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A Study of Wind Turbine Blade Power Enhancement Using Aerodynamic Properties

S. Senthilkumar[1], M. Gokulraj[2], G. Sivaraj[3], P. Maniiarasan[4]
[1, 2, 4] (Department of Aeronautical Engineering ,Nehru Institute of Engineering Technology, India)
[3](Department of Aeronautical Engineering , Bannari Amman Institute of Technology, India)

Abstract: *Technological advancements have improvised them over time. In this paper we shall glance at the features. Wind energy is the most popular renewable energy. In order to increase the use of wind energy, it is important to develop wind turbine rotor models with high rotation rates and power coefficients. These elemental forces are summed along the span of the blade to calculate the total forces and moments exerted on the turbine. This study aimed at manufacturing highly efficient wind turbine rotor models using NACA profiles.*
Keywords: *Blade, NACA profiles, Power coefficients, Wind turbine, Wind energy.*

I. INTRODUCTION

A wind turbine is a kind of turbo machine that operates externally (without casing) and wind is generally considered to be incompressible, but sometimes the blade velocity at the tip may exceed 0.3 Mach and at such high blade speeds, wind may be considered as compressible at that region. Therefore the air density in the compressible region should be calculated separately from the incompressible region. In the incompressible region one should consider the free stream density of the air.

The abbreviation “HAWT” is used to indicate “Horizontal Axis Wind Turbine” and the term “VAWT” is used for its vertical case. We will focus on HAWT systems in this study rather than VAWTs. The axis “horizontal” implies that the rotor main shaft of the machine is parallel to the ground; on the contrary “vertical” implies the rotor main shaft is perpendicular to the ground. HAWT rotors decelerate the air rather than accelerating, and their tip speeds are much lower than those of aircraft propellers. Rotor blades aerodynamic features are very important. It is necessary to put forward the power value that can be obtained from rotor blades, real rotor blades have to be produced. And this means cost. For this reason, first miniature blades can be produced and the test can be conducted on these miniature rotor blades. This, along with theoretic studies, will help us to have a good opinion.

II. MODEL DIMENSIONS

As the technology developed, wind turbines were also improved just like the other technologies until recent times and they are continuously evolving. As it was mentioned earlier there are also VAWTs which geometrically differ from HAWTs. The world’s largest horizontal axis wind turbine built on Hawaii Island, manufactured by Boeing Aerospace Industry. This turbine has a rotor diameter of 97.5m and has a rotor swept area of 7,470m2. Its rated power is 3.2 MW .

HAWTs are most preferable wind power machines due to their effectiveness when compared with VAWTs, but VAWTs have some superiorities upon HAWTs. One of them is they do not need any yaw mechanism and their installation is more easy and so their maintenance as well.
Scale model of this project is NTK/41 wind turbine.

- Scale ratio 1:120
- Model dimensions
  Rotor Diameter : 340 mm
  Hub Diameter : 60 mm
  Blade length : 140 mm
  No. of blades :

III. WIND TURBINE DESIGN

Blade element theory assumes that blades can be divided into small elements that act independently of surrounding elements and operate aerodynamically as two-dimensional airfoils whose aerodynamic forces can be calculated based on the local flow conditions.

These elemental forces are summed along the span of the blade to calculate the total forces and moments exerted on the turbine. The other half of BEM, the momentum theory, assumes that the loss of pressure or momentum in the rotor plane is caused by the work done by the airflow passing through the rotor plane on the blade elements. This coupling of two theories ties together blade element momentum theory and sets up an iterative process to determine the aerodynamic forces and also the induced velocities near the rotor.

We have two equations derived from a consideration of blade forces which express the axial force and torque in terms of the lift and drag coefficients of the aerofoil **(Equations 1 & 2)**

$$\frac{a}{1-a} = \frac{\sigma'[C_L \sin\beta + C_D \cos\beta]}{4Q\cos^2\beta} \qquad (1)$$

$$\frac{a'}{1-a'} = \frac{\sigma'[C_L \sin\beta - C_D \cos\beta]}{4Q\lambda_r \cos^2\beta} \qquad (2)$$

IV. TORQUE & THRUST EXERTED ON A HAWT BLADE

When the incoming flow interacts with a HAWT blade, it tries to turn the blade around its axis of rotation, and tries to push the blade in the axial direction. These two main forces are called “lift” and “drag” do so. The forces acting on a (2D airfoil) HAWT blade.The torque exerted on the shaft axis a blade section comes from both lift and drag, and they are opposite in direction, but thrust components from both forces are same in direction (towards the axial direction). Higher the torque the wind turbine will be able to deliver more power. Higher the thrust the captured wind power would be lower and the cost of supporting tower will be higher.

V. COMPUTATION ANALYSIS

There are many CFD packages available in the market today. Auto desk CFD simulator and Auto desk CFD simulator packages improve the capability of analyzing a flow and meshing the element respectively. Auto desk CFD simulator is one of the most popular flow analysis packages in use today.

GEOMETRY NOMENCLATURE

The blade has a length (x L), a depth (y L), and a height (z L).The blade length is aligned with the x axis, the depth with the *y* axis, and the height with the *z* axis. The flow is assumed to be symmetric about a plane that bisects the blade in the y-direction and therefore only half the blade is modeled.

MESH

A model that has already been meshed and it has only 130’000 polyhedral cells. Note that at least 5 million cells, with hexagonal in the near-wall regions, would be necessary to obtain reliable and detailed results in such a case.

SPECIFY MATERIAL PROPERTIES

Define the materials is air And it is properties of

Density = 1.225 kg·m-3
Viscosity = 1.464e-5 kg·m-1·s-1

Those values correspond to the ICAO norm. Auto desk CFD simulator means dynamic viscosity as we consider air as incompressible and are not looking for heat transfer problematic, we don’t need to specify properties.

BOUNDARY CONDITIONS

Blade model is “wall” with “blade” (in the field “Zone Name”).We considers our model as a wind-tunnel model. So the blade is a stationary wall, the viscosity makes the air stick at the blade coachwork, so no slip the coachwork is very smooth, so a roughness of zero. Ceiling of the wind-tunnel and Side wall of the wind-tunnel are specified shear for this will allow the air to slip on the ceiling wall. This is not realistic, but so, we can use a very coarse mesh without boundary layer problems. Velocity is 25 m·s-1 in the Speed field. Correspond to 90km/h. and 0.05m in the “Roughness Height” field.

Inlet is 25 m·s-1 in the “Velocity Magnitude” field as the blade doesn’t move, the air has to in the positive x-direction. Outlet is Zero Pa in the “Gauge pressure” field means we have atmospheric pressure at the outlet.

INITIALIZE THE FLOW FIELD

Initialize the "Compute From"-inlet. This will attribute to all cells of the model, the velocity, pressure and turbulences values that we defined for the inlet

OPERATING CONDITIONS

Let the 101325 Pa which corresponds to the ICAO-Norm. Auto desk CFD simulator works with relative pressure.

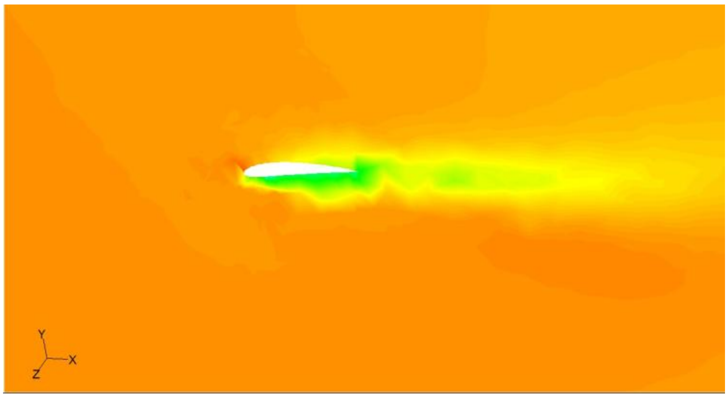

Figure 1: computational analysis of NACA 4420

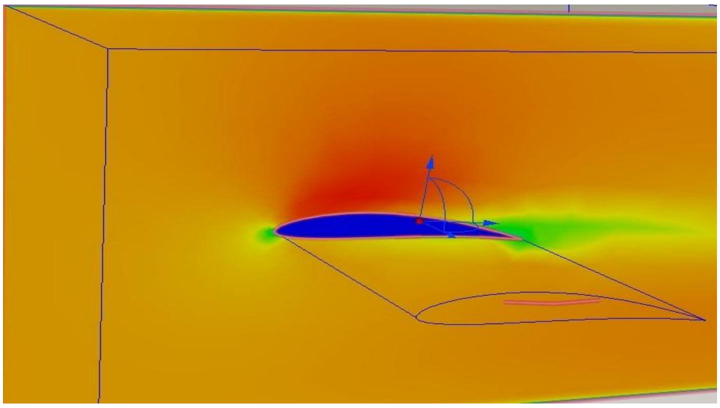

Figure 2: computation Analysis of NACA 65420

VI. CONCLUSION

The Lift/Drag ratio is calculated for different angle of attack ranges from 0^o to4 ^{o} for the velocity ranges from 3 to 12 m/sec. The lift/drag ratio for different angle of attack is shown in Table.1.

Angle of attack	NACA 4420	NACA 65410
0	50.7	61.3
1	59.7	73.80
2	67.2	82.3
3	70	80.23

Table 1: Lift/drag ratio comparison of NACA 4420 and NACA 65420

For comparison NACA 4420 and NACA 65420 a rectangular blade was designed with the same platform area. This NACA 65410 blade does produce more power compared to the NACA 4420 blade but not as much as the twisted blades. All four upwind pointing NACA 65420 do result in lower thrust compared the rectangular blade tip, while the downwind pointing NACA 65420 results in comparable or even higher thrust.

Based on the present investigation it is seen that NACA 65420 has the best overall power performance of the upwind pointing, but the increase in power of around 0.8% for wind speeds larger than 6 m/s is relatively low and must be compared to the increase in thrust of around 1.3%. But pointing the NACA 65420 downstream seems to increase the power production even further. The effect of sweep and cant angles is not accounted for in the present investigation and could improve the performance of the NACA 65420s even more.

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