International Journal of Advance Research In Science And Engineering http://www.ijarse.com
IJARSE, Vol. No.3, Issue No.8, August 2014 ISSN-2319-8354(E)

AERODYNAMIC ANALYSIS OF 3D MODEL HORIZONTAL AXIS WIND BLADE OF AIRFOIL S809

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ABSTRACT

The wind turbine tower and the ground are not included in the flow model and a uniform wind speed profile is assumed at the entrance of the domain. The aerodynamics of HAWT are investigated using a commercial FEM and CFD code. The Specifications of an existing middle-sized turbine starting from the classical Blade Element Momentum (BEM) method is adopted for the design of the rotor. The active part of the blade is extended to the hub; following the design tendencies of modern wind turbines.Angle of Attack of wind was a 4° acting on 3D model the wind turbine blade which airfoil based on the S809. The action of flow through the airfoil blade was the aerodynamic flow of wind on the result at simulation. The CFD analysis done give the stream line result generates on the lifting force and drag force. The static structure analysis of blade like cantilever beam was also be analysis, the CFD pressure transfers to the static structure model.

I. INTRODUCTION

The demand for the power around the world is continuously increasing very rapidly, as the stock of conventional sources of energy (i.e. fossil fuels) is limited and decreasing very fast and the earth's ecological balance is being damaged beyond its sustainable limit.Wind energy is a source of renewable power which comes from air current flowing across the earth's surface. Wind turbines harvest this kinetic energy and convert it into usable power which can provide electricity for home, farm, school or business applications on small (residential), medium (community), or large (utility) scales [1].

Generally there are two main types of wind turbine i.e. Horizontal axis wind turbine and Vertical axis wind turbine. The rotation of shaft is parallel to the ground is called as Horizontal axis wind turbine and the rotation of shaft is perpendicular to the ground is called as Vertical axis wind turbine.

Horizontal Axis wind turbines have a better efficiency as compare to the Vertical Axis wind turbine. HAWT produce more electricity at wide range farm in any type of field at both low and high speed of the wind. Maximum industries is working on this sector and doing optimized of wind turbine in every parameter. Mainly the focuses of optimization in wind turbine are the blade and rotor size. Blade parameter are tip speed ratio, twisting angle, chord length, pitch angle and lift & drag coefficient, that are the point to optimized the blade for maximize the blade efficiency at every condition of wind [6].

II. MATERIAL AND METHOD

2.1 Material

Selection of material of wind turbine blade is also the main property function in the efficiency of the blade turbine design. There are many materials available in the market which can be use to select the material, but in the observation of deferent material we select the carbon fiber 395 as a blade material. Carbon fiber 395 has some benefits which cause we selected:

- Low material density
- Excellent Stiffness
- Higher graphitization level
- Elevated temperature performance

2.2 Method

Betz law [7] was first formulated by the German Physicist Albert Betz in 1919. Betz law can be used to determine the power from an ideal turbine rotor, the thrust of the wind on the ideal rotor and the effect of the rotor operation on the local wind field. This simple model is based on a linear momentum. The law states that it is only theoretically possible to convert a maximum of 59.3% of the kinetic energy in the wind to mechanical energy using a wind turbine, and that this maximum power output occurs when the downstream wind has 1/3 the speed of the upstream wind.

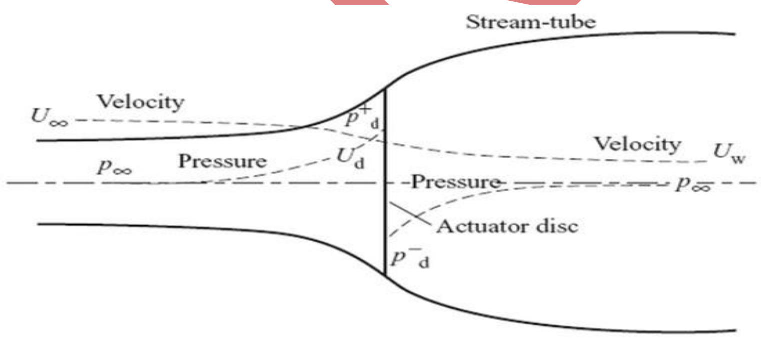

Figure 2 Pressure and Velocity evolution through the actuator disk

Power generated due to wind speed is given by following equation.

$$Pw = \frac{1}{2} \times \rho \times A \times u^3 \times Cp$$

Where, Pw= Power of wind (watt)

ρ = Air density (Kg/m3) (1.225 Kg/m3)

A= Area of segment of the wind being considered

u = Undistributed wind speed (m/s).

Cp=Coefficient of Power =16/27 (According to Betz)

Wind Turbine need a calculation for a blade which is the main preference for designing and the basic principal is blade element momentum (BEM) theory who gives the angle of twist and Chord length of Airfoil of blade. Better performance of blade, design parameter includes airfoil shape, design angle of attack, design tip speed ratio and wind speed which are the parameter design consideration of aerodynamic design blade. BEM theory is capable to use for valuation of forces on blade for design, optimization and calculation of steady load.

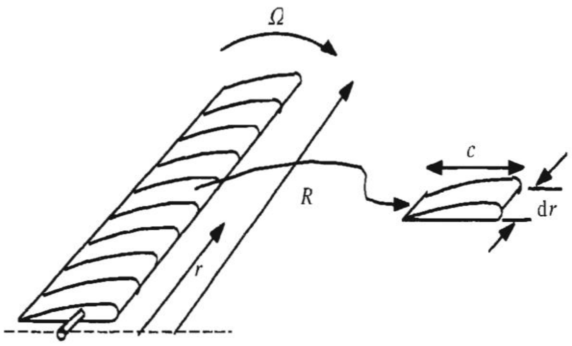

Figure 3 Schematic Of Blade

C = Airfoil chord length

dr = Radial length of element

r = Radius

R = Rotor radius

Ω = Angular velocity of rotor

The angle of attack is the angle between relative velocity of wind and chord length. For getting the performance of wind turbine, angle of attack facture display more significant role. Angle of attack is a function of the blade's angle to the plane of rotation. It is the first characteristics in choose of airfoil and for high lift to drag ratio determine by the angle of attack, the blade's angle with respect to the apparent wind, the blade's shape and its ratio. In this paper we consider 4^{o} as a angle of attack. The air attack to the blade at the reference line of blade is called chord line.

The basic coefficient of forces are working on blades are lift coefficient and drag coefficient which are acting at the tangential force and longitudinal force on the blade. This forces are perpendicular to the direction of wind flow.

Lift coefficient $C_L = \frac{F_L}{1/2\rho V_0^2 c}$

Drag coefficient $C_D = \frac{F_D}{1/2\rho V_0^2 c}$

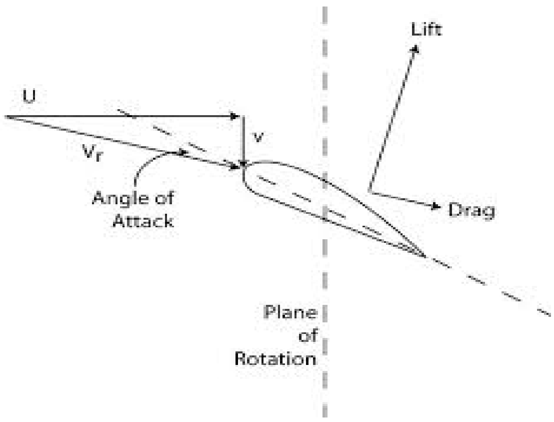

Figure 4 Lift And Drag Forces

III. DESIGN PARAMETER

The design parameters are calculated as per formulas use in design of blade. In this paper we are consider S809 profile of blade and done 14 segment of blade for the more consideration of the result. Design blade parameters and airfoil of blade from hub to root figure are given below which are uses to modeling of wind turbine blade.

IV. RESULT

Above airfoils are kept in modeling software (Solidwork) and make 3D model of blade which is interact with the environment. The angle of attack of air is 4° maintain in the environment. The Whole model is transfer to the ansys fluent software and meshing the geometry on it that is show in figure below.

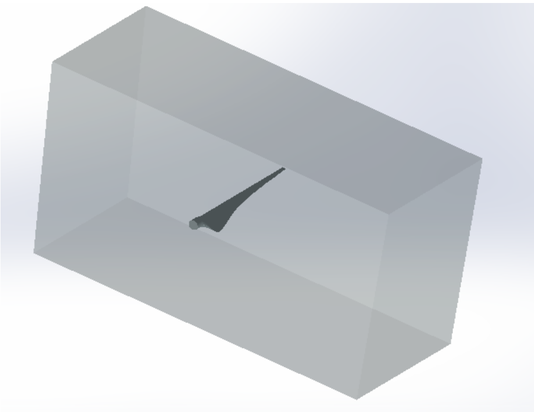

Figure 7 3D Model Of Blade With Computational Domain

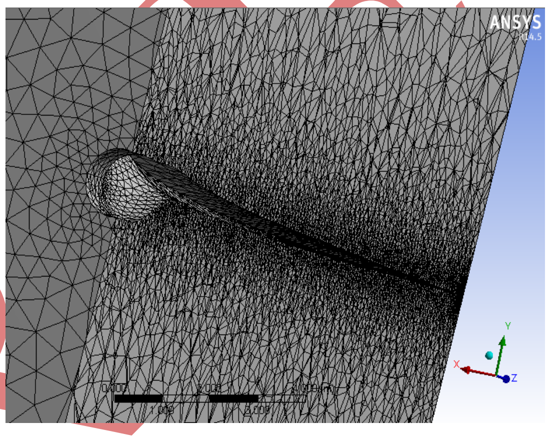

Figure 8 Meshing Of Model

The Environment domain type is air and fluid type is Air ideal Gas that all consider parameter in ansys Fluent workbanch, also we define inlet an outlet parameter in the geometry[5]. The Experimental velocity of air is 9m/s and pressure velocity scheme is consider as sample with spatial discretization gradient is least squares cell based and wind momentum is to be Second order upwind [2,3]. Define all boundary condition, after that initialized the solution from the inlet and start the calcultaion. After calculation we get the result the streamline flow of air and pressure conture show in figure.

Presure is produce the forces which is acting on a blade and that is maximum 122.82 Pa and this forces transfer in to static structure model as consider the cantilever beam.

Object Name	Equivalent Stress	Equivalent Elastic Strain	Total Deformation
Maximum	1.2067e+006 Pa	1.9366e-005 m/m	3.38e-003 m

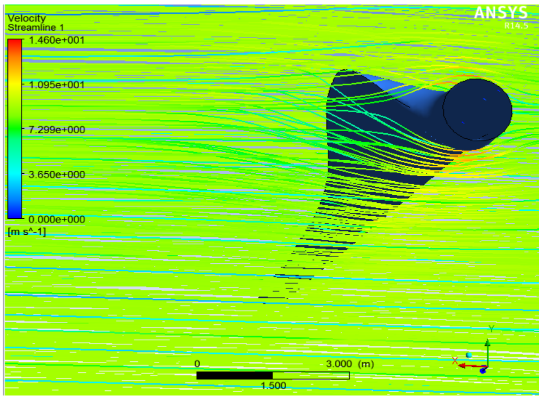

Figure 9 Velocity Streamline Of Air

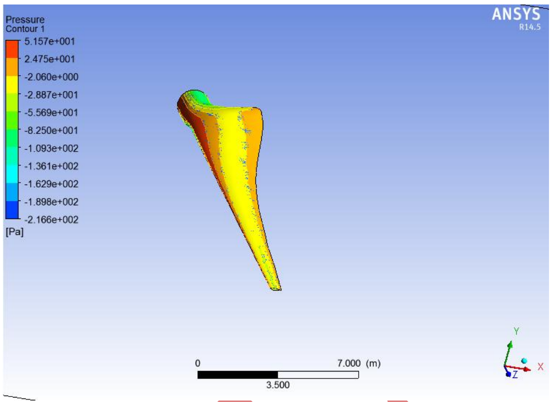

Figure 10 Pressure Contour In Blade

CFD Load Transfer Summary For Static Structure Analysis

All values correspond to the CFD results before the application of any Scale or Offset operations set in Mechanical.

CFD Computed Forces from CFD Results File	Mechanical Mapped Forces for Mechanical Surface
X-component = 160.28 N Y-component = -606.75 N Z-component = 28.862 N	X-component = 168.14 N Y-component = -580.3 N Z-component = 28.281 N

There are the following results and figure:

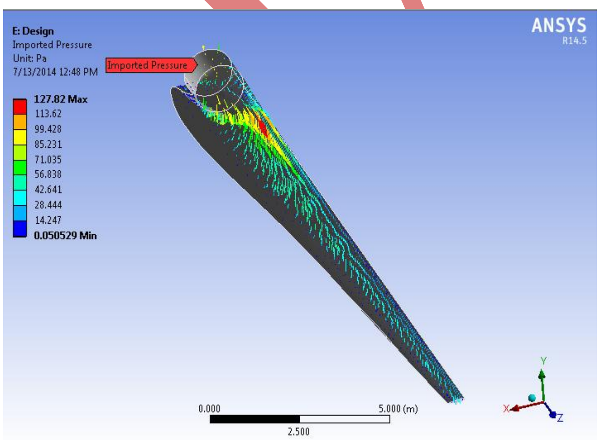

Figure 11 Force Distribution From Blade

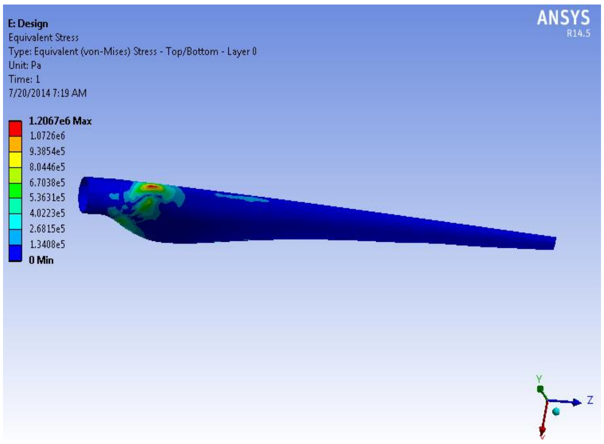

Figure 12 Stress Distribution Analysis

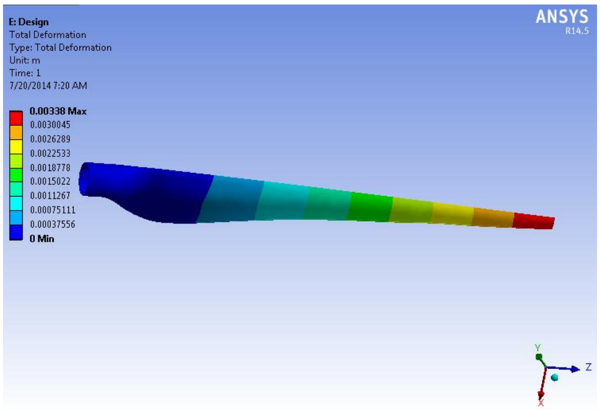

Figure 13 Strain Distribution Analysis

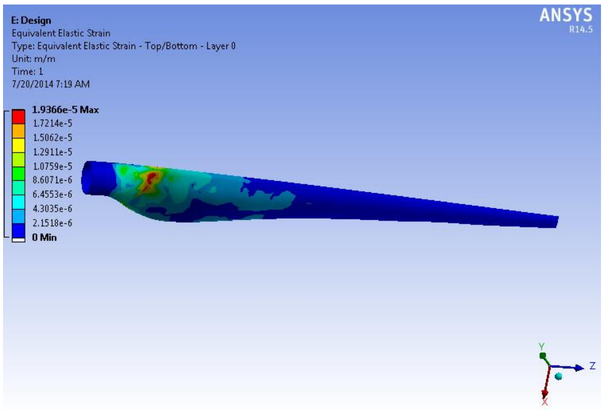

Figure 14 Total Deformation Analysis

V. CONCLUSION

In this paper, the horizontal axis wind turbine blade with airfoil S809 is design at different parameter and analysis of wind flow. For CFD analysis of wind blade is done on ansys fluent software and the static structure module use for static analysis. Figure 9-10 shows the stream line distribution of wind into the blade and also more concentrating area. The wind velocity of angle of attack is 4° at 9m/s and that developed pressure contour in the blade. The pressure is converted into the force parameter and study of static structure analysis of blade at considers a cantilever bean. The blade hub portion is fixed and the forces distribute over the blade at CFD load transfer to static structure module as show in figure 11. The Analysis of static structure, Stress, strain and deformation result got and that is show in figure 12-14.

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