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# Aerodynamic investigation of horizontal axis wind turbine

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## Abstract:

*Wind energy is renewable, pollution free and abundant in the earth and it can reduce the dependency on fossil fuel for energy requirement. Wind energy is different form of solar energy, and it will available till sun is available. Large amount of wind energy can be continuously generated from wind source, that's why large horizontal axis wind turbines are being installed to produce power, for more power extraction aerodynamic parameters associated with blade geometry and the material for blade are important. so in this paper we will discuss about the various aerodynamic characteristics which is important in terms of large power extraction with less material and cost expenditure.*

## Keywords:

HAWT; aerodynamics; airfoils

## Introduction

Wind energy power production are directly depends upon the interaction held between the rotor and the balde. In a horizontal axis wind turbine the mean power output and mean loads are determined by the aerodynamic forcesgenerated by the mean wind. Practical horizontal axis wind turbine designs use airfoils to transform the kinetic energy in the wind into useful energy.

## Airfoil nomenclature

Figure 1 shows airfoil nomenclature and its terminology is as following:
Chord length – length from the LE to the TE of a wing cross section that is parallel to the vertical axis of symmetry
Mean camber line – line halfway between the upper and lower surfaces
Leading edge (LE) is the front most point on the mean camber line,
Trailing edge (TE) is the most rearward point on mean camber line
Camber – maximum distance between the mean camber line and the chord line, measured perpendicular to the chord line
- 0 camber or uncambered means the airfoil is symmetric above and below the chord line

Thickness – distance between upper surface and lower surface measured perpendicular to the mean camber line [1].

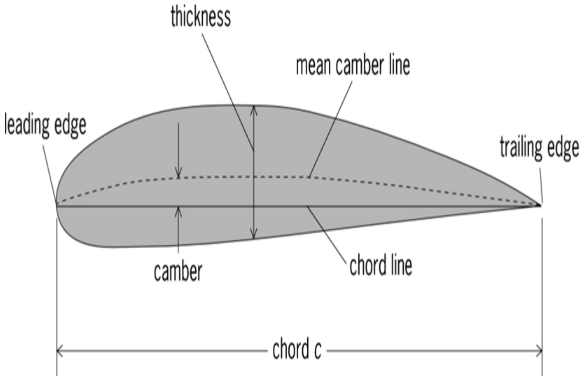

Fig.1. Airfoil nomenclature

## Lift and Drag

Lift on a body is defined as the force on the body in a direction normal to the flow direction. Lift will only be present if the fluid incorporates a circulatory flow about the body such as that which exists about a spinning cylinder. The velocity above the body is increased and so the static pressure is reduced. The velocity beneath is slowed down, giving an increase in static pressure. So, there is a normal force upwards called the lift force. The drag on a body in an oncoming flow is defined as the force on the body in a direction parallel flow direction. For a windmill to operate efficiently the lift force should be high and drag force should be low. For small angles of attack, lift force is high and drag force is low. If the angles of attack (α) increases beyond a certain value, the lift force decreases and the drag forces increases. So, the angle of attack plays a vital role.

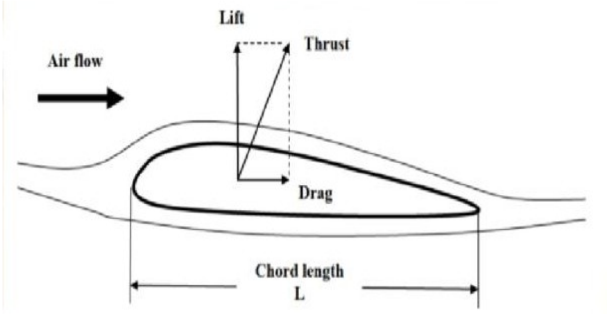

Fig.2. Forces on a stationary rotor blade

## Aerodynamic performance

The efficiency of rotor basically depends on the aerofoil,which is used to reduce the pressure on the upper surface to increase the lift which generates sufficient torque.The power coefficient and the torque generated can be optimized by maximizing the lift coefficient (CL) and the lift to drag(L/D) ratio for aerofoil [2,3]. High L/D ratio contributes to high values of torque and which is desirable for small sized rotors and significant in gaining good response at low wind speed to generate maximum power [2,4,5].

$$\eta_{aero}=1-(c_{D}/c_{L})\cot\varphi\ /1+(\ c_{D}/c_{L})\tan\varphi \qquad (1)$$

$$\tan\phi = (1-\alpha)/\ \lambda_{r}(1+\alpha) \qquad (2)$$

where $\phi$ is the in flow angle and $\lambda r = \omega r/V_o$ is local speed ratio at any station represented in velocity diagram shown in Fig.3[6]. From the above Eq. (1), it can be seen that the aerodynamic efficiency is substantially influenced by lift to drag ratio and flow angle.

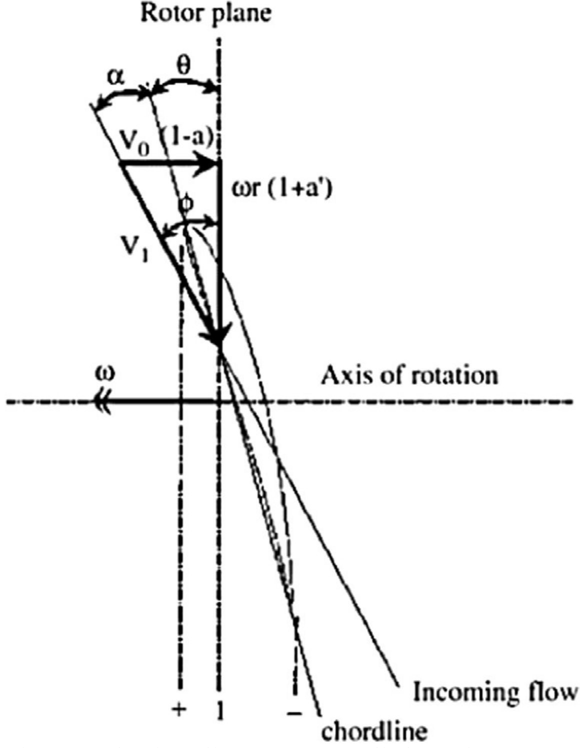

Fig.3. velocity diagram at radial station [6].

Parameters associated with blade geometry optimization are important, because once optimized, shorter rotor blades could produce similar power compared to one that is not optimized and larger in diameter. Increasing the power extraction from the low wind areas, aerodynamic optimization of the rotor is very essen- tial, which is to be coupled with optimization of chord and twist distribution, number of blades, selection of airfoil geometry, and the tip speed ratio (TSR) [6].

Flapwise (chord) distribution and edgewise (bladethickness) distribution and twist distribution based on blade element momentum theory,BEM.Eq. (6) gives the chord distribution along the bladespan.

$$C(r) = \frac{4\pi r\, F \sin\phi}{N_B\, C_L[[(\lambda_r + \tan\phi)/(1-\lambda_r \tan\phi)] - (C_D/C_L)]} \qquad (6)$$

where $N_B$ is the number of blades, $C_D/C_L$ is ratio of the airfoil section, F is the tip loss factor, λr=λ. r is the local speed ratio at radial distance r along the blade, $\lambda=\omega R/V_o$ is the design tip-speed ratio, ω is the rotational speed of the blade, $V_o$ is the free stream wind velocity at hub height and R is the rotor radius. The twist distribution based on the twist of the zero lift line [7] is givenby

$$\theta_p = ((R\alpha_t/r) - \alpha_t) - k(1 - r/R) \qquad (7)$$

Where θp is the pitch angle, R is the radius of the blade, r is the radial location, αt is the angle of attack at the tip of the blade and k is the acceleration factor (a constant) such that $k > 0$.

## Low Reynolds number airfoil:roughness effect or leading edge flap

Low Reynolds number airfoils generally loses its performance due to laminar separation bubbles, which is encountered by adding small trips or tabulators on the upper surface leading edge and it reduces the length of laminar separation bubble,and quickly produces the turbulent boundary layer. The addition of trips causes an overall increase in drag except for the airfoils that have suffered from severe laminar separation effects under clean conditions. Also drag polar shows that for fixed transition the performance is essentially Reynolds number inde-pendent as the drag polar,forms almost a single curve. Roughness affects a significant increase in the overall drag and canal so negatively affect the lift characteristics and thus aerodynamic performance with simulated leading-edge roughness is likely to be useful in the airfoil selecting process.[8]

## Effect of pitch angle on starting performance

The starting characteristics was analysed in the 5kW wind turbine for two different pitch angles. At a large pitch angle,the blade takes 10s to reach their maximum speed of 50rpm at wind speed of 8m/s and at a lower pitch the blade takes 50s to start at same wind speed for the operational rotor speed of about 300rpm. A significant trade-off between starting and operating performance has been identified [9].

## Conclusion

Aerodynamic analysis of blade profile is very much important before the desiging of HAWT. There are so many blade profiles available we have to choose proper one according to their characteristics , location and wind speed for maximum power output. blade profile should be such that in which darg force should be minimum and lift force should be maximum at an proper angle of attack.

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