Design And Manufacturing Of Low Cost Blade Less Windmill

Prof. M.M. Dhere[1], Swaraj Pawar[2.1], Shivtej Pol[2.2], Vaibhav Makhar[2.3], Arjun Vhanmane[2.4]

[#]Department of Mechanical Engineering, Sinhgad Institute Of technology and Science, Narhe

[1]mmdhere_sits@sinhgad.edu

[2.1]swarajpawar17@gmail.com

[2.2]shivtejpol123456@gmail.com

[2.3]vaibhavpmakhar@gmail.com

[2.4]vhanmanearjun@gmail.com

Abstract

Power Generation with bladeless windmill gives a new approach to capturing wind energy. The device used to capture the wind energy should have a specific aerodynamics shape which responses to the wind velocity very rapidly. As the wind bypasses over a structure, its flow changes and generates a certain oscillation pattern. Once the forces are strong enough, the structure starts oscillating continuously. Instead of avoiding these aerodynamic disturbances our structure maximizes the resulting oscillation and captures that energy. Actually the design of such structure is different than the present windmills. There is no usual tower, nacelle and blades; the device has a fixed mast, a power generating transducers and a hollow, lightweight and semi rigid fiberglass mast at the top. This puts the technology at the very low capital range. It also makes it highly competitive not only against generations of energy from alternative or renewable sources, but even compared to conventional technologies.

Keywords— Vorticity, Mast, Nacelle

I. INTRODUCTION

We are stepping towards becoming a global super power. It shows that we are counting in the list of developing countries on the basis of economical development. Hence its requirement of energy is going to increase in the coming years. To meet its energy requirement, Thermal Energy cannot be the primary source of energy, this is because coal is depleting very fast. It is approximated that within few decades coal will get exhausted completely. The next choice of energy is solar power, but it has lower efficiency and it is very costly. India is fifth largest country in power generation from the wind. As the regions with high wind speed are limited, the installation of conventional windmill is limited. Windmills that would provide safe, simple, and affordable and work on lesser wind speeds are necessary to produce.

The Bladeless Windmill is a concept which works on the phenomenon of vortex shedding to capture the energy produces from it. Generally, structures are designed to minimize induced vibrations in order to minimize mechanical failures. But here, we are trying to increase the vibrations in order to convert vortex induced vibrations into electricity. The paper studies the better structure and generating more efficient energy than traditional windmill. This study also focuses on identifying the effect of governing parameters on the energy generation efficiency by vortex induced vibration.

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The parameters studied were aerodynamic profile of mast, height of structure and intensity of oscillations according to speed of mast. Some key characteristics of performance can be outlined, like the range of flow velocities (reduced velocity) where efficiency is significant.

Finally, it must be noted that however, the analysis here in presented should be seen only as an approximation to the real problem. For example, it is clear that the real vortex induced vibration situation (a complete fluid - structure interaction problem) is more complex than that of a forced vibrations one, where the body is oscillating at a fixed amplitude and frequency. This point has been largely discussed in the literature, and the question of whether forced vibration tests can be used to predict vortex induced vibration behavior has been addressed by several important investigators being still open.

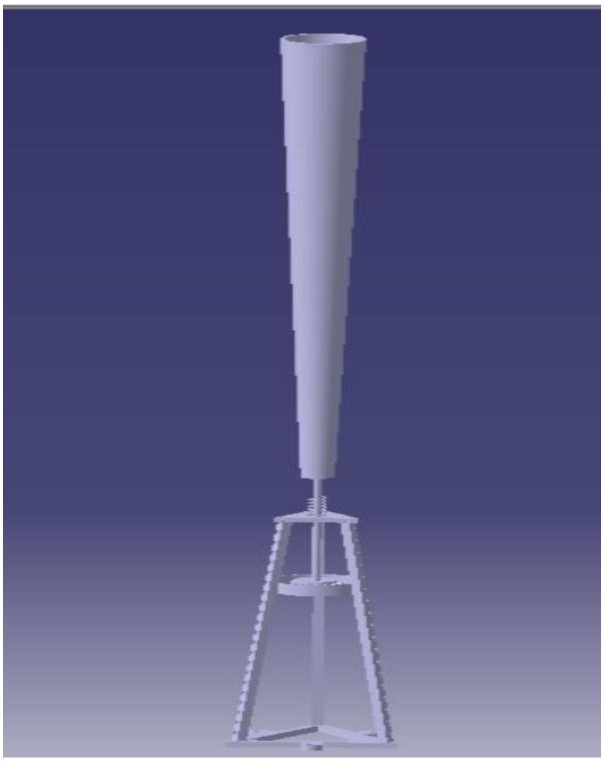

Fig.1 3D model of bladeless windmill

Morse and Williamson have studied that under carefully controlled condition there is very close correspondence between free and forced vibration experiments. With this idea in mind, we believe that results presented in this paper can be representative and, from an engineering point of view, the parametric analysis of the present study can help to efficiently design a device to extract useful energy from vortex induced vibration.

II. PROBLEM STATEMENT

Design of bladeless wind mill having catchment area 5 m^2, installation area 1.3×1.5 m^2, and power generation capacity 10 KW with wind velocity of 2 m/s at an altitude of 1840 feet.

III. COMPONENTS

Different components required for making of bladeless wind mill are:

1. Mast: Mast is a circular cross section light in weight structure made of polypropylene material. Mast breaks the wind that generates the oscillatory movement. Polypropylene

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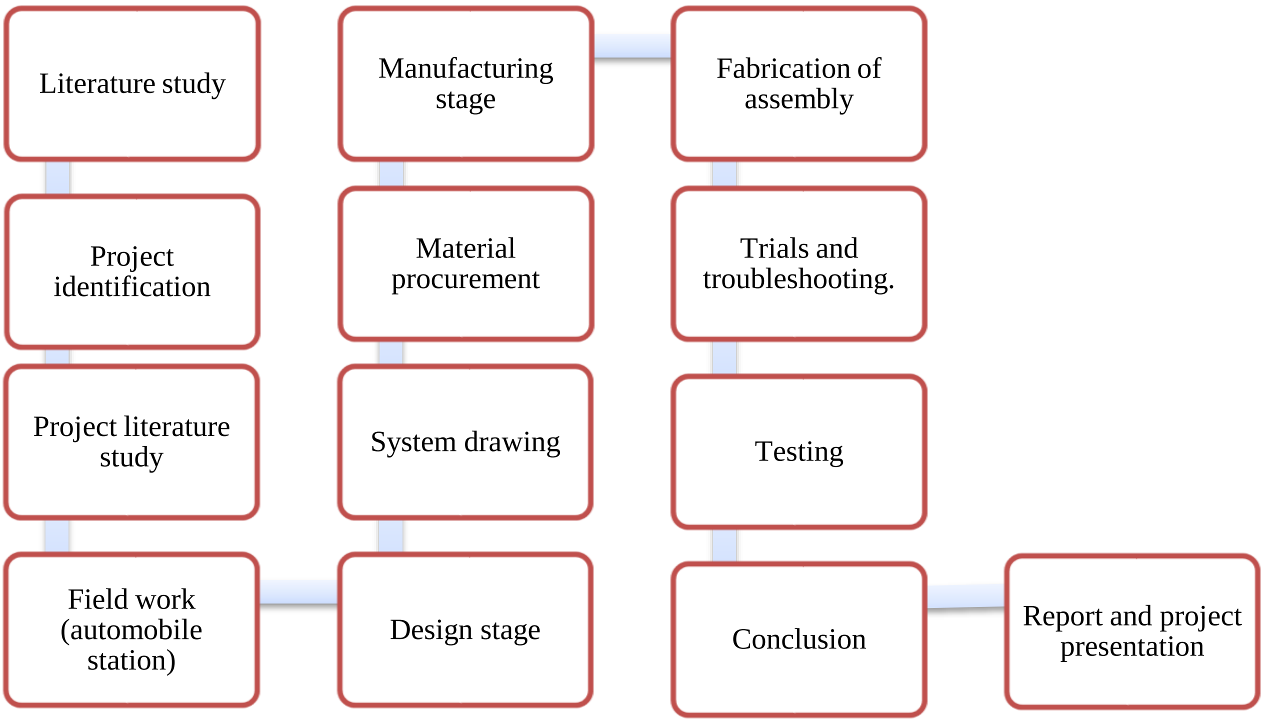
material is used to manufacture the mast. The density of the polypropylene is 0.904 gm/cm^3. This material is light in weight and able to sustain the high air velocity.

2. Shaft: Shaft is the intermediate member which connects the mast and the inner circular disc. Shaft is made of mild steel. The shaft gives strength and flexibility to the movement to the mast with help of spring and helps in to create oscillatory motion. The material used for the shaft is middle carbon steel.
3. Spring: Spring is member which is connected to the shaft which is used for oscillation of mast and to regain to its original position during oscillation. Generally spring is made up of high carbon steel. It has property like high hardness, strength, low ductility.
4. Piezo Electric Transducer: It is type of transducer which generates the electricity by applying force on it. When force is applied on it potential difference is created across the piezo electric transducer. Material used in piezoelectric transducer is quartz crystal which generates potential difference after sticking on each other.
5. Disc: Disc is supported to bottom of the shaft which is connected to the mast with the help of shaft; Disc is made of cast iron due to its high strength. Disc is a part which strikes in piezo electric transducers. Disc is circular in shape.
6. Base Frame: The whole structure is supported on the base frame. Base frame is fixed at the earth surface. All the other parts are mounted on the base frame. Base frame is made of three inch square pipe of mild steel.
7. Power collecting Unit: The unit is used for the collecting the voltage generated due all piezos. In which positive terminal from all the piezos is connected to the one end and other negative terminals are connected to another end, so due to this all the energy is collected at one end.

IV. METHODOLOGY



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V. WORKING

In this project the electricity is generated by wind energy by a resonance phenomenon produced by an aerodynamic e effect called vortex shedding as the wind passes over a blunt body, the flow is modified and generates a cyclical pattern of vortices. The wind strikes on the mast, it begins to oscillate once the frequency of these forces is close enough to body's structural frequency. Due to which vibration is created. This vibration is transferred to the shaft made of steel and connected to the mast due to which shaft also get specific motion with respect to the mast oscillates. This vibratory motion is further transmitted to the base with help of the shaft. The base contains outer disc which is connected with piezo electric transducers. The shaft again connected with the inner disc, due to the motion of shaft and inner disc the inner disc strikes the piezo electric transducers which are connected to the outer disc. The outer disc is further connected to the base. Due the striking of the inner disc on the piezo electrical transducer it get compressed with a force and due the principle of the piezoelectric effect the potential difference that is voltage is generated across the piezo electric transducers due to the generation of potential difference the electric energy is generated. After generation of electric energy from all the transducers it is collected at one unit to increase the power.

VI. CALCULATION

Mathematical and Physical Terms:-

The Reynolds number: - The Reynolds number is the ratio of a fluid's inertial force to its viscous force. Inertial force involves force due to the momentum of the mass of flowing fluid.

$$Re= \frac{U \times D}{\nu}$$

Strouhal Number (St):-Strouhal Numbers is a dimensionless number which describes oscillating flow mechanisms. It is an integral part of the fundamentals of fluid mechanics given as,

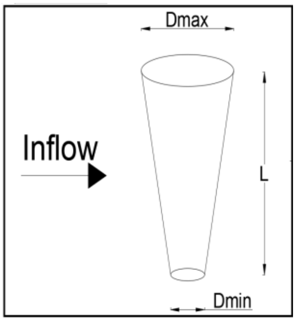
$$St= \frac{f_s \times D}{L}$$

Taper Ratio: - Taper Ratio is the ratio of the Length of the mast and the difference between diameters of the mast.

$$r= \frac{L}{D_{max} - D_{min}}$$

Cylindrical Aspect Ratio:-Aspect ratio is defined as the ratio of height to the weight of a particular feature on a component or the whole component itself.

$$\text{Cylindrical Aspect Ratio} = \frac{L}{D}$$



Considering the notations as,

D_{max}= Maximum Diameter of mast

D_{min}= Minimum Diameter of mast

Mean Diameter $D = \frac{D_{max} + D_{min}}{2}$

L= Length of mast

U= Air velocity

ν = Kinematic viscosity

fs= Oscillation frequency

Let's fix length as L = 2 m = 2000 mm

Now from previous research paper and past study we take,

Cylindrical Aspect Ratio = $\frac{L}{D_{max}}$ = 10

$$\frac{2000}{D_{max}} = 10$$

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D_{max}= 200mm

Now consider, Fig.2 Mast

$$r = \frac{L}{D_{max} - D_{min}}$$

The taper ratio lies between 14-19 so selecting 16 as a taper ratio r=16 and put Dmax = 200mm

$$16 = \frac{2000}{200 - D_{min}}$$

D_{min}= 75mm

Now taking standard value as,

D_{min} = 80 mm

Natural Frequency:-

As already discuss about the Reynolds number and the Strouhal number, for the fluid flowing over the surface of the body have Reynolds number between $300 < Re < 3\times10^5$ for better frequency of vibration.

From graph of relation between Strouhal number and Reynolds number it is seen that for the Reynolds Number 3×10^5 Strouhal number is 0.2.

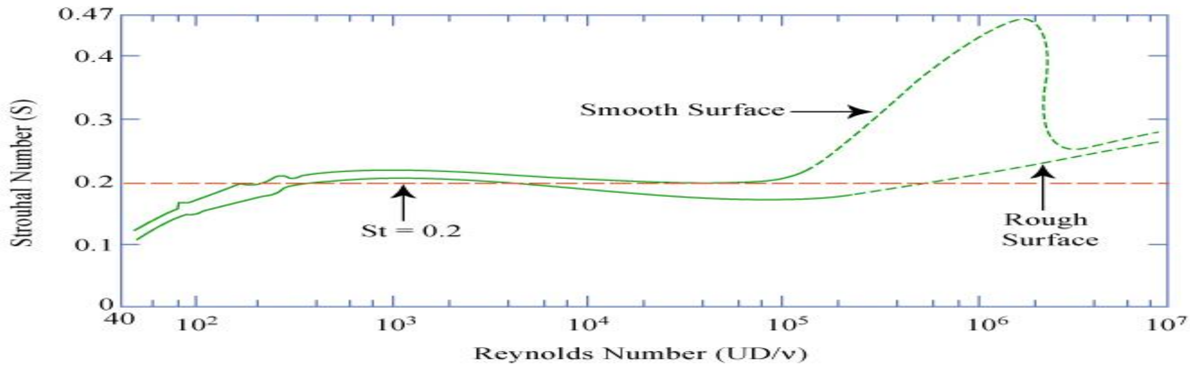

Fig.3 Strouhal No. vs. Reynolds No. [14]

Strouhal number is given by, $St = \frac{f_s \times D}{L}$

Now $D = \frac{D_{max} + D_{min}}{2}$

$$D = \frac{200+80}{2}$$

D = 140 mm

Put U = 2m/s, D = 0.140m, L= 2m and St = 0.2 in Strouhal number equation,

$$0.2 = \frac{f_s \times 0.140}{2}$$

Therefore, $fs = 2.85$ Hz

$fs = 3$ Hz

This is the oscillation frequency of the mast, for the proper oscillation this oscillation frequency should be equal to the natural frequency of the mast. The natural frequency of the mast is to be calculated by using the ansys software.

Force acting on the surface of the mast:-

Surface area of the mast,

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$$S = \pi \times (R1 + R2) \times L$$

Putting R1 = 0.1m; R2 = 0.04m and L = 2m

$$S = \pi \times (0.1 + 0.04) \times 2$$

Therefore, $S = 0.879m^2$

Now from the properties the polypropylene sheet, Density δ= 904kg/m^3 thickness of polypropylene sheet taken as, t=2mm

Therefore, Mass of the mast (m),

$$m = \delta \times S \times t$$

$$m = 904 \times 0.879 \times 0.002$$

Therefore, $m = 1.5kg$

Projected area of the mast exposed to wind,

$$A = (R1 + R2) \times L$$

$$A = (0.100 + 0.040) \times 2$$

Therefore, $A = 0.280\ m^2$

Force of the air on the projected area,

$$F = \delta \times A \times V^2$$

Here, δ = Density of air = 1.225kg = m^3

$$F = 1.225 \times 0.280 \times 22$$

Therefore, $F = 1.3N$

Lift force is the required force for the movement of the mast with certain velocity of the air striking on its body.

$$\text{Lift force} = 0.5 \times \delta \times U^3 \times D \times L \times C$$

$$F_l = 0.5 \times 1.225 \times 2^3 \times 0.140 \times 2 \times 0.6$$

Therefore, $F_l = 0.823N$

It has been seen that lift force is less than the force acting on the projected area of the mast hence the mast should oscillate easily.

I. ANALYSIS

Analys is done using the ansys software for calculating the natural frequency and the stress generated on the model. There are the certain steps involve while using the ansys software. The steps involve are defining material properties, meshing, applying boundary conditions and finding final output results.

Meshing:-

Statistics	
Nodes	20190
Elements	7042

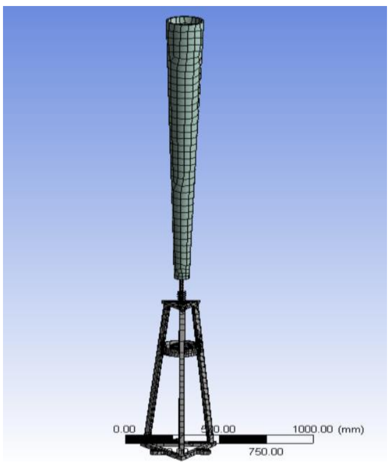

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Fig.4 Meshing

There are two types of analysis are done that are Modal Analysis and Static Structural Analysis

Modal Analysis: - This analysis is done for finding natural frequency

Boundary Conditions: - Boundary conditions applied is the fixed support at the bottom of the base frame

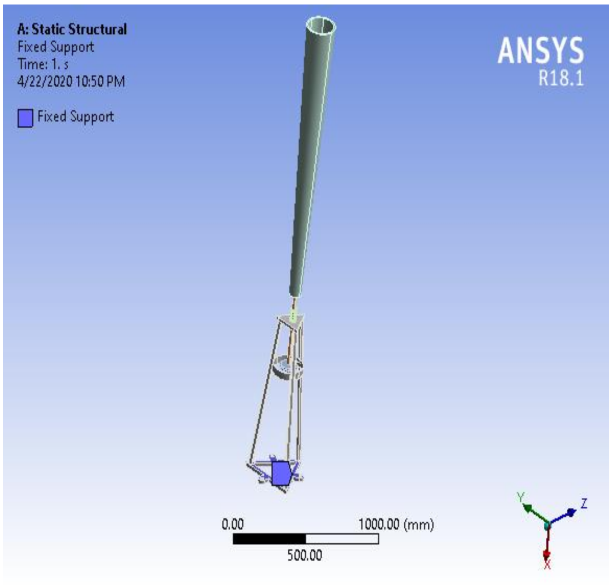

Fig.5 Boundary Condition for Modal Analysis

Results:-

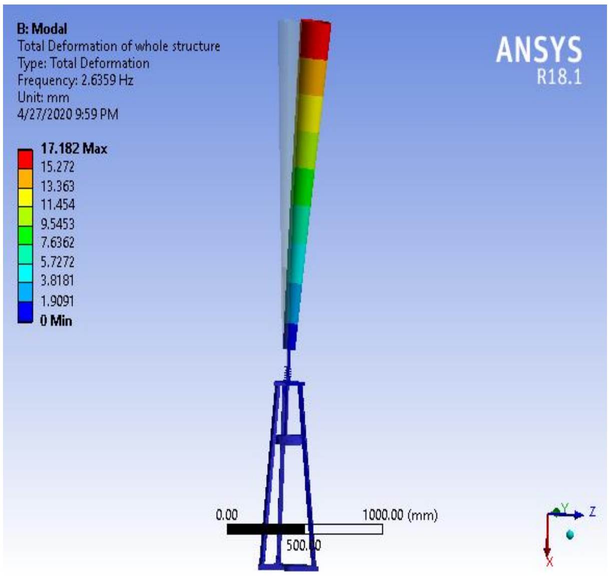

Fig.6 Modal Analysis

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	Mode	Frequency [Hz]
1	1.	2.6359
2	2.	3.1492
3	3.	18.691
4	4.	20.577
5	5.	28.266
6	6.	33.151

Fig.7 Natural Frequencies

Fig.7 gives the results of the natural frequencies of the model and the results shows that natural frequency is 2.63 Hz which is nearly equal to the calculated oscillating frequency. Hence it gives that design model is satisfying all the required conditions and also works without failure.

Static Structural Analysis: - The analysis gives the stress generated and total deformation of the model

Boundary Conditions: - Boundary conditions applied are the fixed support at the bottom of the base frame and force is applied on the mast

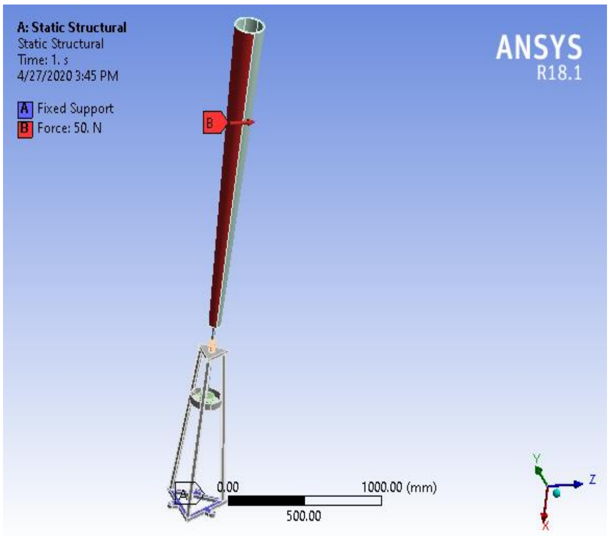

Fig.8 Boundary Condition for Static structure Analysis

Results:-

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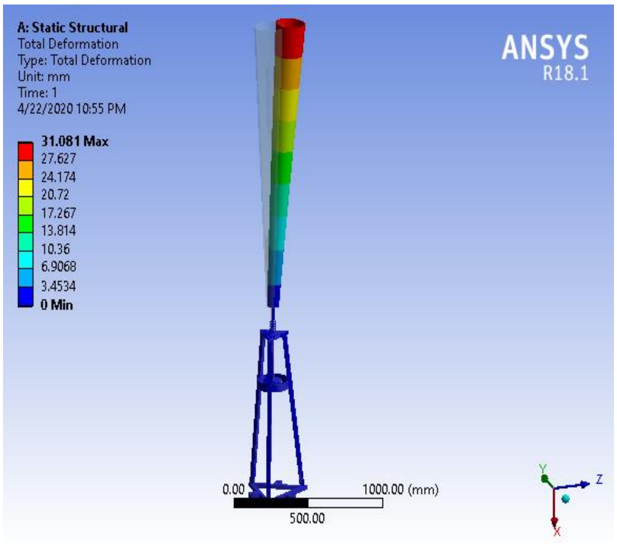

Fig.9 Total Deformation

It has been seen from the above result that the total deformation is 31.08 mm which is in limiting conditions.

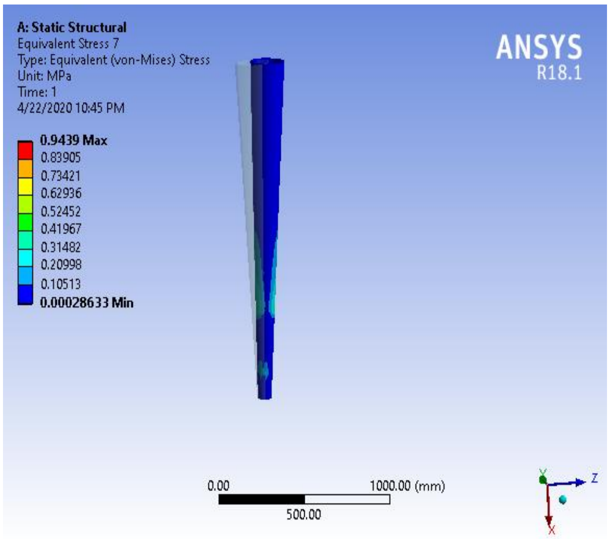

Fig.9 Stress Generated on Mast

It has been seen that from the above result that stress generated on the mast is less than the yield stress of the material of mast that is polypropylene sheet that is 35 MPa.

VII. CONCLUSION

Research paper deals with the conversion of wind energy into electrical energy with the help of bladeless windmill. Wind velocity is first converted into the mechanical energy in the form of

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vibrations. Then vibrations are used to give motion to the mast, the, mast is connected to the disc with the help of the shaft, the disc strikes the piezo electric transducer and generates potential difference across it which further then converted into the electrical energy. Energy then collected and stored in batteries and then supplied. This study on the bladeless windmill conclude that for power generation with the help of the wind energy, the bladeless windmill is more efficient, easily available, simple in structure, less in cost, less in size than the traditional wind mill. This windmill can also be able to set at low altitude than traditional windmill.

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