Design and Analysis of Bladeless Wind Turbine

Nithin *Badri*[1], Vamshi *Peddolla*[1], Hutchinson *Gottumukkala*[1], Jyothi *U.S.*[1] and Aparna *S*[1]

[1]Department of Mechanical Engineering, Gokaraju Rangaraju Institute of Engineering and Technology, Hyderabad, Telangana 500090, India

Abstract. The idea of bladeless windmills is based on the vortex shedding effect hypothesis. A wind-powered generator with the fewest moving elements is the vortex bladeless windmill. The oscillation or vibration caused by the wind is used to generate the electric current. As a result, piezoelectric material or a linear alternator are used to generate electricity. In this project effort, we attempted to increase the vortex-induced vibrations of the turbine built of Epoxy Carbon UD (230GPa) by altering the design of the mast and base. The maximum deflection is 0.22775m (condition 7) at 10 m/s^2 acceleration.

1 INTRODUCTION

India is moving closer to becoming a global superpower right now. Coal cannot supply the required amount of energy. It is anticipated that the coal reserves will run dry in a few years. Solar power is the next option for meeting the demand, but it's lesser concentration per unit area makes it more expensive. The capacity of wind power in India ranks fifth in the world.[1] Putting in place traditional wind turbines has limits to areas with high wind speeds. One such idea is the Bladeless, which uses the vortex-shedding phenomenon to capture energy. Structures are designed to minimise vortex vibrations to lower mechanical failures. [2] Vibrations are build to change over vortex vibrations into power. The ability to predict a system's produced power without spending money is another important concern in renewable energy systems.[3] VBT is one of the most recent bladeless turbines that experts have suggested, and it heralds the start of a huge industry revolution. Many researchers worldwide have started experimental and research investigations to enhance VBT because this type of turbine does not have the drawbacks that the turbines of the previous generation did.[4] Problems involving fluid-structure interaction include the application of forces to a solid entity that is malleable by a fluid. The solid body deforms as a result of these forces, altering the flow of the fluid. Due to the complexity of this interaction, numerous intriguing physical events appear.[5] The present idea aims to use wind and vibration to generate power, however this will be challenging given that air has a lower density than other fluids like water.[6] (VIV)Vortex induced vibrations are oscillations that the body experiences because to an external fluid flow.

*Corresponding author: aparna.siripuram@gmail.com

As an illustration, consider the VIV of a cylinder that is submerged in air that is travelling at a specific speed and striking the cylinder perpendicular to its centre axis.[7] The effectiveness of renewable energy sources has significantly increased over the past few years, with wind energy playing a crucial role. similar to the generators used to capture wave energy.[8] The cylinder oscillates in response to the wind, producing power via an alternator. A completely new methodology is used by bladeless wind turbines to harness wind energy. Wind shears off the downwind side when it passes one of the cylindrical structures.[9] Oscillation-type windmills produce less electrical energy than other types, which is why they are not used in commercial applications. Its key benefits include having fewer moving components, requiring less installation area, being lightweight, and costing less because it lacks a gearbox and blades.[10]

1.1 Product architecture and components

The main part of the project is a turbine, which has shaft bearings and an electrical generator attached to one end of the shaft. The generators are connected to the control panel via wires, which also connect the controller, battery, and converter to the standard for switching between DC and AC.

1.1.1 Mast

Fiberglass and carbon fibre make up the light circular section structure. Due to the mast's role as a windbreaker, the turbine oscillates there instead of tuning by creating moment and displacement.

1.1.2 Rod

While minimizing energy loss, the rod gives the moment strength and flexibility.

1.1.3 Generation system

The kinetic energy of the wind is transformed into electricity via a motor coupled to the rack-and-pinion mechanism.

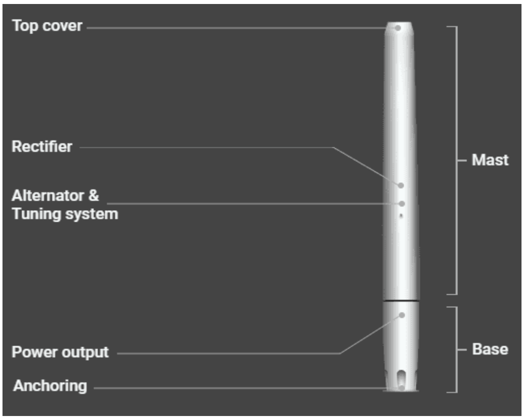

Fig. 1. Vortex bladeless turbine architecture and components

1.2 Vortex shedding effect

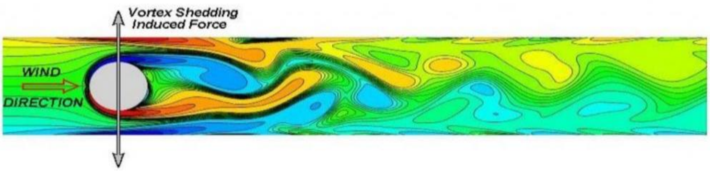

Fig. 2. Vortex shedding effect

Mechanical engineering makes extensive use of the non-linear resonance phenomenon known as vortex-induced vibration (VIV). For instance, it can be observed in civil engineering constructions like tall buildings, power lines, bridges, and thin chimney stacks. Due to its potential to substantially jeopardise structural integrity or performance dependability, VIV is typically seen as a negative impact. But as this study shows, it is possible to use large vibration to draw valuable energy from the surrounding flow. Vibration Caused by a Vortex A fluid's pressure shifts from free steam pressure to stagnation pressure as it moves towards a bluff body's leading edge. When the flow speed is low or when the Reynolds number is low without turbulence, the pressure on the bluff body's two sides stays symmetric. As the flow speed reaches a crucial number and the pressure on both sides of the bluff body becomes unstable, a regular pattern of vortices known as vortex street or Kármán vortex street appears. Z Both liquid and air flow can be controlled using this method. The boundary layer will split at some point along the surface of the body depending on the specific surface shape. This split layer that connects the wake and the free stream will probably produce fluid rotation because its outer side, which is in contact with the free stream, flows faster than its inner side, which is in contact with the wake. As a result of this spin, distinct vortices are produced, shed from the back of the body, and proceed down the wake. In the flow behind the body, a vortex street, or pattern of periodic, alternating vortex shedding, is frequently observed. Because the pattern of shed vortices is not symmetrical about the body, any vortex street has an irregular pressure distribution on the upper and lower sides of the body. A net lift force that is perpendicular to the flow direction is thus produced. Because the vortices are constantly shed, the lift forces that are placed on the body change over time as well, which can generate oscillatory motion.

2 EXPERIMENTAL WORK

2.1 Numerical model

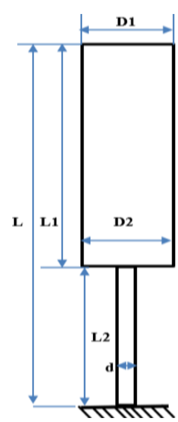

Fig. 3. Figure showing the dimensions of the design

D1 – Upper Diameter
D2 – Lower Diameter
L1 – Length of Mast
L2 – Length of Rod
L – Total Length
d – Diameter of Rod

 https://doi.org/10.1051/e3sconf/202339101040

2.2 Experimental Procedure

The vortex bladeless windmill model is analysed using ANSYS 16.0 software to calculate the windmill's deflection values.

Table 1. Loading conditions

Definition	
Type	Hydrostatic Pressure
Applied By	Surface effect
Coordinate System	Global Coordinate System
Fluid Density	1.2 kg/m^3
Hydrostatic Acceleration	
Define By	Components
X Component	10 m/s^2(ramped)

Table 2. Conditions and dimensions of design model

		CONDITIONS									
		Existing dimensions	**Decreasing minimum diameter**			**Changing the length of both mast and rod**			**Increasing the length of rod**		
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
PARAMETERS AND THEIR DIMENSIONS (MM)	**D1**	200	200	200	200	200	200	200	200	200	200
	D2	200	120	100	80	100	100	100	100	100	100
	L1	2000	2000	2000	2000	1750	1500	1250	1500	1500	1500
	L2	250	250	250	250	500	750	1000	1000	1250	1500
	L	2250	2250	2250	2250	2250	2250	2250	2500	2750	3000
	D	20	20	20	20	20	20	20	20	20	20
DEFLECTION(m)		0.1697 M	0.19 39m	0.19 96m	0.20 52m	0.20 81m	0.21 77m	0.22 77m	0.21 17m	0.20 38m	0.20 69m

The above values are the deflection values of turbine under various conditions from Ansys.

3 RESULTS AND DISCUSSION

1. The table below shows the different parameters of maximum deflection design. These are the desired design parameters.

Table 3. Maximum deflection parameters and dimensions

PARAMETERS	DIMENSIONS
D1	200
D2	100
L1	1250
L2	1000
L	2250
d	20
MAXIMUM DEFLECTION (m)	0.22775 m

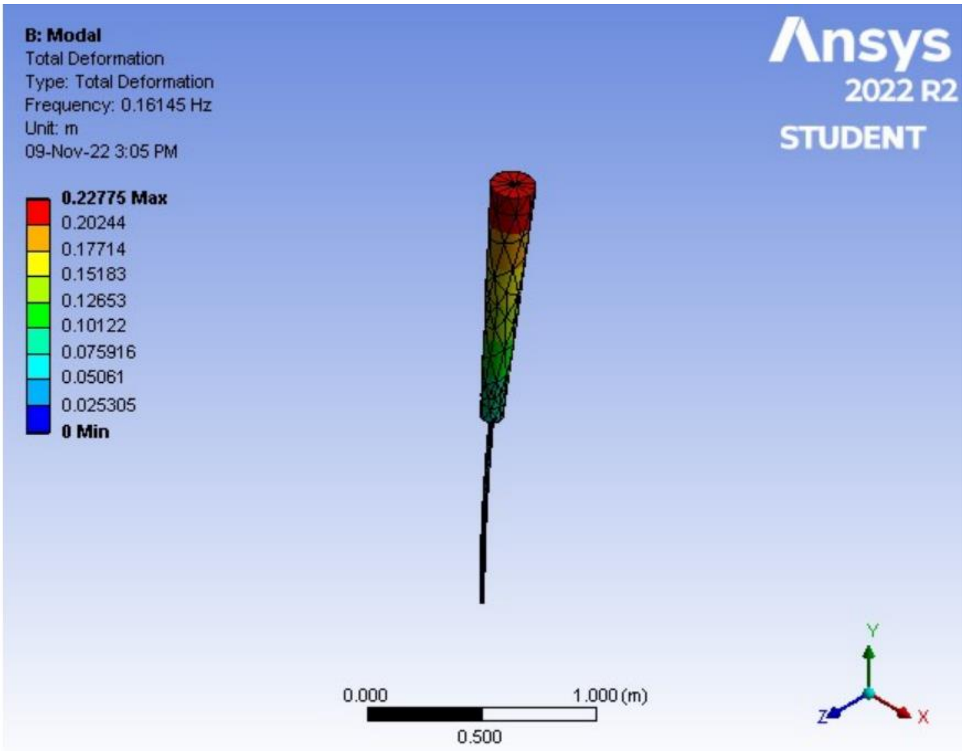

Fig. 4. Figure showing maximum deflection - 0.22775m at condition 7 from ansys analysis

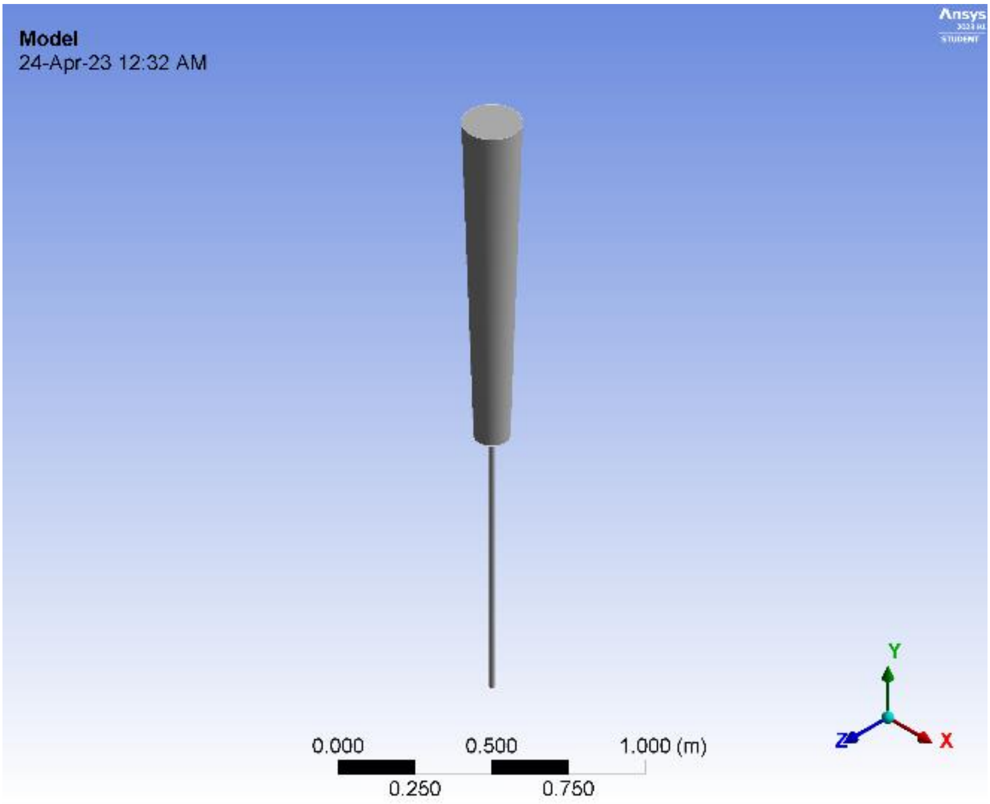

Fig. 5. Figure showing the final model of the design analysis

2. The vertical mast made of Epoxy Carbon UD (230GPa) of dimensions concluded in Table 5 gives maximum deflection of 0.22775m (condition 7) at 10 m/s^2 acceleration.
3. In comparison to conventional wind turbines, the bladeless variant produces energy at lower wind speeds and uses less area while also being very inexpensive.

4 CONCLUSIONS

The turbine made of epoxy carbon UD (230GPa) with the dimensions from Table 5 is the one that lends the greatest deflection, according to the aforementioned data, making it the most suited for the creation of vortex tubes. It has been discovered through experiments that the maximum deflection is greater, i.e. The majority of applications for vortex bladeless windmills are modest and call for little electricity. Due to its ease of manufacture, ease of design, and need for less space than a conventional windmill, it is the most preferred alternative. Because there are fewer moving components, the key benefit is that maintenance costs are reduced. This type of windmill can be used for home appliances or other applications where less electricity is needed in the future as this project progresses.

References

1. J.Mendina, M.Draper, M.Usera, ‘‘Simulation of vorticity wind turbines, Heliyon’’, **22**, 6–26, (2020)
2. BlayanSantosh Fernandes, ShreeramaP R, ThilakRaj, “ The vortex-shedding phenomenon to capture bladeless Wind Power Energy Genertion”, **9**, 5-6 (2016)
3. GauraoGohate, Abhilash Khairkar, Sameer Jadhav, “The capacity of wind power in India ranks fifth in the world”, **11,** 3, (2016)
4. BanafshehSeyed-Aghazadeh, Yahya Modarres-Sadeghi, T. Senior, A. Alderson, “ Vibrations are build to change over vortex vibrations into power ”, **5**, 8-10, (2014)
5. Barrero-Gila, Santiago Pindadob, Sergio Avilac, “Extracting energy from Vortex-Induced Vibrations: A parametric study”, **7**, 41-43, (2012)
6. Cajasa, G. Houzeauxa, D.J. Yanezb, M. MierTorrecillaa, “ Problems involving fluid-structure interaction ”, **14**, 46, (2020)
7. Giosan, P. Eng., “ The idea aims to use wind and vibration to generate power ”, **8**, 6, (2015)
8. SvendOle Hansen, “Vortex induced vibrations of structures’’, **16**, 5-20, (2007)
9. T. Senior, A. Alderson,‘‘ The generators used to capture wave energy’’, **8**, 25-36 (2014)
10. Hildingsson, S. & Westin, T., ‘‘Yawing system for adjusting a wind turbine renewable energy sources’’, **16**, 91-98, (2016)
11. World watch Institute, “Renewables 2005: Global Status Report prepared for the Renewable Energy Policy Network, Washington DC ”, **11**, 5, (2005)
12. D. Patel, "Impact of Wind Turbine Generators on Network Resonance and Harmonic Distortion," Electrical and Computer Engineering (CCECE), 2010 23rd Canadian Conference on, pp. **1**, 25-32, (2010)
13. Williamson, Charles HK, and R. Govardhan, "Vortex-induced vibrations.", **36**, 413-455, (2004)
14. Harshith, K., and Blayan Santosh. "Bladeless wind power generation." International Journal of Scientific Research and Development 3, **4**, 66-73, (2016)