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DESIGN ,FABRICATION & ANALYSIS OF A HELICAL VERTICAL WIND TURBINE

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Abstract- *This interactive qualifying project focused on the ever advancing hybrid vehicle technology and its integration with wind energy. The main objective of this project is to design and fabricated a self-starting small vertical axis wind Turbine (VAWT) .This VAWT s can be mounted over the roof of the car or in front of the cooler. Usually, a car moves through a layer of fluid and this fluid layer always is a disadvantage for the moving car because it poses a drag force due to moving forward . In this research project, we are going to use this force for developing electrical energy. This VAWT is build to achieve RPM at minimum wind speed. The Twisted blade is the main function which plays the role to rotate it at minimum wind speed. Our optimized view for this project is to set this VAWT in a car and run it by wind. From experiment 11.77 watt power can be generated when the turbine is run at 112rpm for the wind speed is 6m/s.*

Keywords: small VAWT, Fluid layer, Drag force, Efficiency, Angle of attack

1. INTRODUCTION

As modern culture and technology continue to develop, the growing presence of global warming and irreversible climate change draws increasing amounts of concern from the world's population. With the recent surge in fossil fuels prices, demands for cleaner energy sources, and government funding incentives, wind turbines have become a viable technology for power generation. Currently, horizontal axis wind turbines (HAWT) dominate the wind energy market due to their large size and high power generation characteristics. However, vertical axis wind turbines (VAWT) are capable of producing a lot of power, and offer many advantages.

The mechanical power generation equipment can be located at ground level, which makes for easy maintenance. Also, VAWT are omni-directional, meaning they do not need to be pointed in the direction of the wind to produce power. Finally, there is potential for large power generation with VAWT because their size can be increased greatly. However, there are also downfalls to the VAWT. Firstly, boundary layer affects from the ground influence the air stream incident on the VAWT, which in some cases leads to inconsistent wind patterns. Secondly, VAWT are not self-starting; currently, an outside power source is required to start turbine rotation until a certain rotational speed is reached. The0 main objective of this project is to design and build a self-starting vertical axis wind turbine. The self-starting issues surrounding VAWT will be tackled by the use of alternative blade profiles and pitching mechanisms.

A vertical axis wind turbine has several advantages over the more traditional horizontal wind turbine, especially in uneven wind conditions where a horizontal wind turbine has to change directions, which puts stresses on the bearings and tower and dissipates energy. In contrast, the VAWT is propelled by wind from any direction, and gravitational stresses on the vertical axis turbine are even, allowing lighter and larger construction. This vertical-axis wind turbine incorporates 3 involute spiral sails in a configuration that utilizes the mass momentum of the wind to spin the sails around a central mast. Force is applied to the sails by the wind both entering and leaving the turbine, allowing maximum extraction of energy from the wind.

2. LITERATURE REVIEW

The major components of a typical wind energy conversion system include a wind turbine, generator, interconnection apparatus and control systems. Wind turbines can be classified into the vertical axis type and the horizontal axis type. Most modern wind turbines use a horizontal axis configuration with two or three blades, operating either down-wind or up-wind. A wind turbine can be designed for a constant speed or variable speed operation [1]

Vertical axis wind turbine can be divided into two major classifications. Savinious type turbines are drag based like the simple wind anemometer. Darrieus type turbine on other hand based on Bernoulli's principal that faster moving air is relatively lower in pressure .this turbine have airfoil like blades. Each turbine has its respective advantages and disadvantages. sovinius type turbines work well with low speed wind and self-starting .Darrieus type turbines have just difficulty in starting and operate better under high speed wind conditions.[2]Here we are working on self-starting on Darrieus type turbine and using this **.**

3. WIND TURBINE DESIGN PARAMETERS

The wind turbine parameters considered in the design process are: Swept area; · Power and power coefficient; · Tip speed ratio; · Blade chord; · Number of blades;· Angle of attack

3.1 Swept Area

The swept area is the section of air that encloses the turbine in its movement, the shape of the swept area usually depends on the rotor configuration, this way the swept area of an regular HAWT is circular shaped while for a regular straight-bladed vertical axis wind turbine the swept area has a rectangular shape and is calculated using[3]: $S = 2RL$

where S is the swept area [m^2], R is the rotor radius [m], and L is the blade length [m].The swept area limits the volume of air passing by the turbine. The rotor converts the energy contained in the wind in rotational movement so as bigger the area, bigger power output in the same wind conditions.

3.2 Power and Power Coefficient

The power available from wind for a vertical axis wind turbine can be found from the following formula[3]:

$pw = \frac{1}{2} \rho s v^3$

where Vo is the velocity of the wind [m/s] and ρ is the air density [kg/m^3], the reference density used its standard sea level value (1.225 kg/m^3 at 15ºC), for other values the source (Aerospaceweb.org, 2005) can be consulted. Note thatavailable power is dependent on the cube of the airspeed.

The power the turbine takes from wind is calculated using the power coefficient[3]:

$$C_p = \frac{\text{Captured mechanical power by blades}}{\text{Available power in wind}}$$

Cp value represents the part of the total available power that is actually taken from wind, which can be understood as its efficiency.This power coefficient only considers the mechanical energy converted directly from wind energy; it does not consider the mechanical-into-electrical energy conversion, which involves other parameters like the generator efficiency.

3.3 Tip Speed Ratio

The power coefficient is directly dependent on tip speed ratio, can be defined as the ratio between the tangential speed at blade tip and the actual wind speed[3].

$$TSR = \frac{\text{Tangential speed at the blade tip}}{\text{Actual wind speed}} = \frac{R\,\omega}{Vo}$$

Where ω is the angular speed [rad/s], R the rotor radius [m] and Vo the ambient wind speed [m/s]. Each rotor design has an optimal tip speed ratio at which the maximum power extraction is achieved.

3.4 Blade Chord

The chord is the length between leading edge and trailing edge of the blade profile[3] (Fig.1),

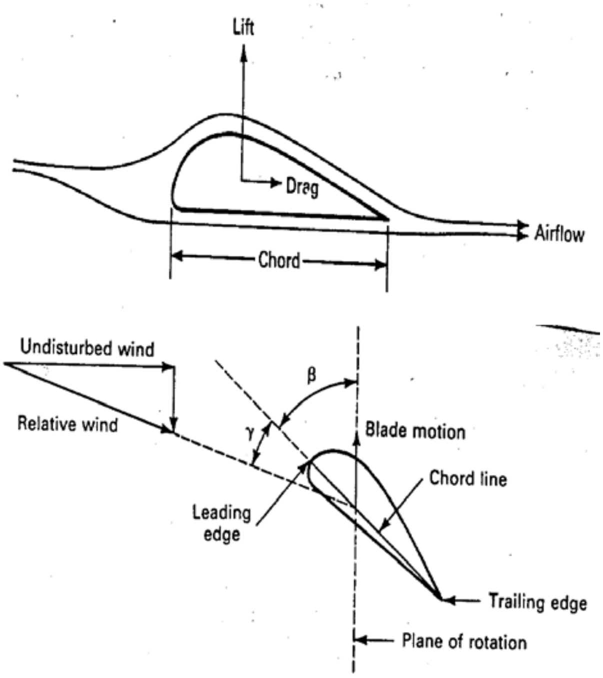


Fig.1: Wind turbine blade profile

The chord line is the straight line connecting the leading and trailing edges of an airfoil. The plane of rotation is the plane in which the blade tips lie as they rotate. The blade tips actually trace out a circle which lies on the plane of rotation. Full power output would normally be obtained when the wind direction is perpendicular to the plane of rotation[4].

A bigger chord advances also the point of maximum torque, blades with smaller chords need a bigger tip speed ratio to develop maximum torque and it can affect the self-starting capabilities.

3.5 Number of Blades

The number of blades has a direct effect in the smoothness of rotor operation as they can compensate cycled aerodynamic loads. For easiness of building, four and three blades have been contemplated.

The four-bladed design has better behavior at low rpm, but the three bladed rotors present a much quicker response, which can be further improved using a lighter material and can be very useful to take profit from brief gusts. The four bladed rotor will not be further considered in the design.

3.6 Angle of Attack

The angle of attack which is defined as the angle between the blade chord and the resultant air velocity vector.

A positive initial angle of attack broadens the range of angular speed operation and a negative one shortens it ,this is interesting when fixing the maximum rpm. Furthermore the torque is influenced the same way resulting in a lower maximum power coefficient and torque for negative angles of attack. The initial angle of attack for our design will be set at 0 degrees as the advantages of a different angle of attack are, according to this model, only evident at higher tip speed ratios than the intended for the model.

One important parameter of a blade is the pitch angle, which is the angle between the chord line of the blade and the plane of rotation. The pitch angle is a static angle, depending only on the orientation of the blade. Angle of attack which is a dynamic angle, depending on both the speed of the blade and the speed of the wind. The blade speed at a distance r from the hub and an angular velocity ωm is rωm. A blade with twist will have a variation in angle of attack from hub to tip because of the variation of rωm with distance from the hub. The lift and drag have optimum values for a single angle of attack so a blade without twist is less efficient than a blade with the proper twist to maintain a nearly constant angle of attack from hub to tip. Even the blades were twisted to improve the efficiency. When the blade is twisted, the pitch angle will change from hub to tip. In this situation, the pitch angle measured three fourths of the distance out from the hub is selected as the reference [4] that's why we choose the twisted type blade in our designed turbine.

Table-1 Turbine Parameters

Swept Area	.0924m^2
Number Of Blade	3
Blade Length	.44m
Chord Length	.06m
Angle Of Attack	20°-45°
Pitch Angle	120°
Rotor Radius	.105m

4. THEORETICAL BACKGROUND

4.1 Lift and Drag Force

.Lift and drag coefficients are dependant on the Reynolds number and the angle of attack. When the lift and drag coefficients are determined, the lift and drag forces can be calculated using the following equations, respectively.

$$F_l = \frac{1}{2}\rho_{air}W^2 \times cl \times bl \times C_l$$
$$F_d = \frac{1}{2}\rho_{air}W^2 \times cl \times bl \times C_d$$

Where Fl: lift force (N)
Fd: drag force (N)
bl: blade length (m)
Cl: lift coefficient
Cd: drag coefficient

The lift and drag forces were then resolved into components parallel and perpendicular to the blades path of rotation. The following four equations were used to resolve the lift and drag forces into parallel and perpendicular components.

$$F_{l,hlep} = F_l \cos\left[\left(\frac{90\pi}{180}\right) - \left(\frac{\alpha_{actual}\pi}{180}\right)\right]$$
$$F_{l,circ} = F_l \sin\left[\left(\frac{90\pi}{180}\right) - \left(\frac{\alpha_{actual}\pi}{180}\right)\right]$$
$$F_{d,hurt} = F_d \cos\left(\frac{\alpha_{actual}\pi}{180}\right)$$
$$F_{d,circ} = F_d \sin\left(\frac{\alpha_{actual}\pi}{180}\right)$$

where

$F_{l,help}$: Force in direction of travel (N)

$F_{l,circ}$: Force contributing to centrifugal force (N)

$F_{d,hurt}$: Force opposing motion of blade travel (N)

$F_{d,circ}$: Force contributing to centrifugal force (N)

α_{actual} : Angle of attack with added pitching (rad)

Finally, parallel forces are added, and perpendicular forces are added to obtain expressions for F1 and F2, as given by equations

$$F_1 = F_{l,help} - F_{d,hurt}$$
$$F_2 = F_{l,circ} + F_{d,circ}$$

Where F1: forces contributing to torque (N)
F2: centrifugal forces (N)

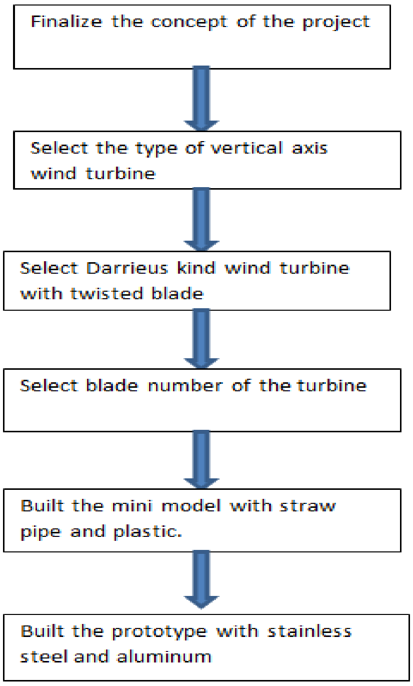
The resulting forces, F1 and F2, are the forces experienced by a turbine with one blade rotating about a central axis. To obtain the forces experienced by a turbine with 2 blades, the forces are split at 180º and doubled. For example, the forces experienced by the first blade at 90º are the same forces to be experienced by the 2nd blade at 270º. This was also done for a 3-blade turbine; however, the forces were split at 120º, and added three times[5].

5. MATERIALS AND METHODOLOGY

On this VAWT we used various types of material and set up. We also measured various types of parameters on this case. We evaluated this design on various process .
Materials:

1. Almunium
2. Stainless steel
3. Bearings
4.Bolts connections

Total procedure is given in a flow chart:



6. DESIGN AND FABRICATION

Design: The designed different components of the turbine are given below

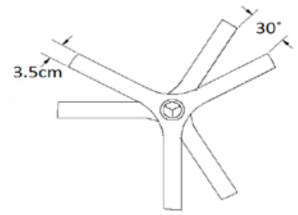


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Fig.2(a)Top view of the helical turbine rotor

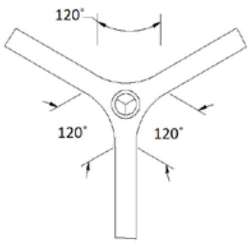


Fig.2(b)Angular deviation of the rotor triangle

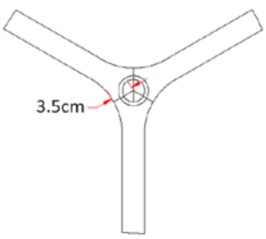
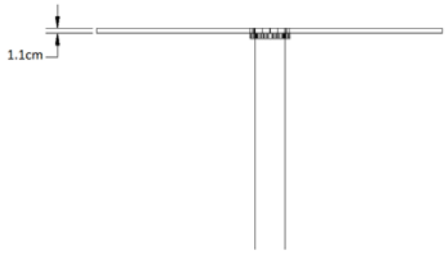


Fig.2 (c) Hub diameter of the rotor



Fug.2(d) Side view of hub and rotor

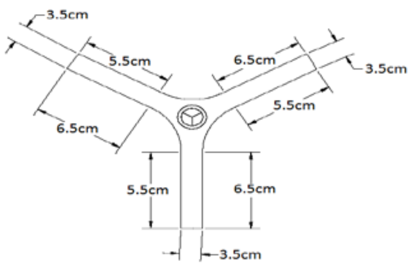


Fig.2 (e) Total dimension of the rotor and hub

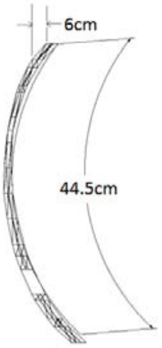


Fig.2(f) Dimension of twisted blade

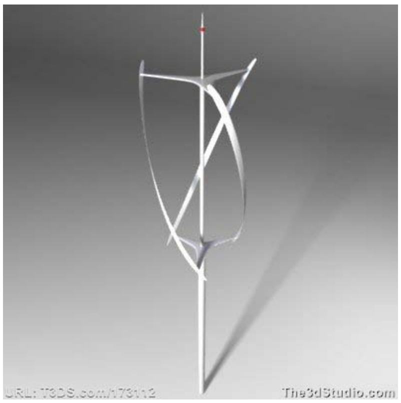


Fig.2(g) 3D Auto CAD view of the helical wind turbine

Fabrication

Total fabrication is oriented in two parts one is molding and casting of rotor and another one is assembling of the blades. We used aluminum for molding and casting of the rotor .according to the précised dimensions which we figured out earlier.

Another part of this turbine is blade, designing the blade is most précised part .we took a stainless steel as our metal. For the seeking of advantage we selected 1mm stainless steel(ss) .Next stage of fabrication we twisted the sheet.

After fabricating the various parts of the turbine we assembled. We used two bearings both top and bottom .These two bearings manipulated the rotation of the rotor . two bolt connections one is above and another is at the below of the rotor . Blades are connected with rotor by screw joints . we used a holder to hold the turbine.

Fig.3 Helical wind turbine top and front view

7. RESULTS AND DISCUSSION

7.1 Results

By using the following equation, turbine specification, measured wind speed and rotor rpm, the following drug and wind power is calculated.

The drug force for wind turbine**[5]**

$$F_d = \frac{1}{2}\rho_{air}W^2 \times cl \times bl \times C_d$$

For the turbine
Chord length, cl=0.06m
Blade length ,bl =0.44m
Coefficient of drag, C_d=2.00
(Usually for curved vane ,C_d=2.30 [6], we assumed for this curved blade ,C_d=2)

for 30^{O}C consider ρ_{air}=1.18 slug/m^3 [6]

Wind power, $\mathbf{P_w = \frac{1}{2} \rho s v^3}$
Where
V=wind velocity
Swept area, S=2RL
R=radius of the rotor=5.5cm
L= length of the blade=44.5cm

Table-2 Calculated drag force & wind power corresponding measured wind speed and rotor rpm

Wind Speed (m/s)	Rotor RPM	Drag Force (N)	Wind Power (watt)
2.8	48	0.24	1.20
4.4	75	0.60	4.64
5.5	90	0.94	9.07
6	112	1.12	11.77

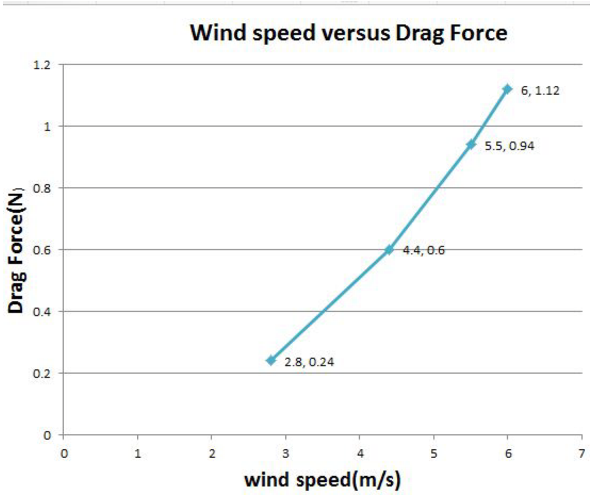


Fig.5 Drag force corresponding wind speed

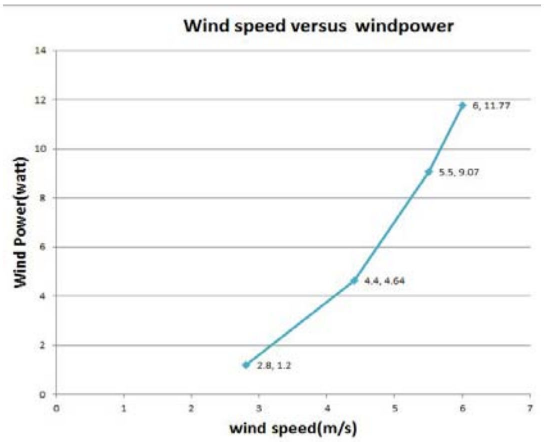


Fig.4: Wind power to the corresponding wind speed

Discussion:

The aim of this research project is to design and fabricated a self-starting small vertical axis wind turbine (VAWT). This VAWT s can be mounted over the roof of a car or in front of the cooler. By using the car drug force the turbine can be run and developing electrical energy. This energy will work for driving the car or vehicle.

We have designed a helical vertical wind turbine of the size; length 44cm, rotor radius 5.5 cm, cord length 0.06m.

After designed the total fabrication of the turbine was done in the local workshop in the form of moulding, casting and machining process. Finally the turbine was tested in the fluid mechanics laboratory of CUET.

In this project so far we compared wind speed versus drag force and wind power which was shown in the Table-2 and Fig.4 and Fig.5. From the figures it was found that with the increases the wind speed the corresponding drug force was increases and power generation also increase. 11.77watt power was found for the wind speed 6m/s at that time the rotor was run at 112 rpm.

8. CONCLUSION

This VAWT is build to achieve RPM at minimum wind speed. That's why we used drag force of the wind flow. The Twisted blade is the main function which plays the role to rotate it at minimum wind speed. Our optimized view for this project is to set this VAWT in a car and run it by wind. From experiment 11.77watt power can be generated when the turbine is run at 112rpm for the wind speed is 6m/s.

9. ACKNOWLEDGEMENT

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10. REFERENCES

1. R. Mittal, K.S.Sandhu and D.K. "An Overview of Some Important Issues Related to Wind Energy Conversion System (WECS).
2. C T. Carper "Design and construction of vertical axis wind turbine using dual layer vacuum forming".
3. J Castilo "Small scale vertical axis wind turbine design".
4. G. L. Johnson "Wind Energy Systems".
5. J D Coste, D McKay ,B Robinson, and S W, S Wright "Vertical Axis Wind Turbine".
6. www.wikepedia .com
7. Google image