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VORTEX BLADELESS: A NEW PARADIGM WIND MILL

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Abstract: - This paper discusses with need of renewable energy sources to be more feasible. The purpose of this paper is describing concept which can take place of traditional windmill in future. Vortex induced vibration is use to make compact device that is able to harvest wind and transform it into electric energy with the use of vortex shedding and piezoelectric material. This paper will focus on design constituent, working principle and CFD analysis of small prototype.

Keywords: Vortex shedding, Piezoelectric, Renewable, Prototype

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INTRODUCTION

India's increasing population and decrease in traditional resources has led to use of renewable energy efficiently. Due to this there is significant increase in renewable energy installed capacity is growing rapidly. India is the fourth largest wind power producer in the world. In 31st January 2017 the installed capacity of wind power was 28,871.59 MW, mainly spread across the South, West and North regions.[6]

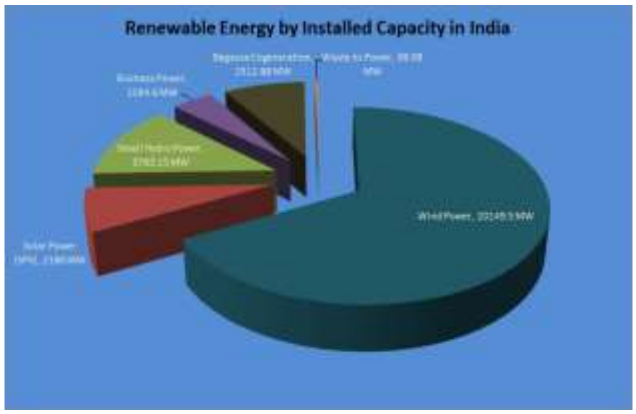


Fig 1 Renewable energy by installed capacity in India

From the above data we come to know that there is huge potential for generating power with the help of win In general, vertical & horizontal wind turbines are used for harvesting energy from the wind. These traditional wind turbines are replaced by "Vortex Bladeless Wind Mill". Vortex bladeless is a project whose objective is to develop a new concept of wind turbine without blades called vortex wind mill that uses Vortex Induce Vibration (VIV). In this, vortex induce vibration of a circular tapered cylinder is taken as a potential source for energy harvesting.

Following issue concerned with the traditional wind mill

- Conventional windmill required huge investment for assembling the part of windmill.
- It requires land/places where high velocity wind is available frequently throughout the year.
- Due long height and mostly build in open place they prove fatal to birds due to rotation of the birds.
- If not designed properly they produce low frequency noise which is bad for human health.
- Transportation of huge windmill parts is very costly and risky.

- Space required for wind mill farm is 60 acres per megawatt capacity of wind farm
- The cost of manufacturing different parts of wind mill is very high. Normal wind mill required Rs 180000-480000 per kilo watt.

2 Working principle of Vortex bladeless windmill

This concept is based on **fluid dynamics**. In **vortex-induced vibrations (VIV)** motions induced on bodies interacting with an external fluid flow, produced the motion producing periodical irregularities on this flow [7]. Due to this interacted body gets certain vibrating motion and we can harness that motion to generate power .To generate electricity with the application of VIV principle we require to convert linear mechanical motion to voltage. To harvest maximum amounts of energy from vortex induced vibration the airfoil must get expose to adequate force to cause oscillation. The force is dependent on a number of factor including the shape of airfoil, orientation of the airfoil, and velocity of fluid flow. The inclusion of this factor along with others such as weight, size, and durability will allow for the development of a feasible VIV wind harvesting device. The shape of the airfoil finds the magnitude of the force that is generated by airflow. In conventional applications, such as aircraft and land-based vehicles, airfoils are designed to generate force in one direction. This design element allows for the airfoils to be asymmetrical along a vertical cross-section, an attribute that provides the opportunity for maximum lift force generation. Conversely, an airfoil designed for a VIV harvesting device does not offer such a luxury. VIV airfoils function through the generation of lift forces in two directions perpendicular to airflow. Because of this, the airfoil must be symmetrical when analyzed through a vertical cross-section (Fig 2)

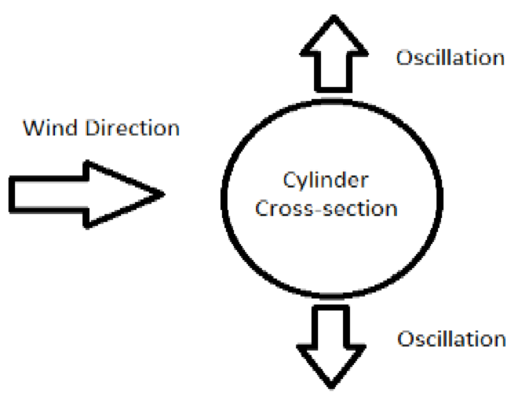


Fig 2.Working principle

The shape most commonly used for this application is a cylinder. The cylinder best utilizes the vortex shedding property of fluid flow that produces oscillation because of its simple, aerodynamic shape. The cylindrical airfoil is also easy to produce, replicate, and work with as a material component. The orientation of the airfoil determines the direction in which the lift force is applied. When horizontal, the lift force is applied vertically, and when the airfoil is vertical the lift force is applied horizontally. The difference between these two orientations is highlighted by the ability for the vertical airfoil to incur lift force from multiple flow directions. Despite this capability, the design of a vertically oriented VIV wind harvesting device yields significant complications, most notably the lack of a feasible medium to turn multi-directional oscillation into electrical energy. Because of this, the horizontally oriented airfoil is a more appropriate design choice. The determination of airfoil orientation drastically affects the nature of oscillation and the power generation capability.

The velocity of fluid flow is an independent variable that must be accounted for in the design of any wind harvesting device. In order for the device to efficiently and consistently maintain mechanical motion, whether rotational or oscillatory, the airfoil must be positioned with its chord length parallel to the fluid flow. In order to accommodate for the unpredictable and inconsistent nature of wind, the VIV device must have the capability to either rotate to face the airflow or generate oscillation from flow in a multitude of directions. This design consideration is unique to wind harvesting VIV devices, as the fixed hydroelectric VIV products would not experience operational wind flow frequently enough to be effective.

In this we will have to consider a multitude of variables when designing and constructing a VIV wind harvesting device. To maximize the efficiency and feasibility of the device, a harmonious equilibrium between dependent variables must be established, accounting for even the most unfavorable of operational conditions. With the evolution and optimization of VIV wind harvesting devices, their energy production can grow to rival the rotational energy generation of wind turbines.

3. Materials

The material form which the cylindrical airfoil is directly correlates to device performance. The most importance attributes to this project are material density, rigidity, surface finish, availability cost .By sorting out from glass fiber, carbon fiber, moldable plastic it was conclude to select glass fiber as material for the project.

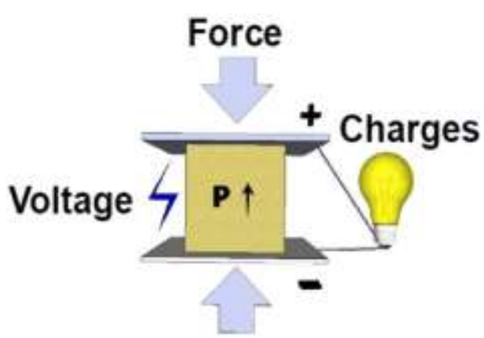
3.1Glass fiber (GFR)

Glass fiber is a composite material of glass cloth and polyester resin. As the weight of the airfoil directly correlates to the force required to induce movement, fiberglass would require less lift force, allowing for the airfoil to reach natural frequency oscillation at lower flow velocities. Additionally, fiberglass is reasonably affordable, it also does not require specialized machinery to work with, and can be molded to replicate most geometric shapes, contributing to its feasibility as an airfoil material.one of the disadvantages of glass fiber is low surface finish. To enhance surface finish of glass fiber components are sanded down to a smooth surface and then finish with a glossy resin. Due to this reason glass fiber was selected.

Properties	Value
Tensile strength	3345 MPa
Compressive strength	1080MPa
Density	2.58gram/cm^3
Thermal expansion	5.4µm/m.c̊

3.2 Piezoelectric material

Piezoelectric Materials are the smart materials which convert mechanical stress or strain into electrical potential and vice versa i.e. application of electrical potential to the material yields to mechanical displacement. While the former is known as direct piezoelectric effect, the latter is reverse piezoelectric effect. The piezoelectric material in the piezoelectric system has different modes of operation. The modes are characterized by piezoelectric strain constant, mechanical strain to electrical voltage.[1]



Fig,3 Working of piezoelectric material

4. CAD model and dimension

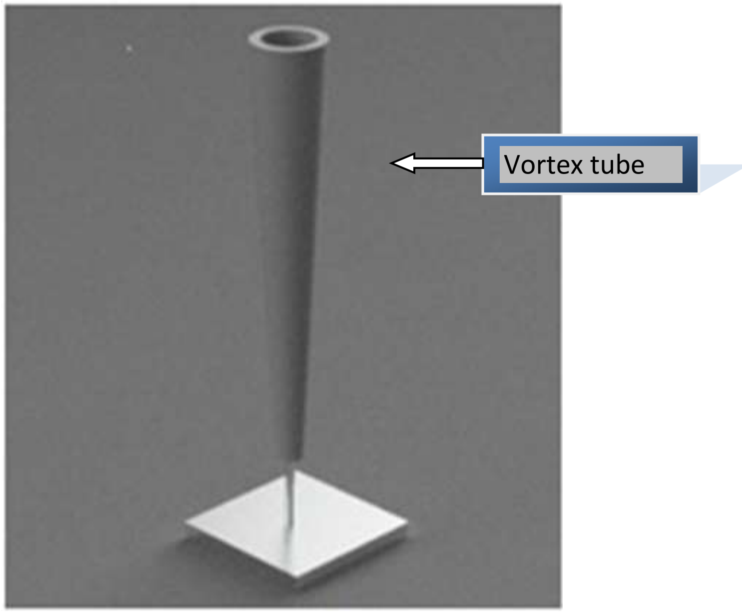


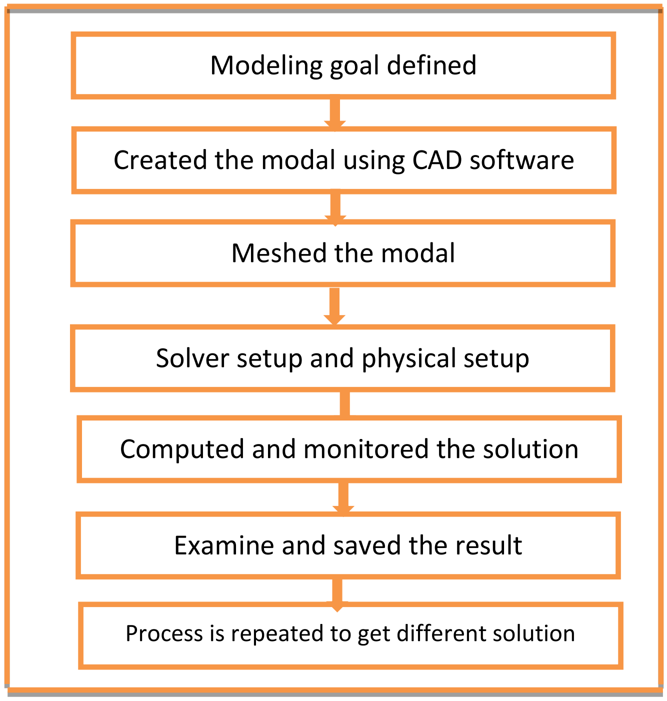
Fig 4 Cad model

For calculating dimension of vortex tube we have selected Pune as a working location. And according to Pune metrological conditions it has 3 m/s as average annual velocity. According to this data vortex tube was designed.

Dimension	Value (mm)
Dmax	200
Dmin	100
Height	2250
Rod dia	26

4.1 **CFD Analysis**

Steps of CFD analysis:



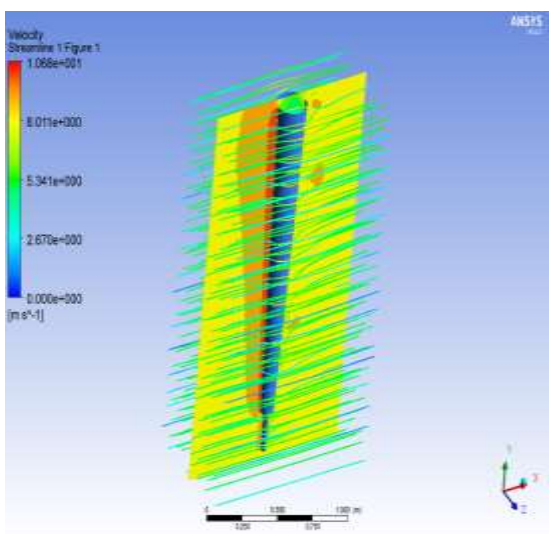
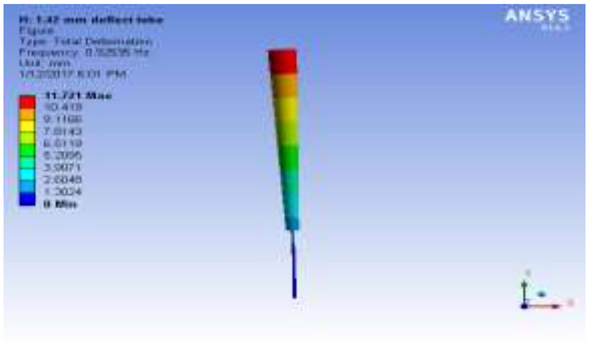
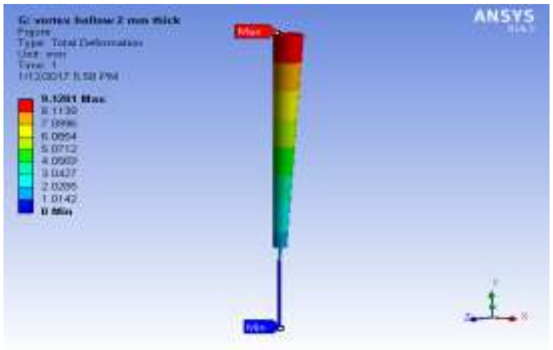


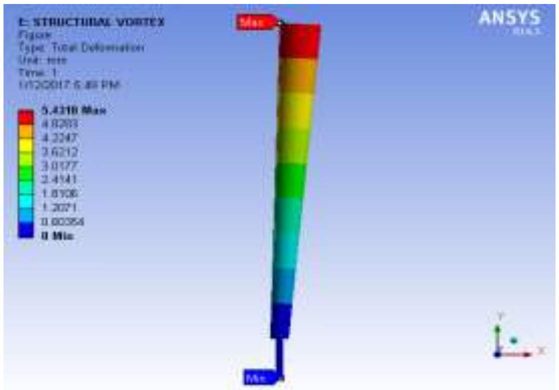
Fig 5 Streamline of wind on vortex tube



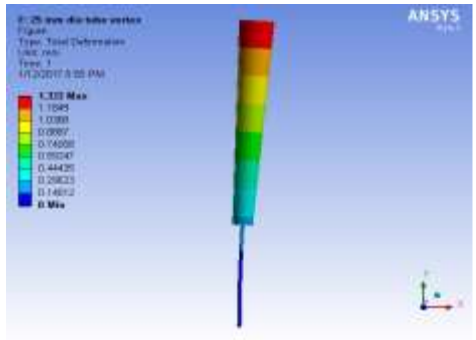
Case 1



Case 2



Case 3



Case 4

By doing CFD analysis on number of cases we have selected the model which will be giving maximum deflection due to that maximum force will be applied on the piezoelectric material and good amount of energy will be generated.

Various cases results are shown below:

Case no	Material		Deflection	
	Vortex tube	Support	Min(mm)	Maxi(mm)
1	Glass fiber	Glass fiber (solid)	0	11.7
2	Glass fiber	Glass fiber(hollow 2mm thick)	0	9.121
3	Glass fiber	Structural steel	0	5.438
4	Carbon fiber	Structural steel (25 mm dia tube)	0	1.33

5 Conclusions

The study focuses on identifying India's huge potential of energy and utilizing in effective manner. Vortex Induced vibration application in generating alternative energy can be a viable solution for all sustaining problem related to the conventional windmill. More research will be done in future t harvest maximum of energy from vortex tube. For that number of different design experiment will be done in future. Vortex bladeless can be seen as future alternative energy generator .At last we concluded that this idea is feasible and applicable at all places.

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