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RESEARCH PAPER ON BLADELESS WINDMILLS BASED ON THE PRINCIPLE OF VIBRATION

Engineering

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ABSTRACT

The bladeless windmills uses a radically new approach for capturing both intermittent wind energy pulses and constant wind flow under specified wind velocity and pressure. The windmill utilizes the energy of vorticity, an aerodynamic effect (vortex shedding).As wind strikes a fixed structure, its flow changes and a cyclical pattern of eddies or vortices are formed in the vicinity of the structure. As these forces go strong, the structure starts vibrating. Consequently, these aerodynamic instabilities can be utilized to run a linear alternator or a crankshaft. The natural frequency of the structure should not match with the frequency of vibration, which is one of the design criteria, our design takes care of this major criteria. The design of our windmill is entirely different from a traditional windmill. Instead of the huge tower, nacelle and blades, this device has a conical frustum mast made up of fiber-glass (pivoted at one-third length from bottom), a crankshaft, a crank, a connecting rod and a hinge joint. The hollow and light weight mast makes this device portable and user-friendly. Also, this low cost components opens a way for low cost renewable source of energy.

KEYWORDS:

Bladeless windmills, Vortex, Pollution, spring, dynamics of machinery.

1. INTRODUCTION

In the 21st century, secondary (usable) energy resources has become indispensable part of societies' needs. Also, one of the major problem faced by many developing countries like India and China, is that of pollution, air pollution being the major one. The wide gap between supply and demand for energy resources is required to be met in near future where the paucity of fossil fuels is imminent.

In Bladeless windmill, mass of the 'mast' and the elasticity of the 'spring' makes it a vibrating system. This turbine harnesses vorticity, the spinning motion of air or other fluids. When wind strikes the conical mast, flow of the wind gets sheared off because of the obstruction and thus causing vortex or eddies currents to form. This vortex then exerts force on the mast, causing it to vibrate. The kinetic energy of the oscillation can be converted to electrical energy via linear alternator.

The construction of the bladeless windmill is quite simple. The conical mast is pivoted vertically with the help of through cylindrical rod held within in a roller bearing in such a way that it can vibrate in only one direction. The portion below the point of pivot is covered with the help of a metal sheet so that the necessary moment is generated by wind force striking the projected surface area above the pivot. The upper section of the mast flutters in the wind while a crank rod is connected at the lowermost point on the mast (100mm above the edge from design) via hinged joint (rolling contact joint).

The crank rod is connected to a crank shaft which is allowed to rotate freely and supported on the roller bearing in the housing.

2. HISTORY OF BLADELESS POWER GENERATION

The idea emerged in 2002 when David Yáñez, the co-founder of a vortex bladeless startup company, saw a video of the Tacoma Narrows Bridge disaster and led him to the idea of a bladeless wind turbine. This new technology seeks to overcome issues related to traditional wind turbines such as maintenance, amortization, noise, environmental impact, logistics, and visual aspects.

3. WORKING METHODOLOGY

The bladeless windmills run on the principle that when wind is allowed to strike the column mast, it tends to vibrate and this vibrational energy is further converted to mechanical (crank shaft) or electrical energy (direct connection to alternator).

When the wind impinges on the projected surface area of the mast from one specified direction, stream lines of the wind tend to depart and get sheared off. Further passage results into the formation of wind currents called vortices or eddies. When they are strong enough to overcome the internal resistance offered by the mechanism (crank shaft or direct linear alternator), the mast vibrates due to spring connected at outside surface of the mast. The then spring is connected to the foundation seat. The connecting rod is bound to transmit this vibration to the crank. The crank shaft can be connected to a generator further. We can also connect the lower end of the mast with the linear alternator directly.

Obviously, we can use a rectifier circuit to transform this A.C. current to D.C. current and charge a battery or connect it the load.

4. EXPERIMENTAL CALCULATIONS AND SPECIFICATIONS

Mast:

Larger Radius of the mast, $R_1 = 0.125$ m
Smaller Radius of the mast, $R_2 = 0.0625$ m
Height of the mast, $L = 1$ m

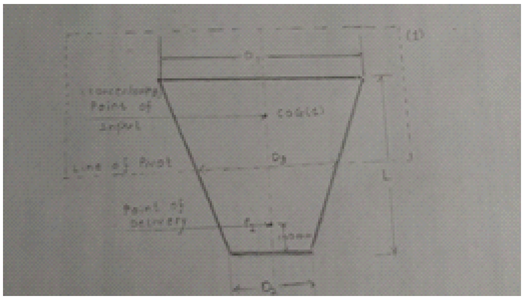


Figure : POINTS ON MAST

Lateral Surface area of the mast (open), $S=\pi \times (R_1+R_2)\times L$
$= 3.14\times(0.0625+0.125)\times1.00$
$=0.5887\ m^2$

Density of the Fibre glass, $\rho=1760\ kg/m^3$
Thickness of the FRP sheet, t=2 mm

Mass of the mast, $m=\rho\times S\times t$
$=1760\times05887\times.002$
$=2.068$ kg

Centre of gravity, C.G (from the bottom end)
$=1-\{h(R_1^2+2R_1R_2+3R_2^{2)}\}/\{4(R_1^2+R_1R_2+R2^2)\}$
$=1-0.39$
$=0.61$ m

Velocity of the wind, v=40 m/s (Gujarat, India)
Projected area of the mast exposed to wind,

$A= (R_1+R_2)\times l$
$= 0.1875\ m^2$

Force of the wind on the projected area,
$F_1= \rho_{air}\times A\times v^2$
$=1.225 \times 0.1875\times 11.12^2$
$=28.40$ N

Radius of the mast at the point of pivot, R_3
Applying theory of proportionality,

$R_3=R_1\times0.39$
$=0.125\times0.39$
$=0.048$ m

Centre of gravity of frustum portion above the pivot, L_1
$= h_{upperfrustom} - \{h_{upperfrustom}(R_1^2+2R_1R_3+3R_3^{2)}\}/\{4(R_1^2+R_1R_3+R_3^2)\}$
$=0.61-0.22198$

$L_1=0.388$

So, Centre of gravity of the frustum above the pivot from the bottom of the whole mast=0.338+0.39=0.778

Lower end of the mast connected to the hinge = =100 mm
Point of pivot=1/3×L   (from the bottom)
=333 mm (experimental for maximum deflection)

Net distance of Point of hinge from point of pivot $L_2= 233$ mm
Mechanical advantage

$F_1\times L_1 = F_2\times L_2$
$F_2= 28.40 \times 0.388/0.233$
$F_2= 47.29$ N

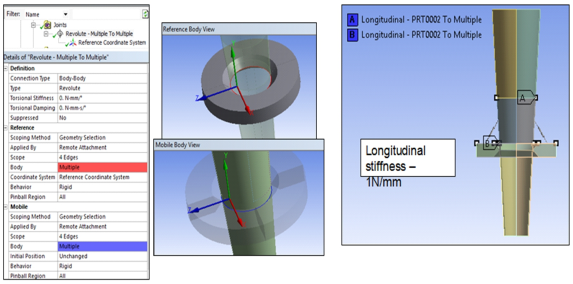
The loss at the rolling contact hinge joint and crank shaft offset is close to 10% (found by experiments)

The length of the connecting rod >>>> crank radius
And thus, effect of arc can be neglected.

The net force on the crank shaft is = 42.56 N
The crank radius is 25mm
The net Torque at the end of the crank shaft is P =0.025×42.56N
=1.06 Nm

Spring:

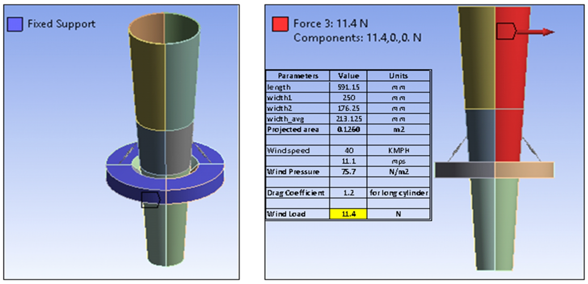
The design of the spring is based on the dynamics of machinery. The D' Alembert's principle is used to determine the natural frequency of the system. The analysis was done with the help of ANSYS software. The results are as shown:



Details of "Revolute - Multiple To Multiple"

Definition	
Connection Type	Body-Body
Type	Revolute
Torsional Stiffness	0. N·mm/°
Torsional Damping	0. N·mm·s/°
Suppressed	No
Reference	
Scoping Method	Geometry Selection
Applied By	Remote Attachment
Scope	4 Edges
Body	Multiple
Coordinate System	Reference Coordinate System
Behavior	Rigid
Pinball Region	All
Mobile	
Scoping Method	Geometry Selection
Applied By	Remote Attachment
Scope	4 Edges
Body	Multiple
Initial Position	Unchanged
Behavior	Rigid
Pinball Region	All

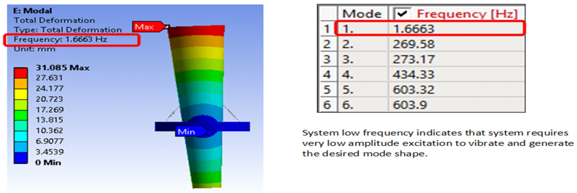
Figure 1: CONTACT POINTS



Force 3: 11.4 N
Components: 11.4,0.,0. N

Parameters	Value	Units
length	591.15	mm
width1	250	mm
width2	176.25	mm
width_avg	213.125	mm
Projected area	0.1260	m2
Windspeed	40	KMPH
	11.1	mps
Wind Pressure	75.7	N/m2
Drag Coefficient	1.2	for long cylinder
Wind Load	11.4	N

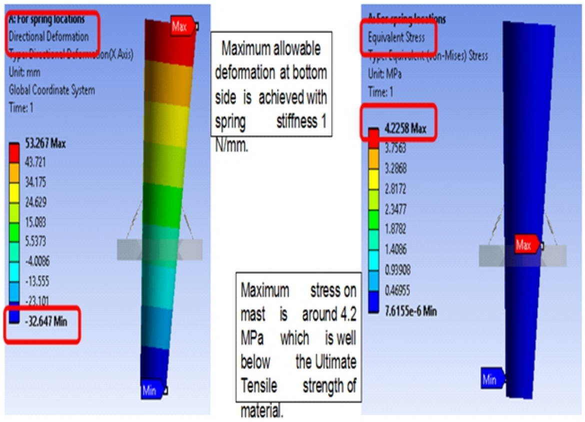
Figure 2: LOAD AND BOUNDARY CONDITIONS



	Mode	☑ Frequency [Hz]
1	1.	1.6663
2	2.	269.58
3	3.	273.17
4	4.	434.33
5	5.	603.32
6	6.	603.9

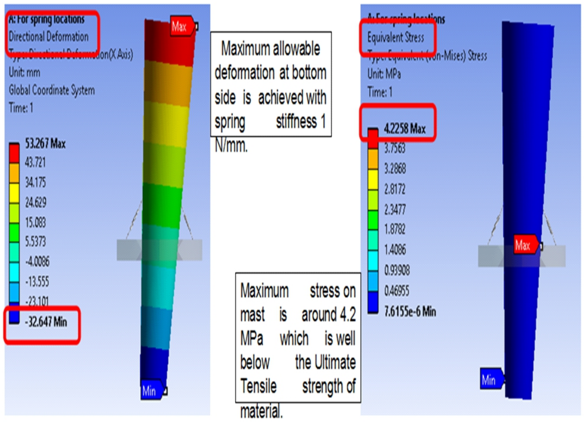
System low frequency indicates that system requires very low amplitude excitation to vibrate and generate the desired mode shape.

Figure 3: MODAL ANALYSIS-FUNDAMENTAL FREQUENCY



Maximum allowable defomation at bottom side is achieved with spring stiffness 1 N/mm.

Maximum stress on mast is around 4.2 MPa which is well below the Ultimate Tensile strength of material.



Maximum allowable deformation at bottom side is achieved with spring stiffness 1 N/mm.

Maximum stress on mast is around 4.2 MPa which is well below the Ultimate Tensile strength of material.

Figure 4: STATIC ANALYSIS

Parameters	Value	Units
Bottom Height from Pivot point	380	mm
theta (5 degree)	0.087266	Rad
Tan theta	0.087489	-
Displacement (Maximum)	**33.2**	**mm**

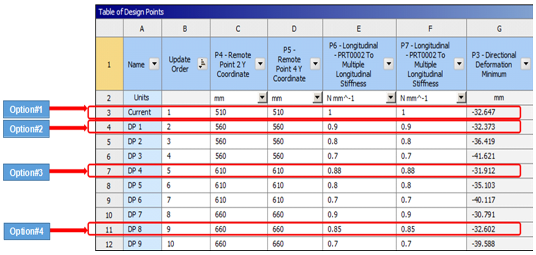


Table of Design Points

	A	B	C	D	E	F	G
1	Name	Update Order	P4 - Remote Point 2 Y Coordinate	P5 - Remote Point 4 Y Coordinate	P6 - Longitudinal - PRT0002 To Multiple Longitudinal Stiffness	P7 - Longitudinal - PRT0002 To Multiple Longitudinal Stiffness	P3 - Directional Deformation Minimum
2	Units		mm	mm	N mm^-1	N mm^-1	mm
3	Current	1	510	510	1	1	-32.647
4	DP 1	2	560	560	0.9	0.9	-32.373
5	DP 2	3	560	560	0.8	0.8	-36.419
6	DP 3	4	560	560	0.7	0.7	-41.621
7	DP 4	5	610	610	0.88	0.88	-31.912
8	DP 5	6	610	610	0.8	0.8	-35.103
9	DP 6	7	610	610	0.7	0.7	-40.117
10	DP 7	8	660	660	0.9	0.9	-30.791
11	DP 8	9	660	660	0.85	0.85	-32.602
12	DP 9	10	660	660	0.7	0.7	-39.588

Figure 5:SPRING STIFFNESS AND LOCATION

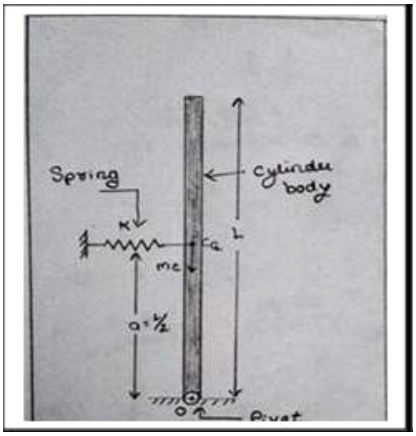


Figure .6 SCHEMATIC DIAGRAM [8]

$$wn = \sqrt{\frac{(K\ \ L^2\ \ -2Mc\ \times g\,L\ )\ /\ 4}{I}}$$

$$fn = \frac{1}{2\,\pi}\sqrt{\frac{(K\ \ L^2\ \ -2Mc\ \times g\,L\ )\ /\ 4}{I}}$$

ref.[8]

5. ADVANTAGES

The bladeless windmill does not have any sliding contact joints which reduces the frictional losses in the system thereby reducing wear and tear. The system does loose some electrical conversion capacity, but other pros nullifies this factor.

The material used in the mast is Fibre glass which exhibits high strengths and low weight. Also, The FRP sheets show high environmental resistance. Fire hardness, sound structural integrity and non-corrosive nature makes the device more portable, user friendly and cost effective with durability.

The space required by these windmills is very small. Consequently, 15 windmills can be employed within the same area where one or two conventional windmills are employed. It currently takes up 30% of the area of a conventional generator, with maximum deflection at the top end.

The components of bladeless windmills takes about 35 minutes to assemble. Which is noticeably low when compared to conventional ones.

The provision of crank mechanism and spring makes this windmill run smoothly and swiftly in comparison to other bladeless windmills.

The impact on the bird population is expected to be much smaller, because it does not require the same type of wind velocity, wind force and large area earlier deforested. Besides this. The oscillation frequency is just 14 Hz, the impact sound level is negligible making it possible in future to have noiseless wind farms.

6. DISADVANTAGES

The efficiency of the energy extraction for bladeless windmills from the wind is 40%, while that of conventional windmill is 59.3%.

Thus, it cannot substitute thermal and nuclear power plants, traditional windmills and hydroelectric power plants.

This technology is in development phase and requires huge stakes by investors.

The Major problem faced by this windmill is that it requires a starting torque.

The output power depends directly on the height of the mast.

7. APPLICATIONS

Bladeless wind energy can be used in a variety of industries and applications, including marine off-grid systems, industrial applications, remote telemetry and mobile base stations for houses, schools and farms.

Bladeless energy for agriculture: Remote power systems are needed more and more in the world of farming. Whether it's for powering electric fencing, power water pumping, powering lighting in stables and chicken shade or powering underwater cameras at salmon farms-bladeless energy can be built in small scale as well as large scale to meet the needs. Small scale bladeless wind turbine energy for households are designed to bring energy to an off grid locations and matching it with solar panels and supplement it This is cost effective for houses where solar energy production is intermittent. Also, it can be used for residential battery charging and grid connection.

Bladeless energy for telecoms: with more and more mobile communication and broadband technology being deployed in rural and remote areas, providing power for the transmission equipment can be a problem. Bladeless energy can provide off-grid power solutions needed to support telecom infrastructure.

Bladeless wind energy for off-grid lighting: small scale bladeless wind turbine generators are ideal for providing efficient and reliable lighting in off-grid locations. The bladeless energy generates free renewable energy which can be stored in battery, illuminated when it gets dark. Streets, playgrounds, parks and car parks are good examples to name a few.

Bladeless energy can also be utilized for Rail signalling: large parts of rail network lack convenient mains electricity. Bladeless wind power generators can be installed near railway signals to supply power to the signalling systems.

8. CONCLUSION

The bladeless windmills can offer promising results in near future with respect to efficiency, capacity and productivity.

This topic is a great area for research and so far the results are encouraging.

Further, developments can be done in the mechanism which is converting vibrations to electricity.

The results above are based on 1 m prototype along with ANSYS analysis software outcomes.

The purpose of this paper is to form some basis for the research in the field of renewable resources of energy in near future and be an encouragement for generations to come.

The project has five main advantages: Less space requirement, less impact on fauna, less noise, better running, multiple uses due to its portability and use in case of intermittent pulses of wind and its low cost

Moreover, some disadvantages such as starting torque requirement, low extraction efficiency can be solved with optimization and changes in design.

The use of rack and pinion, direct alternators and slotted link mechanisms can be done instead of crank mechanism.

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