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DESIGN AND ANALYSIS OF BLADELESS WIND TURBINE

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Abstract - *The efficiency of renewable energy sources has increased dramatically in recent years, and wind power has been one of the biggest responsibilities. The growing demand for electricity has led several countries to turn to renewable energy sources, and wind power is one of the related energy sources, and the demand for wind turbines that produce energy efficiently has started to increase. It would be very useful to develop new wind turbines if they could mimic the properties that make photovoltaics one of the most important energy sources in the distributed energy sector. In terms of large-scale wind power, offshore technology (turbines installed at sea) is very promising. The aggressive nature of the marine environment, particularly the corrosion of moving mechanical plant parts, is one of the many problems encountered in marine areas.*

If there is a device that can harvest wind energy without major maintenance, mechanical parts such as gears, bearings, etc. become an important advantage. The oscillations or vibrations produced by the wind are used to generate electric current. How Vortex Induced Vibration (VIV) works. Therefore, electricity is generated using permanent magnets and copper coils.

***Key Words*: Renewable resources, Bladeless Wind Turbine, Vortex Induced Vibration.**

1.INTRODUCTION

In the 21st century, the main problem faced by various countries like India and China is the growing population with enormous electric energy demands which require excessive use of primary energy resources (coal and fossil fuels) to fulfill the energy demands with a destructive strike to the environment by the form of air pollution. in such conditions where energy is the prominent key for development and a constant hole for the non-renewable energy reserves, and with no other resources to cope with the energy requirement a massive energy deficiency is imminent. But due to more and more advancements in the sector of renewable energy, Society can generate clean energy without harming and environment and can generate energy with the resources easily available in the surroundings such as solar energy, wind energy, tidal energy, etc.

The research mainly focuses on the use of wind energy to generate electricity. Major products that use wind energy are wind turbines. The most basic picture for wind turbines is the three blades spinning and energy being generated with the help of a motor, the most recent advancement shows energy can be produced without any help of blades on the turbine or a bladeless wind turbine. The basic principle remains the same use of wind energy to produce electricity but producing much higher energy and with a different mechanism than the traditional way of energy generation.

The bladeless wind turbine uses the vibrational energy generated by the wind to produce energy. The bladeless wind turbine consists of a tapered frustum pole called the "mast" and a rod which connects the base and the mast to support and develop pulsation for the eddy currents which will be generated by the alternating system in the base of the turbine. When the wind current strikes the mast it produces a to and fro motion for the mast and one end of the mast is fixed and supported with the rod which is connected to the base to other end being free and subjected to shear force by the wind which will lead to oscillations. The Kinetic energy generated by the mast is transformed into electrical energy with the help of a Permanent Neodymium Magnets and Copper Coils. The way that the energy conversion system works is that when the air flows around the mast creating vortices of air, when resonance occurs between the mast and the air it starts to oscillate leading to generation of electricity with the help of energy conversion system.
Renewable energy sources have been receiving increasing attention in recent years due to their potential to address the energy crisis and reduce greenhouse gas emissions. Among the various forms of renewable energy, wind energy is one of the most promising sources. Traditional wind turbines have been used to harvest wind energy, but they have some limitations such as high noise levels, bird and bat collisions, and visual impacts. To overcome these limitations, researchers have been exploring

alternative wind energy harvesting technologies such as bladeless wind turbines.

[1] It conducted a study on bladeless wind power generation and discussed the advantages of this technology over traditional wind turbines. They presented a design and simulation of a bladeless wind turbine and discussed its working principle. [2] It conducted a parametric study of energy extraction from vortex-induced vibration (VIV), which is a phenomenon that can occur when a structure is placed in a flowing fluid. They investigated the influence of different parameters on the VIV response of a cylinder and presented a methodology for designing a VIV-based energy harvesting system. [3] uses finite element analysis to investigate the vortex-induced response of multistory rectangular buildings. The study focused on the effects of different geometrical parameters on the vortex shedding and vortex-induced vibrations of the building. [4] studies the vortex-induced vibrations for energy harvesting and discussed the potential of this technology to harvest energy from the wind. The study focused on the vortex-induced vibrations of a circular cylinder and presented a mathematical model for predicting the energy harvested from the vibrations. [5] investigated the influence of taper ratio on vortex-induced vibrations of tapered cylinders in the cross-flow direction. They presented experimental results and discussed the effects of different taper ratios on the VIV response of the cylinder. [6] presented a study on fluid-structure interaction in high-performance computing multi-code coupling. The study focused on the development of a coupling framework for simulating fluid-structure interactions and presented a numerical simulation of a cantilever beam in a flow field. [7] presents a study on the generation of electricity using a bladeless wind turbine. They conducted an experimental investigation of a prototype bladeless wind turbine and discussed the performance of the turbine in different wind speeds. [8] presented a design analysis and prototype of a vortex bladeless wind turbine. They discussed the working principle of the turbine and presented a simulation of the turbine's performance.

Overall, these studies demonstrate the potential of alternative wind energy harvesting technologies such as bladeless wind turbines and VIV-based energy harvesting systems. The studies also highlight the importance of understanding fluid-structure interactions for designing efficient wind energy harvesting systems.

2. Experimentation and Methodology

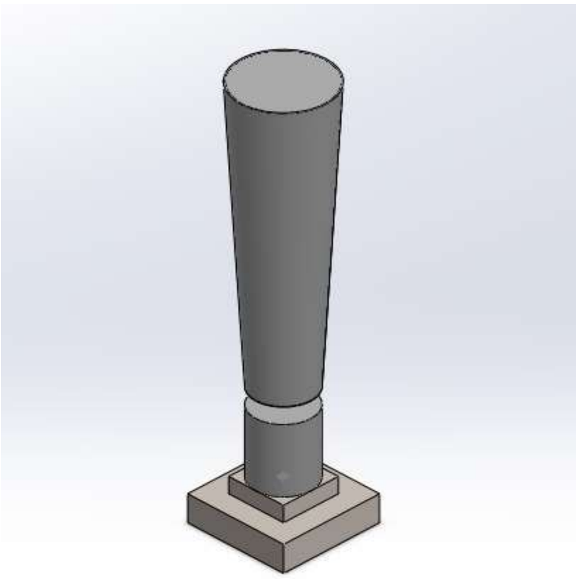
Vortex Bladeless is a vortex-prompted vibration resounding breeze generator. It saddles wind energy from a peculiarity of vorticity called Vortex Shedding. Bladeless innovation comprises of a hollow frustum fixed upward with a vertical flexible rod. The chamber oscillates on a breeze range, which then produces power through an energy conversion framework. As such, a wind turbine isn't a turbine. A bladeless wind turbine catches the energy from the wind by a reverberation peculiarity delivered by a streamlined result called vortex shedding. In liquid mechanics, as the breeze goes through a dull body, the stream is changed and produces a recurrent example of vortices. When the recurrence of these powers is sufficiently close to the body's primary recurrence, the body begins to waver and goes into reverberation with the breeze. This is otherwise called Vortex Actuated Vibration (VIV).

Vortex Shedding is a wavering stream that happens when a liquid, for example, air or water streams past a feign (rather than a smoothed out) body at specific speeds relying upon the size and state of the body. In this stream, vortices are made at the rear of the body and separate occasionally from one or the other side of the body. Vortex shedding behind a round cylinder. In this activity, the stream on the different sides of the cylinder is displayed in various varieties of colors, to show that the vortices from the different sides substitute.

The model is shown in Fig.1. The system is designed with a cylindrical cone tapering down from top. The frustum is created in purpose for efficiently directing the wind downward. The wind acting in the downward direction makes the linear component rotates. The inner surface is arranged in a circular way to create a vortex. The system has different modes of oscillation. The most commonly used geometrical shape for modeling vortex bladeless is a tapered or non-tapered cylinder as it is the best alternative to produce the vortex shedding property of fluid flow and the oscillation is produced because of its simple aerodynamic shape [1].

The manufacturing of the cylindrical air foil is easy using any material and the design using the same and also an unambiguous task. Glass fibre is a composite material of glass fabric and polyester resin. It requires less lift force since the weight of the glass fibre is less, allowing for reaching natural frequency oscillations at lower velocity. On comparing the two materials, glass fibre can resist both compressive and tensile forces as well. Glass fibre is easily available and lower cost than carbon fibre. Special machining process can be avoided, and it can be manufactured into number of geometric shapes, thus contributing to its feasibility as an air foil material. For these reasons fibre material is selected for the mast design and nylon is selected as rod material due to its flexibility, light weight, and easy availability.[1]

The Methodology is that the basic demand for a project, because of it defines the right begin and conditions for the work to be done. Correct designing and execution of the workflow decide the successful completion of the project. Methodology of the study can comprise the event of the planned style of vortex bladeless turbine for 2nd and 3D model victimization SolidWorks and pure mathematics sketching in Ansys Fluent. The CFD simulation is then run in each style of model. Throughout this technique, the 2nd model analysis is solely a solid circle (plan view). This is to grant a more robust understanding of acting the CFD simulation and relate it with world events.



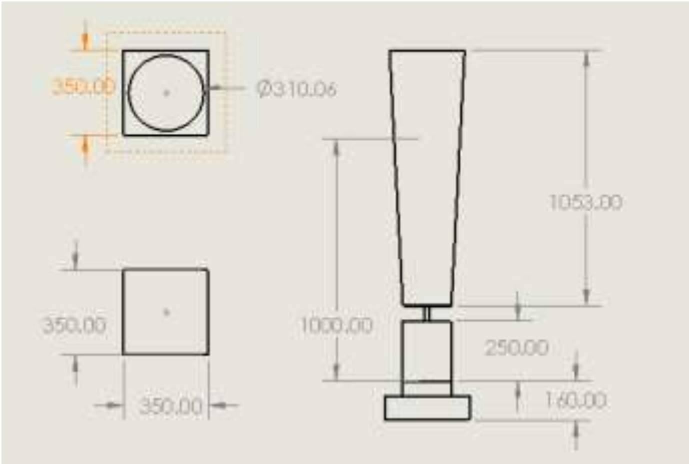


Fig-1.(a) 3d CAD of BWT
(b) 2d Sketch Model of BWT

3. Mathematical Formulation

The formula of Pressure is Force upon Area, in which Pressure P is acting on the mast of the turbine, Force acting on the Mast of the Turbine is F, and Area of the Mast Frustum is A,

$$P = F/A \quad (1)$$

Force F can be calculated by the formula given below,

$$F = 0.5\rho u^3 DLC \quad (2)$$

Where,

ρ = Density of air in Mumbai = 1.225 Kg/m^3,

C = Coefficient of lift force = 0.6,

D = Average diameter of the mast = 260mm,

U = Average velocity of air in the given region = 4.2 m/s,

Let's Substitute the values above in Eq.(2),

After substituting the values in the formula above we get,

$F=0.5 \times 1.225 \times 4.2^3 \times 0.25 \times 2.25 \times 0.6 = 6.37$ N ~ 7N.

Mast frustum area can be calculated by the given formula below,

$A= \pi \times r \times L= 0.82m^2$,

Where,

r = average radius of the frustum

L = length of the mast

On substituting the values area is obtained as approximately 10^6 mm2.

Substituting the values of F and A in Eq. (1) gives a pressure as approximately.
8.57 Pa.
Formula of Taper Ratio for Mast Frustum,

Taper Ratio (R_t) = $\frac{L}{Dmax+Dmin}$ = 1.35 / 0.32 + 0.2 = 3

The Length of the Bladeless Wind Turbine is considered to be 1350mm.
Mean Dia. (D) = $\frac{Dmax+Dmin}{2}$ = 320 + 200 / 2 = 260mm.

Deflection can be calculated as,
For glass fibre,

Value of Young's Modulus is, E=76 N/m^2,
Moment of Inertia, I=5 kgm^2,

Total Height of the turbine, L=1.35m,

Weight can be calculated as, W= mg = 1kg x 10Nm^2/kg^2
Therefore,

Deflection= $\frac{WL^3}{3EI}$ = 10 x 1.35^3 / 3 x 76 x 5 = 0.0215m = 21.5mm
Calculation of Power Output:
$P(v) = 1/2\rho A v^3$

ρ = air density at the wind turbine (kg/m^3),
A = area covered by the oscillating mast (m^3),
v^3 = wind speed cubed (m^3/s^3).
Theoretically Calculated Power Output values:

Velocity	Power Output
2.2m/s	5.3W
3.2m/s	16.45W
4.2m/s	37.21W
5.2m/s	70.62W
6.2m/s	119.7W
7.2m/s	187W

Table 1. Power Output Table

Material Properties:

Material	Density (g/cm^3)	Tensile Strength (MPa)	Compressive strength (MPa)	Thermal Expansion (μm/m* °C)
Glass Fiber (Mast)	1.79	3445	1480	5.4
Nylon Rod (Connecting Rod)	1.14	40-100	6-162	14
Stainless steel 304 (Base)	7.8-8	514	170-310	17

Table 2. Material Properties

3.1. Analytical task

The average velocity in Mumbai is 4.2 m/s. According to this data we found from the internet we can use it for the analysis. We can consider the various notations of the turbine as follows,

Dmax = Maximum Diameter of the Mast of Turbine = 320mm

Dmin = Minimum Diameter of the Mast of Turbine = 200mm

D = Average Diameter of the Mast of Turbine = 260mm

d = Diameter of the connecting rod = 20mm

L1 = Height of the Mast = 1050mm

L2 = Height of the rod = 1000mm

L = Total Height of the Turbine = 1350mm

U = Average Velocity in Mumbai = 4.2m/s

4. Results and Discussions

The results show that glass fiber is a better material for manufacturing of the model of Bladeless wind turbine as it shows great physical properties better than other materials. After reading various articles and research paper, we found out that increasing the height of the turbine increases the deflection as well as the power generating capacity too. Deflection of the turbine can be obtained by static structural analysis of the turbine after applying 8.57MPa of pressure on the mast frustum surface by considering air velocity as 2.2m/s.

The bladeless wind turbine is used mostly in areas where electricity demand is less. The bladeless wind turbine is easy to design, construct and manufacture and needs less maintenance compared to traditional wind turbines. It has various applications in various sectors.

Structural Analysis was done on ANSYS 2021 software.

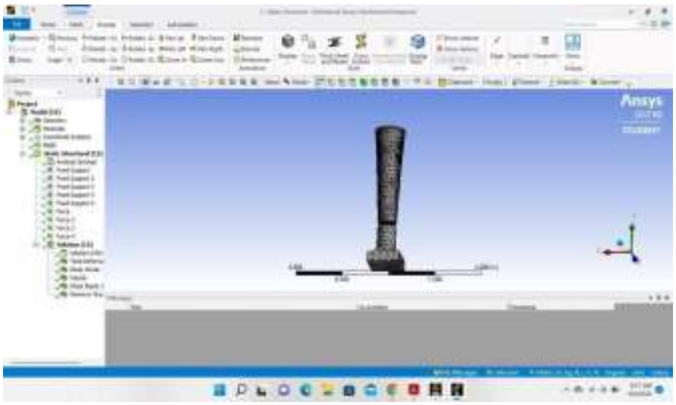


Fig 2. Meshing of BWT

In Fig 2. Meshing is done of the 3D model of the bladeless wind turbine on the ANSYS 2022 software.

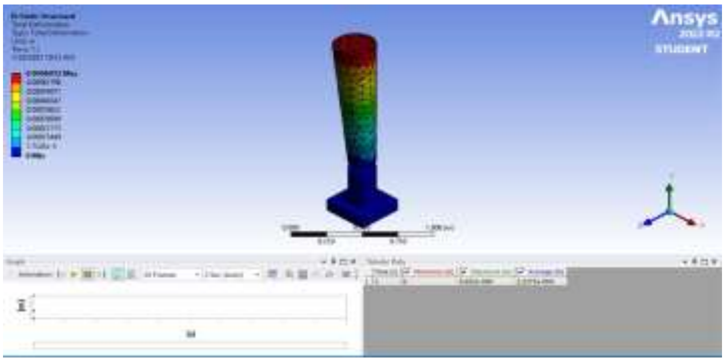


Fig 3. Total Deformation Analysis of BWT

In Fig 3. Total Deformation of the Bladeless Wind Turbine was found after applying certain parameters such as wind speed v = 4.2m/s. We get $6.95e^{-4}$ m Max. Total Deformation.

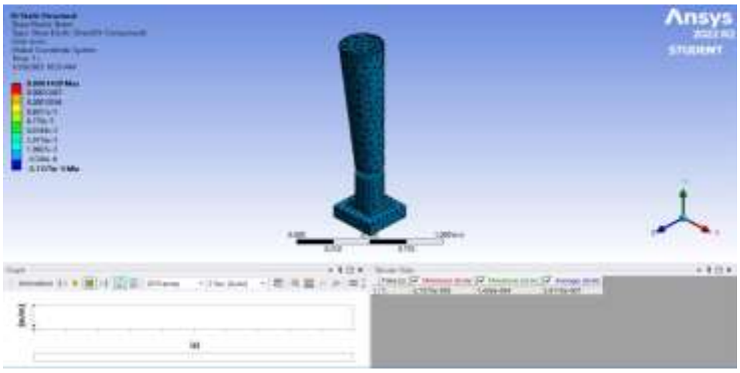


Fig 4. Shear Stress Analysis of BWT

In Fig 4. Shear Stress of the Bladeless Wind Turbine was found to be $1.43e^{-4}$ m/m Max after the analysis.

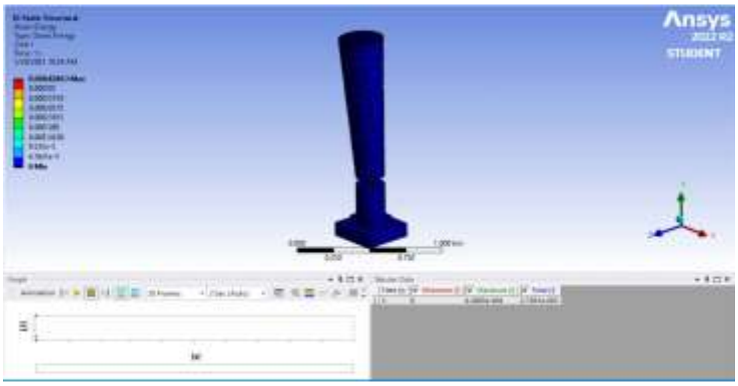


Fig 5. Strain Energy Analysis of BWT

In Fig 5. Max Strain Energy of the Bladeless Wind Turbine is found to be $4.28e^{-4}$J after the analysis.

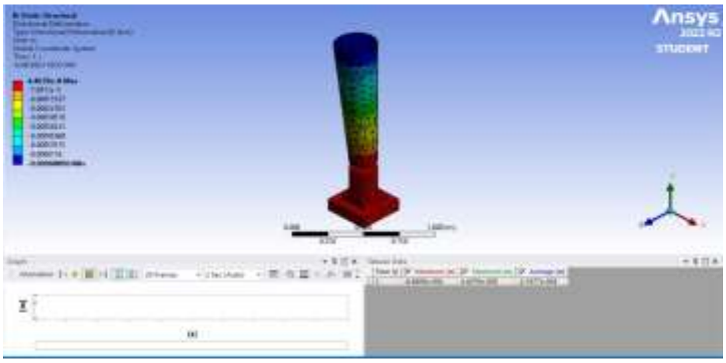


Fig 6. Directional Deformation Analysis on BWT

In Fig 6. Which represents the directional deformation of the BWT we get Max directional deformation as $4.408e^{-8}$m.

5. Conclusion

In conclusion, the design and analysis of the vortex bladeless wind turbine has demonstrated its potential as a viable alternative to traditional wind turbines. By eliminating the need for blades, this innovative design reduces the risk of wildlife fatalities, noise pollution, and maintenance costs. The vortex-induced vibration phenomenon, which allows the turbine to harness energy from the wind through oscillations, has been thoroughly studied and optimized to improve energy efficiency. Despite some challenges, such as the need for stable wind conditions and the limitation of power output, the vortex bladeless wind turbine presents a promising solution for sustainable energy generation. In synopsis, the generation of power is made feasible by the little construction of a bladeless turbine. Profoundly efficient power is created. This undertaking will fulfill the requirement for nonstop age of power. This project utilizes less space thus exceptionally efficient for the electrification of rural India.

Further research and development are needed to optimize its design and address its limitations, but the potential benefits make it a worthwhile area of study for future renewable energy technologies.

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