

# Vortex Bladeless Wind Energy Conversion System Mast Design

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**ABSTRACT:** Nowadays, the non renewable energy sources are gone to depth of the earth, so we obviously need to produce energy by using renewable energy source. The traditional blade wind turbine are used to produce energy but its cost is very high and it have many disadvantages like as capital cost, maintenance cost, running cost, friction loss and it is also dangerous to conventional windmills. The concept of bladeless windmill works on the theory of vortex shedding effect. Vortex bladeless windmills are a wind powered generator that generates electricity with minimum moving parts. It generates the electric current by using the oscillation or vibrations produced due to wind. Its working principle of vortex induced vibration (VIV). Hence the electricity is generated by using linear alternator or piezoelectric material. Generally structure are designed to minimize vortex induced vibration (VIV) in order to minimize mechanical failures. But in this project work we try to increase the vortex induced vibration with maximum deflection and most suitable geometry of bladeless windmills which is used to produce electricity with experimental and geometrical approach.

**KEYWORD:** Vortex induced vibration (VIV)

## I. INTRODUCTION

There are two ways of producing the energy from windmill which is through rotational windmills and oscillation windmills. In rotational windmills the rotating turbine blades are mounted to shaft of gearbox is used to convert the rotational energy of blades into mechanical energy and this mechanical energy is used to run the generator. The generator is used to convert mechanical energy into electrical energy in suitable form.

Oscillation type windmills are used to produce less amount of electrical energy that's why it is not used in commercial application. Its main advantages is that it has less moving parts, less space is required for installation, light in weight and cost is also less because it is bladeless and gearbox is also absent. When body is interacting with the external flowing fluid have some velocity then the body produced the motion is nothing but the VIV. When a fluid is passed on the object then VIV is produced vibration is perpendicular direction with the object.

In the oscillation type windmills the most suitable geometrically aerofoil shape is cylindrical. The cylinder produces the effect of VIV because of its symmetry along its centreline. As some velocity of air is passing on cylinder which is placed vertically it starts to oscillate in the horizontal direction due to air force or velocity of air and which is hanging by a spring or any supporting elements like light rod. In our design because of wind flow the mast of the wind mill vibrates and VIV develops, by this vibration the magnet and coil placed inside the mast will also vibrate and a voltage developed in the coil and this voltage is considered as the output electricity.

## II. RELATED WORK

The main aim of this project is to effectively conduct design, analysis and experimental of vortex bladeless windmill. The study focuses on effective design of mast, maximize the deflection of bladeless windmill which is used to produce electricity in future with experimental and geometrical approach. A 3D model of system is developed in ANSYS to determine the required results the analysis is done by using ANSYS 16.0 software.

The VIV bladeless wind turbine consists of a relatively long cylinder that is either flexible or mounted on a flexible structure exposed to air flow. We consider for BWTs that differ in the shape of the cylinder and its mounting structure. In BWTs the periodic shedding vortices in the air flow along the z direction induced vibration in the y direction. The

amplitude of the vibrations is considerable when the frequency of vortex shedding is close to the structural natural frequency that is known as lock in phenomenon.

- BWT1: A right circular flexible cylinder
- BWT2 : A conic flexible cylinder
- BWT3 : A right circular rigid cylinder mounted on a flexible beam
- BWT4 : A conic rigid cylinder mounted on a flexible beam

1. BWT1

In BWT1 the turbine is a uniform rigid cylinder that can be modelled as a clamped free Euler Bernoulli beam exposed to air flow. Considering the distributed aerodynamic force expression on the beam element then the equation of motion is expressed by Euler Bernoulli equation as:

$$\frac{\partial^4}{\partial x^4} (EIY(x, t)) + \rho_s \frac{\partial^2 Y(x, t)}{\partial t^2} = \frac{1}{2} \rho V^2 DC_L(x, t)$$

Equation 1: Equation of motion

2. BWT 2

Consider BWT2 the turbine is a tapered conical flexible cylinder attached to the ground similar the previous section the equation of motion is derived based on the Bernoulli beam theory as

$$\frac{\partial^2}{\partial x^2} \left[ EI(x) \frac{\partial^2}{\partial x^2} Y(x, t) \right] + \rho_s A(x) \frac{\partial^2 Y(x, t)}{\partial t^2} = \frac{1}{2} \rho V^2 D(x) C_L$$

Equation 2: Equation of motion

3. BWT 3

It consists of a flexible stand and a rigid mast. The flexible stand enables the BWT to vibrate while the mast causes the vortex shedding and generates an oscillatory aerodynamics force. In this configuration the aerodynamic forces on the stand can be neglected because it is relatively narrow. Hence to study the lock in phenomenon the stand can be modelled as a clamped free Euler Bernoulli beam. The effect of mass and inertia of the mast and the distributed fluctuating lift force on the mast can be replaced by a resultant point force and a resultant point moment on the tip of the stand.

4. BWT 4

BWT4 a conical rigid cylinder mounted on a flexible beam the configuration is similar to BWT3 except for the shape of the mast which is changed to conic shape. The conical shape of the mast enhances the lock in phenomenon over a wider range of wind speed.

### III. METHODOLOGY

The area Kuttikkanam is selected for calculating dimension of vortex mast and according metrological conditions of Kuttikkanam getting the average yearly velocity is 3m/s. According to this data vortex tube was designed. Let we consider a Tapered cylinder

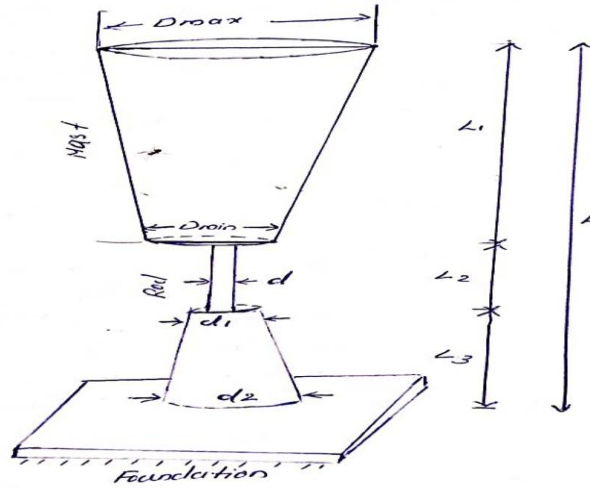


Fig: 1 Numerical model of mast

Consider the notation as follows

$D_{max}=200\text{mm}$

$D_{min}=60\text{mm}$

$d=20\text{mm}$

$d_1=40\text{mm}$

$d_2=60\text{mm}$

$L_1=1000\text{mm}$

$L_2=150\text{mm}$

$L_3=300\text{mm}$

$L=1450\text{mm}$

Mean Dia (D) =  $(D_{max}+D_{min})/2$

=  $(200+60)/2$

= 130mm

Taper ratio (Rt) =  $L_1/(D_{max}-D_{min})$

=  $1000/(200-60)$

= 7

$L_1/D = 1000/130$

= 7.6

Now from research paper we studied that the taper ratio lies between 7 to 9 so from data we consider 7 as taper ratio (Rt).

Static structural analysis of vortex bladeless windmill is carried out by ANSYS 16.0 software to determine deflection values of the windmill. The static structural analysis done on two different materials for the comparison study. The selected two materials are

1. Carbon alloy steel
2. PVC

Material	Density	Modulus of elasticity	Tensile strength	Bulk modulus	Thermal expansion
Carbon alloy steel	$7.85\text{g/cm}^3$	200GPa	635 MPa	140 GPa	$11.7 \times 10^{-6} \text{ m/m}^\circ\text{c}$

Table 1 : Properties of carbon alloy steel



Material	Density	Modulus of Elasticity	Tensile strength	Bulk modulus	Thermal Expansion
PVC	1.38 g/cm <sup>3</sup>	0.00300-4.83 GPa	52 MPa	4.7 GPa	50.4*10 <sup>-6</sup> m/m*c

Table 2 : Properties of PVC

**IV. SIMULATION RESULT**

**In the case of carbon alloy steel**

For static structural analysis we have to calculate the load applied on the surface of mast,  
 The weight of the steel tube is calculated to be around 22.195Kg so by converting it to Newton we get load = 22.195\*9.81=217.737N  
 Therefore  $w = 217.737/1000$   
 $= .217 \text{ N/mm}$

The moment of inertia for circular pipe is found out to be 2898119.22 mm<sup>4</sup>

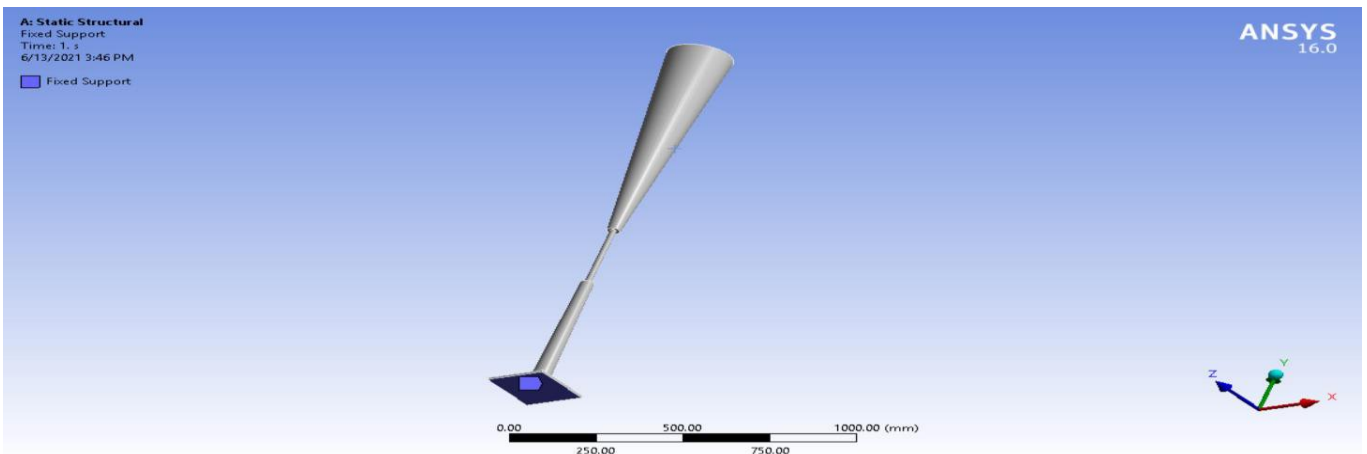


Fig2 : Assembly drawing

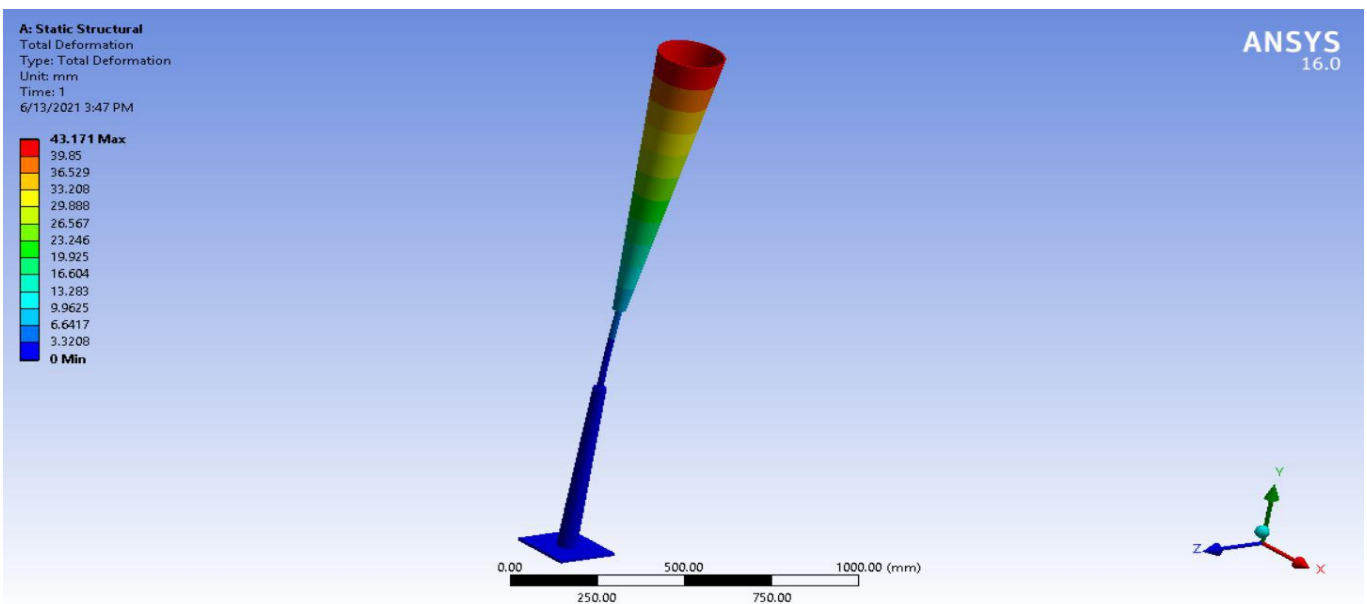


Fig 3: Total deflection

Maximum Total Deformation = 43.171 mm

Minimum Total Deformation = 0 mm

**In the case of PVC**

The weight of the PVC tube is calculated to be around 2.55 Kg so by converting it to Newton we get load= 2.55\*9.81= 25 N

Therefore  $w = 25/1000 = 0.025 \text{ N/mm}$

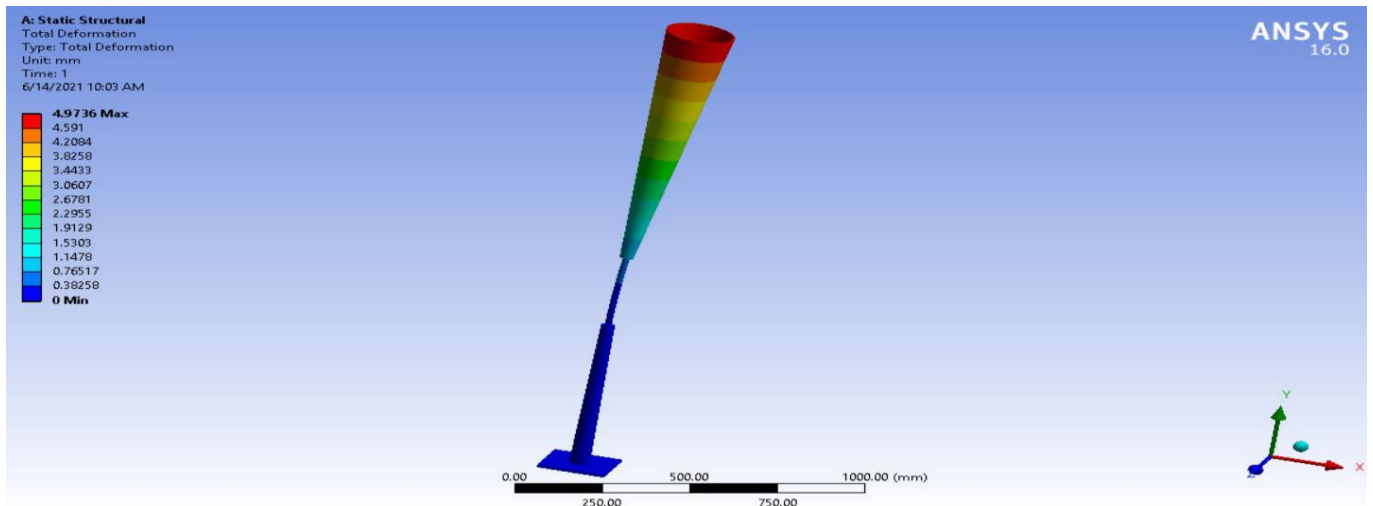


Fig 4: Total deformation

Maximum Total Deformation = 4.973mm

Minimum Total Deformation = 0mm

Various models can be used for the production of mast of a vortex wind turbine but in this project we are modelling the best and most efficient design for producing maximum electricity with minimum lift force, by the help of fig 2.1.2 and fig 2.1.3 we can conclude that in low wind speed the right circular flexibility mounted turbine BWT3 can deliver a high power while in high wind speed the conical flexibility mounted turbine BWT4 has a better power output.

For the production of vortex wind mill the suitable geometry and accurate dimensions are necessary by the help of mathematical calculations and ANSYS software we found that BWT4 is better geometry, by this equations

- Mean Dia =  $(D_{max} + D_{min}) / 2$
- taper ratio =  $L1 / (D_{max} + D_{min})$
- $(L1/D) = (L1/D_{max})$

we can find the accurate dimensions for the mast.

We got deflection of carbon alloy steel and PVC by the help of static deformation analysis

Carbon alloy steel maximum deflection = 43.171mm

Minimum deflection = 0mm

PVC Maximum deflection = 4.973 mm

Minimum deflection = 0 mm

**V. CONCLUSIONS**

From the above results, the carbon alloy steel is the most suitable material for manufacturing of vortex tube because it gives maximum deflection. By comparing static analysis results the deflection of carbon alloy steel is greater than the PVC. The maximum deflection of PVC is 4.973mm but the maximum deflection of carbon alloy steel is 43.171 mm, but carbon alloy steel is not easily available and high expensive. If we select carbon alloy steel for the production the production rate will be high because it needs several operations to change its shape. PVC is easily available and not much expensive compared to carbon steel. PVC can change its shape very easily there is no any need of special treatments, so in this project we are taking PVC as our material for mast.

Vortex bladeless windmills are mostly used in small applications where less amount of electricity is required. It is most preferable solution as compared to conventional windmill due to it have simple in construction, easy to design, easy to



manufacture and less space required. The main advantage is that it requires low maintenance cost because of less moving parts. For future use of this project work we can use this type of windmill for home appliances or where less amount of electricity is required.

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