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# Experimental Investigation on Two Configuration of Vertical Axis Wind Turbine

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***Abstract***

*The main objective of this work is to compare the two proposed configurations of vertical axis wind turbine with and without load condition. It involves fabrication of two proposed configuration of same capacity of 150 W and testing rpm for the model, for various wind velocity and comparing power obtained. Performance of VAWT such as coefficient of power is flow around the blade. A great degree of design versatility in vertical axis turbine gives the economically viable energy solution for remote area, by analysing a drawback such as poor self-start, low initial torque and low coefficient of power should be overcome for majority of wind generation in vertical axis type. Vertical axis turbine has various configurations in nature. However, there are certain advantages and disadvantages with different configurations. Horizontal axis turbine is used in wind power generation, VAWT due to lower efficiency they are not used majorly in power generation but VAWT has certain advantages over HAWT such as operational independence of wind direction owing to its vertical axis operation it does not require yaw mechanism, simplicity in construction and maintenance. A detailed review on various configurations available till now and the work done on the each configuration must be studied. The various parameters that must be analysed thoroughly for the performance improvement include type of blade, number of blade and blade angle, tip-speed ratio and forces acting on the blade with respect to the wind velocity and altitude of wind turbine.*

***Keywords:*** *Savonius, Tip-speed ratio,* $C_P$

## INTRODUCTION

Wind energy is an alternative source of fossil fuel and is plentiful, renewable and readily available in nature and it does not produce anything harmful to the environment. Energy is extracted from wind using wind turbines to produce mechanical and electrical power. Wind energy is consistent in nature but it may vary in short time interval. Wind results from air in motion. Air in motion arises from a pressure gradient.

On a global basis, one primary forcing function that causes surface winds from the poles toward the equator is convective circulation. Solar radiation heats the air near the equator, and this low density heated air is buoyed up. At the surface, it is displaced by cooler, denser and higher pressure air flowing from the poles.

Wind is basically caused by solar energy irradiating the earth and the obvious fact of land and water with their unequal solar absorptivity and thermal time constants. During day light the land heats up rapidly compared to nearby sea or water bodies, and there tends to be a surface wind flow from the water to the land. At night the wind reverses, because the land surface cools faster than the water. Local winds are caused by two mechanisms. The first is differential heating of land and water. The second mechanism of local winds is caused by hills and mountain sides. The air above the slopes heats up during the day and cools down at night, more rapidly than the air above the low lands. This causes heated air during the day to rise along the slopes and relatively cool heavy air to flow down at night, and this is why wind energy is considered a part of solar energy. [4]

Wind turbine is a machine for converting the kinetic energy in the wind to mechanical energy. If used for producing mechanical energy, directly used for machinery such as pump and grinding stones, is called wind mill. If mechanical energy is converted into electrical energy, itth6t is called wind generator. Wind energy conversion devices are commonly known wind as turbines because they convert the energy of the wind stream into energy of rotation and the components which rotates is called rotor. Wind turbine produces rotational motion, as wind energy is readily converted into electrical energy by connecting the turbine to an electric generator. The combination of wind turbine and generator is referred as aero generator. The axis of rotation is vertical.

There are two main types of VAWT's, the Savonius and the Darrieus. The Savonius type rotor blade is a simple wind turbine that operates based on drag concept. According to Savonius, rotor can be designed with two or three blades, in single stage or multi-stages.[1] VAWT's typically operate closer to the ground, which has the advantage of allowing placement of heavy equipment, like the generator and gearbox, near ground level rather than in the nacelle. However, winds are lower near ground level, so for the same wind and capture area, less power will be produced. Another advantage of VAWT over the HAWT is that it doesn't require a yaw mechanism, since it can harness wind from any direction. As stated vertical-axis rotors can be either drag-or-lift based. The cup anemometer is an example of a drag-based, vertical axis wind device. The drag on a cup is greater when its concave side faces the wind which causes the device to rotate.

## THEORETICAL CALCULATION FOR SAVONIUS VAWT

**Wind power, p** is defined as the multiplication of mass flow rate ρAV and the kinetic energy per unit mass, $1/2V^2$.

The wind power is denoted by the equation of

Power = 1/2ρAv3cp (1)

Wind speed is the major element that affects the power output. The three wind speed parameters involved in this is cut-in speed, rated wind speed and cut-out speed.

Vcut-in = 0.5 Vavg

VRated = 1.5 Vavg

Vcut-out = 3.0 Vavg

**Swept area (A)** for Savonius Wind Turbine is calculated by multiplication of rotor diameter, D and the rotor height, H. The larger the swept area, the larger the power generated.

Area = Diameter × Height (2)

**Aspect ratio** is to evaluate the aerodynamic performance of Savonius rotor. Savonius rotor is designed with rotor height twice of rotor diameter and this leads to a better stability with proper efficiencies.

Aspect ratio (α) = Rotor height (H)/Rotor diameter (D)

**Tip speed ratio,** λ is defined as the ratio of the linear speed of rotor blade ω. Rto is the undisturbed wind speed. ωis the angular velocity and R represent the radius revolving part of the turbine. The maximum tip speed ratio that Savonius rotor can reach is 1. [5]

Tip speed ratio $\lambda = \omega R/V$ (4)

**Solidity** is related to tip speed ratio. A high tip speed ratio will result in a low solidity. Solidity as the ratio of blade area to the turbine rotor swept area. For VAWT, the solidity is defined as

Solidity $\sigma = n\, d/R$ (5)

Where n is the number of blades, d is the chord length or can be defined as the diameter of each half cylinder, and R is radius of wind turbine.

**Over lap-ratio** is defined as blades overlap distance with respect to shaft of wind turbine.

Overlap ratio $\beta$ = overlap (e) – diameter of shaft/rotor diameter (6)

**Co-efficient of power** is defined as the amount wind power can be converted into useful power. Using tip-speed ratio $\lambda$, the Cpcan be calculated

$Cp = CD\, \lambda\, (1-\lambda)2.$ (7)

**MODELING**

Modelling is the process of producing a model, where a model is a representation of the construction and working of some system of interest. A model is similar to but simpler than the system it represents. One purpose of a model is to enable the analyst to predict the effect of changes to the system. On the one hand, a model should be a close approximation to the real system and incorporate most of its salient features on the other hand, it should not be so complex that it is impossible to understand and experiment with it.

Modelling is done using CATIA software, in this straight blade and curved blade is modelled for given specification as shown in table1. In this curved blade, overlap of blades is considered. The proposed model of two different configurations is shown in fig 1. Dimensions of rotor are shown in table 3.

***Table 1: Design parameters***

| | |
|---|---|
| Power Generated | 150W |
| Swept Area | 1.21m2 |
| Wind Speed | 7 m/sec |
| Aspect Ratio | 1 |
| Tip Speed Ratio | 1.0 |
| Solidity | 2.01 |
| Diameter – Height | 1.1 m – 1.1 m |
| Number of Blade | 2 |

***Table 2. Dimension of rotor***

| | |
|---|---|
| Rotor Diameter D | 1100 mm |
| Rotor Height H | 1100 mm |
| Chord Length d | 575 mm |
| Blade Thickness t | 2mm |

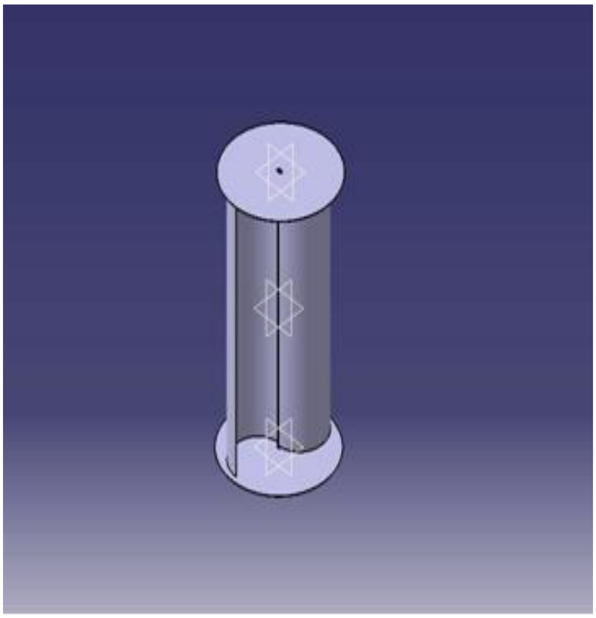

***Fig. 1(a): Straight rotor VAWT.***

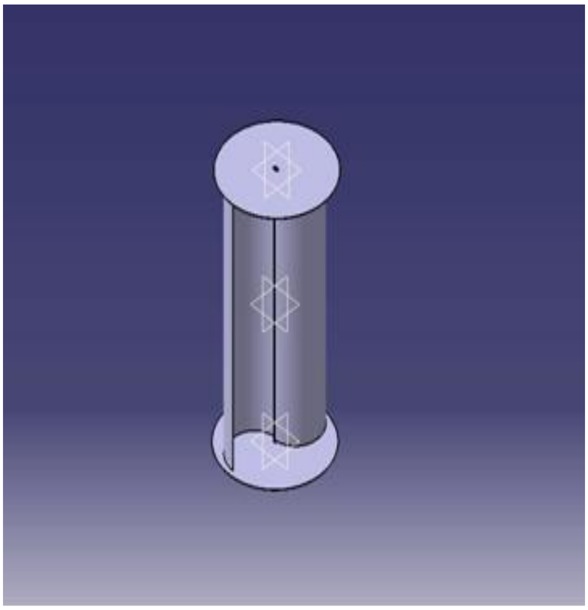

***Fig. 1(b): Curved blade VAWT.***

## FABRICATION

The fabrication of both curved and flat vertical axis wind turbine is done using G.I sheet. Purchased G.I sheet metal sheared according to the blade configuration, and the sheared material is folded into curved shape for curved VAWT and sheet metal is sheared taper for straight VAWT. Then sheared rotoris are welded with vertical G.I hollow shaft by gas welding. Necessary rips are provided in the back of blade for better strength, as shown in fig 2.

*Fig. 2(a): Curved rotor*

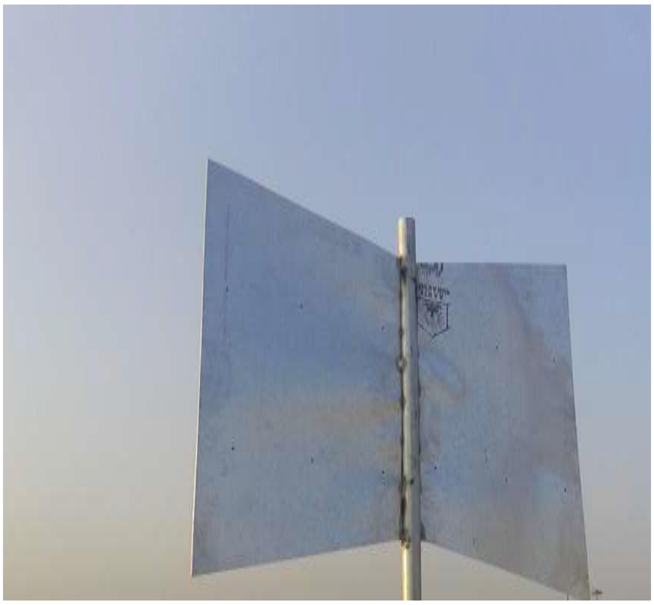

*Fig 2 (b): Straight rotor*

*Frame Fabrication*

The M.S steel plate is purchased for the required dimension of 80×30cm.The hole is done for the diameter of 5cm at the centre of the plate. The L-angle is purchased for the length of 8m, and cut for the purpose of stand. Two ball-bearings with four bolt housings are bolted on the frame as shown in fig 3.

***Fig 3: Frame Setup***

*Curved Vawt*

The curved vertical axis wind turbine as shown in fig 4 (a) is made of G.I Sheet and it is fitted to the frame using two ball bearings with four bolted housings. It is Savinous type two blade vertical axis wind turbine with overlap. Then the model is tested for rpm (revolutions per minute) without load and rpm, power are tested with load. The dynamo is fitted at the bottom of the model and rpm, power are measured for various wind velocities. The characteristic of curved VAWT is shown in Table 4.

***Fig 4 (a): Curved VAWT***

*Flat Vawt*

The straight blade vertical axis wind turbine is, as shown in fig 4(b), fabricated using galvanized iron sheet and is two blade Savinous type, without overlap over blades. The rotor is welded with shaft using gas welding and it is fitted to the frame using two ball-bearings with four bolt housings. The dynamo is fitted at the bottom of model and is tested with and without load condition. Instruments like Anemometer, Tachometer, voltmeter and ammeter are used to measure wind velocity, RPM, voltage and current respectively. The characteristics of straight VAWT are shown in table 5.

***Fig 4(b): Straight VAWT***

### *Digital Anemometer*

An anemometer or wind meter is a device used for measuring wind speed, and is a common weather station instrument. The term is derived from the Greek word anemos, meaning wind, and is used to describe any air speed measurement instrument used in meteorology or aerodynamics.

- ***Specification***

Range 0-30m/s

Weight 58.9 g

Current consumption .3mA

### *Digital Tachometer*

A tachometer (revolution-counter, rev-counter, RPM gauge) is an instrument measuring the rotation speed of a shaft or disk, as in a motor or other machine. The device usually displays the revolutions per minute (RPM) on a calibrated analogue dial, but digital displays are increasingly common. The word comes from Greek (tachos"speed") and metron ("measure"). The digital tachometer (in fig 4 c) is used to measure the RPM in two configurations of vertical axis wind turbine and to compare the both the models in load and unload conditions. RPM for two configurations is shown in table 3.

***i. Measuring Consideration***

- The non reflective area must always be greater than reflective area, if the shaft is normally reflective.

- It must be covered with black tape or black paint before attaching reflective tape.
- Shaft surface must be clean and smooth before applying reflective tape.
- Then the laser is to be pointed on the reflective tape and for a minimum sampling time of 8 seconds.

### *ii. Specifications*

Range 2.5 to 99999 rpm

Sampling time .8 sec

Weight 220 g

Detecting distance 50 to 250 mm


***Fig 4 (c): Digital tachometer***

***Table 3: RPM for Two Configurations***

| Velocity | curved blade rpm | straight blade RPM |
|---|---|---|
| 1 | 19.1 | - |
| 2 | 24.1 | 22 |
| 3 | 38.4 | 33 |
| 4 | 52.8 | 47 |
| 5 | 83.4 | 71.4 |
| 6 | 111 | 87.9 |
| 7 | 119 | 98 |

*Table 4: Characteristics of Curved VAWT*

| Velocity(m/s) | Rpm | Voltage (V) | Current(A) | Power (W) | Cp |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | 16.36 | 12 | 1.2 | 14.4 | 0.05 |
| 3 | 28 | 15 | 2 | 30 | 0.118 |
| 4 | 39 | 20.2 | 2.4 | 48.8 | 0.192 |
| 5 | 69 | 24 | 3 | 72 | 0.284 |
| 6 | 95.4 | 30 | 3.5 | 105 | 0.415 |
| 7 | 104.57 | 36.7 | 4 | 146.8 | 0.58 |

*Table 5: Characteristics of Straight VAWT*

| Velocity(m/S) | Rpm | Voltage(V | Current(A) | Power(W) | Cp |
|---|---|---|---|---|---|
| 1 | | | | | |
| 2 | | | | | |
| 3 | 23.5 | 14 | 2 | 28 | 0.11 |
| 4 | 38.17 | 18 | 2.2 | 39.6 | 0.156 |
| 5 | 57.2 | 19 | 2.5 | 47.5 | 0.187 |
| 6 | 76.3 | 23 | 3 | 69 | 0.27 |
| 7 | 86.8 | 28 | 3.5 | 98 | 0.38 |

## RESULTS AND DISCUSSION

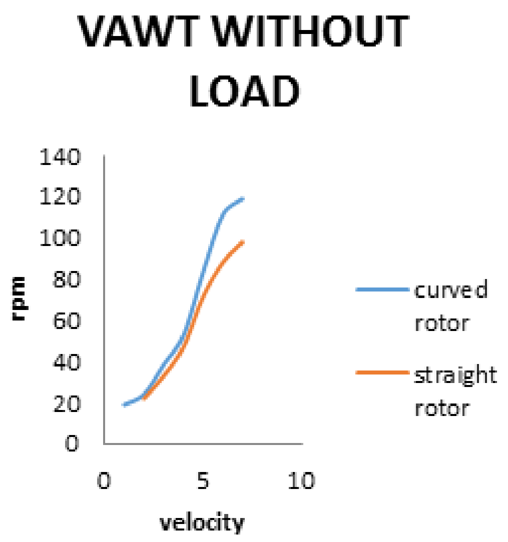


*Fig 5 (a): VAWT without Load*

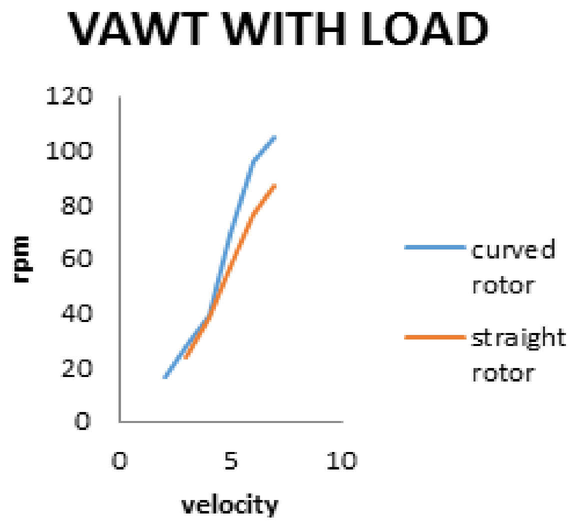


*Fig 5 (b): VAWT with Load*

From the Fig 5 (a) & (b) shows that the curved rotor experiences higher RPM (revolution per minute) when compared to straight rotor in both (with and without load) conditions for various wind velocities.

Fig 5 (c) shows the characteristic of curved vertical axis wind turbine such as RPM, voltage, current, and power with respect to the wind velocity.

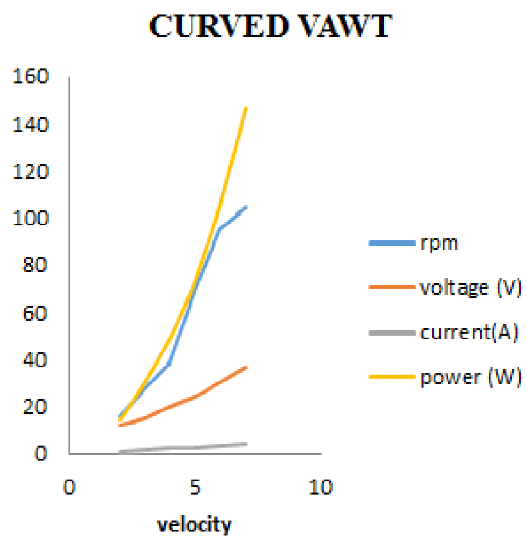


*Fig 5 (c) Characteristics of Curved VAWT*

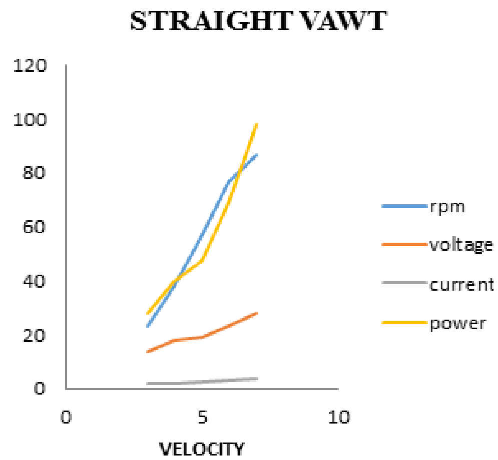


*Fig 5 (d) Characteristics of Straight VAWT*

Fig 5 (d) shows the characteristics of straight vertical axis wind turbine such as RPM, voltage, current, and power with respect to the wind velocity.

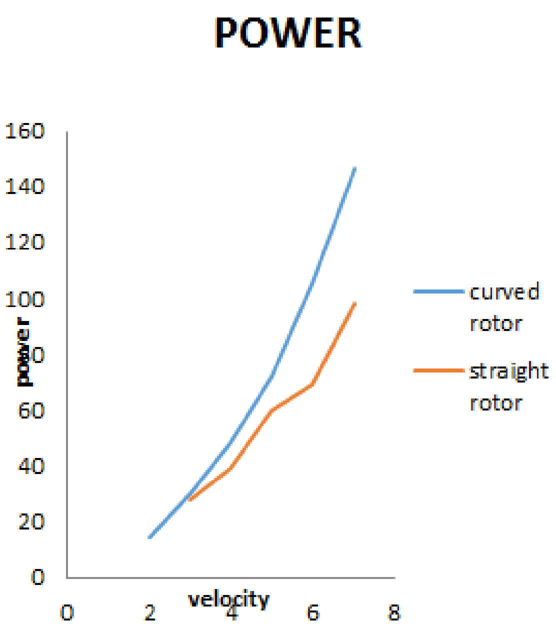


*Fig: 5(e) Power curve*

Fig 5 (e) shows the comparison of power output of the two proposed configuration and the curved VAWT experiences higher output then straight VAWT, for various wind velocities. The power output generated in straight rotor is from 3 m/s but in curved rotor the power output is generated from 2 m/s of wind velocity.

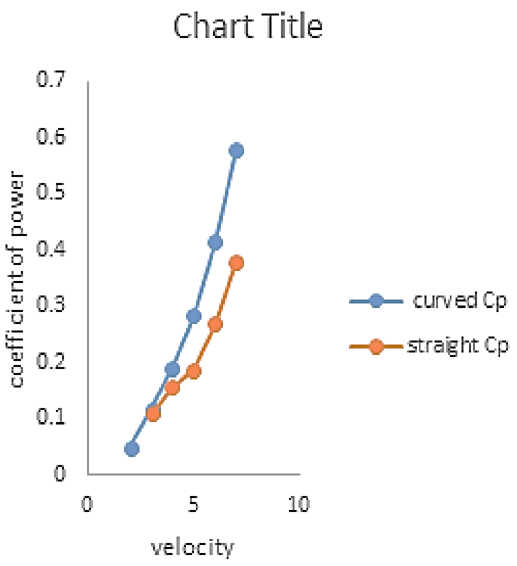


***Fig. 5(f): Coefficient of power***

Fig 5 (f): Coefficient of power shows that maximum Cpvalue of .5 achieved in curved vertical axis wind turbine, when compared to the straight VAWT value 0.38.

**CONCLUSION**

The experimental result on VAWT with respect to fabricated configurations, such as straight and curved vertical axis wind turbine are generated by comparing the RPM for the two configurations for various wind velocities, with and without load of same capacity the curved rotor experiences higher rpm (revolution per minute) for various wind velocity. The comparison of power output of the two proposed configurations and the curved VAWT experiences higher output of 146 W, then straight VAWT of 98 W. The power output generated in straight rotor is from 3 m/s but in curved rotor the power output is generated from 2m/s of wind velocity and the maximum Cpvalue of .5 achieved in curved vertical axis wind turbine, when compared to the straight VAWT value 0.38. From the result of experiment, the curved-Savonius vertical axis wind turbine shows better result and it is suitable for small scale wind productions.

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