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Design and Analysis of Vertical Axis Double Stage Savonius Wind Turbine

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Abstract:
This paper presents the design and analysis of vertical axis double stage Savonius wind turbine to generate electrical energy from wind energy. The Savonius rotor was designed with the rotor diameter of 2 m and the rotor height of 4 m. The 3D model of Savonius rotor blade was made by utilizing SolidWorks software. Computational Fluid Dynamics (CFD) analysis and structural Finite Element Analysis are presented in this paper. CFD analysis was done to obtain the pressure difference between concave and convex surface of the rotor blade and structural FEA was done to obtain the structural response of blade.

Keywords: Vertical axis wind turbine, Savonius, Rotor blade, Rated wind speed, Double stage, Renewable Energy

I. INTRODUCTION

The improvements of renewable energy particularly wind energy become widely since 1973 because of the oil crisis issues. At present, almost ninety percent of the world's energy originated from the burning of fossil fuels, i.e. coal, normal gas, petroleum oils, etc. Almost every people use fossil fuels to meet all their energy needs, for example, fuelling vehicles, producing electricity for house hold purpose and running industries. The population development will make the need of energy sources gets to be higher and also the cost of fossil fuels. At the same time there is an issue with the world wide environmental change as a consequence of carbon dioxide and sculpture-dioxide emissions from the burning of fossil fuels. By using renewable energy to reduce the carbon emissions coming out from vehicles and industries. The international energy agency reported that just a little extent of the energy comes from hydro-power and nuclear power, and a much little part from renewable energy source, for example, winds energy, solar energy, bio mass, geo thermal energy and tidal waves. Wind energy is an environmental friendly energy source and also to alleviate the environmental changes from greenhouse gasses emitted by the burning of fossil fuels. It was evaluated that approximately 10 million MW of energy available in the worlds wind energy. Wind turbine is a device is used to convert wind energy to generate electrical power. Wind turbines are classified into two categories, horizontal axis wind turbine and vertical axis wind turbine. Savonius wind turbine is simple in construction and it is operated on drag concept. It has good starting torque. Savonius rotor is 'S' in shape.

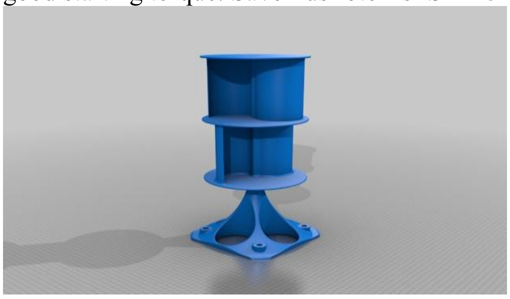

Figure.1. Double stage savonius wind turbine

II. ADVANTAGES

i. It is independent of wind direction no additional force is required to drive mechanism.
ii. Savonius wind turbine has good starting torque.
iii. It is simple in construction and also maintenance is easy.
iv. It has low noise and emissions.
v. can be grouped more closely in wind farms, increasing the generated power per unit of land area.
vi. can be installed on a wind farm below the existing HAWTs; this will improve the efficiency (power output) of the existing farm.
vii. research at Caltech has also shown that a carefully designed wind farm using VAWTs can have an output power ten times that of a HAWT wind farm of the same size
viii. hey are omni-directional and do not need to track the wind. This means they don't require a complex mechanism and motors to yaw the rotor and pitch the blades.

III. THEORY AND DESIGN

From the different measured values of mechanical torque and rotational speed, the mechanical power can be estimated at each wind speed as:

1) Pm=T.ω (W)
T =mechanical torque
w= angular speed

The angular speed:

2) ω= 2πn/60 rad/s
n= shaft speed

The mechanical torque:

3) T= F.r
r= radius of pulley

The force on the rotor shaft:

4) F=(m-s)gm= mass (kg)
g= gravitation acceleration
s= spring balance (kg)

The power coefficient Cp and static torque coefficient Cts:

5) $C_p = P_m/P_w$

Where,

$P_w = 1/2(\rho A V^3)$

q= air density (kg/m^3)

A= area (m^2)

V= wind speed (m/s)

The power coefficient:

6) $C_p = g\pi r n(m-s) / 15\rho A V^3$

The static torque coefficient:

7) $C_{ts} = 4T/\rho D^2 V^2 H$

Wind velocity is the major significant component that influence the power output. The wind speed parameters include in this project is cut-in speed, rated wind speed, cut-out speed. Jain (2011) expressed that the three wind speed parameters related to power performance as follows [6].

$V_{cut\text{-}in} = 0.5\ V_{avg}$

$V_{rated} = 1.5\ V_{avg}$

$V_{cut\text{-}out} = 3.0\ V_{avg}$

All there wind parameters depended up on average wind speed value, Vavg was found at 7 m/s

Wind speed parameter	Equation	Calculation
Cut-in speed, Vcut-in	Vcut-in = 0.5 Vavg	3.5 m/s
Rated wind speed, Vrated	Vrated = 1.5 Vavg	10.5 m/s
Cut-out speed, Vcut-out	Vcut-out = 3.0 Vavg	21 m/s

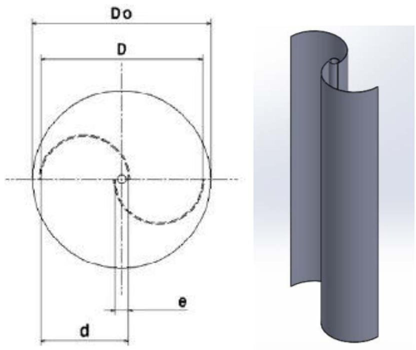

Figure.2. Design model of Savonius rotor blade in SolidWorks

IV. SIMULATION AND ANALYSIS

There are two kinds of simulation and analysis were done in this paper i.e. computational fluid dynamics (CFD) analysis by using ANSYS 15.0 and structural analysis by using solidworks structural simulation. A. Computational fluid dynamics (CFD) analysis.

The purpose of this analysis is to obtain the pressure difference between the convex and concave surface. The pressure difference between the convex and concave surface of the rotor induced drag force the drag force turns the blade. The pressure difference was obtained by using computational fluid dynamics (CFD) analysis by using ANSYS 15.0 software. The flow type in this paper were external flow analysis. External flow analysis were static analysis.

a) External flow analysis

The flow type of Savonius rotor blade is considered in this paper as external flow since it involves a solid model which is fully surrounded by the flow. The fluid flow is not bounded by any outer surface the flow is bounded by the computational domain boundaries. The computational domain is non uniform is defined to 3m that means the Savonius rotor is enclosed by this region and volume is fixed in this region as shown in Fig. 3.

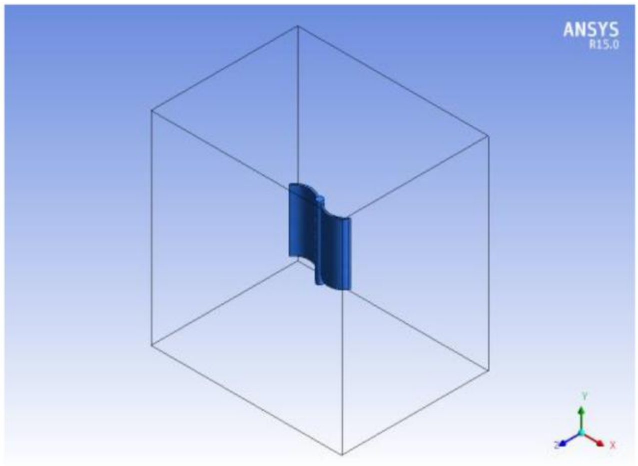

Figure. 3. Iso view of Wireframe

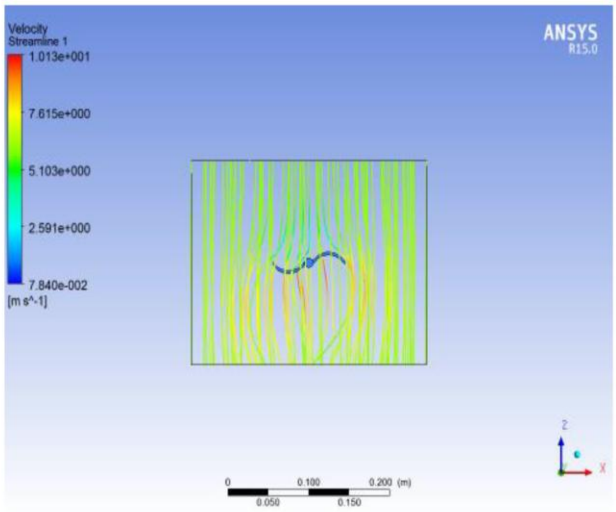

Figure. 4. Streamlines

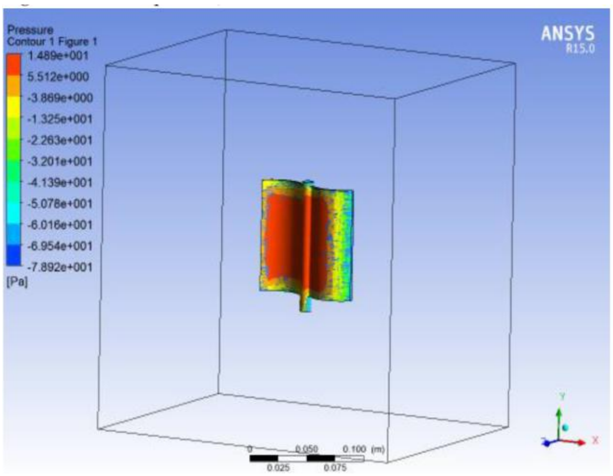

Figure. 5.Contour Pressure

- **Structural analysis**

The structure of rotor blade is analysed utilizing Finite Element Analysis (FEA) static method by Solidworks simulation software.The FEA analysis is performed on only one blade because the two rotor blades are symmetry. The static FEA result is translated in two criteria: stress distribution and deformation. Initial step of FEA analysis is allotted material to the rotor blade model where aluminium 1060 alloy was the material chosen. Then the fixed constrains are applied on the top, centre and bottom of the blade edge (where the blade is connected to shaft) as shown in Figxx The blade is stay in a static position only. The load applied for this analysis is Force with 600 N is obtained from the aerodynamic analysis. And the force is equally distributed on the concave blade region.

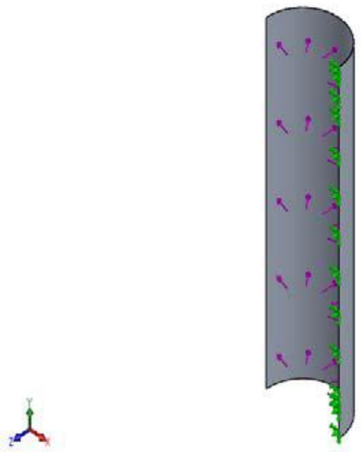

Figure.6. Boundary condition of the Rotor blade

Fig. 7 shows the meshing of the blade model by using tetrahedral shape mesh elements and also shows the FEA result of the blade model which presents the stress distribution over the blade.

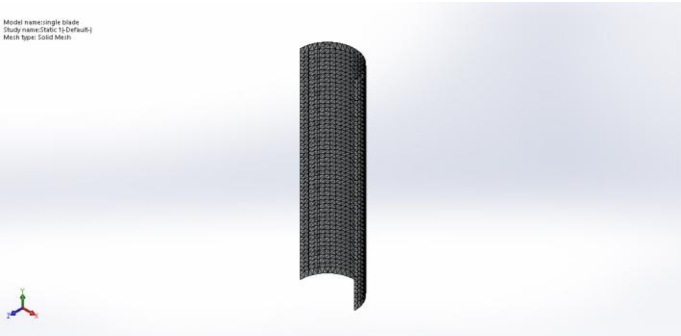

Figure.7. Meshing of rotor blade in SolidWorks

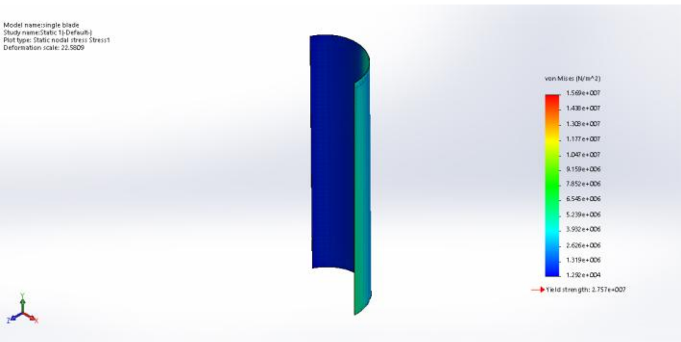

Figure.8. Stress distribution of Rotor blade

Fig.xx shows the stress distribution of rotor blade. The maximum and minimum Von Mises stress for the rotor blade are 15691100 Pa and 12922 Pa respectively. The outcome is satisfactory in light of the fact that the maximum Von Mises stress is much lower than the Yield strength of the material applied for the rotor blade. Figxx shows the deformation of the rotor blade under the given load. And the maximum Displacement is 19.0711 mm at the edge of the rotor blade. The rotor blade is acceptable because it is small in relation to the general size of the rotor blade.

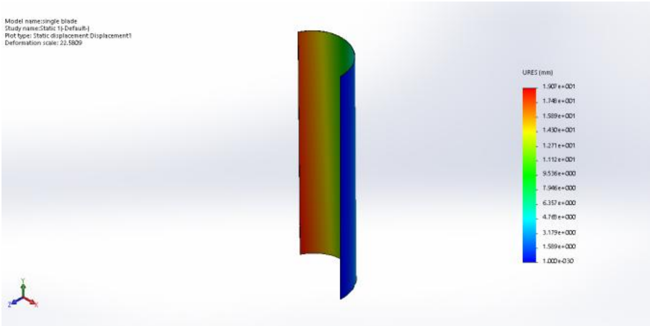

Figure.9. Deformation of Rotor blade

V. RESULTS AND DISCUSSION

At the end of analysis we find that double stage savonius wind turbine is more efficient than single stage savonius wind turbine and with the proper blade design and dimensions we can get maximum result. Computational fluid dynamics (CFD) analysis was performed to obtain the pressure difference between the convex and concave surface of Savonius rotor blade. While FEA analysis was performed to obtain the stress experienced and maximum deformation of the rotor blade. From the computational fluid dynamics analysis, it is found that the concave blade region experience high pressure while the convex region experience low pressurefor the two blades Savonius.

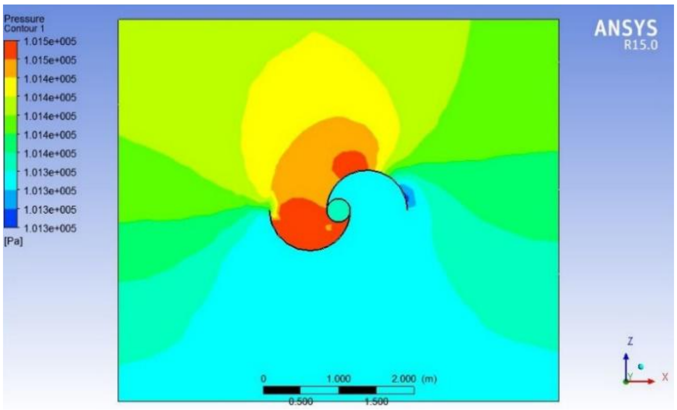

Figure.10. Pressure distribution on Savonius wind turbine

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