AERO-DESIGN ANALYSIS FOR MODIFIED DARRIEUS BASED-STRAIGHT BLADED VAWT SYSTEMS

E.Zuhair Ahamed[1], A. R.Gowtham Ram[2]

[1]*Department of Mechanical Engineering, BITS Pilani-Dubai Campus*
[2]*Department of Mechanical Engineering, BITS Pilani - Dubai Campus*

Abstract

This Innovated model of Darrieus Straight bladed Vertical Axis Wind Turbine system is the construction of a Three-bladed rotor system with each modified turbine blades suited to withstand on different circumstances. The modified blades are thus adjusted in a manner of the air flow striking close enough on the rotor. This paper presents a mean for reducing the loss of air flow during the process of a vertical-axis wind turbine (VAWT) by modifying each blade.

The model was designed in such a way that one part of the turbine has an additional semicircular plate attached on the direction of wind, while the second rotor has a alteration in this design with air deviating wing which proves to be efficient. This modification results in the maintaining the lift and drag force on wind-blades. The generator can be driven by this modified Darrieus SBVAWT system to produce electricity, especially for agricultural purposes. For this purpose, three dimensional CFD analyses have been performed on a straight-bladed Darrieus-type rotor. The Darrieus rotors have been designed using CATIA and the model was tested for computing mesh by CFD software for finding the various factor of the VAWT system. The performance was analyzed and a result of the Darrieus rotor was obtained, which shows that this model can purely withstand. The changes made in the design of the turbine blades have proved to be efficient.

Keywords: *VAWT, Straight blade, Air foil, Power coefficient.*

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1. INTRODUCTION

The Current world has already in progress to benefit from the need of renewable energy by means of many invention or different kinds of improvement in the form of constructing various windmills, even thou they lead to good comfort ability for human beings. The world will always need some energy which does not pollute the environment or result in less consumption of resources, to which the use of renewable sources has always become essential. When considering all the applicable types of renewable energy, Wind energy and solar energy are utilized in most of the country for generating electricity. Wind energy plays an important role in an essential role in developing energy for the environment and creating a sustainable life for human being. This energy can be harvested practically, if developed properly which can result in providing maximum benefit for the survival of human's progress. The advantage of applying changes in this wind based renewable energy is for the factor considered cheaper and efficient than the remaining types of renewable energy, which is highly expensive.

The Darrieus Based VAWT system is one of the most frequently used windmill system. The Darrieus type VAWT was invented by French engineer Georges Jean Marie Darrieus in 1925 and it was patented in the USA in 1931 [5]. It comes in two configurations, namely straight-bladed VAWT system and Eggbeater system also known as curved-bladed. Even thou, these types of renewable energy sources are gained plentifully, there is also slight variation in energy from all the constructed windmill system. This slight variation has always caused a huge loss to the environment need and thus this energy can be harvested accordingly to gain maximum benefit for an effective living.

Many aspect play an vital role in the designing of a wind turbine rotor, including aerodynamics modeling, generator, blade, strength and rigidity, noise levels etc. But since a small wind energy conversion system's success is largely dependent on maximizing its energy extraction, rotor aerodynamics play a critical role in the minimization of the cost of energy [10].

This creates a variation in forces about the axis of rotation. The curvature of the blades allows the blade to be stressed only in tension at high rotating speeds.

The functioning of every wind-turbine blades is to turn around the rotor by means of air flow striking. Hence, the rotor spins at a rate unrelated to the wind speed, and usually many times faster [7]. The energy arising from the torque and speed may be extracted and converted into useful power by using an electrical generator [6]. The demand for windmill showing the total installed capacity in many types of energy has increased rapidly and widely over decades, as year past the demand for renewable energy.

Moreover, establishing a high investment of windmill by means on building efficient windmill system does not pollute the environment. An additional benefit of a VAWT over the HAWT is that it doesn't necessitate the use of a yaw mechanism, since it can act in all direction o wind. Various researches has clearly indicated that accurate designing of the wind turbines has the power and potential to compete with other types of renewable sources of energy and can be economically feasible [2]. Increasing the major significance of this VAWT system can always result in increase its usage for power generation.

2. STRUCTURAL DESCRIPTION

Darrieus wind turbine is one of the most important types of Vertical axis wind turbine (VAWT). The major aim in developing an effective windmill system based on Darrieus rotor mechanism is by analyzing the drag force or lift force of an aerodynamics effect on the wind turbine. The most efficient way to convert wind energy into electrical or mechanical energy is offered by wind turbines that operate as a lifting-device. The Darrieus rotor is a vertical axis wind turbine (VAWT) provided with two or more blades working on the basis of an aerodynamic airfoil. Vertical-axis wind turbines (VAWTs) have been studied by various researchers using modern analysis techniques. The blades are normally bent and are connected to the shaft at the upper and lower side. One of the advantages of using the lift principle is that it has high power coefficients (Cp) which can be recognized for windmills using the drag principle. Airflow over any surface creates two types of aerodynamic forces— drag forces, in the direction of the airflow, and lift forces, perpendicular to the airflow. Either or both of these can be used to generate the forces needed to rotate the blades of a wind turbine.

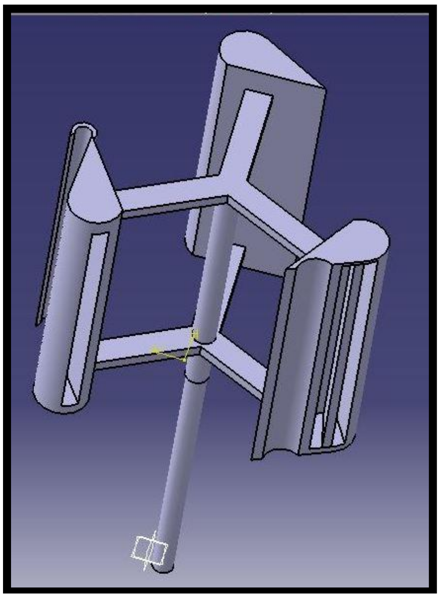

Fig.1 Designing of Darrieus SB-VAWT

The Darrieus-type straight bladed VAWT is designed with two or more airfoil blades vertically mounted on a rotating shaft or framework. As the rotor spins, the airfoils move forward through the air in a circular path. As the blades rotate it experiences a head-on air flow (headwind).This force projected about the center of rotation, i.e. the turbine axis, gives a positive torque to the shaft, thus helping it to rotate in the direction it is already travelling. In considering any path to aerodynamics testing, the basic criteria to be identified is 2 types :"Drag force", a force striking in all rotor, where one flow leads to thrust force, while other flow "Lift force" leads to speeding up of rotor motion. These are the forces which can lead to the movement of the turbine blades.

3. MODIFIED DESIGN IN THIS MODEL

The modified Darrieus Straight bladed Vertical axis wind turbine has mainly focused on developing an aerodynamic supported model .It is designed in such a way that, the rotor has an additional semi-cylindrical shape attached, where these shape support the direction of air-flow, which could boost up the side portion to rotate more quickly and fast as compared to normal rotor. The air can get through to the semi-cylindrical shape by the opened spaced at the opposite end of the thicker area.

The other advantage of this model in helping the air flow strike the rotor, is that the turbine blades have been modified by designing a thicker edge at the end of the rotor blade, which could help the rotor start swinging more quickly when the air strikes in the inner portion of the rotor. Thus this design has shown a positive result in reducing the drag force.

The second rotor in this model has a free air-flow blade which deviates the air, when striking on one-half of the rotor and which supports the movement of air in another half of the rotor. These blades fitted were designed to reduce the drag force, so that the rotor can rotate freely with less drag force.

This cross plate wing helps in deviation of some amount of air flow in a streamline flow path on the side which could boost up the force. In other words, it could lower the flow of air in Lower drag force area.

4. MATHEMATICAL PROCEDURE

The "k Epsilon Model" for Turbulent Kinetic Energy (k)

In the present study, the standard k-e turbulence model with standard wall condition was used [2].

The Standard k-€ equations can be represented as :

$$\frac{\partial}{\partial t}(\rho k)+\frac{\partial}{\partial x_i}(\rho k u_i)=\frac{\partial}{\partial x_j}\left[\left(\mu+\frac{\mu_t}{\sigma_k}\right)\frac{\partial k}{\partial x_j}\right]+G_k+G_b-\rho\varepsilon-Y_M+S_k \quad (1)$$

***For dissipation -€* :**

$$C_1=\max\left[0.43,\frac{\eta}{\eta+5}\right],\ \eta=S\frac{k}{\varepsilon} \quad S=\sqrt{2S_{ij}S_{ij}} \quad \textbf{(2)}$$

In these equations, P_K represents the generation of turbulence kinetic energy due to the mean velocity gradients, calculated in same manner as standard k-epsilon model. P_b is the generation of turbulence kinetic energy due to buoyancy, calculated in same way as standard k-epsilon model. In these sets of equations, G_k represents the generation of turbulence kinetic energy due to the mean velocity gradient G_b generation of turbulence kinetic energy due to buoyancy Ym representing the contribution of the fluctuating dilation in compressible turbulence to the overall dissipation rate C_2 and C_{1s} are constants are the Prandtl number S_k are user-defined terms.

5. ANALYSIS & BOUNDARY CONDITION

5.1 Meshing

Meshing generation has always been considered as one of the most important for defining a geometry structure. The precision for meshing is to define a separate constrain for separate individual Finite elements analysis.

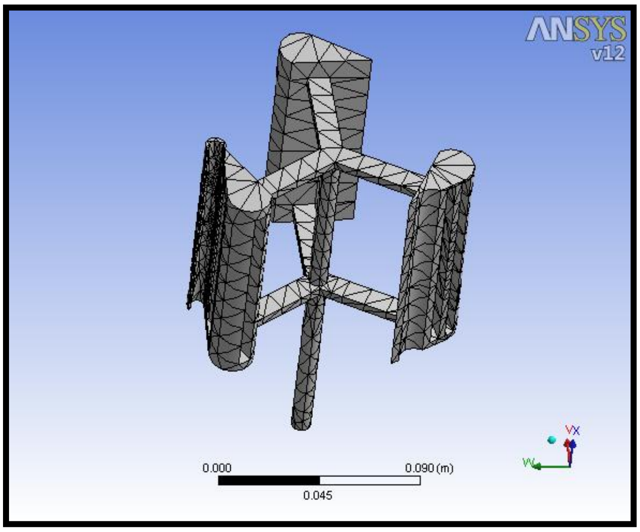

Fig 2: Meshing analysis

5.2 Total Deformation

Deformation is the transformation of a body from a reference configuration to a current configuration. A configuration is a set containing the positions of all particles of the body. A deformation may be caused by the use of external load and forces such as pressure change or temperature variation within the structure

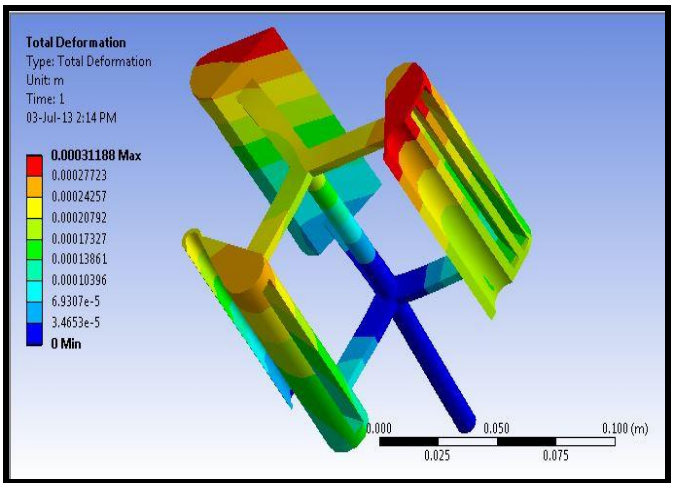

Fig 3: Total Deformation

5.3 Elastic Strain

Strain analysis is methods to find equivalent strain in the following materials and structures subjected to applying loads by means of a particular constrain. Strain is a description of deformation in terms of relative displacement of particles in the body.

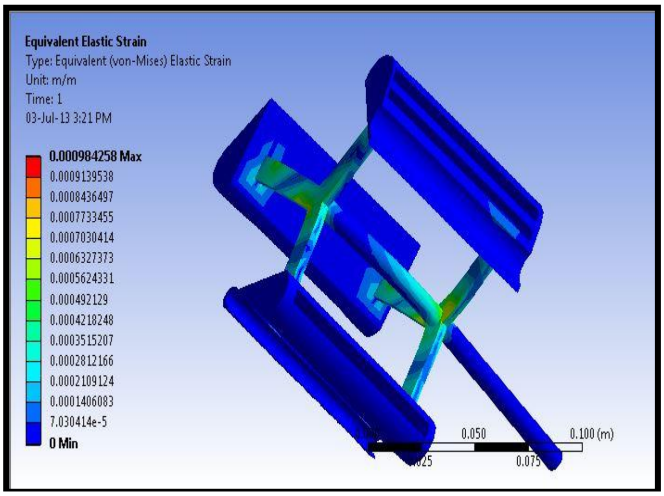

Fig 4: Equivalent strain

5.4 Stress Analysis

According to the Von-Mises theory, a ductile solid will yield when the distortion energy density reaches a critical value for the material. The von Mises stress is an equivalent or effective stress at which yielding is predicted to occur in ductile materials

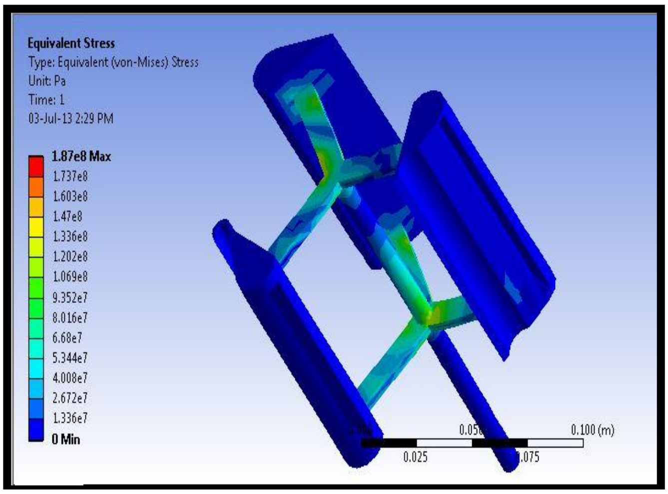

Fig 5: Stress Analysis

5.5 Safety Factor

Factor of safety is based on safety margin and safety factor, is a term for the structural capacity of a system beyond the expected loads or actual loads. Large factors of safety for a particular regions point out that you can save material from that specific region. Many codes have need of a minimum factor of safety varying from 1.5 and 3.0

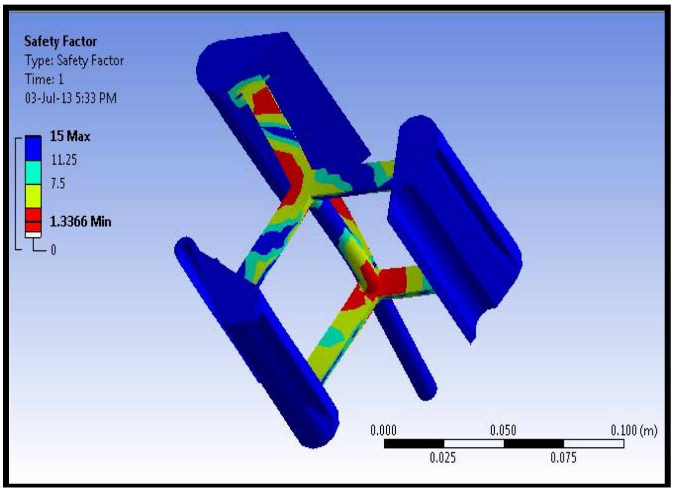

Fig 6: Determination of Safety Factor

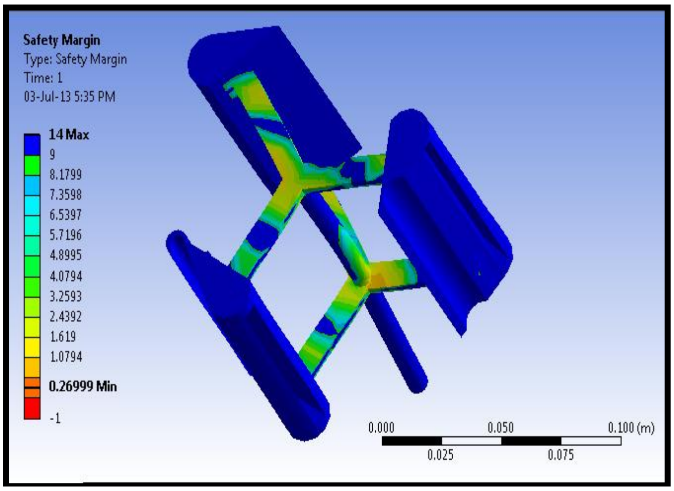

Fig 7: Analysis of Safety Margin

5.6 Thermal Analysis

Thermal analysis is one of the main aspect of thermal engineering that concerns the heat generation and exchange of thermal energy between physical bodies. Heat transfer is classified into various mechanisms, such as Thermal analysis, Directional Heat flow, Heat flux and Transfer of energy

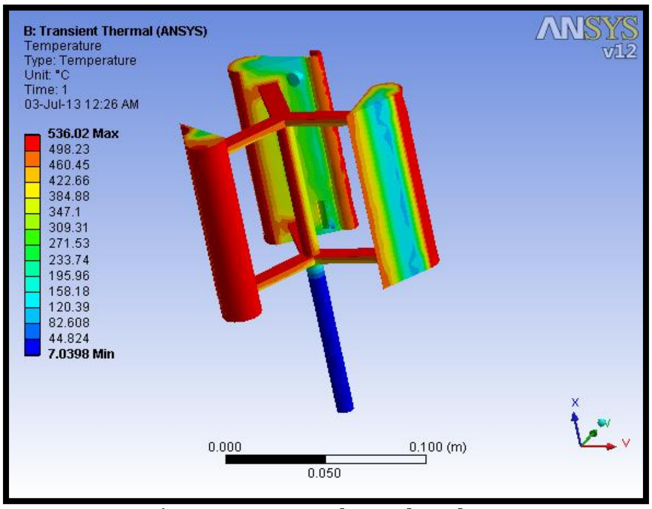

Fig 8: Transient Thermal analysis

5.7 Thermal Analysis for Heat Flux

Heat flux or **thermal flux** is the rate of heat energy transfer through a given surface. The measurement of heat flux is most a temperature difference over a piece of material with known thermal conductivity

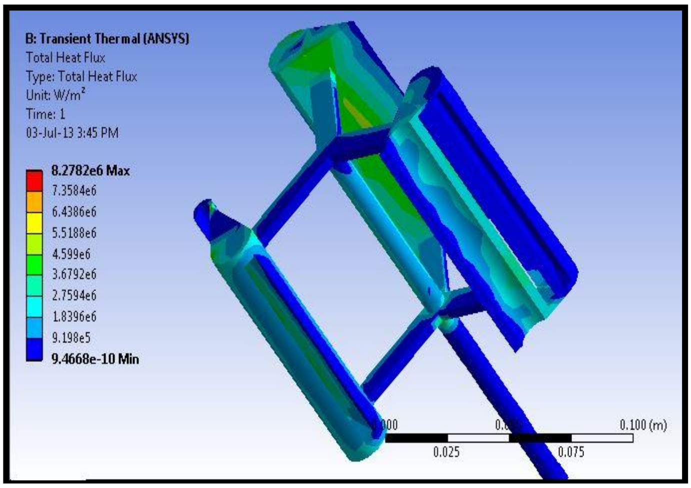

Fig 9: Thermal Analysis for varying heat flux

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7. CONCLUSION

This research paper has focused on developing newly based modified Darrieus SB VAWT system. This project was focused on constructing an effective Darrieus SBVAWT system on the basis of an aero-dynamical analysis done on designing the model Concerning the 2D and 3D cases, the solver has proven to be capable of handling complex fluid structure interactions such as the wind blowing on a wind turbine making the blades spin. The design for the Darrieus SBVAWT was designed using Catia software. Various types of analysis were done on this research paper to work with the reliability of the wind turbine. The structural feasibility was analyzed by Finite Element Analysis method to obtained the maximum deformation and stress experienced by the rotor blade. This concluded that the newly designed Darrieus SBVAWT was capable to withstand the aerodynamic ability on the turbine.

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