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DESIGN AND COMPUTATIONAL FLOW ANALYSIS ON SAVONIOUS WIND TURBINE

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ABSTRACT

The principle of wind turbine uses wind kinetic energy to electric power. We observed that the turbine efficiency mainly dependent on parameters like material selection and design criteria. Since here we have mainly focused on turbine for low wind speed, which is of Savonious wind turbine. The parameters affecting the Savonious wind turbine are aspect ratio, primary overlap ratio and secondary overlap ratio. To improve the efficiency of the turbine we have used the maglev phenomenon. The design is small and robust to be placed in a tool post, to obtain available energy from it. Since we make use of Savonious type of blade it is one of the simplest turbine. From the top view it would look like “S-shape” cross-section. Because of its curvature, experiences less drag when moving against the wind. The flow analysis is done by using ANSYSIS WORKBENCH V14.5.

KEYWORDS: Savonious blade and Maglev (magnetically levitated).

INTRODUCTION

As a solution for the world energy problem greater attention all over the world is paid towards the use of renewable energy resources. A renewable resource is a resource which is replaced naturally and can be used again. Some of the examples are solar energy, wind energy, biomass etc. Since Wind energy is one of clean energy resources it is very important. Winds are caused by the heating of the atmosphere by the sun, the rotation of the Earth, and the Earth's surface irregularities to extract the wind energy we use the wind turbines.

The wind turbines are basically classified based on its applications. Based on the rotation of the axis of wind turbine it is classified as horizontal wind axis turbine and vertical axis wind turbine.

Savonious turbines are one of the simplest turbines. Aerodynamically, they are drag-type devices, consisting of two or three blades (vertical – half cylinders). A two blades Savonious wind turbine would look like an "S" letter shape in cross section. The Savonious wind turbine works due to the difference in forces exert on each blade. The lower blade (the concave half to the wind direction) caught the air wind and forces the blade to rotate around its central vertical shaft. Whereas, the upper blade (the convex half to wind direction) hits the blade and causes the air wind to be deflected sideway around it.

DESIGN CRITERIA

Power coefficient's depends on the design parameters like number of blades, number of stages, overlap ratio, aspect ratio, end plates etc. Where aspect ratio is defined as ratio of blade height by blade radius and overlap ratio is defined as the ratio of difference between eccentricity and shaft diameter to blade radius.

PROBLEM STATEMENT

The main objective of the dissertation work is to reduce friction through bearings by replacing it with magnetic bearings, since the magnetic bearings also eliminates the suspension system because it eliminates mechanical vibration and noise it also eliminates the need of lubricants like in conventional bearings and also reduces the maintenance cost. Initial torque is minimal due to its magnetic levitation phenomenon.
Most of the turbines experience mechanical stresses due to its curvature and majorly affected by wind turbulence. Whereas Savonious wind turbine is far more resistant to mechanical stresses.

LITERATURE REVIEW

The research effort and directions related to the present work will be identified through literature survey.
[1] N.H. Mahmoud et al, observed that different geometries of Savonius wind turbines are experimentally studied in order to determine the most effective operation parameters like number of plates, with or without end plates, number of stages, aspect ratio, overlap ratio etc., Looking on to his collective work, Modi et al reported the optimum value of aspect ratio is 0.77 and overlap ratio is 0.25. Mojola examined the performance of Savonius wind turbine under seven values of overlap ratio and concluded that the effect of overlap ratio on rotor performance depends on its tip speed ratio. Shankar observed that two blades have almost 50% higher peak power output than three blades in Savonius wind turbine.
[2] Jean-Luc Menet et al, observed that different geometries of Savonius wind turbine are studied through numerical simulation of the flow. Using specific comparison method, namely L-sigma criterion, Menet have shown that despite Savonius wind turbines poor efficiency, the Savonius rotor are in fact more resistant to mechanical stress than all fast running wind turbines. The overlap ratio is the parameter which influences the structure of the flow inside the rotor and consequently its aerodynamic performances. The shaft gives the mechanical strength, but it could create a blockage effect inside rotor. Here the researchers have concluded that the height of the rotor should be two times of rotor diameter. The rotor should have two blades with end plates and double stage rotor. The aspect ratio is of 0.5, the primary overlap ratio should be in the range of 0.15d to 0.3d and the secondary overlap ratio should be equal to zero.
[3] Liu Shuqin et al observed that magnetic bearings reduce the friction in place of conventional type of bearings in the wind turbine. The magnetic bearings eliminate suspension system because it eliminates mechanical vibration and noise, it also eliminates the need of lubricants like in conventional bearings and also reduces the maintenance cost. Initial

torque is minimal due to its magnetic levitation phenomenon. Maglev engineering research centre, Shandong University, China has committed to the magnetic bearing research and related product development. The magnetic bearings are classified as. Active magnetic bearing system which is having electro magnet and control system to control the magnetic field, passive magnetic bearing system in which permanent magnet or semi-conductor of simple in design and low cost, hybrid magnetic bearing system which combines both active and passive magnetic bearing system. By applying the magnetic levitation phenomenon the manufacturing and operating cost is reduced.

[4] Mohammed Hadi Ali et al observed that experimental comparison and investigation to study the performance to make a comparison between two and three blade Savonius wind turbine. Two models are tested in subsonic wind tunnels under low wind speed of 2 to 6 m/sec showed that as the blades increases the drag force against the wind also increasers which in turn decreases the net torque working on the blades.

The blades are fabricated from aluminium sheets. Aluminium is the best choice due to its light weight, corrosion resistance, rigidity, recyclable material, easy to construct and low cost. The researcher found that the optimum parameter values are aspect ratio equal to one and primary and secondary overlap ratio equal to zero.

[5] Minu John et al, observed that the maglev wind turbines can use 1.5m/sec as a starting speed and maximum speed of 40m/sec. it would increase the generation capacity by 20% over conventional wind turbine and decreases operational cost by 50%. It uses permanent type neodymium (rare-earth) magnets rather than electro magnets. Therefore it doesn't require electricity to run. The four different classes are ALNICO, ceramic, samaricum cobalt and neodymium iron boron. Out of all these neodymium iron boron offers high flux density operations and ability to resist de-magnetization at room temperature.

DESIGN PARAMETERS AND MATERIAL SELECTION

DESIGN CONSIDERATIONS

From literature review the basic dimensions of the turbine blade are concluded on going of several iterations. Then the 2 dimensional model is initially developed and later 3 dimensional model is developed by using SOLID EDGE V19. The 2 dimensional view is placed in figure1.

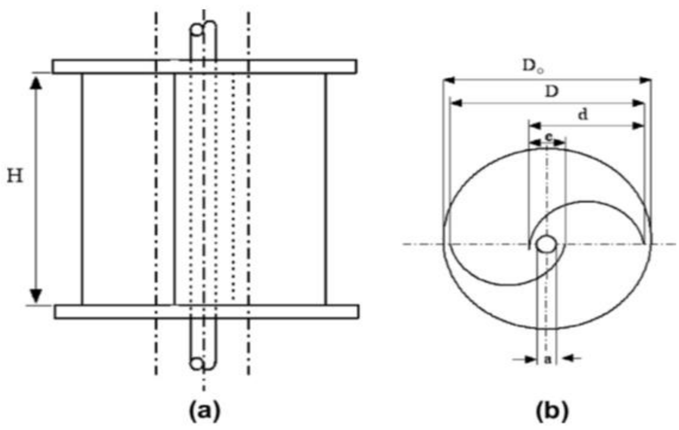

Figure 1: 2D diagram single-stage Savonious rotor: (a) elevation view; (b) plan view

An aspect ratio of 1.25 and the height of blade (H) is taken as 25cm.

$\alpha = H/D$

$1.25 = 25/D$

$D = 20$ cm.

The end plates diameter is 10% more than the rotor blade

I.e., $D_0 = 1.1D$

$D_0 = 22$ cm.

The primary overlap ratio is taken as 0.25 due to the literature survey study.

$\beta = (e-a)/d$

Where, the rotor radius is 10 cm and the shaft diameter is assumed as 1.4cm.

$0.25 = (e-1.4)/10$

$e = 4$ cm.

The secondary overlap ratio is taken as zero.

Table 1. Design specifications of the blade.

Parameters	Values
H	250mm
D	200mm
D_O	220mm
e	40mm
a	1.25
β	0.25

MATERIAL SELECTION

Aluminium is selected as a blade, shaft and end plates material because of its reliable parameters. The aluminium is having density 1/3 that of steel and it is of lower fatigue level than steel, also it is good conductor of heat and ductile in nature. Aluminium has good reliability and low tensile strength, considering the above properties it made us to choose aluminium as a blade, shaft and end plates material also it is economical to fabricate.

RESULT AND DISCUSSIONS

Initially the 2D and 3D model is developed by using SOLID EDGE V19 and Computational Flow analysis in the vertical axis were extracted from ANSYS WORKBENCH V14.5 and various velocities are applied on to the blades to display the three-dimensional turbulent features around the blades. For the conventional Savonious blade, due to its uniform geometry along the blade axis, the flow fields at each horizontal section are identical. Flow analysis for different orientation of blades is given below:

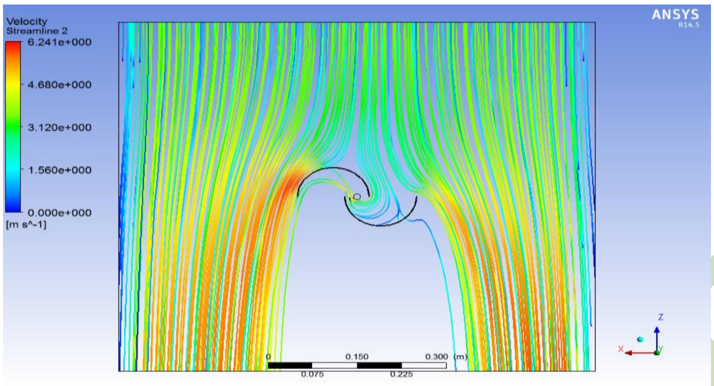

Figure 2: Velocity streamline (top to bottom)

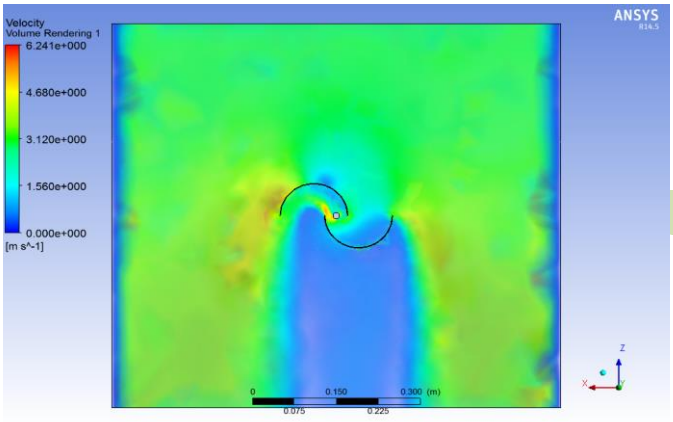

Figure 3: Velocity volume rendering (top to bottom)

In the above flow analysis it is observed that the flow is from top to bottom at a velocity of 3.5m/s. From the figure 2 Shows the maximum flow is absorbed by the blade curvature and also a part of is escaped through the given eccentricity is striking the other blade curvature. Figure 3. Shows that the maximum volume of air is struck to the blade curvature is absorbed by it, whereas the other end of the blade doesn’t experience the air flow.

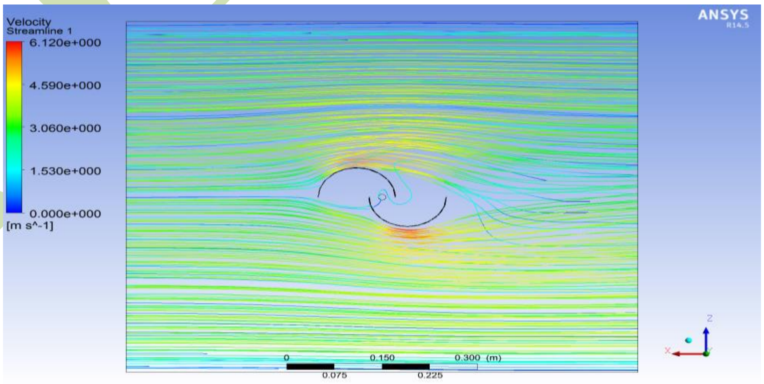

Figure 4: Velocity streamline (left to right)

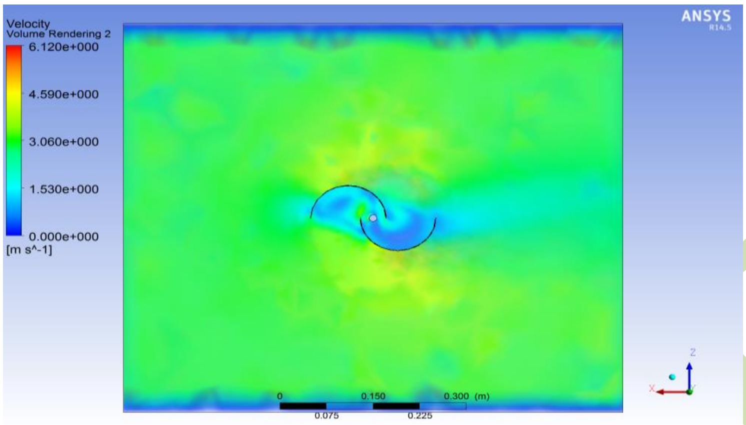

Figure 5: Velocity volume rendering (left to right)

In the above flow analysis it is observed that the flow is from left to right at a velocity of 3.5m/s. figure 4. Shows that there is maximum intensity of air is at outer periphery, these maximum intensity regions are longitudinally eccentric that makes it rotate. Figure 5. Shows that the maximum velocity volume is at the outer periphery of the blades.

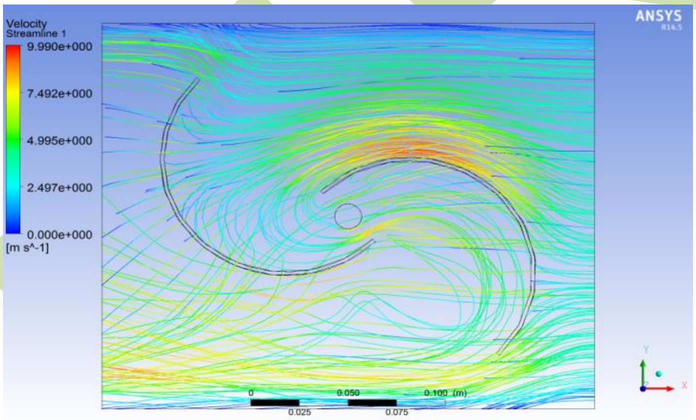

Figure 5: Velocity streamline (angled)

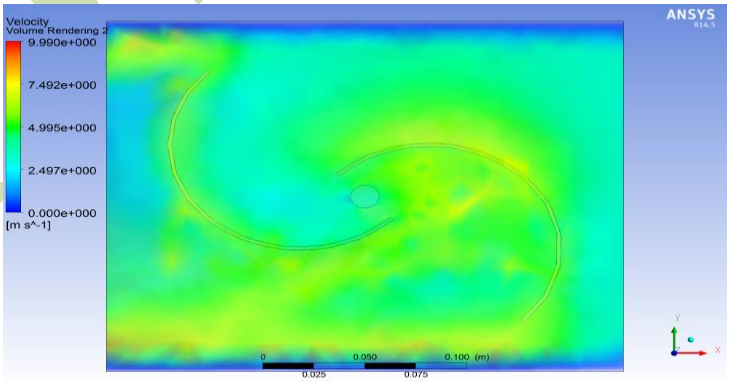

Figure 6: Velocity volume rendering (angled)

In the above figure 5 and 6, flow directional is randomly provided and simultaneously the blades are exposed at different angles and analysed that the flow at different angles also provides the blade to rotate in a unidirectional way in a continuous manner. The flow velocities are altered and analysed to choose the best suitable velocity range and corresponding pressure are tabulated in table 2. For the entire analysis velocity of 3.5 m/sec is considered as the best.

Table 2. Pressure developed for different velocities.

Sl no.	Velocity(m/sec)	Pressure(pascals)
1	1	12.28
2	2	49.51
3	3.5	151
4	5	308.8

CONCLUSION

For the assumed aspect ratio and a velocity of 3.5m/sec is best suited and design considerations are feasible for the small capacity power generation of around 3.5watts, based on the theoretical calculations. Further the use of magnetic levitation has increased the initial torque development of blades which is required for rotation. Also a total air flow in all directions is absorbed and more area of exposure on the blades can be experienced. The eccentricity provided in the blades helps to overcome drag.

SCOPE OF FUTURE WORK

Further the experimental work can be continued with the concluded design parameter and by choosing proper generator which has be coupled to the blade shaft. And also blade materials can be altered in order to reduce weight, increase stiffness. Future work on design for blades by using polymers, composites of aramid fibres and carbon fibres are suggested.

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