Design, Analysis and Prototype of Vortex Bladeless Wind Turbine

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Abstract - *The development of eco-friendly power generation has substantially improved with new advancement in renewable energy sources. To meet the energy requirements and to produce a clean energy source, we have opted an unconventional idea of wind turbine that has no blades. The idea is to convert vibration caused by tapping of the wind to electrical energy by means of a piezoelectric crystal. The Vortex Bladeless Turbine swings back and forth instead of spinning, upon the action of wind. This phenomenon is called the Vortex Shedding Effect. Usually the vibrations of mechanical components are reduced but in this case the vibrations are used to produce the output which is the major key to produce a safe and clean energy source.*

***Key Words*: Vortex Shedding Effect, *Vibration*, Mast, Piezo-electric, Bladeless Turbine**

1. INTRODUCTION

India is a country with largest costal lines. These coastal lines are the source for the wind energy but industries have their eye on burning of coal to produce electricity. Burning of coal emits carbon dioxide which would affect the environment causing acid rain, global warming. Development of wind power in India began in 1990s. At present the Indian wind energy sector has an installed capacity of 21,141.36 MW. Any improvement in efficiency will lead to more energy production. Our Vortex Bladeless Wind Turbine is an alternative for conventional wind generation process and a replacement for coal as an energy source.

2. WORKING PRINCIPLE OF BLADELESS VORTEX WIND TURBINE

The energy conversion happens in the mast, where the wind strikes the column mast shown in **Fig -1** and makes it to vibrate. This vibration is converted into electrical energy. This phenomenon is called Vortex Shedding Effect. Vortex shedding is an oscillating flow that takes place when a fluid such as air or water flows past and bluffs (As opposed to streamlined body at curtained velocities, depending on shape and size of the body). When the wind impinges on the projected surface area of the mast from one specified direction, steam lines of the wind tend to depart and get sheared off. This results into formation of wind current called vortices. Once the mast vibrates, vibration passed to the spring connected to the foundation seat. The foundation seat is fixed with the piezoelectric crystals. The piezoelectric converts vibration into electrical energy. Then electrical energy is stored in a battery. Thus the stored dc current is used to charge a battery or connect it to the load.

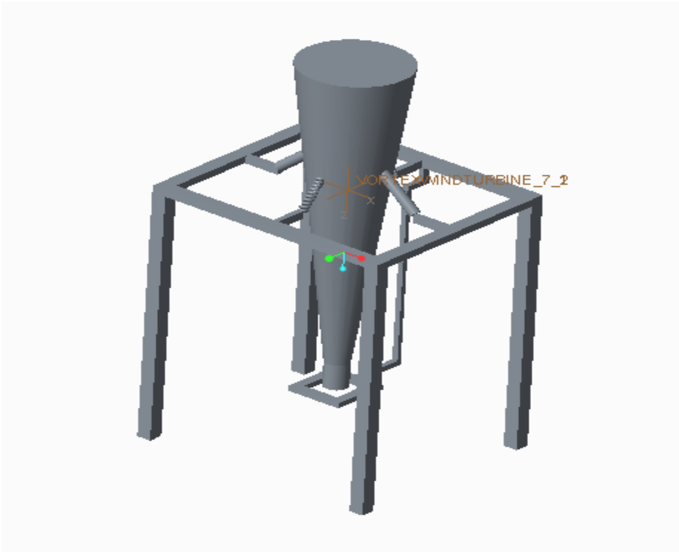

Fig -1: Vortex Bladeless Wind Turbine

3. CALCULATION

The natural frequency of the body is calculated by using torque method.

$$fn = 1/2 \; (((KL^2 - 2Mc * g\,L)/4) / I)$$

fn	-	Natural frequency
I	-	Moment of inertia of conical frustum
K	-	Spring stiffness.
L	-	Length of conical frustum.
Mc	-	Center of mass of conical frustum
g	-	Acceleration due to gravity.

3.1 MOMENT OF INERTIA

$$I = (1/3)\; Mc * L^2$$

I	-	Moment of inertia of conical frustum
K	-	Spring stiffness.
L	-	Length of conical frustum. (1.219 m)
Mc	-	Mass of conical frustum (0.7986 kg)
G	-	Acceleration due to gravity. (9.81)

$$I = (1/3)\; Mc * L^2$$
$$= (1/3) * 0.7986 * 1.219^2$$
$$= 0.395 \text{ kg m}^2$$

3.2 SHEDDING FREQUENCY CALCULATIONS

$$St = Fs * D / U$$

St - Strouhal No (0.2)
Fs - Shedding frequency
D - Diameter (0.2m)
U - Velocity of fluid (2.8 m/s)

$$St = Fs * D / U$$
$$0.2 = Fs * 0.2/2.8$$
$$Fs = 2.8$$

Therefore shedding frequency is 2.8 Hz

3.3 SPRING STIFFNESS CALCULATION

For achieving resonance, we equate the natural and vortex shedding frequency

$$(((KL^2 - 2Mc * g L)/4) / I) = fn$$

For designing a spring to sustain the high stress develop in resonance condition .It is necessary to calculate the value of stiffness under resonance condition.

$K = (4 I fs2 \times 2\pi + 2 Mc \times g L) / L^2$

$K = (4. 0.3959. 2.7999. 2 \times 2\pi + 2. 0.7986 \times 9.81. 1.2192) / (1.48645)$

$K = 50.3171$ N/m

3.4 LIFT FORCE CALCULATION

Lift force developed at the upper end of the conical frustum and coefficient of lift force C is assumed to be 0.6 based on previous study.

$$F = 0.5 \rho U 3D L C$$

ρ - Density of air
C - Coefficient of lift force

Density of air =1.225 Kg/m3
Diameter of conical frustum (D) = 0.2 m
Velocity of air (U) = 6 m/s
Length of conical frustum (L) = (1.219 m)

$$F = 0.5 \rho U 3D L C$$
$$F = 0.5 * 1.225 * 6 * 3 * 0.2 * 1.219$$
$$F = 2.687 \text{ N.}$$

Therefore, Lift force F is 2.687 N.

3.5 POWER CALCULATION

The oscillation produce by the vortex shedding is converted in to rotary motion and then into power.

$$P = KCp(1/2)\rho AV^3$$

P - Power output, Kilowatts
Cp - Max Power coefficient(0.35)
P - Air density, lb/ft³ (0.0765)
A - Rotor swept area
V - Wind speed, kmph(21.6)

$$K = 0.000133$$
$$A = \pi DL$$
$$= 3.14 * 0.656168 * 3.999$$
$$A = 8.239ft^3$$
$$P = 0.000133*0.35*(1/2)*0.0765*8.239*(21.6)^3$$
$$P = 0.1478KW$$
$$P = 147.83W$$

4. ANALYSIS

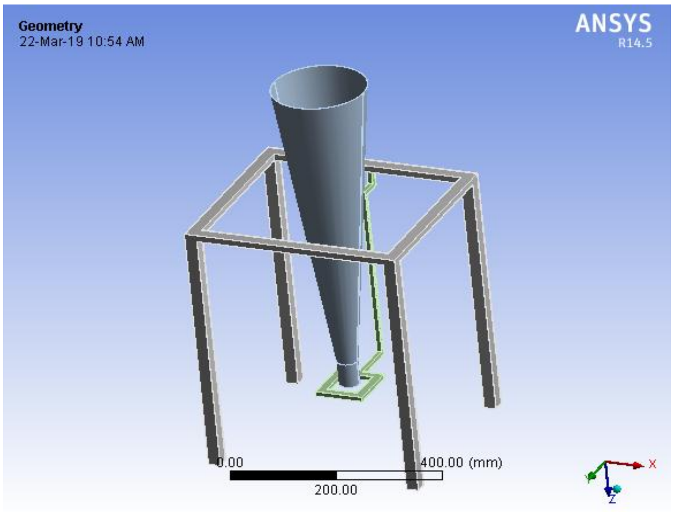

Fig -2: Geometry of Vortex Turbine

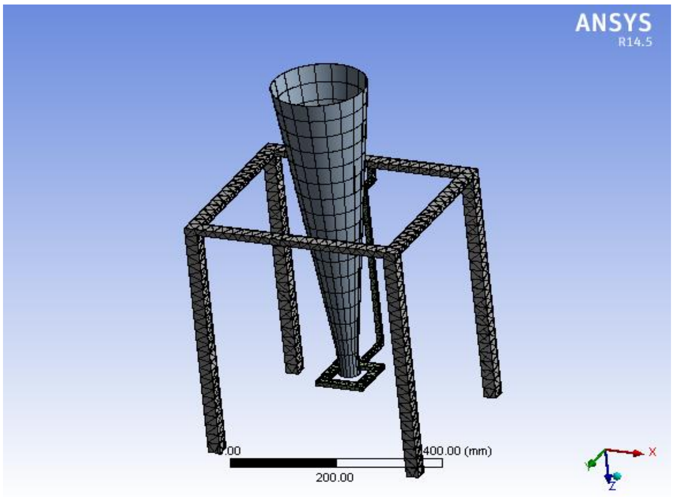

Fig -3: Meshing of Vortex Turbine

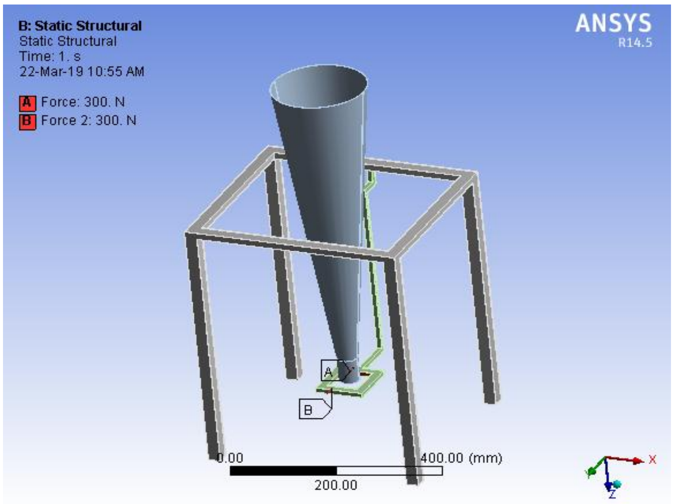

Fig -4: Loading Condition

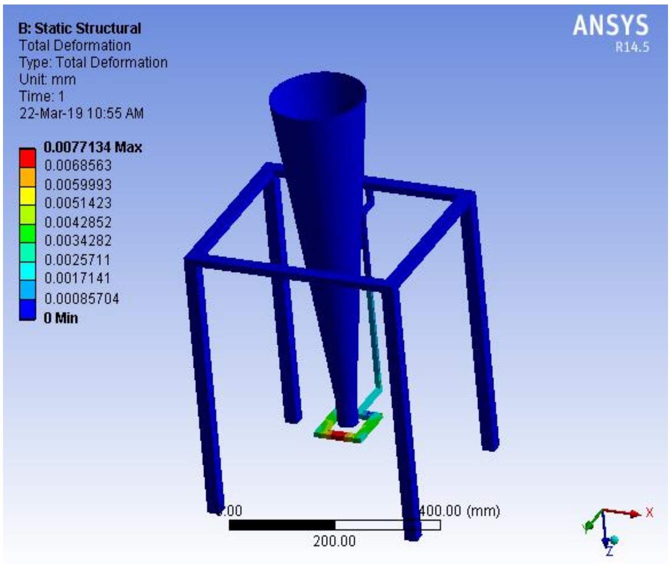

Fig -5: Deformation of Vortex Turbine

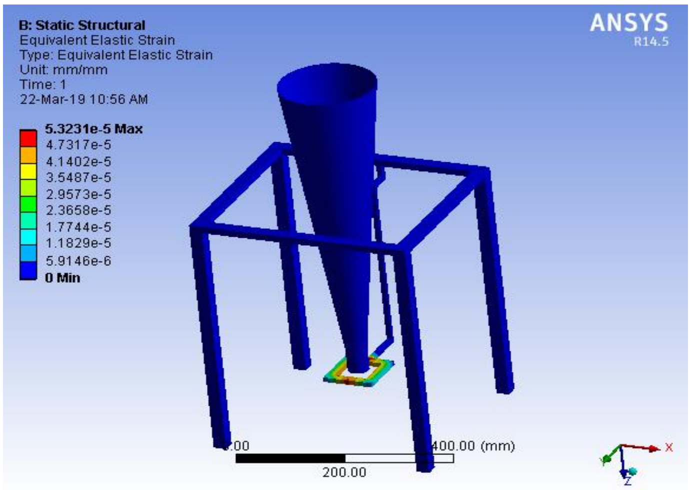

Fig -6 Equivalent Elastic Strain

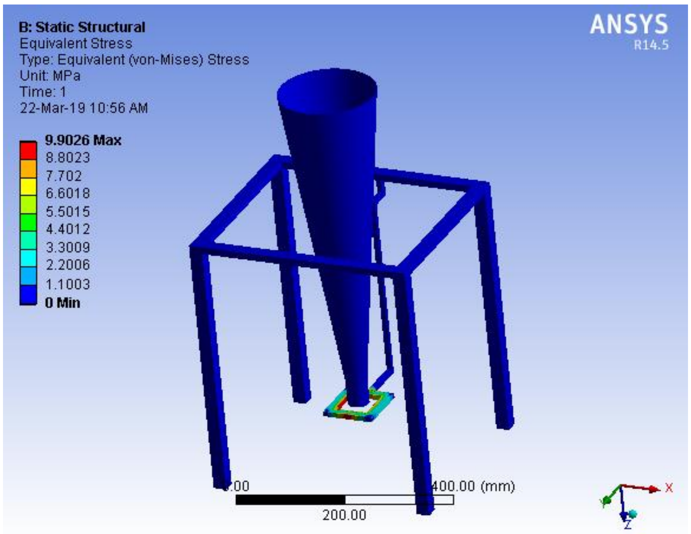

Fig -7: Equivalent Elastic Stress

In this analysis we have shown the deformation, equivalent elastic strain and the equivalent elastic stress of the Vortex Bladeless Turbine. Considering the force acting as 300N which is proportional to the velocity of wind acting on the mast.

5. PHOTOGRAPH

Fig -8: Prototype of Vortex Bladeless Wind Turbine

6. CONCLUSIONS

The growing energy demand and depleting energy resources urges the need of renewable resources. The Innovative approach to the conventional energy production is that vibration plays a major hand in the production of electricity. We convert wind energy into vibration and in turn use this as a source for producing electricity. In every other field vibration is considered as a flaw, but we have used vibration as a factor for producing eco-friendly energy. Bladeless wind energy helps us to achieve these criteria utilizing less area, Generation of high power, Economical. The project uses less space area hence highly economical for the rural electrification.

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