Design & Analysis of Savonius VAWT for 50W Rated Power output

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Abstract— World energy demand rate is continuously increasing due to the more industrialization and demands in developing countries for the rural electrification so the usage of conventional sources has increased. To avoid the bad effect of fossil fuels and to meet the demand of world energy more emphasis is given on Non conventional sources of energy. Wind energy is one of the good sources of energy. Wind power is the conversion of wind energy into a useful form of energy, for example to make electrical power, mechanical power, wind pumps for water pumping or drainage, or sails to propel ships etc.There are mainly two types of wind turbine i.e. Horizontal Axis Wind Turbine and Vertical Axis Wind Turbine. The objective of this project is to design and analysis of Savonius VAWT for the rated 50W power output due to its advantages over the other wind turbine like it require low wind speed to rotate, low manufacturing cost and Survive in all weather condition. A prototype rotor blade was fabricated, tested and efficiency checked. The blades are designed by the use of Pro-E software and analyzed by the use of Ansys-14 software.

Keywords— Wind turbine, HAWT & VAWT, Savonius VAWT, design parameters, Glass fiber, PRO-E, Ansys-14, efficiency of rotor blade.

1. INTRODUCTION

World energy use increased more than ten times before over the 20th century, predominantly from fossil fuels (i.e. coal, oil and gas) and with the addition of electricity from nuclear power. In the 21st century, further increases in world energy consumption can be expected, much for rising industrialization and demand in developing countries for the rural electrification. For solving the world energy problem and the bad effect of conventional sources of energy on environment more attention all over the world is giving on the use of renewable energy sources. Purchases of energy account for 5–10% of gross national product in developed economies. [1] The need of renewable energy become more significant now a days due to several issues such as global environment problem, the depleting of fossil fuel thus raise the oil price as well and economic concern. In this situation, government already takes smart action in promoting, enforcing and enhancing the renewable energy by the policy or act. The study of the impact of wind energy on the future and product development should be performed to ensure that it will be very profitable to satisfy the electricity demand of the community. [2] Wind power is the conversion of wind energy into a useful form of energy, for example to make electrical power, mechanical power, wind pumps for water pumping or drainage, or sails to propel ships etc. Large wind farms consist of hundreds of individual wind turbines which are connected to the electric power transmission system. Offshore wind farms are more frequent and powerful winds than the other available land-based installations but construction costs are considerably higher& also maintenance. Small onshore wind facilities are used to provide electricity to isolated locations and utility companies increasingly buy surplus electricity produced by small domestic wind turbines. [3] [6] Wind turbine technology offers cost-effective solutions to eliminate costly use of conventional sources used to generate electricity. Additionally, this technology provides electrical energy without greenhouse effects or deadly pollution releases. Furthermore, wind turbine installation and electricity generating costs are lower compared to other electrical energy generating schemes. A wind turbine is the reverse of an electrical fan. Design & Analysis of Savonius VAWT for 50W Rated Power output 2. A wind turbine converts the kinetic energy of the wind into electrical energy. Wind turbines come in different sizes and types, depending on power generating capacity and the rotor design employed. [4] There are two kinds of wind turbines according to the axis of rotation to the ground, horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT). VAWTs include both a drag type configuration like Savonius wind turbine and a lift-type configuration like Darrieus wind turbine. Savonius wind rotor has many advantages over others in that its construction is simpler and cheaper. It is independent of the wind direction and has a good starting torque at lower wind speeds. [5] The objectives of this research were thus to design and develop a Savonius rotor blade for 50watt rated power output with locally available materials and compare its performance and production cost with the existing blades. The blades were made using glass reinforced fibre because of the material's light weight. This factor enabled the rotor to rotate at very low wind speeds, it is also long lasting and does not rot hence can survive in all weather conditions. A prototype rotor blade was fabricated, tested and efficiency checked. The blades are designed by the use of Pro-E software and analyzed by the use of Ansys-14 software.

2. LITERATURE REVIEW

Muhammad Mahmoud Aslam Bhutta et.al, [5] in this paper a review on the different configuration and design techniques has been studied by the author. It was learned that coefficient of power (CP) for various configurations is different and can be optimized with reference to Tip Speed Ratio. Latest emerging design techniques can be helpful in this optimization. Furthermore, flow field around the blade can also be investigated with the help of these design techniques for safe operation. He concluded that various vertical axis wind turbines can offer solution to the energy requirements ranging from 2 kW to 4 MW with a reasonable payback period. Coefficient of power can be maximized by selecting a suitable TSR range for various configurations. VAWTs offer good

possibility of building integrated designs. Cross flex type VAWT can be used on high rise buildings in the cities where free stream velocity greater than 14 m/s is available.

FrederikusWenehenubun et.al, [7] has conducted an experimental study on performance of Savonius wind turbine related to number of blade. In this experiments he compare 2, 3, and 4 blades wind turbines to show tip speed ratio, torque and power coefficient related with wind speed. A simulation using ANSYS 13.0 software will show pressure distribution of wind turbine. The results of study showed that number of blades influence the performance of wind turbine. Savonius model with three blades has the best performance at high tip speed ratio. The highest tip speed ratio is 0.555 for wind speed of 7 m/s. Also Wind turbine rotor with four blades has high torque compared with two or three blades wind rotor. He concluded that four blades wind turbine has good performance at lower tip speed ratio, but three blades wind turbine has the best performance at higher tip speed ratio.
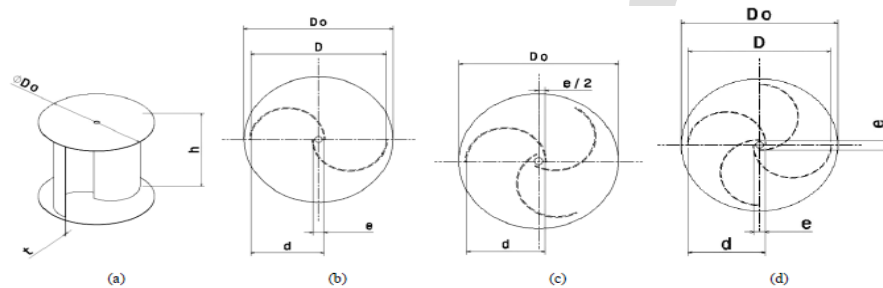

Figure 2.1 Design of wind turbine model (a) and the cross section of turbines with (b) two blades (c) three blades, and (d) four blades. [7]

Widodo et.al, [11] presents the design and analysis of the Savonius rotor blade to generate 5 kW power output. The relevant design parameters and theories were studied in this paper and used to determine related design geometry and requirements of the Savonius rotor blade. The Savonius rotor was designed with the rotor diameter of 3.5 m and the rotor height of 7 m. The 3D model of Savonius rotor blade was created by using Solid Works software. Computational Fluid Dynamics (CFD) analysis and structural Finite Element Analysis (FEA) are presented in this paper. CFD analysis was performed to obtain the pressure difference between concave and convex region of the blade while FEA was done to obtain the structural response of the blade due to the wind load applied in term of stresses and its displacements.

M.A. Kamoji et.al, [12] He made the experimental investigation on single stage modified Savonius rotor to improve the coefficient of power and to obtain uniform coefficient of static torque. To achieve these objectives, the rotors are being studied with and without central shaft between the end plates. Tests in a closed jet wind tunnel on modified form of the conventional Savonius rotor with the central shaft is reported to have a coefficient of power of 0.32. Investigation is undertaken to study the effect of geometrical parameters on the performance of the rotors in terms of coefficient of static torque, coefficient of torque and coefficient of power. The parameters studied are overlap ratio, blade arc angle, and aspect ratio and Reynolds number. The modified Savonius rotor with an overlap ratio of 0.0, blade arc angle of 124_ and an aspect ratio of 0.7 has a maximum coefficient of power of 0.21 at a Reynolds number of 1, 50,000, which is higher than that of conventional Savonius rotor (0.19). Correlation is developed for a single stage modified Savonius rotor for a range of Reynolds numbers studied.

U.K. Saha et.al, [13] He conducted a Wind tunnel tests to assess the aerodynamic performance of single, two and three-stage Savonius rotor systems. Both semicircular and twisted blades have been used in either case. A family of rotor systems has been manufactured with identical stage aspect ratio keeping the identical projected area of each rotor. Experiments were carried out to optimize the different parameters like number of stages, number of blades (two and three) and geometry of the blade (semicircular and twisted). A further attempt was made to investigate the performance of two-stage rotor system by inserting valves on the concave side of blade. All the tests have been conducted in the range 6–11 m/s. He concludes that the optimum number of blades is two for the

Savonius rotor whether it is single-, two- or three-stage. Twisted geometry blade profile had good performance as compared to the semicircular blade geometry. Two-stage Savonius rotor had better power coefficient as compared to the single- and three-stage rotors. Valve-aided Savonius rotor with three blades shows better performance coefficient as compared to the conventional three-bladed rotor.
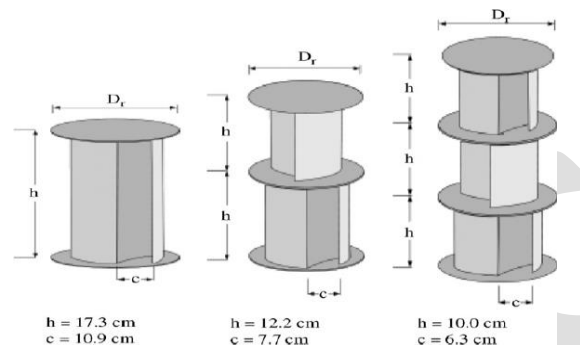

Figure 2.2 Solid models of single-, two- and three-stage rotor system. [13]

Sukanta Roy et.al, [14] He made a computational study to assess the influence of overlap ratio on static torque characteristics of a vertical axis wind turbine. The study is performed with the help of a finite volume based computational fluid dynamics (CFD) software package Fluent 6.3. The computational model is a two-bladed conventional VAWT having overlap ratios of 0, 0.10, 0.15, 0.20, 0.25 and 0.30. Initially, a comparative analysis is made using various k turbulence models and then the results are compared with the experimental data available in literature. The flow field around the turbine model is also studied with the help of static pressure contour analysis. Based on this computational study, it is realized that an overlap ratio of 0.20 eliminates the effects of negative static torque coefficient, provides a low static torque variation at different turbine angular positions and also gives a higher mean static torque coefficient as compared to the other overlap ratios. An optimum mean static torque coefficient of 0.224 is obtained with δ =0.20 at U= 10.44 m/s. The increase of the static torque with the increase of overlap ratio is mainly due to increased pressure on the concave side of the turbine returning blade.

N.H. Mahmoud et.al, [15] in this paper author has studied experimentally different geometries of Savonius VAWT in order to determine most effective operational parameters like number of blades of two blades (2b), three blades (3b) and four blades (4b); single stage (1st.) and double stages (2st.); overlap ratios (b) of 0, 0.2, 0.25, 0.3 and 0.35 and aspect ratios of 0.5, 1, 2, 4 and 5 besides the existence and absence of end plates. The blades of rotors are made from light plastic (PVC) tubes with different diameters (0.3, 0.2, 0.1 and 0.08 m). The end plate is fabricated from light wood plates with 2.5 mm thickness. The diameter of the end plate (Do) is greater than the rotor diameter by 10% in order to have a good performance as recommended previously by Mojola, Menet& Blackwell et al. The steel shaft which is used here has 14 mm in diameter and 62 cm in length for all models. He found that, the two blades rotor is more efficient than three and four ones. The rotor with end plates gives higher efficiency than those of without end plates. Double stage rotors have higher performance compared to single stage rotors. The rotors without overlap ratio (b) are better in operation than those with overlap. The results show also that the power coefficient increases with rising the aspect ratio (a). The conclusions from the measurements of the static torque for each rotor at different wind speeds verify the above summarized results of this work.

Mohammed Hadi Ali [16] made an experimental comparison and investigations to study the performance and to make a comparison between two and three blades Savonius wind turbine. For this purpose, two models of two and three blades were designed and fabricated from Aluminum sheet, each of them has an aspect ratio of (As = H/D =1), the dimension is (H = 200 mm height and diameter D = 200 mm) and the blades were made of semi − cylindrical half of diameter (d = 100 mm). The two models were assembled to have (overlap e = 0 and a separation gap e' = 0). These two models were tested and investigated by using a subsonic

wind tunnel that was fabricated for this purpose under a low wind speed due to many reason mostly that the Savonius wind turbine has its maximum performance at (λ = TSR = 1) and a high starting torque at low wind speed. It was observed from the measured and calculated results that the two blades Savonius wind turbine is more efficient, it has higher power coefficient under the same test condition than that of three blades Savonius wind turbine.

(a)   (b)
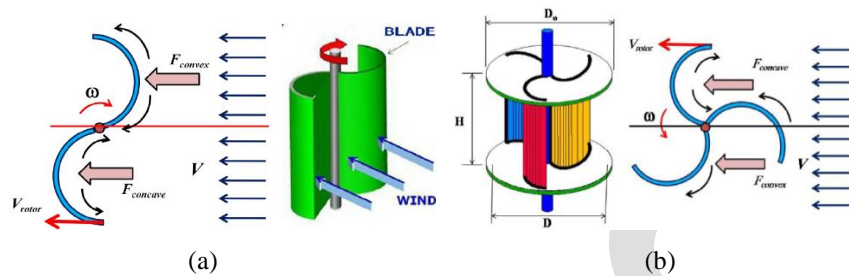
Figure 2.3 (a) Schematic drawing showing the drag forces exert on two blade Savonius

(b) Schematic drawing showing the drag forces exert on three blade Savonius. [16]

J.-L. Menet [17] studied a double step Savonius rotor for local production of electricity. He design, develop and ultimately build a prototype of such a rotor, which was considered as a complete electromechanical system. The building data were calculated on the basis of the nominal wind velocity V =10 m/s. Particular care was necessary to choose the appropriate generator, which was finally a rewound conventional car alternator. It is clear that this kind of rotor is cheaper to build than a conventional horizontal axis wind machine (airscrew). Besides, it should produce enough electricity to charge a conventional ''starting battery''. Thus it is particularly adapted to local production of electricity, such as in sailing applications, to generate electricity on a sailboat.
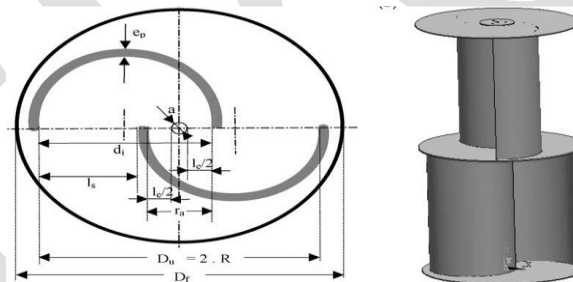

Figure 2.4 Scheme of the present prototype. [17]

3. PROBLEM IDENTIFICATON & OBJECTIVES

3.1 Problem Identification

Now a day's every country facing the problem of energy, as the prizes are increasing day by day. Many developing country have faces the problem of energy production as well as scarcity. Lots of people in remote area have faces problem of electricity at their home. Four out of five people without electricity live in rural areas of the developing world, especially in peripheral urban and isolated rural areas.Climate changed now have been another problem for developing countries as due to increasing in electricity consumption, during the generation of electricity about 940 gm of Carbon Dioxide gets emitted to environment and this CO2 increases the temperature of environment and green house effect. Global energy-related CO2 emissions are set to grow by 52% between 2003-30.This green house effects damage the ozone layers.

3.2 Barriers to Small Wind Turbine Technology

3.2.1 Technology Barriers, High Cost of Wind Turbine, Power Electronics Issues

3.2.2 Market Barriers, Lack of effective standards, Information about the wind resource , Insufficient capitalization , Complicated financial impact

3.3 Objective and Scope of Present Work

1. In order to reduce the cost of the turbine, and to make wind energy more attractive for rural electrification.
2. The manufacturing of wind mill blade by using epoxy materials is best suited. It is relatively light weight material and having excellent fatigue properties.

The objectives of this dissertation are;

1) To design, develop and ultimately build a Prototype of such 50 Watt Savonius VAWT rotor blade for domestic used.
2) Analyzed the design blade for impacting drag and lift force.

4. WINDMILL

4.1 Working of Windmill

The working of wind mill is very simple as the air comes in the structure the working blades rotates which is connected to main rotor shaft by the supporting arms the main rotor is coupled to a generator from where we can get the output. The power in the wind can be extracted by allowing it to blow past moving wings that exert torque on a rotor. The amount of power transferred is directly proportional to the density of the air, the area swept out by the rotor, and the cube of the wind speed. [4][8]

4.2 Components of a Wind Turbine

The wind turbine usually has six main components, the rotor, the gear box, the generator, the control & protection system, the tower and power system. These main components are shown in the figure.
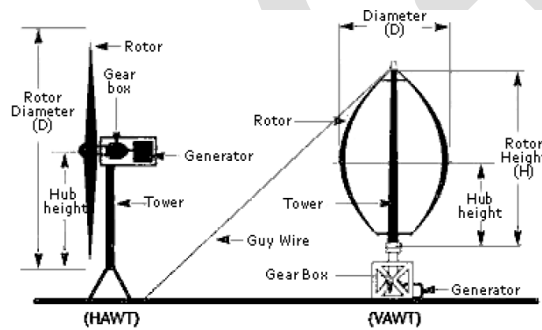

Figure 4.1 Wind turbine components [8]

5. METHODOLOGY

5.1 Design Theory

5.1.1Power in Wind

The energy transferred to the rotor by the wind depends on the air density, the swept area of the rotor and wind speed. A wind flow, can be understood as a set of moving particles, which develops a energy flow (flow of air through a turbine) or wind power (power available in the air) stream through the area A, defined by the square-cube law:

$$\text{Pwind} = \frac{1}{2}\rho AV^3 \text{…………….......................} [1] \; [6][9]$$

5.1.2 Power Coefficient

When a wind turbine is crossed by a flow of air, it can get the energy of the mass flow and convert it in rotating energy. This conversion presents some limits, due to the Betz' law, Cp=0.59. Power coefficient Cp is given by

$$C_p = P/(0.5\rho AV3) \text{………………………..} [2]$$

The maximum power coefficient, C_p for Savonius rotor is 0.30. Hence, the C_p value used in this project is 0.30 and the power output, P with considering the power efficiency is:

$$P = 0.15 \; \rho AV3 \text{…………………………….} [3] \qquad [8] \; [9]$$

There are various factors which are going to affecting on the performance of the Savonius vertical axis wind turbine. The performance of VAWT is given in terms of co-efficient of performance indicated by C_p. Here are the fish bone diagram or cause effect diagram which shows the various factors which are affecting on the performance of the Savonius vertical axis wind turbine.
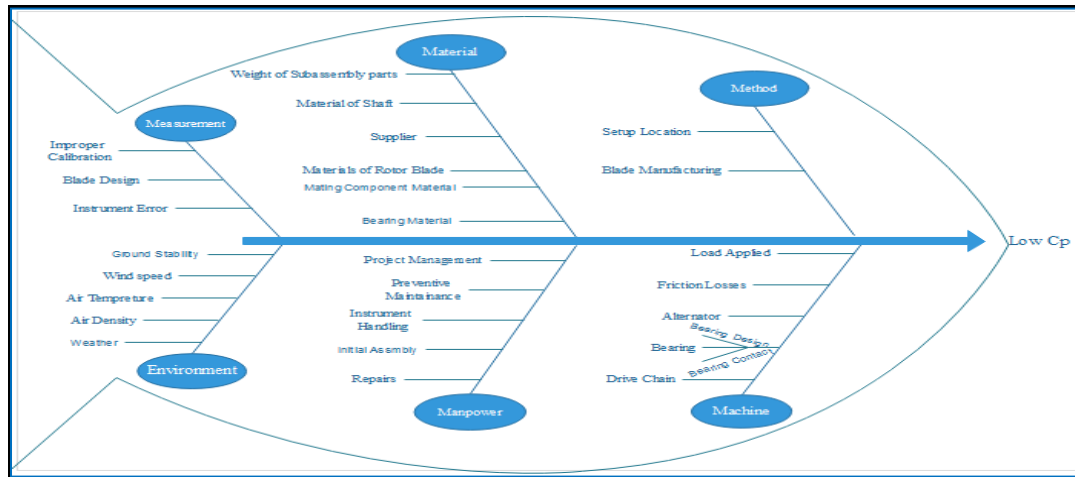

Figure 5.1 Fishbone Diagram

5.1.3 Important Wind Speed Consideration

These all speed parameters are depending on the average wind speed. For design of the rotor the average speed of air is consider as 4 m/s[AccuWeather.com].The details of cut-in speed, rated wind speed and cut-out speed as summarize in table below:

Table 5.1: Wind Speed Parameters Calculation

Wind Speed Parameter	Equation	Calculation
Cut-In Speed	Vcut-in=0.5 Vavg	2 m/s
Rated Wind Speed	Vrated= 1.5 Vavg	6 m/s
Cut-Out Wind Speed	Vcut-out = 3.0 Vavg	12 m/s

5.1.4 Blade Diameter, Swept Area

The power is directly proportional to the swept area by the turbine rotor having the expression:

$A = \pi R^2$ ……………………………………………. [4]

For the swept area for Savonius Wind Turbine blade is given below, the swept area for Savonius blade is obtained by multiplication of rotor diameter, *D* and the rotor height, *H*.

The power output of blade is improved with the swept area.

A=D H …………………………………………………… [5]

Savonius rotor is designed with rotor height twice of rotor diameter this lead to better stability with proper efficiency. [14]

H =0.82m

5.1.5 Aspect Ratio

The aspect ratio of Vertical axis wind turbine is defined as the ratio between blade length and rotor radius.

The aerodynamic performance of Savonius rotor can be evaluated by the aspect ratio. The aspect ratio for Savonius rotor is given by

AR=H/D ………………………………………………… [6]

5.1.6 Tip Speed Ratio

The tip speed ratio is defined as the ratio of the speed of the extremities of a windmill rotor to the speed of the free wind. Drag devices always have tip-speed ratios less than one and hence turn slowly, whereas lift devices can have high tip-speed ratios (up

to 16:1) and hence turn quickly relative to the wind. Savonius model with three blades has the best performance at high tip speed ratio. The highest tip speed ratio is 0.555 for wind speed of 7 m/s. [8]

High tip speed ratio improves the performance of wind turbine and this could be obtained by increasing the rotational rate of the rotor. [11]

$$\lambda = \omega.R / V \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots [7]$$

Where,

ω=angular velocity, R represents radius revolving part of the turbine, V = Undisturbed wind speed.

Maximum tip speed ratio that Savonius can reach is 1.

$$\lambda = 1 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots [8]$$

5.1.7 Overlap Ratio

The overlap ratio of rotor in this study is 0 and given by the following equation [12]

$$Overlap\ Ratio = m/D \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots [9]$$

Where;

m=Distance between two rotor subtracted by shaft diameter, D=Rotor diameter

5.1.8 Solidity

Solidity is related to tip speed ratio. A high tip speed ratio will result in a low solidity. According to researcher solidity define as the ratio of blade area to the turbine rotor swept area; also solidity is usually defined as the percentage of the area of the rotor, which contains material rather than air. High solidity machines will have a low tip-speed ratio and vice versa.

Table 5.1: Solidity ratios of various rotors [3]

Types Of Rotor	Solidity	Types Of Rotor	Solidity
Savonius Rotor	1	High Speed Horizontal axis Rotor	0.01 to 0.1
Multi-blade water pumping wind rotor	0.7	Darrieus Rotor	0.01 to 0.3

5.1.9 Number of blades

It was found that, the two blades rotor is more efficient than three and four ones. [13][14][15]

Table 5.2: Summaries of Rotor Blade Design

Parameter	Value	Parameter	Value
Power Generated	50 watts	Tip Speed Ratio	1
Swept Area	0.38m2	Solidity	2.11
Rated Wind Speed	6 m/sec	Diameter	0.41 m
Aspect Ratio	2	Height	0.82 m
Number of Blade	2		

5.1.10 Effect of end plates

To study the effect of end plates, rotors with and without end plates are tested at constant values of other considered parameters. Rotors with end plates give higher mechanical power than rotors without end plates. This is because the existence of end plates increases the amount of air which strikes the blades of Savonius rotor.

5.2 Calculation of the Shaft and the Bearings

It is possible to estimate the compressive stresses on the shaft of the rotor, due to the axial loading, using for example the empirical Johnson Eq. [23], and to choose the diameter which ensures a safe load: a=14 mm. This shaft, which has been made by machining a steel bar, is completely described in reference [17]. Note that it must set the bearings. The complete calculation of the bearings can be found in reference [17].

5.3 Choice of the Generator

The car-alternator which was used is a TATA INDICA and was modified as follows: It is provided with charging lamp for to notify the charging status. The testing of the alternator for three angular velocities (100,200, 300) while charging a classical 12 V battery.

5.4 Material Usage in Current Wind Turbine

In general the materials used for wind turbines are Steel, Aluminum, Copper and Reinforced Plastic. Because Glass / Epoxy has a lower value of density as compared to Aluminum and a high strength to weight ratio. The best VAWT blade design can be achieved by choosing a material which has low density and high strength. Composite materials, with a right orientation of plies, are best choice to achieve these features. These features help to achieve a high strength to weight ratio which in turn reduces the overall weight of the blade and centrifugal forces acting on it.[18][19] By using Hand layup method glass fiber reinforced material is prepared for rotor blade. In this project we have used E-glass fiber. The following are certain important properties present in the materials. [11]

6. MODELING & ANALYSIS

The modeling for exist design is carried out in Pro/ENGINEER software and Finite elements analysis in ANSYS-14.0.
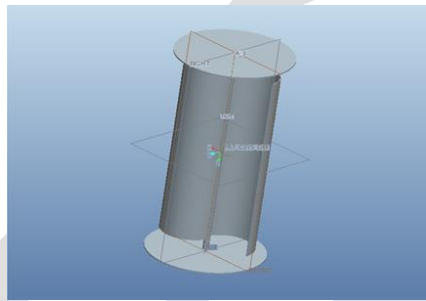

Figure 6.1 3D model of Savonius rotor

Table 6.1: Summaries of rotor blade design and the material properties of E-glass fiber

Parameter	Value	Parameter	Value
Swept Area (A)	0.38 m^2	End Plate Thickness (*tf)*	1 mm
Rotor Diameter (*D)*	0.41 m	Density	1.85e9kg/m3
Rotor Height (*H)*	0.82 m	Young's modulus	3.33 e5Gpa
End Plate Diameter(*Df)*	0.41 m	Poisson's ratio	0.09
Chord Length (*d)*	0.37 m	Tensile strength	217 – 520 Mpa
Overlap Distance (*e)*	0	Compressive strength	276 – 460 MPa
Blade Thickness (*t)*	2 mm		

6.1 Physics of Problem

6.1.1 Modeling

In this section the brief process for modeling is describe. The basic steps in modeling can be divided as follows:

1. Set the Preferences   2. Pre-Processing   3. Solution   4. Post Processing

2.1 Define element types ,Defining material properties, Creating a model, Mesh the give area, Apply displacement constrains

6.1.2 Pre-processor

Whether the element lies in 2D or 3D space. For analysis of blade we select the SHELL63 elements. SHELL63 can be adjusted for Non uniform materials. In this section the problem of physics such as stress and deflection are calculated when the blade undergoes the uniformly distributed load of wind.
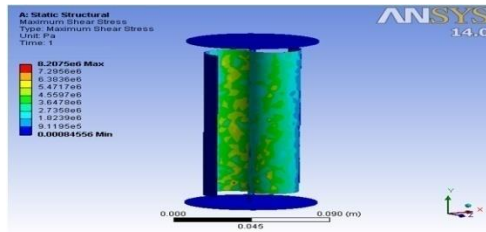
Figure 6.2 Maximum Shear Stress of Blade in ANSYS

The model which has to be design having the thickness of 2 mm, diameter 410 mm, chord length 370 mm and length of 820 mm.

- **Generating the Mesh**

Free Mesh: It has no element shape restrictions. The mesh does not follow any pattern. It is suitable for complex shape areas and volumes.

Mapped Mesh: It restricts element shapes to quadrilaterals for areas and hexahedra (bricks) for volumes. It typically has a regular pattern with obvious rows of elements. It is suitable only for "regular" areas and volumes such as rectangles and bricks.

The two Savonius rotor blades are symmetry, the analysis is performed on blade, the fixed constraints fixtures are applied on the top, bottom and center of the shaft, the fixtures constrained all translational and all rotational degrees of freedom. Therefore, the blade is stay in a static and fixed position. The load for this analysis is force with 2.93 *N* obtained from the aerodynamic analysis and equally distributed on the concave.

3. Solution

The stresses, strain developed and the total deformation due to force applied on blade are shown below
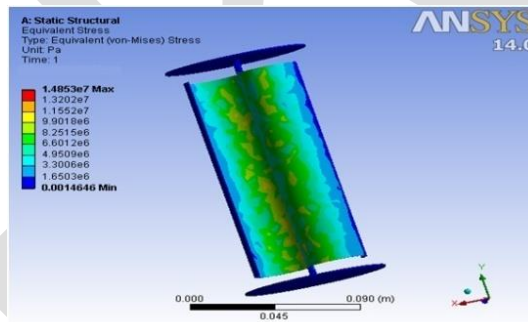

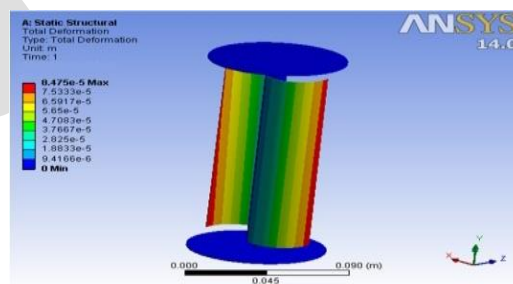*Figure 6.3 Equivalent Elastic Strain for Savonius Rotor Blade*

Figure 6.4 Maximum Deformation

The maximum and minimum Von Misses stress for the Savonius rotor blade are 1.04853×10^{7} Pa and 1.46×10^{-3} Pa respectively. Figure shows the deformation of the model under the given load, the maximum displacement is 0.847 mm at the edge of the blade. The deformation is acceptable because it is small in relation to the overall size of the blade structure.

6.2.1 Computational Flow Analysis

The blade of Savonius rotor blade experience the drag force as the solid model is fully surrounded by the flow. This fluid flow is bounded by the Computational Domain boundaries. After the input data is ready, the model then is entering the meshing process. The contour cut plot display the higher pressure region and lower pressure region as red and blue color respectively as shown in figure The pressure is high near the concave surface and is low near the convex surface. The maximum pressure is found 112.02 kPa. The density of air over the concave and convex surfaces is equally distributed. The red spotted region shows the maximum density of air. The maximum density of flow air found to be 1.23 kg/m^3.

7. Experimental Setup

The experimental setup is shown in figure 7.1. The experimental setup consists of alternator, wind turbine blade, shaft. The blades are attached to the shaft with nut & bolt. The alternator is attached to battery for storing the charges. The different reading was noted for equal interval of type. The voltmeter and ammeter is used to note down the current and voltage. The present experimental investigations are concerned with geometry of Savonius VAWT which is test at open air condition to predict performance with different parameters like existence & absence of end plates; with & without separation gap.
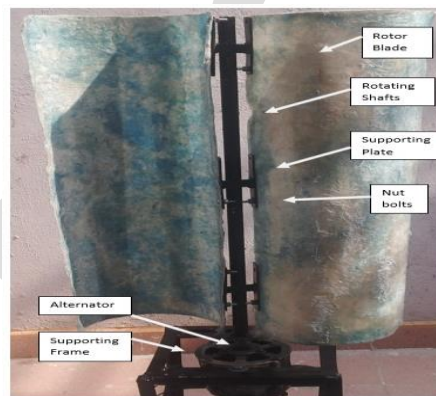

Figure 7.1 Experimental Setup

Measuring Instrument:-

Digital laser tachometer- Angular velocity was measured in units of revolutions per minute (rpm) using a digital laser tachometer. The operational range of this instrument is 2.5 to 99,999 rpm and is accurate to ± 0.05%. This model was capable of measuring wind speeds up to 30 m/s, at an accuracy of ± 0.1 m/s

Digital Multimeter-Digital multimeters, also known as DMMs, are among the most widely used electronic testing instruments. DMMs are often referred to as the tape measure of the new millennium.

Digital anemometer-The hand-held digital anemometer, shown in Figure 31, measured the wind speed at the turbines face. This model was capable of measuring wind speeds up to 30 m/s, at an accuracy of ± 0.1 m/s

8. RESULTS AND DISCUSSION

8.1 Experimental Results

The experimental results were noted and calculated for study out the maximum power delivered by the wind mill and computational analysis gives structural stability of the prototype. Readings shows the good performance by using the composite material as compared to PVC material. Here with PVC material got the highest Cp value of 0.21 at the TSR 0.8 where as I got the maximum value of Cp is 0.26 at the TSR 0.8. That means the performance of the composite rotor blade is good as compared to the PVC rotor blade at low wind speed.
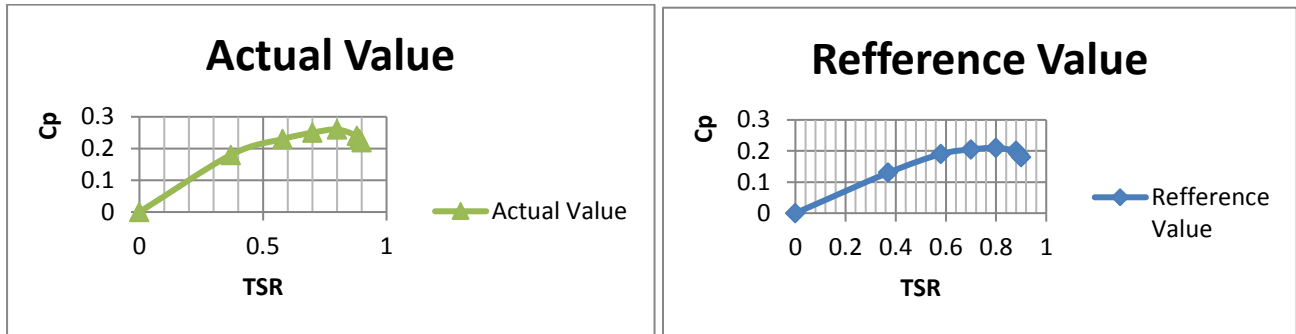
Graph 8.1 Comparative Graph TSR Vs CP

8.2 Validation of Experimental and Computational Results

The validation of results is very important to accepting the results. The validation of experimental results is presented on the basis of comparison between previous research studies, while the computational results are validated using the analytical calculation. The following table 8.1 show the comparison of results obtained analytically and computationally.

Table 8.1: Summary of Computational and Analytical Results

Sr.No.	Parameters	Computational	Analytical
1	Shear Stress (Pa)	0.0008455-8.55e6	24.19
2	Maximum Deformation (mm)	0.847	0.8131

9. CONCLUSION

Finite Element Analysis method is used to obtain the maximum deformation and stress experienced by the rotor blade. The structure of the Savonius rotor blade is analyzed using ANSYS software and Pro-E Software is used to generate three dimensional model of blade. The maximum power output is obtained 13.91 W at wind speed of 6.5 m/s. It is clear from the experimentation the performance would be improves with medium flow of wind speed.

For finite element analysis E-glass fiber material is taken into consideration. From the CFD analysis, it is found that the concave region of blade experience high pressure while the convex blade region experience low pressure for two blades of Savonius rotor. The maximum pressure from flow analysis is 112.03kPa.The high pressure region produces 2.93 N of drag force that spinning the Savonius wind turbine. The maximum deformation of the Savonius rotor blade is 0.847mm.

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