# DESIGN AND DEVELOPMENT OF FOLDABLE AND PORTABLE WINDMILL

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**Abstract -** *Wind is becoming a competitive energy source, dragging more and more attention as a renewable, economically viable and greener alternative to traditional sources. Large scale wind farms connected to national power grids are today very common in Europe and USA. In the other end of wind power generation spectrum, we find small-scale wind turbines designed and built to be used at isolated spots such as farms in the Argentinean Patagonia. In these small scale applications, the impossibility to connect to the national power grid adds an additional interest to the use of wind turbines as a source of electric energy.*

*In many cases a need of portable energy device is needed where in small electronic gadgets , like cell phones, laptop, tabs etc are to be charged while in travel, the present work focuses on a design development and analysis of such portable wind turbine system with USB charging system and integral battery system. An aerodynamic study of a small-scale portable wind turbine is performed, using simplified theoretical models and 2D and 3D ANSYS calculations. Turbine power output is estimated and compared with experimental measurements. Pressure distribution over the blades is calculated, in order to perform ANSYS analysis.*

## 1. INTRODUCTION

In recent days, mobile phone has become an omnipresent personal electronic device in people's daily lives. Users are always alert for cell phones that have an advanced technology. However, the difficulty for charge phone battery which probably due to a power supply problem has not yet been resolved satisfactorily. Despite the advanced technology of mobile phone, the battery still cannot meet the increasing power demand due to the rapidly increasing functionalities of the mobile phone. Therefore, it is highly desirable to reduce the dependency of the mobile phone battery charging on the power supply of harvesting renewable energy from the environment.

There are several resources of renewable energy such as solar, wind, tidal, geothermal and biomass. The wind power is among the best candidates due to its wide availability. In addition to producing clean energy, wind turbines also do not need any transportation fuel that can be harmful to the environment. Modern wind turbines are capable to produce power at reasonable cost which causes the system to be more efficient and reliable. By using wind turbine, wind energy will be converted into electrical energy to produce power supply which act as mobile charger.

Turbines commonly categorized into two types, namely Vertical Axis Wind Turbines (VAWT) and Horizontal Axis Wind Turbines (HAWT). HAWT has the main rotor shaft and electrical generator at the top of a tower. The orientation of the main rotor of HAWT must be in the direction of the wind while arrangement for VAWT must be perpendicular to the ground. Although VAWT is less efficient in aerodynamic performance rather than HAWT, but VAWT has drawn great attention due to good starting-torque performance and low starting wind speed. The advantage of VAWT is capable to catch the wind from all directions and at lower wind speeds without requiring in the direction of the wind compared to horizontal axis wind turbines. The blade airfoil cross-section and extract the wind by thrust upwards due to the pressure difference between the two sides of the blade. When the air is incident on the aerofoil-shaped, it moves faster than the blade of it underneath.

This makes the air pressure underneath the bar higher than the above and due to the pressure of unequal blade having upward thrust. The efficiency of wind turbine depends on the rotor design parameters and airfoils choosing, blade chord and twist angle correction. Aerodynamic performances play important roles in maximum efficiency of the rotor. Besides that, aerodynamic also play important role in a wind turbine. Aerodynamic lift is known as the force that responsible for the power yield, which generated by the turbine. This paper will discuss about the parameter that need to be considered in designing multi-directional wind turbine as portable mobile phone charger.

With the rapid advances in technology, mobile phone features a variety of important roles in daily life. However, many circumstances occur where the cell phone cannot be charged. Therefore, renewable energy source technology like solar energy has been introduced to solve this problem. However, a problem occurs when there is no sunlight or the light is not sufficient enough to charge solar energy effectively. In order to overcome this problem, a research has been carried out with consideration of renewable resources and maintaining sustainability of energy to charge mobile phone battery. At present, a solution to overcome this problem has been introduced. Hence, the objective of this project is to implement portable mobile phone charger by using a multi directional wind turbine.

## 2. PROBLEM STATEMENT

There are many problems that come with the use of this type of vertical axis wind mill. Vertical wind mill has very large in size. Vertical wind turbine are stationary once it fixed it cannot carry, once it installed it is stationary. It cannot use in other way. Also the power generation by the vertical axis wind mill small compared to the horizontal axis wind turbine. Decrease the level of efficiency when compared to the horizontal axis wind mill. Vertical axis wind mill are very difficult to erect on tower, which means they are installed on base, such as ground or building.

## 3. OBJECTIVES

1) To make the vertical axis wind mill to portable by reducing its size so that we can carry anywhere place there is absence of electricity or electricity is highly cost. We can generate electricity.
2) By making the vertical axis wind mill foldable so that it can reduce the larger size of the wind mill and make it compact to ensure less space consumed.
3) Increases the efficiency of the wind mill by designing certain parameter.

## 4. DESIGN

**Wind Turbine Design Parameters**

The various parameters involved in the performance testing of the vehicle is listed below:

1. Swept area.
2. Power and power co-efficient.
3. Tip speed ratio.
4. Blade chord
5. No. of blades.
6. Solidity.
7. Initial angle of attack.

### 4.1 Swept Area

The swept area is the section of air that encloses the turbine in its movement.

For circular section,

$$A_s = \pi \times r^2$$

For rectangular section,

$$A_s = 2 \times r \times L$$

Where,

As = swept area [m2]

r = the rotor radius [m]

L = blade length [m]

### 4.2 Power and Power Co-efficient

Wind speed data can be obtained from wind maps or from the meteorology office. Unfortunately the general availability and reliability of wind speed data is extremely poor in many regions of the world. However, significant areas of the world have mean wind speeds of above 3m/s which make the use of wind pumps an economically attractive option. It is important to obtain accurate wind speed data for the site in mind before any decision can be made as to its suitability. Methods for assessing the mean wind speed are found in the relevant texts (see the 'References and resources' section at the end of this fact sheet).

The power in the wind is proportional to:

- The area of windmill being swept by the wind
- The cube of the wind speed
- The air density - which varies with altitude

The formula used for calculating the power in the wind is shown below:

$$P_W = ½ \rho A V^3$$

- $P_W$ is power in watts available in the wind (W)
- ρ is the air density in kilograms per cubic metre ($kg/m^3$)
- A is the swept rotor area in square metres ($m^2$)
- V is the wind speed in metres per second (m/s)

The fact that the power is proportional to the cube of the wind speed is very significant. This can be demonstrated by pointing out that if the wind speed doubles then the power in the wind increases by a factor of eight! It is therefore worthwhile finding a site which has a relatively high mean wind speed.

## 4.3 Power Coefficient:-

Although the power equation above gives us the power in the wind, the actual power that we can extract from the wind is significantly less than this figure suggests. The actual power will depend on several factors, such as the type of machine and rotor used, the sophistication of blade design, friction losses, the losses in the pump or other equipment connected to the wind machine, and there are also physical limits to the amount of power which can be extracted realistically from the wind. It can be shown theoretically that any windmill can only possibly extract a maximum of 59.3% of the power from the wind (this is known as the Betz limit). In reality, for a wind pump is usually around 30% to 40% and for a large electricity producing turbine around 45% maximum (see the section on coefficient of performance below) so, modifying the formula for 'Power in the wind' we can say that the power that is produced by the wind machine can be given by:

$P_M = ½.C_p \rho A V^3$ where:

- $P_M$ is power (in watts) available from the machine
- $C_p$ is the coefficient of performance of the wind machine
- Coefficient of performance can be calculated by following formula,

$$Cp = \frac{\text{Capture mechanical power by blades}}{\text{Power available in wind}}$$

### 4.4 Tip Speed Ratio

It is defined as the ratio between the tangential speed at blade tip and the actual wind speed.

$$\text{Tip speed ratio} = \frac{\text{Tangential speed at the blade tip}}{\text{Actual wind speed}}$$

$$\lambda = \frac{nwr}{V}$$

Where,

w = Angular velocity (rad/s)
r = Rotor radius (m)
V = Wind speed (m/s)

### Effect of Rotor Tip Speed Ratio

The choice of the tip speed ratio for a particular wind turbine design depends several factors. In general a high tip speed ratio is a desirable feature since it results in a high shaft rotational speed that is needed for the efficient operation of an electrical generator.

**A high tip speed ratio however entails several possible disadvantages:**

1. Rotor blade tips rotating at a speed larger than 80 m/sec will be subject to erosion of the leading edges from their impact with dust or sand particles in the air, and will require the use of special erosion resistant coatings much like in the design of helicopter blades.
2. Noise generation in the audible and non audible ranges.
3. Vibration, particularly in the cases of two or single bladed rotors.
4. Starting difficulties if the shaft is stiff to start rotation.
5. Reduced rotor efficiency due to drag and tip losses.

6. Excessive rotor speeds would lead to a runaway turbine, leading to its catastrophic failure, and even disintegration.

### Tip Speed Ratios of Different Designs

The theoretical maximum efficiency of a wind turbine is given by the Betz limit around 59 percent. Practically, wind turbines operate below the Betz limit. In Fig. 1 for a two bladed turbine, if it is operated at the optimal tip speed ratio of 6, its power coefficient would be around 0.45. At the cut-in speed, the power coefficient is just 0.10, and at the cut-out speed it is 0.22. This suggests that for maximum power extraction a wind turbine should be operated around its optimal wind tip ratio.

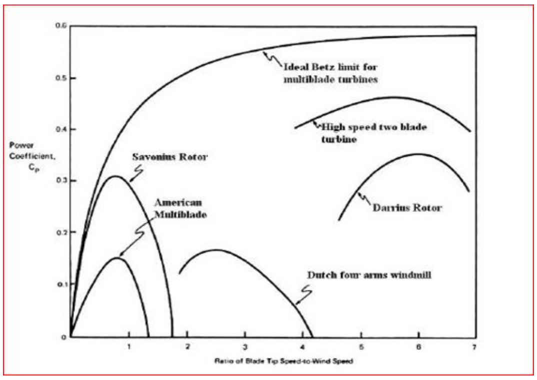


Fig 4.1:- The power coefficient as a function of the tip speed ratio for different Wind machines design

Modern horizontal axis wind turbine rotors consist of two or three thin blades and are designated as low solidity rotors. This implies a low fraction of the area swept by the rotors being solid. Its configuration results in an optimum match to the frequency requirements of modern electricity generators and also minimizes the size of the gearbox required as well as increases efficiency. Such an arrangement results in a relatively high tip speed ratio in comparison with rotors with a high number of blades such the highly successful American wind mill used for water pumping in the American West and all over the world. The latter required a high starting torque. The relationship between the rotor coefficient Cp and the tip speed ratio is shown for different types of wind machines.

## 4.5 Blade Chord

The chord is the length between leading edge and trailing edge of the blade profile.

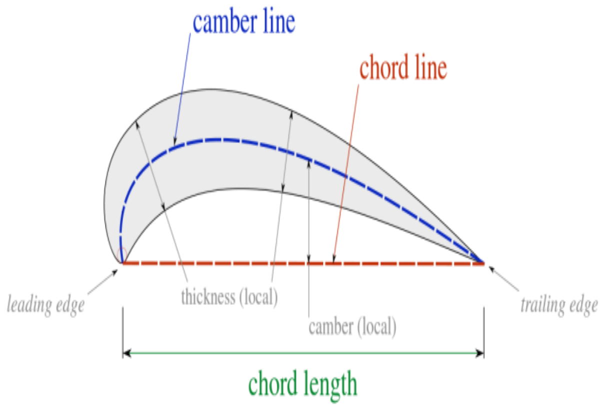


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Fig 4.2:- Blade Chord

## 4.6 Number of Blades

The number of blades has a direct effect in the smoothness of rotor operation. From various references it is conclude that two or four blades are more suitable for vertical axis wind turbine.

## 4.7 Solidity

It is defined as the ratio between the total blade area and the projected turbine area. Solidity is usually defined as the percentage of the circumference of the rotor which contains material rather than air.

**Effect of number of blades on solidity**

It is shown in the graph that as the number of blades on the rotor increases, the rotor blade material increased and solidity of wind turbine increased proportionally. The higher rotor solidities require a lower angular velocity to obtain the maximum amount of power produced for a certain wind speed. Moreover, a slight reduction in rotor efficiency with the increase of rotor solidity can be observed.

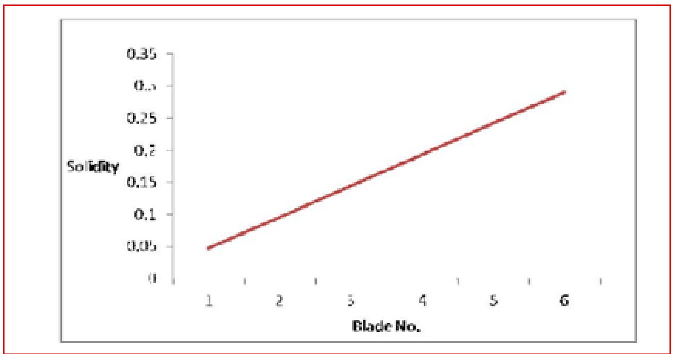



Fig.4.3:- Graph Between the Solidity and Number of Blades

## 4.8 Initial Angle of Attack

The initial angle of attack is the angle the blade has regarding its trajectory, considering negative the angle that locates the blade's leading edge inside the Circumference described by the blade path.

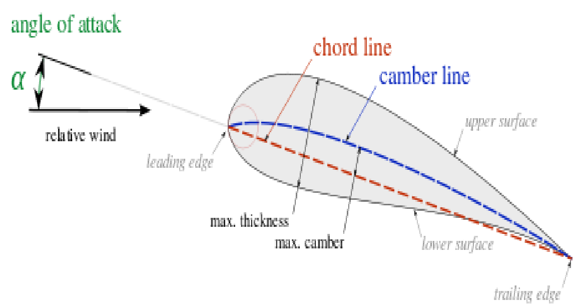



Fig. 4.4:- Initial angle of attack

## 4.9 Calculations:-

### 4.9.1 Design of Turbine

MATERIAL SELECTION : - Ref :- PSG (1.10 & 1.12) + (1.17)

Table 4.1:- Material Specification of Nylon

| DESIGNATION | ULTIMATE TENSILE STRENGTH $N/mm^2$ | YEILD STRENGTH $N/mm^2$ |
|---|---|---|
| **FDM NYLON 12** | 48 | 32 |

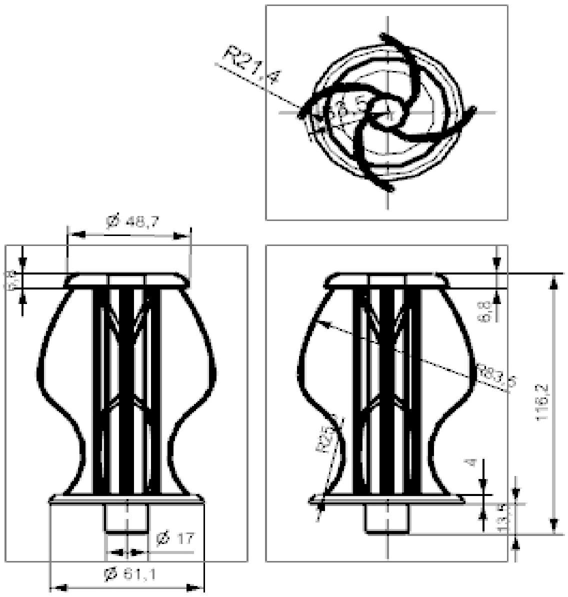



Fig 4.5:- Turbine Drafting

- **CONSIDER LIGHTING A 40 W BULB FOR ABOUT AN YEAR…**

On an average the bulb would be used daily for about 8 hours

So the amount of energy required per year would be given by
= 40*3600*8*365
= 420.48*103 KJ/Year
**= 116.8 Kwh**

Following assumptions are taken into account for estimation:-

1) **Coefficient of performance:- 0.40**
2) **Wind speed :- 11.11m/s**
3) **Density of air:- 1kg/m³**
4) **Capacity factor :- 0.3**(it means 30% of the time ,wind machine is producing energy at rated power )
5) **Transmission Losses :- 10 % & Generator losses :- 10%**
6) **Number of hours in a year :- 8760 hour**

- **Power density of wind (ideal)**

= 0.5* Air Density* Velocity3
= $0.5*1*(11.11)^3$
= **822.79watt/m2**

- **Overall loss Factor**

**=** Coefficient of performance * Transmission Losses * Generator losses
= 0.40 *0.9*0.95
= **0.5**

- **Actual power density**

= Ideal Power Density * Overall Loss Factor
= 822.79* 0.5
= 411.39watt/m2
= **3603.77 KWh/m2**

**Area of the Rotor**

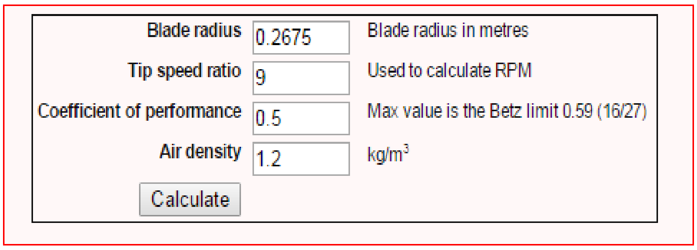
$$= \frac{\text{Total annual energy required}}{\text{Useful energy density}}$$

$$= \frac{116.8}{3603.77}$$

= **0.0324 m2**

So in order to have an area of 0.324 m2 there are numerous combinations of diameter and height which the rotor can have .So ANSYS iterations were carried out on various combinations and the best was selected. The results of ANSYS simulations are discussed in the coming sections.

**Online Application Standard Result:-**



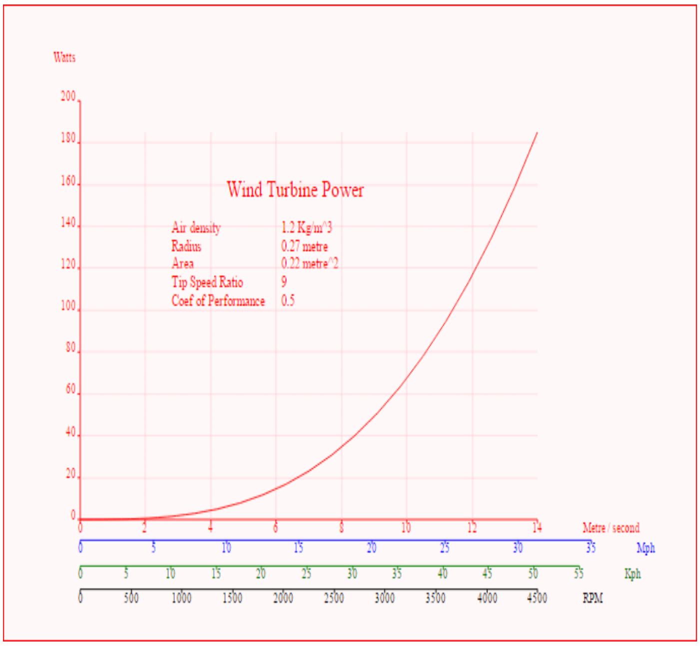



Fig 4.6:- Graph Between Power and Speed

### 4.9.2 Design of Rotor Shaft.

Material Selection : - Aluminum 6061

Table 4.2:- Aluminum 6061 Specification

| Designation | Ultimate Tensile Strength N/Mm² | Yeild Strength N/Mm² |
|---|---|---|
| Aluminum 6061 | 607 | 386 |

**ASME Code For Design Of Shaft.**

Since the loads on most shafts in connected machinery are not constant, it is necessary to make proper allowance for the harmful effects of load fluctuations.

According to ASME code permissible values of shear stress may be calculated form various relation i.e.

$fs_{max}$ = 0.18 fyt
= 0.18 x 607
= 110 N/mm²
OR
$fs_{max}$ = 0.3 fyt
=0.3 x 386
=116 N/ mm²

Consider minimum value of these two value

$fs_{max} = 110\ N/mm^2$

Shaft is provided with key way, this will reduce its strength. Hence reducing above value of allowable stress by 25%

$\Rightarrow fs_{max} = 83\ N/mm^2$

This is the allowable value of shear stress that can be induced in the shaft material for safe operation.

- **To Calculate Rotor Shaft Torque**

The drive motor generator is 12 VDC motor coupled to planetary gear box.

Specifications of motor are as follows:

a) Power 5 watt
b) Speed = 500 rpm
c) Gear box: Planetary /epicyclical type (reduction ratio: 1:5)

- POWER(P) = $\dfrac{2\,\pi\,NT}{60}$

Hence input to rotor shaft = 500 rpm

$$\Rightarrow T = \frac{60 \times P}{2 \times \pi \times N}$$

$$= \frac{60 \times 5}{2 \times \pi \times 500}$$

$$\Rightarrow T = 0.0954\ N\text{-}m$$

$$\Rightarrow T\ design = 5 \times T$$

$$= 5 \times 0.0954$$

$$= 0.477\ N\text{-}m$$

**Check For Torsional Shear Failure of Shaft**

Assuming minimum section diameter on input shaft = 10 mm

$$\Rightarrow d = 10\ mm$$

$$Td = \Pi/16 \times fs_{act} \times d^3$$

$$\Rightarrow fs_{act} = \frac{16 \times Td}{\Pi \times d^3}$$

$$= \frac{16 \times 0.477 \times 10^3}{\Pi \times (10)^3}$$

$$\Rightarrow fs_{act} = 24.29\ N/mm^2$$

As $fs_{act} < fs_{all}$

⇒ I/P shaft is safe under torsional load.

### 4.9.3 Design of Ball Bearing

**Step 1**:- Select appropriate bearing from catalogue

| ISI NO | Basic Design No (SKF) | d | D 1 | D | D 2 | B | Basic capacity | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | C N | Co N |
| 16B C04 | 6002 | 17 | 21 | 40 | 36 | 12 | 2850 | 5590 |

Table 4.3:- Std Basic dynamic capacity chart

**Step 2**:- Calculate Radial Load Factor (X) & Axial Load Factor (Y)

X = 1 (i.e. pure radial loading)
Y = 0

**Step 3**:- Equivalent Dynamic Load Capacity

Pe = X x V x Fr + Y x fa.
Where ;
Pe=Equivalent dynamic load ,(N)
X=Radial load factor
V=Race-Rotation Factor
=1.0 for inner race rotating & outer race stationary
Fr= Radial load(N)
= 500N
Y = Axial load factor
Fa = Axial load (N)
=1 x 1 x 500 +0
=500 N

**Step 4**:- Rating life of bearing

$$L_{10} = \frac{L_{10h} \times 60 \times n}{10^6}$$

Assume $L_{10h}$=8760 hr

n =1400rpm

$$= \frac{8760 \times 60 \times 1400}{10^6}$$

=735.84
=740 million revolution

**Step 5**:-Calculate required basic dynamic capacity( Cr )

$L_{10} = (Cr/Pe)^a$
Where,
a = 3 for ball bearing
= 10/3 for roller bearing
$740 = (Cr/200)^3$
= 1810 N

As; required dynamic of bearing is less than the rated dynamic capacity of bearing
Hence, C>Cr the bearing is safe.

## 5. CONSTRUCTION AND WORKING

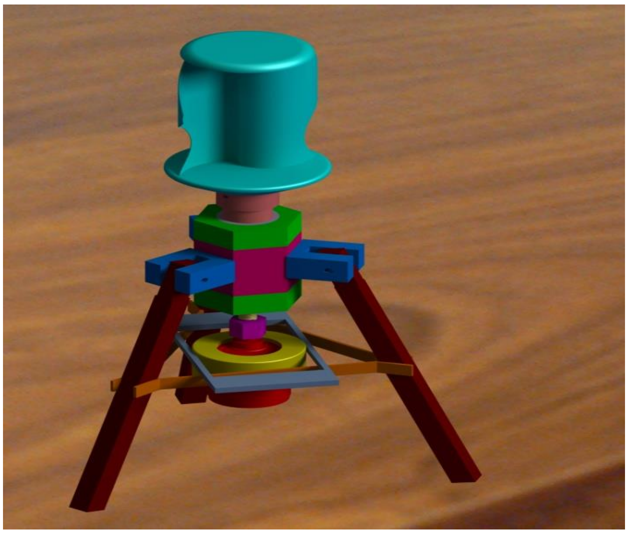


Fig 5. :- Assembly of Foldable and Portable Wind Mill

Vertical-axis wind turbines (VAWTs) have the main rotor shaft arranged vertically. One advantage of this arrangement is that the turbine does not need to be pointed into the wind to be effective, which is an advantage on a site where the wind direction is highly variable. It is also an advantage when the turbine is integrated into a building because it is inherently less steerable. Also, the generator and gearbox can be placed near the ground, using a direct drive from the rotor assembly to the ground-based gearbox, improving accessibility for maintenance. However, these designs produce much less energy averaged over time, which is a major drawback.

When a turbine is mounted on a rooftop the building generally redirects wind over the roof and this can double the wind speed at the turbine. If the height of a rooftop mounted turbine tower is approximately 50% of the building height it is near the optimum for maximum wind energy and minimum wind turbulence. Wind speeds within the built environment are generally much lower than at exposed rural sites, noise may be a concern and an existing structure may not adequately resist the additional stress.

Vertical Axis Wind Turbines are designed to be economical and practical, as well as quiet and efficient. They are great for use in residential areas whereas the HAWT is best for use at a business location. There are two different styles of vertical wind turbines out there. One is the Savonius rotor, and the second is the Darrieus model. The first model looks like a 55 gallon drum that is been cut in half with the halves placed onto a rotating shaft. The second model is smaller and looks much like an egg beater. Most of the wind turbines being used today are the Savonius models. We will take a look more in- depth at both of these types of turbines available.

A wind turbine secures air into a hub, which them turns into a generator. The air that passes through the blades of the wind turbine is spun into the generator through rotational momentum. The VAWT, as the turbines are oftener shortened, feature the following qualities:

- Two to three blades with a vertically operating main rotor shaft – the more blades that you have on the unit, the more wind energy it will receive and the more efficiency it will offer.
- Used less frequently than a horizontal wind turbine.
- The position of the blades is different in the VAWT. On this model, the base of the tower holds the generator, and the blades then wrap themselves around the shaft. People use the VAWT because they can be placed closer to the ground, which makes them acceptable and effective for use at a residential location.
- The VAWT are easier and more affordable to maintain than horizontal units
- One complain that some users have with the VAWT is that is creates less wind energy, which may cause a number of different noises to be heart. Turbulent air flow is also a possibility that can shorten the life of the system.
- Installation of the VAWT onto the roof will cause the wind speed to double for maximum wind turbulence and wind energy usage

### 5.1 Advantages

Following are the advantages of manual seed planter machine are

1) They are always facing the wind – no need for steering into the wind.
2) Have greater surface area for energy capture – can be many times greater.
3) Are more efficient in gusty winds – already facing the gust.
4) Can be installed in more locations – on roofs, along highways, in parking lots.
5) Can be significantly less expensive to build – are inherently simpler.
6) Can have low maintenance downtime – mechanisms at or near ground level.
7) Produce less noise – low speed means less noise.

### 5.2 Applications

1) Domestic use
2) On commercial vehicle
3) Truck and buses
4) Malls and station with high wind density

## 6 ANALYSIS OF PARTS

### 6.1 Analysis of Turbine:-

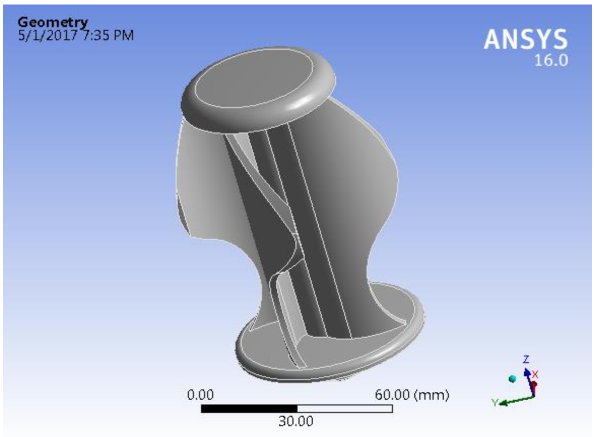



Fig 6.1 Geometry of Turbine

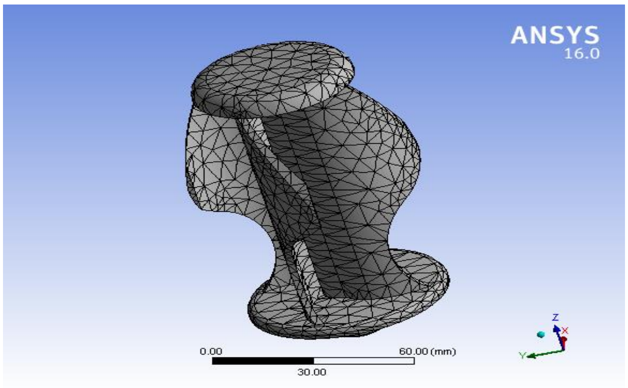



Fig 6.2 :- Meshing of Turbine

Table 6.1:- Meshing Result

| Statistics | |
|---|---|
| Nodes | 22534 |
| Elements | 12191 |
| Mesh Metric | None |

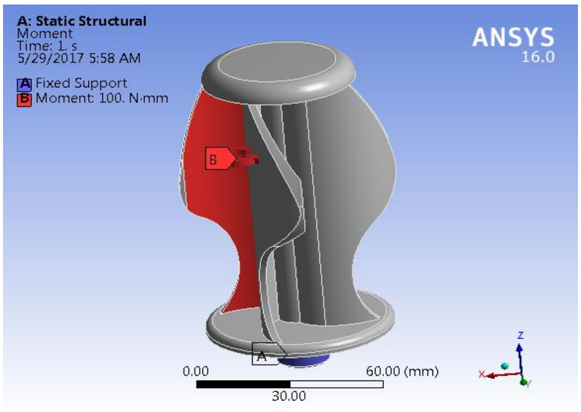



Fig 6.3:- Moment on Turbine

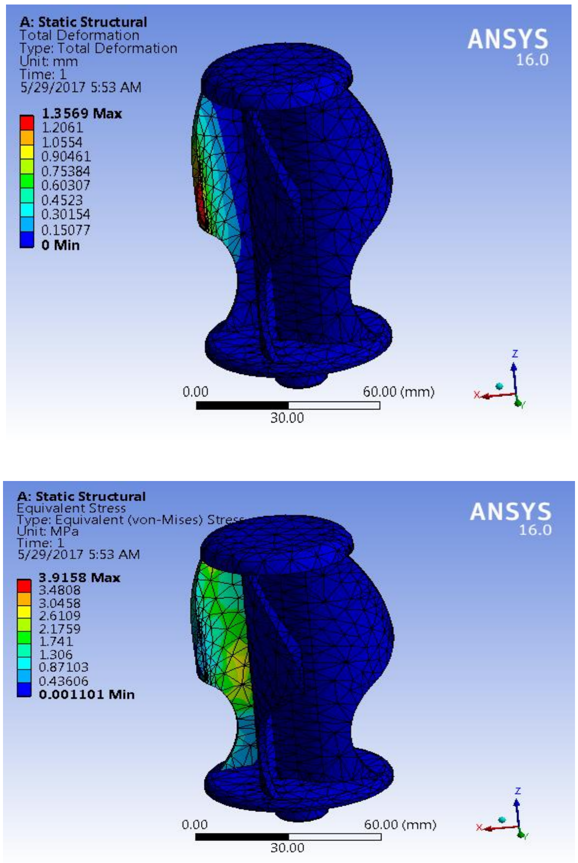



Fig 6.4:- ANSYS Result of Turbine

As the maximum stress (3.91 Mpa) is well below allowable stress of 9.65 Mpa the turbine is safe.

## 6.2:- ANSYS of Shaft

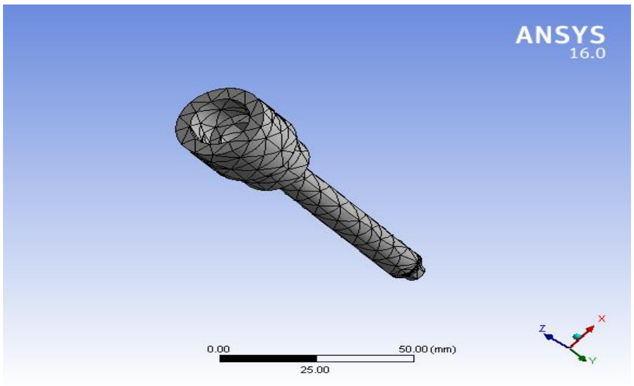



Fig 6.5 :- Meshing of Shaft

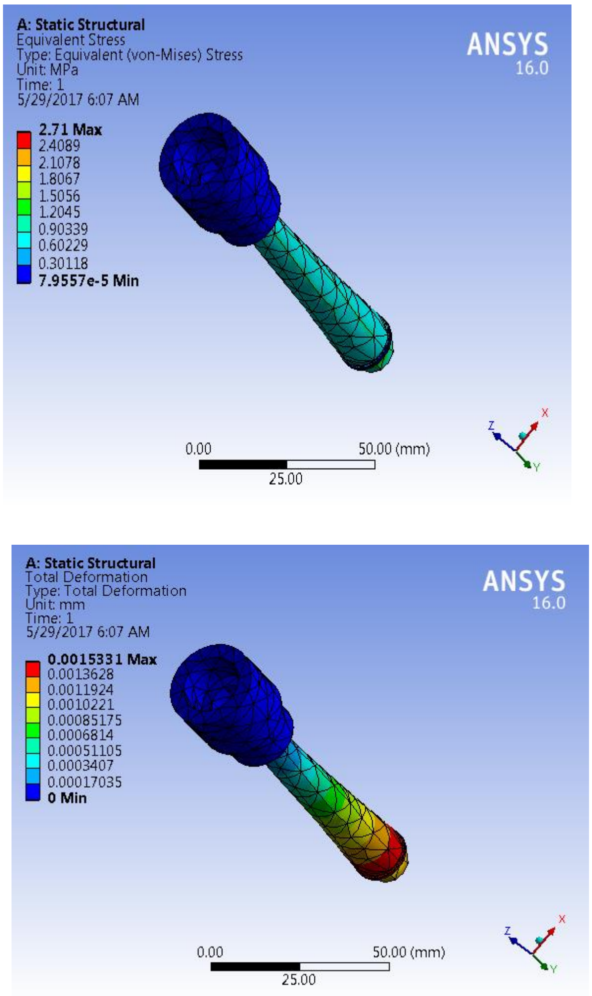



Fig 6.6:- ANSYS Result of Shaft

### 6.3 :- ANSYS of Coupling

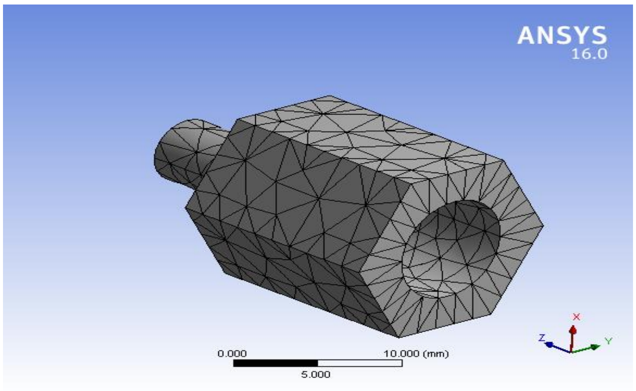
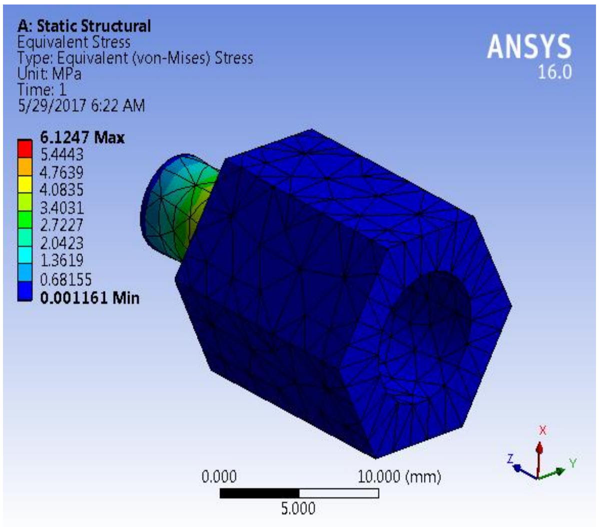



Fig 6.7 :- Meshing of Coupling



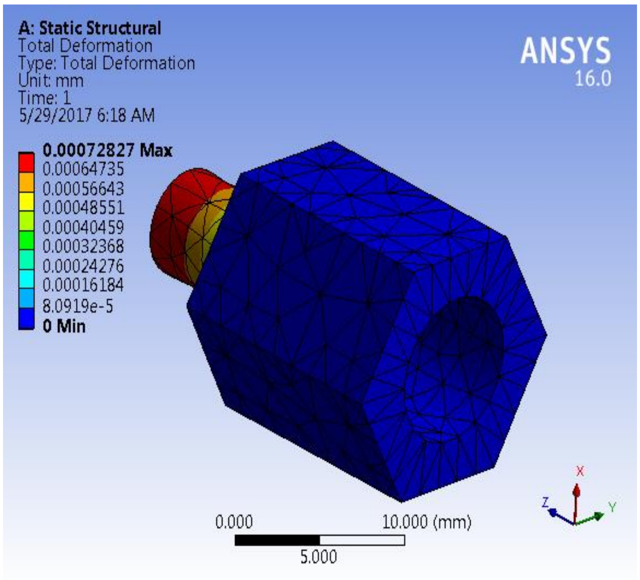




Fig 6.4.2:- ANSYS Result of Coupling

### 6.5 Technical parameters

**Output Power Test Under Constant Voltage**

TABLE 6.2 :- OUTPUT

| Speed(km/h) | Output power(W) | Output volt(V) | Output current(A) |
|---|---|---|---|
| 5 | 0.56 | 6.00 | 0.126 |
| 15 | 1.89 | 6.00 | 0.369 |
| 30 | 4.09 | 6.00 | 0.560 |

## 7. CONCLUSION

The implementation of vertical axis wind turbine on road vehicles or dividers would be a great asset to the ministry of non-conventional energy resources as it would reduce the burden on the consumption of conventional energy sources. These turbines are simple in construction, compact in design and require less investment. Since, turbine is in small size, it can harness a limited amount of wind. Therefore they can be used for low power application such as for mobile charging, street lighting on any busy road. Moreover it can also use to light up the advertisement hoardings. Other application could be in diversions on highways and traffic lights. Since the battery is portable so we can use it in some other location for any low voltage purpose. Thus there is balance between the cost and power available. Future prospect, the addition of speed governing system and control circuit may make the model much acceptable. The emerging trends in the technology have shown a way to use of non-conventional energy sources so efficiently and a little effort at the side may find an effective solution for the bottom of the electrical energy by the society.

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