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PROFILE MODIFICATION OF WIND TURBINE BLADE FOR IMPROVING EFFICIENCY

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ABSTRACT

The main objective of this project is to increase the efficiency of the wind turbine generator during low wind season in order to get repeated orders from the customers, by ensuring better customer satisfaction to compete in the global market. This project describes the behavior of the aerodynamic profiled wind turbine blade after introducing vortex generator on it in order to increase the power generation of the horizontal axis wind turbine generator. In this study, a 41 metre long wind turbine blade suitable for 1.5 MW is analysed with and without vortex generator using CATIA software. In addition, an analysis was made in Computational Fluid Dynamics Software version 14.5 (ANSYS WORKBENCH) to evaluate the performance between them at 12 m/s wind velocity. The outcome of the analysis study revealed that there was improvement in the coefficient of lift of 0.0479 for the wind turbine blade with vortex generator

KEYWORDS: Wind Energy, Vortex Generator, Blade Profile, S818 Aerofoil, Blade Efficiency

INTRODUCTION

India is a country which locates near the equator and also have extensive coastline has large potential for wind energy. Currently Indian energy sector dominated with coal based thermal plants cause large CO_2 emissions which results in environmental pollution in global level. The development of wind power in India began in the 1990s, and has significantly increased in the last few years. At present the Indian wind energy sector has an installed capacity of 21,141.36 MW. Any improvement in efficiency will lead to more energy which may be used to lit homes. The study on the dynamics of the wind blade may help to implement some changes that leads to advancement of the blade structure and thereby extract more power.

AERODYNAMICS OF BLADE

The design, shape and dimensions of the wind turbine is a great factor that is designed according to the wind effects on the surface of blades through Wind Tunnel experiments. The dimensions and shape changes for each turbine according to the location, wind velocity, climatic conditions etc. Each blade produces different torques to rotate which depend upon the airfoil or the cross section of blade. The air flow at the blades is not the same as the airflow far away from the turbine. The very nature of the blade in which energy is extracted from the wind causes air to be deflected by the turbine. In addition the aerodynamics of a wind turbine at the rotor surface exhibit phenomena that are rarely seen in other aerodynamic fields.

In wind turbines, aerodynamics provides method to explain the relative motion between aerofoil and air. The wind passing through the upper and lower surface of the aerofoil produces differential pressure which causes lift.

BOUNDARY LAYER SEPARATION

The normal flow of wind along the wind turbine blade profile without VG is shown in Fig 1. When the wind flows over the surface, the velocity of the air molecules decreases near the surface due to the friction and the viscosity of air molecules. As the wind travels over the surface, the velocity gradient near the surface decreases. At point **'P'**, the velocity gradient of air over the surface becomes zero. At next instant say **'S'**, velocity gradient becomes completely zero and the wind stops following the blade profile. This phenomenon in which the wind flow is no more following the blade profile is called boundary layer separation. The point **'S'** is termed as the point of separation. From this point onwards the air flow get separated and the air from the other regions enter into this region forming swirls. This produces a region of recirculating flow. If the region extends to more distance, air become more turbulent and the lift force is reduced. This problem is seen in all the wind turbine blades.

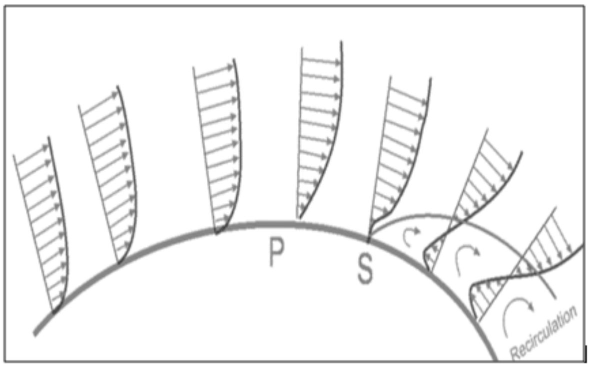

Figure 1: Normal Flow of the Wind along the Blade Profile without Vortex Generator

In this phase, the boundary layer separation is delayed with the help of the VG. At the point **'S'**, a VG is mounted. When the wind flows, the wind is obstructed by the VG at point **'A'**. This obstructed air squeeze into the air stream flowing just above the VG. This highly stressed air expand on reaching the point **'B'** results in the formation of vortexes shown in Fig 2. The dotted line shows the flow separation on the blade profile without VG. So the vortex generated helps to attain the flow near the blade profile thereby supressing the flow separation.

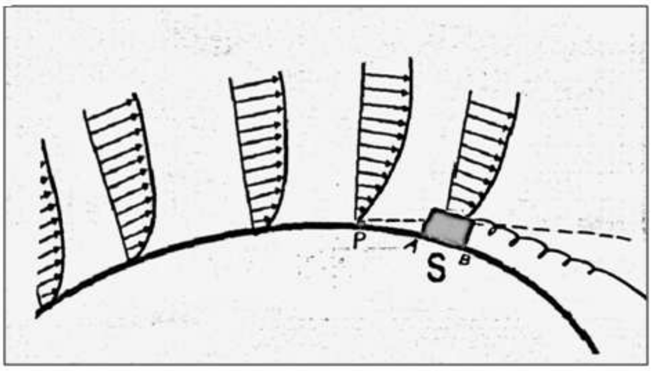

Figure 2: Flow of the Wind along the Blade Profile with Vortex Generator

VORTEX GENERATOR

A VG is an aerodynamic device, consisting of a small vane usually attached on blade of a wind turbine. When the wind is in motion relative to the blade, frictional forces acts between airfoil surface and air. When this happens, the air velocity just above the surface of the blade become zero at the point of separation. To solve this problem, they are often placed on the external surfaces of wind turbine blades. The VG creates a vortex by removing some part of the slow-moving boundary layer in contact with the airfoil surface and thereby delays local flow separation.

VGs are typically rectangular or triangular, about as tall as the local boundary layer, and run in span wise lines usually near the thickest part of the airfoil. When the wind flow reaches the vane, the kinetic energy is suppressed. On the other side of vane velocity is almost zero, so low pressure is produced there. When that wind exits the vane, there will be formation of vortex which has a low pressure and turbulent in nature. A turbulent boundary layer is more attached to surface than a laminar one.

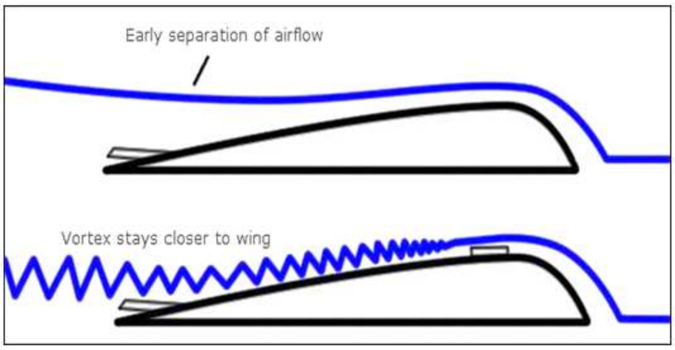

Figure 3: Aerofoil with Rectangular Shaped Vortex Generator

DIMENSIONS OF THE BLADES

Dimensions of the blade is so important that, on the basis of the dimensions the air effects of wind varies. The dimension should be accurate during the drawing and calculations. So the various parameters that should be taken care of during drawing the wind blade are mainly the shape of the airfoil, length of blade, diameter of the root, length of each section, chord length etc. all these vary with the change in wind velocity

Airfoil

An airfoil is not only a shape, it has engineered to increase the lift forces on blade and to lower the drag. The upper side has more length and the wind has to travel more on upper side. So in order to get along with the free stream of air, it gradually increases the velocity of air over the surface leading to lower pressure zone at the upper side. This difference in pressure will lead to lift forces to act perpendicular to the blade profile. According to NREL, there are wide variety of airfoil structures used for wind blades. The standard airfoil used in this is S 818 series airfoils. Coordinates are obtained from the NREL site for standard airfoils

Due to limitations in modelling the only single airfoil structure is utilized instead of three airfoils used in standard blades. As the aim of the experiment is to find the efficiency analysis, it is not affected by this limitation.

Length of the Blade

The length of blade determines the swept area. The wind speed at a particular area is highly influenced by the length. The power extraction depend upon the swept area of the blade. As swept area is dependent upon the diameter of the blade. So length of the blades is also highly dependent on power extraction. The length of blade taken as 41m and the rated wind speed selected as 12m/s.

Vortex Generator

The dimensions of VG is selected according to chord length, angle of attack. The height is 1 to 2 % of the chord length, length is 2 to 3 % of chord length, angle of attack between 15 and 20 degrees and spacing between the as 10 times height. The VG used here is rectangular type. It is placed at the higher camber length of the airfoil section. Usually placed at the point before the point of separation

Dimensions taken at highest chord calculated as

h= 35mm

l= 60mm

Spacing s= 350mm

Placement of VG

The VG is placed at the point of seperation. The height of the vortex should be the height of the boundary layer. In the blade 1 the seperation has been found to be at the centre of the chord so that it is placed at the centre line of the chord extending towards the tip.

SIMULATION

The wind blade is designed according to the required dimension using Catia v2.5 by Dassalt systems. Catia is a modelling software used in various fields. The atmospheric conditions are simulated in the computer using Ansys Fluent v12.0. The drawing of the wind turbine needed and the dimensions have been taken and is drawn through Catia v2.5.

A fluid volume should be created and defined as fluid around the wind blade designed. Inside this volume, the atmospheric conditions are to be simulated. In order to analysis the boundary is applied as Fluid. Boolean is a tool used to create a thin wall layer over the wind blade. In Boolean, subtract wind blade from the boundary layer so as to give a thin wall over the blade. This structure is sent for meshing.

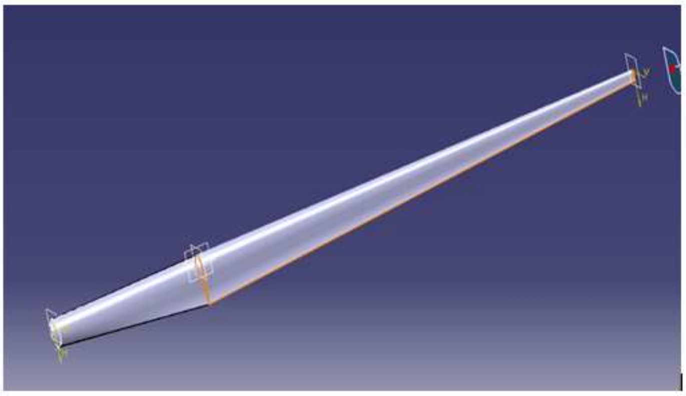

Figure 4: Wind Blade Drawn in Catia V2.5 without Vortex Generator

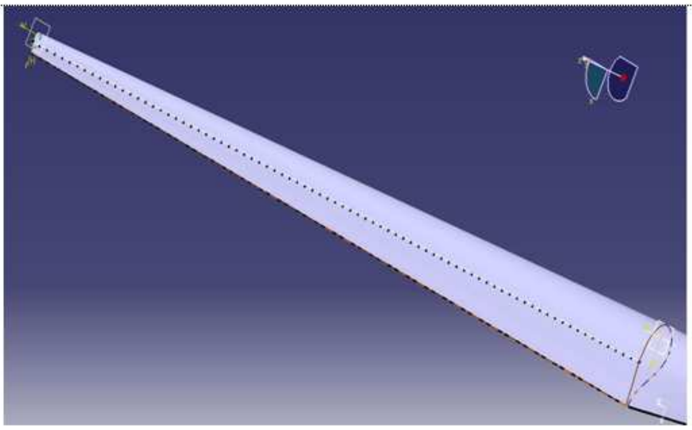

Figure 5: Wind Blade Equipped with Vortex Generator

The most important part of the structure building is the Meshing. Meshing is the phenomenon in which the CAD drawing is converted in a structure build with small geometric structures. These meshes acts as the smallest area at which the simulation concentrates. As the number of meshes increases, the calculation time also increases. Mesh generation is one of the critical aspects of engineering solution.

Table 1 Shows Properties of Air

Property	Value
Density	1.225 kg/m^3
Specific Heat Cp	1006.43 J/Kg-K
Viscosity	1.794 e-05 Kg/m-s
Temperature	288.16 K
Reference Zone	Solid
Air Velocity	12 m/s
Pressure	1.013 bar

Too many cells can leads to increased solving time and chances of error. The mesh can be of different types namely tetrahedrons, polygons, triangular etc. Each element of mesh is analyzed using FEA in the CFD. Each mesh denotes the smallest area used for analysis.

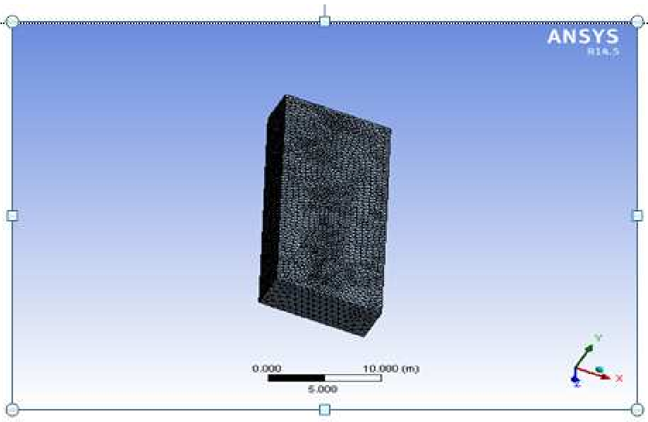

Figure 6: Meshing of the Blade and Fluid Volume

RESULTS AND DISCUSSIONS

Mesh is analyzed in Fluent with all default set values. Current work focused on obtaining smooth flow on the upper surface of the HAWT blade to reduce the turbulence effect. Maximum lift and power generation is obtained by introducing vortex generators over the blades. The results is the increase in efficiency of the wind turbine blade for extracting more power from the wind and better performance at low speeds. This helps to produce more energy from every functioning wind turbine. The result is the change in coefficient of lift between both the wind blades.

Table 2: Shows the Coefficient of Lift Obtained For Both the Blades

	Blade without Vortex Generator	Blade with Vortex Generator
Coefficient of Lift	0.3269	0.4539

It is observed from the Table 2 that the coefficient of lift for the wind turbine blade with VG is 0.4164 and it is only 0.3685 for the blade without VG i.e. increase in the coefficient of lift is 0.0479 for the blade with VG. The above results show that the wind turbine blade introduced with VG is capable of extracting more energy from the wind by retaining the wind over the blade profile for large duration.

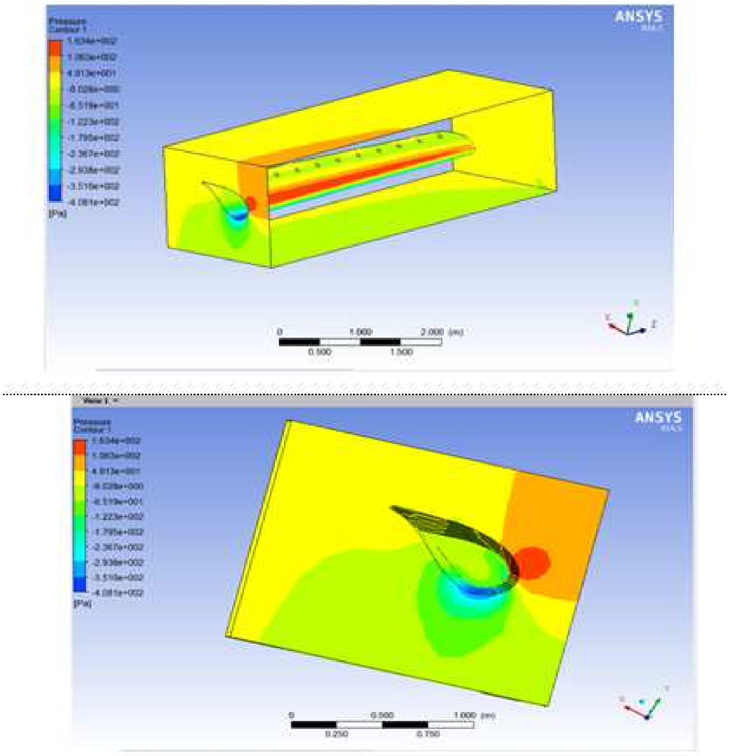

Figure 7: ANSYS Result for the Wind Turbine Blade with Vortex Generator

Table 3 Pressure Contour Detail for the Wind Turbine Blade with Vortex Generator

Parameter	Value
Pressure at the low pressure side	122 Pa
Pressure at the high pressure side	236 Pa
Difference in pressure	114 Pa

It is obvious from Table 3 that the pressure contour at the high pressure side (Fig 7) for the blade with VG is 236 Pa whereas it is 122 Pa at low pressure side. Similarly the pressure contour at the high pressure side (Fig 8) for the blade without VG is 230 Pa and it is only 154 Pa at low pressure side. Further, the difference in pressure of 114 Pa (i.e. 236 Pa – 122 Pa) pertaining to the blade with VG is constituted for the increase in the coefficient of lift by 0.0479

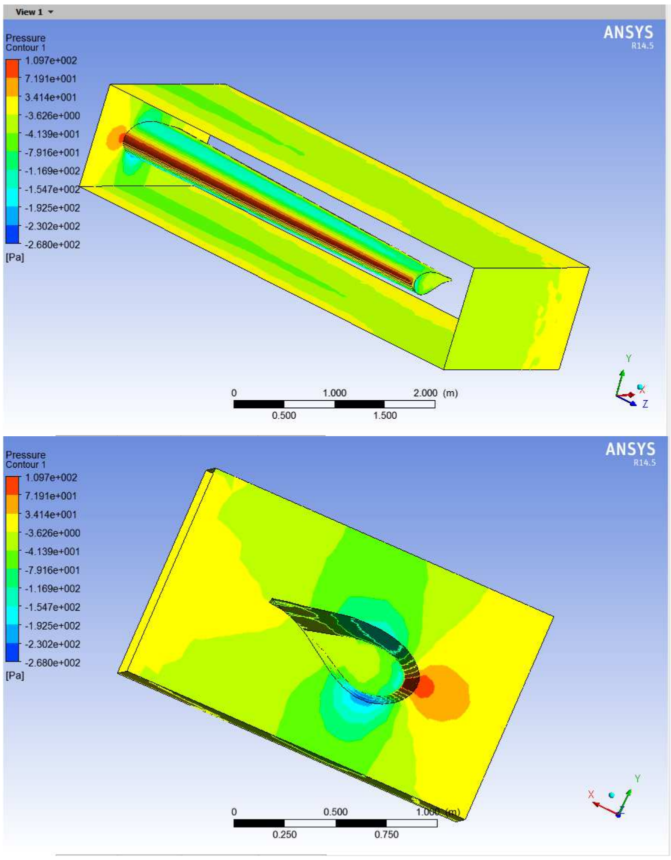

Figure 8: ANSYS Result for the Wind Turbine Blade without Vortex Generator

Table 4: Pressure Contour Detail for the Wind Turbine Blade without Vortex Generator

Parameter	Value
Pressure at the low pressure side	154 Pa
Pressure at the high pressure side	230 Pa
Difference in pressure	76 Pa

It is evident from the Table 3 and Table 4 that the change in pressure contour between the wind turbine blade with and without VG is 38 Pa (i.e. 114 Pa – 76 Pa). The pressure on the high pressure side of the wind turbine blade are almost same. The significant difference in pressure is seen at the low pressure side where the vortex generator is placed.

CONCLUSIONS

The finite volume analysis reveals that the coefficient of lift for the wind turbine blade with vortex generator is more when compared to the wind turbine blade with vortex generator which resulted for more energy extraction. In addition, there is appreciable improvement in the pressure contour for the wind turbine blade with vortex generator. From the foregoing analysis, it is found that the wind turbine blade with vortex generator is more apt for the horizontal axis wind turbine generator. Further experiment can be done for wind turbine blade with triangular and delta shaped vortex generators to evaluate the performance.

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