6.4088$ m/sec

$V_R = (6.4088^2 + 8^2)$

= 10.250 m/s

From fluent software we get the valve of

CL=0.9559, CD=0.001375

Therefore we get the valve of

Drag force $= 0.5x\ \rho x\ VR^2 x\ CD$

$= 0.5x1.225x10.25^2 x0.001375$

FD=0.0881N

Lift force $= 0.5x\ \rho\ x\ VR^2 x\ CL$

$= 0.5x1.225x10.25^2 x0.9559$

FL=76.22N

Resultant Force, $R = (FL2+ FD^2)^{1/2}$

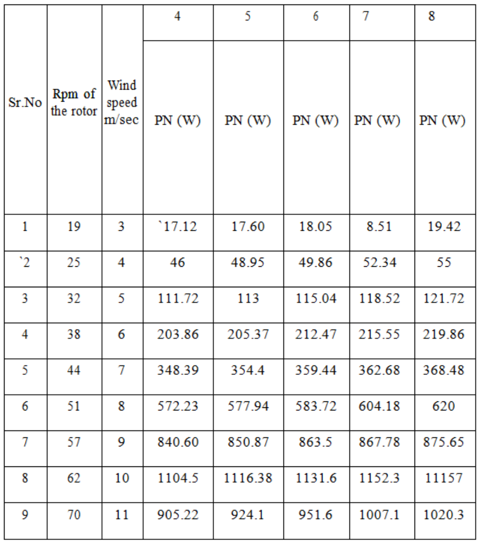
$= (0.0881^2 + 76.22^2)^{1/2}$

=76.22N

Numerical power, $P = (Rx\ V_R)$

=620.43Watts

The table 1 is shown below is the numerical power produced by the wind turbine at different angle of attack and different wind velocity.



Sr.No	Rpm of the rotor	Wind speed m/sec	4	5	6	7	8
			PN (W)	PN (W)	PN (W)	PN (W)	PN (W)
1	19	3	`17.12	17.60	18.05	8.51	19.42
`2	25	4	46	48.95	49.86	52.34	55
3	32	5	111.72	113	115.04	118.52	121.72
4	38	6	203.86	205.37	212.47	215.55	219.86
5	44	7	348.39	354.4	359.44	362.68	368.48
6	51	8	572.23	577.94	583.72	604.18	620
7	57	9	840.60	850.87	863.5	867.78	875.65
8	62	10	1104.5	1116.38	1131.6	1152.3	11157
9	70	11	905.22	924.1	951.6	1007.1	1020.3

Table: 2 Power produced by using wind turbine

To calculate the analytical power developed by the wind turbine, following method is used.

P= 1/2 ρ. A. V^3

P= ½ 1.225*3.141*1.524^2*8^3

= 2287.04watts

The below table-3 shows the analytical power produced by blade at different wind velocity.

Sr.no	Rpm of the rotor	Wind speed (rpm)	Analytical power (Watts)
1	19	3	120.606
2	25	4	235.881
3	32	5	558.361
4	38	6	964.849
5	44	7	1532.144
6	51	8	2287.05
7	57	9	3256.366
8	62	10	4466.894
9	70	11	5945.436

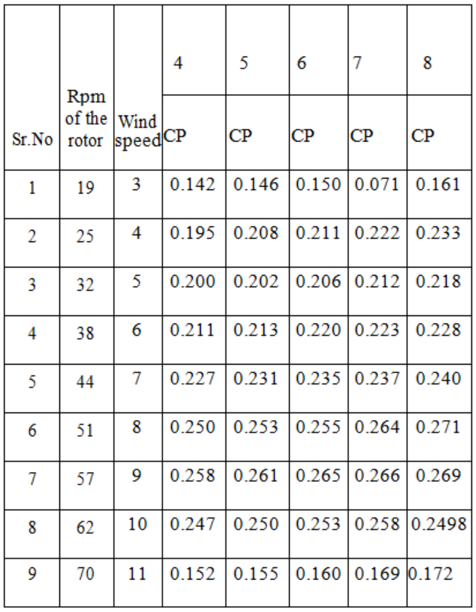
Table: 3 Analytical power produced by wind velocity

CP=Numerical Value/Analytical valve

= 620/22807.04

= 0.271

The below table 4 is obtained by comparing the numerical power with the analytical power. So we can obtain the coefficient of performance at different wind speed and different angle of attack. From the below table we also obtain the value maximum coefficient of performance



Sr.No	Rpm of the rotor	Wind speed	4	5	6	7	8
			CP	CP	CP	CP	CP
1	19	3	0.142	0.146	0.150	0.071	0.161
2	25	4	0.195	0.208	0.211	0.222	0.233
3	32	5	0.200	0.202	0.206	0.212	0.218
4	38	6	0.211	0.213	0.220	0.223	0.228
5	44	7	0.227	0.231	0.235	0.237	0.240
6	51	8	0.250	0.253	0.255	0.264	0.271
7	57	9	0.258	0.261	0.265	0.266	0.269
8	62	10	0.247	0.250	0.253	0.258	0.2498
9	70	11	0.152	0.155	0.160	0.169	0.172

Table: 4 Coefficient of performance of wind turbine

From the result of above table no. 4 we can plot the graph, Fig. No.6 shows the graph of Coefficient of Performance versus Velocity of air V_0.

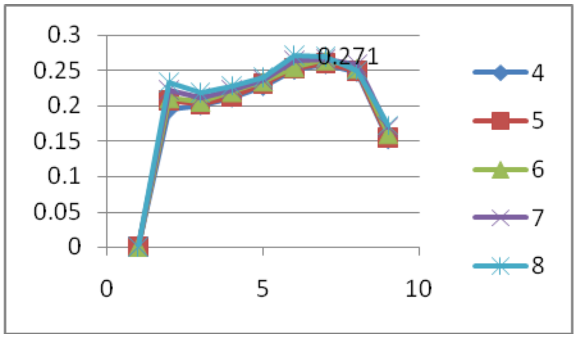


Figure: 6 Graph wind velocity vs CP

7. CONCLUSION

The maximum value of coefficient of performance (CP_{max} = 0.271) was observed at angle of attack 7^0 and 8^0 and the velocity of 8 m/s. This blade can generate maximum power of 620Watts at maximum CP, at angle of attack 8^0 and velocity of air 8m/s. It was observed that value of numerical power increases as angle of attack increases from 4^0 to 8^0, after 7^0 the value of numerical power reduced. Hence critical angle of attack for this blade is 8^0.

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