# Modelling and Development of Flexible Blade Windmill

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**Abstract -** *Wind energy continues to be one among the fastest- growing power generation sectors. In this paper, a small wind turbine was designed innovatively having different structure than the current windmill structure. The blade is an important part of a turbine and has a crucial role in the working of windmill. The objective of this windmill is to utilize the natural resource in a sustainable manner and design a windmill such that its blades will expand and contract based on the action of centrifugal force. If a windmill is designed and constructed in such a way that it can harvest more power over its life period, then it is a sustainable solution to our energy demand.*

***Key Words***: *Wind Energy, Wind mill, Power, power density, stress, Torque, Deflection.*

## 1. Introduction

Renewable Energy Sources are those energy sources which are replenished over the period and cannot be rooted out when their energy is utilized. Technology is the main key to utilize natural phenomenon, such as sun-light, wind, tide waves. A lot of development in the technology has taken place over the time period for utilization of energy from the wind.

Gases flow on large scale is called wind, basically it is relative motion of air with respect to earth. The motioned air arises from a pressure gradient.

Over hundreds of years power has been extracted from the wind with historic designs, known as Windmills. No device, however is well-designed that can harvest all of the winds energy as the wind would have to brought to rest and this would hamper the transit of further air acoss the rotor. [1]

Wind turbines are generally classified as vertical axis wind turbine (VAWT) or horizontal axis wind turbine (HAWT) depending upon the axis orientation of their rotors. A wind turbine operates by slowing down the wind extracting a part of its energy in the process. For horizontal axis wind turbine, the axis of rotor remain horizontal and aligned parallel to the direction of wind stream. [2,3]

Wind being one of resource of renewable energy. Wind mills needs to be set up on specific regions such as on top the hill, deserts etc.

### A. Literature survey

India shows interest in this field nearly at end decade of fifties and starting decade of sixties. For some months we imported the design and then we developed our own but this was not sustained for long time. In very recent years development works in various initiations'. one of the important reason behind this less interest.. An important reason for this lack interest in wind energy can be that, wind in regions of India are relatively low and very appreciably with the seasons. In India wind speed value lies between range 5km/hr. to 15-20km/hr. [3].

Recently, the increasing demand of renewable energy is very well noticed. According to a report by the International Energy Agency, the rise in amount of electricity extracted from renewable energy resources increased from just over 13% in 2012 to 22% the following year.

From early civilisation times wind was used for sailing the boats and for grinding the grains etc. The the concept of using wind energy can found in 4000BC in when Egyptians used to sail the boats with the help of wind. By the 10$^{th}$ century Afghani and Iraqi peoples started wainind mills for grinding the grains.

Wind machines becomes popular because the energy can begin used in number of ways. In 1854 Daniel Halladay in US introduced wind pump. Wind mills were used for various types of works such as extracting oil from seed, sawing timber, raising water from wells etc. In 1880 for first time windmills was used as a source of electricity. The stimulus for the development of wind energy in1973 was due to rising prices of oil and main component resposnsible to drive attension for use of wind mill for electricity was very less emission CO2. In Year 1974, NASA constructed and operated a wind generator having 100 kW capacity. This success encouraged the US firm to manufacture 2.5MW generator vin1987. [4,5,6].

Wind energy is important and crucial source of enrgy of all the sources. The concept of wind energy is transformng the kinetic energy of wind into mechanical energy. This energy drives blades that turn generators that produce electricity. Our project is fitting with wind energy source.

The aim of this project is to design efficient Small Hertical Axis Wind Turbine (HAWT).

## 2. System Design

The requirement of hardware and software for designing of system is as follows:-

- 3 Big wooden blades
- 3 small wooden blades
- 2 circular plates
- Stand
- Nut & Bolts

- Shaft
- Springs
- CATIA(Software)

Mechanical drawing mainly consists of stand, blades and bearings and specification of parts is as follows:-

- Diameter of plates= 24 cm
- Big blade= 60 $*$ 8 $*$ 2 cm
- Small blades= 35 $*$ 5 $*$ 2 cm
- Swept Area= 0.4417 sq. m
- Effective radius= 0.75 m

System design in CATIA is given as follows:-

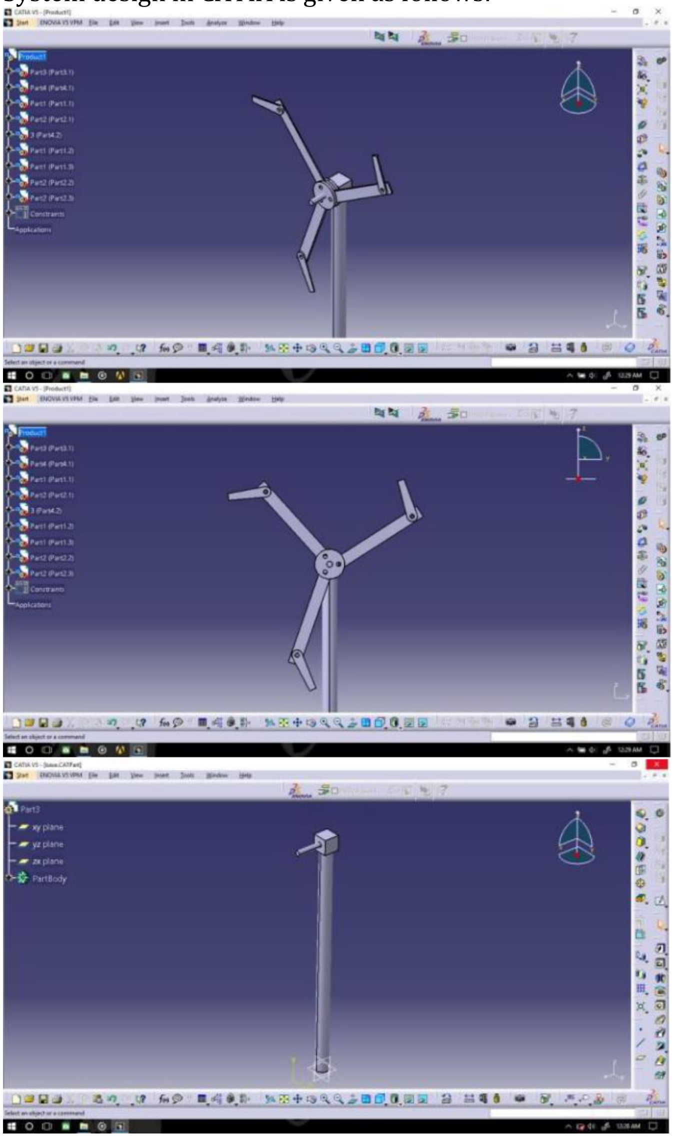


Fig – 1: CAD Model of windmill

### 3. Analysis and Calculation

With the use of fundamental beam bending equation anyone is able to calculate material stresses and local deflection at any point along the beam.

**Calculation:** Properties of material are taken same as that of properties of oak timber which have similar characteristics.

Rho ($\rho$) = 750 kg/$m^3$

MOR (Modulus of Rupture)= 180 MPa

Elasticity modulus= 19.7 GPa

Effective blade dimension= 75*8*2 cm

Area of Load Acting on Blade:

= (75 $*$ 8) sq. meter

= 0.069 sq. meter

Drag Force:

$$F_D = C_D * 0.5 * \rho * U * A$$

$C_D$=2.05

$\rho$=1.21 (air at 20˚C)

U= Wind velocity (m/s)

A= Surface area of blade

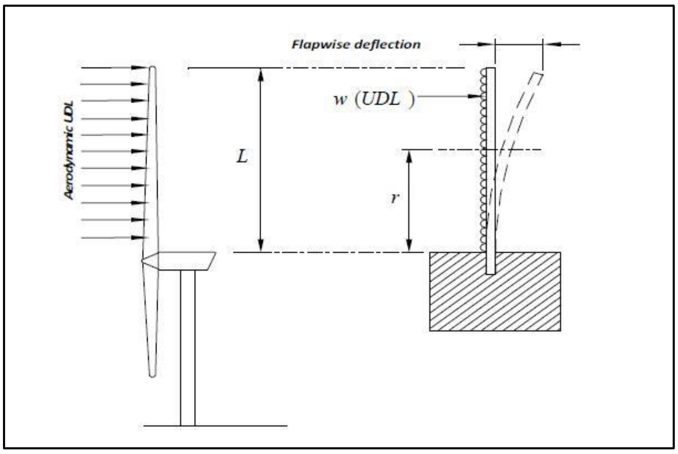



Fig – 2: A blade model uniformly distributed aerodynamic load [2]

$$F_D = 2.05 * 0.5 * 1.2 * 20^2 * 0.0655$$
$$= 32.226 \text{ N}$$
$$= 33 \text{ N (approx.)}$$

Since blade is modelled as cantilever

$$\mathrm{I} = \frac{bh^3}{12} = \frac{8 * 2^3}{12} = 5.333$$

$$\mathrm{Z} = \frac{bh^2}{12} = \frac{8 * 2 * 2}{12} = 2.667$$

Maximum Deflection:

$$\delta = \frac{wl^4}{8EI} = \frac{33 * 75^4}{8 * 19.7 * 10^9 * 5.333} = 1.243 * 10^{-3}\text{m}$$

$$\text{Strss at support} = \frac{wl}{2z} = \frac{33 * 0.75}{2 * 2.667} = 4.21875 \text{ MPa}$$

4.218 MPa is the stress occurred at root of the blade.

Since the MOR is 180 MPa, the blade will easily bear the applied loading (wind speed @20 m/sec).

Wind power generated: (@6m/s Wind speed)

$$P = 0.5 * \rho * A * V^3$$
$$P = 0.5 * 1.21 * 0.15 * 6^3$$
$$P = 19.602\ W$$

Power Density: Unit Power over unit area.

$$\frac{P}{A} = 0.6 * V^3 \text{ watts per m}^2$$

Where,

P= Power
A= Area
V= Wind velocity (m/s)

Table 1: Power Density and Wind speed

| Wind Speed (km per h) | Wind Speed (m per sec) | Power Density (W per m$^2$) |
|---|---|---|
| 1 | 0.278 | 0.013 |
| 10 | 2.778 | 12.86 |
| 25 | 6.994 | 200.939 |
| 50 | 13.889 | 1607.510 |
| 75 | 20.833 | 5425.347 |
| 100 | 27.778 | 12860.082 |

Torque produced by the turbine:

$$T = 0.5 * \rho * A1 * u^2 * r$$

Where,

ρ= density
A1= Swept area
U= wind speed
R= radius

$$T = 0.5 * 1.21 * 0.4417 * 36 * 0.75$$
$$= 7.21 \text{ Nm (Wind speed @6m/s)}$$

By calculations and design validation we constructed a small wind turbine which will maintain its efficiency in low wind speed as well as in high wind speed. The above design is creative and more efficient than the regular small windmill.

**4. Implementation and working**

In this small windmill, as the wind speed increases the blades get expanded because the centrifugal force drives the blade outwards and when the wind speed is reasonably low the blades will contract and will fall inside. As the blades gets expanded it will increase the tip speed which will indirectly will increase the efficiency of the windmill.

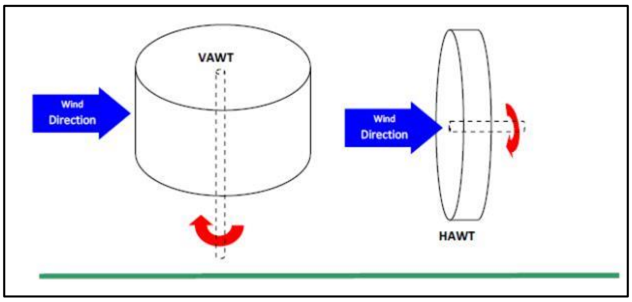
Actual model after calculations and design validation shown as follows:-

Fig – 3: Fabricated blades of windmill

Fig – 4: Actual fabricated model of windmill

Compared to the todays small windmill design, if the length of the blade is increased then there are chances of failure of blade but we have designed a small windmill in such a way that there will be two blade fixed at the ends and linked with spring as the blades will be expandable an contractible depends on wind speed. So there will be less chances of failure of windmill blades.

**Blades:** Many of the wind turbines have two blades or three blades. Wind flowing over the blade tends to lift the




blades.

Fig – 5: Working of blades windmill [2]

**Theoretical Maximum Efficiency:** For increased wind energy extraction High rotor efficiency is desirable and should be increased within the range of economical production.

$$P = 0.5 * \rho \ * A * V^3$$

Where,

P= Energy (W)
ρ= Density (kg/cubic m)
A= Cross sectional area (sq. m)
V= Wind velocity (m/sec)

**Tip Speed Ratio (TSR):** The rotor's rotational speed in relation to the undisturbed wind speed which plays a crucial role for efficiency of turbine. This is called the tip speed ratio, calculated [8] with following formula:

$$\lambda = \frac{\Omega r}{V}$$

Where,

$\Omega$= Rotational speed (rad/s)
$\lambda$ = TSR
r= Radius (m)
V= Wind speed (m/sec)

## 5. CONCLUSION

For the reason of noise, efficiency and aesthetics, the horizontal axis three blade design has an edge over VAWT in the modern wind turbine market for its capacity to work under variable load conditions.

The existing wind mills have a fixed blade length. The range of wind speed they work efficiently is very small. Wind mills are not capable rotate on their own in weak winds in contrary they shatter or breaks in the presence of very strong winds. Thus hindering electricity production.

For small wind turbine we tried to design a windmill which can expand and contract according to the wind speed and compared it with the regular one. Also it will maintain its efficiency in low wind speed as well as high wind speed.

Torque produced by the designed wind mill (7.21Nm) is more than the regular wind mill (6.15Nm), considering the wind speed of 6m/s. So it will be directly reflected in performance of the wind mill efficiency.

Small scale wind energy transformation systems are an efficient, environmentally friendly power source for hospitals, households and many more applications. This wind turbine design is able to withstand variable loading conditions like wind load, centrifugal load and gravity loads.

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