PIEZOELECTRIC BLADELESS WIND TURBINE

Sumit Upadhyaya[1], Radhika Agrawal[2], Nishant Baish[3], Adarsh Shivhare[4], Subash Chand Pal[5]

[1,2,3,4]Student, Department of Mechanical Engineering, Madhav Institute of Technology and Science, Gwalior, Madhya Pradesh, India
[5]Assistant Professor, Department of Mechanical Engineering, Madhav Institute of Technology and Science, Gwalior, Madhya Pradesh, India

---***---

Abstract - *In the current phase, India is venturing towards turning out to be an all-inclusive superpower. This implies that it is leading the list of developing countries in terms of economic development. Therefore the energy requirement of the country will increase at a rapid rate. The present energy generation sources are less economic and non-eco-friendly. They require large investment and maintenance costs. Therefore a turbine with easy design, guarded, quiet, economical, and straightforward working is the necessity of the hour. One such turbine is the Bladeless wind turbine which works on the vortex shedding effect. This turbine is the perfect replacement for the present traditional turbine which has many ruinous effects. Our project aims at such a turbine which doesn't require any fuel for working, and so it is eco-friendly and henceforth it is a beneficial substitute for Traditional wind turbines. It uses a radically new approach to capturing wind energy. Its working principle is to make the hollow mast vibrate at resonating frequency generating vortices which are later converted into electrical energy by the help of piezoelectric sensors. Less moving parts are ensuring least structure vibration and hence negligible wear and tear. The structure also ensures better safety for the birds flying around as no sharp blades are rotating. Also, the consumption of space is less so, more number of units can be installed for large power generation.*

***Key Words*: Piezoelectric sensors, Resonating frequency, Vortices, Vortex Shedding.**

1. INTRODUCTION

The piezoelectric bladeless wind turbine uses a new approach to capturing wind energy. It does so from the streamlined instabilities of the vortex shedding effect. As the wind bypasses around the structure, it changes its flow and creates an alternating pattern of vortices which later absorbed by the mast structure of the turbine and creates resonance by its oscillating motion. There is a classic example of the Tacoma Narrow Bridge of Washington, which collapsed within 4 months of its inauguration due to the vortex shedding effect. Where all engineers and specialists try to avoid and reduce these vibrations from their technologies, we use it as our main source of energy. Hence the turbine comes out to be a renewable source of energy which is the major requirement of the present era. Rather than the same old tower, enclosure and blades, our device uses a fastened mast and a piezoelectric system. The energy created by the resonance in the mast is transferred to the disc attached at its bottom and later transferred to the piezoelectric system, where hence electricity is generated. Due to the small structure of the system, it can be even used at a small scale such as at the top of a building. This puts the technology at the low vary of capital intensity for such comes, it conjointly makes it extremely competitive not solely against generations of different or renewable energy, however even compared to traditional technologies.

Fig-1: Difference between conventional and bladeless turbines.

Table- 1: Difference between conventional and bladeless turbine.

PARAMETER	CONVENTIONAL WIND TURBINE	BLADELESS WIND TURBINE
MODE OF OPERATION	It generates electric power with blades.	It generates electric power without blades.
MODE OF GENERATION	It captures wind energy using the rotational motion of the wind.	It captures wind energy using vorticity.
STRUCTURE	The design is sturdy and there are high wear and tear.	The design is sturdy and there is minimal wear.
SAFETY	It is not safer for birds that suffer from a collision with blades.	It is safe for birds and other flying animals.
MAINTENANCE	It is not feasible to maintain as it has a	It is easy to maintain and the

	high maintenance cost.	cost of that is minimal.
CONSTRUCTION	It has more moving parts.	It has fewer moving parts.
EFFICIENCY	It has high efficiency.	It has comparatively low efficiency but overall is high.

2. BLOCK DIAGRAM

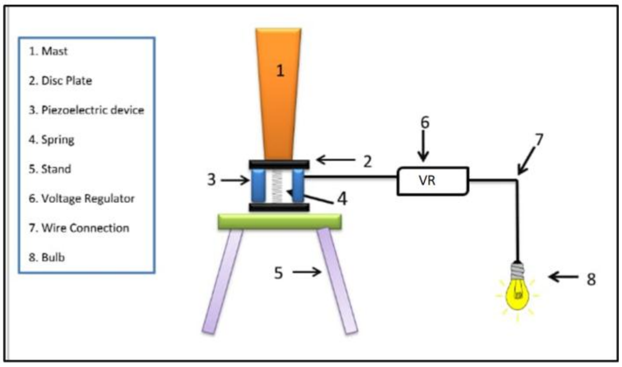

Fig- 2: Block diagram of Bladeless turbine

2.1 Mast
A frustum shaped structure made up of stainless steel (gauge 26) is used. It absorbs the aerodynamic effect taken from the environment and oscillates with the particular amplitude to generate energy which it later transfers to the corresponding components.

2.2 Discs
Two circular discs made of iron are used. On one of the discs, the mast is welded and is used for uniform application of induced stress on the piezoelectric chips, and the other disc is used to place the piezoelectric chips.

2.3 Piezoelectric System
It is used to generate an electric charge on the application of mechanical stresses. It consists of various sub-components like PCB board, Diodes, capacitors, etc.

2.4 Springs
Four helical springs with one end connected to the circular disc and another end to the foundation of the device. They are used to provide vibratory motion as well as constraint motion to the mast.

2.5 Stand
It is the base onto which the whole step-up of the mast, disc, and the piezoelectric chip is mounded. It provides strength and support to the mast for its oscillation at high frequencies.

2.6 Voltage Regulator
It maintains the output voltage at a constant value.

2.7 Wires
Copper wires are used in the piezoelectric system for various connections and also to connect the battery and the LED bulb.

2.8 Battery
It is used to store the power generated by the piezoelectric system for later use.

2.9 Bulbs
The bulbs are used for lighting and to show the power output.

3. WORKING METHODOLOGY

The fundamental methodology we utilized in our undertaking is to convert the kinetic energy of air into physical-mechanical stress. After this, with the help of a piezoelectric sensor we covert that mechanical pressure into the alternating impulse of charge flow i.e. current. To saddle the active vitality of air, we use a vertical structure which is called the mast. The mast has a diverging cylindrical shape which is connected at the bottom of sturdy support through welding. It can be considered as a cantilever beam with uniformly varying load. At the point when air with high velocity makes an impact on the mast, it starts to vibrate with a certain amplitude and in a certain direction concerning the welded joint. As we know from the concept of resonance, every material has its natural intermolecular frequency. When that frequency matches the frequency of mast vibration, resonance occurs. Mast starts to vibrate with larger amplitude and after that we covert the large amplitude vibration into vertical stress on the piezoelectric sensors through a metal plate called Disc which is welded at fixed support of mast. This vertical stress is transferred on to another plate on which our whole piezoelectric circuit is placed. Now we have successfully converted the air kinetic energy into the normal stress on piezoelectric sensors. When stress is applied on the piezoelectric sensor i.e. piezoelectric chips they produce charge which on connecting through wires produces current.

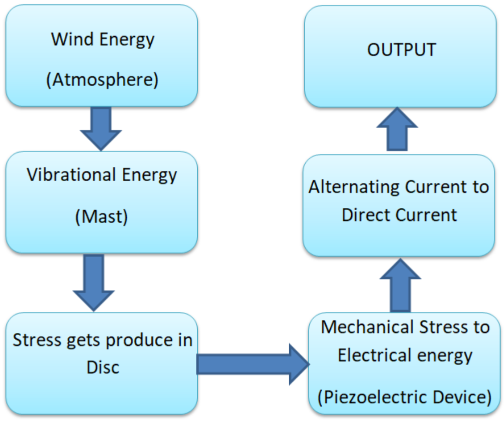

Fig- 3: Working of Bladeless turbine

3.1 BASIC WORKING OF PIEZOELECTRIC CHIPS

Piezoelectric sensors are the devices that convert mechanical stress into electric current. It has crystals of quartz that have the special property of developing a potential difference on the application of physical stress. The crystal of quartz has a hexagonal structure with the alternative presence of anion and cation on vertices. The centre of symmetry of positive and negative ion is on the structural symmetry of figure i.e. on the centroid of hexagonal structure. On the application of stress, the centre of anions and cations shift by some distance and create the potential difference and on connecting the wires with the crystal the charge tends to flow from the negative to a positive end. This flow of charges results in the flow of current.

3.2 BASIC WORKING OF MAST SYSTEM

The 4 springs are attached to the bottom of the vertical mast to keep it vibrating for a longer time and with further enhanced amplitude by restoring its vibrational energy into potential energy of spring. But as our stress is variable in the direction the current produced is alternating that is why we used a full-wave rectifier circuit. A full-wave rectifier circuit has four rectifiers connected in a Wheatstone bridge condition that pass the current in a single direction. The combination of the full-wave rectifier circuit and piezoelectric chips is our main piezoelectric system. After getting unidirectional current we can utilize the output directly or can magnify the output or even we can store that output for further use with the help of batteries.

4. ANALYSIS

4.1 NUMERICAL ANALYSIS

- **Larger Radius of the mast,**
  $R_1 = 0.10$ m
- **Smaller Radius of the mast,**
  $R_2 = 0.04$ m
- **Height of the mast,**
  L = 1 m
- **Lateral Surface area of the mast (open),**
  $S = \pi \times (R_1 + R_2) \times L$
  $= 3.14 \times (0.10 + 0.04) \times 1.00$
  $= 0.4392\ m^2$
- **Average Velocity of the wind,**
  v = 30 to 40 km/h
- **Projected area of the mast exposed to wind,**
  A $= (R_1 + R_2) \times L$
  = $0.1400\ m^2$
- **Force by the wind on the projected area,**
  F $= \rho_{air} \times A \times v^2$ (where ρ_{air} is the density of air)
  $= 1.225 \times 0.1400 \times 8.34^2$
  = 11.93 N

4.2 STRUCTURAL ANALYSIS

SOFTWARE USED: CATIA V5

STEP 1: We have used CATIA V5 software for designing and stress analysis, and the numerical analysis was done by keeping in mind the structural figure. In this step, the designing of the Piezoelectric Bladeless turbine is done. All the dimensions are taken accordingly.

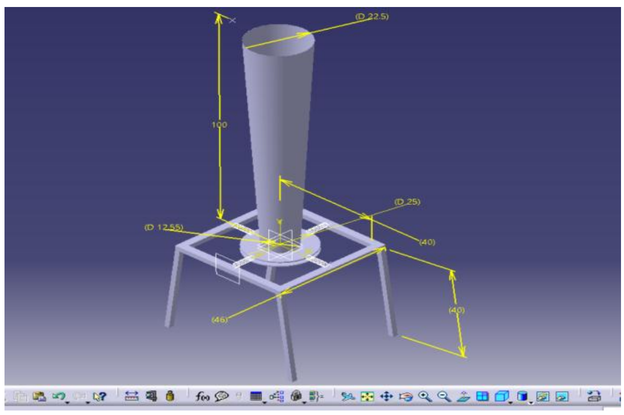

Fig- 4: Designing of Bladeless turbine.

STEP 2: In this step, the mast is given the desired material in which it will be fabricated so that analysis can be done accurately. For this purpose, **Stainless steel** (gauge 26) is used as it has numerous advantages:-

- High Tensile and compressive strength
- Temperature resistance
- Extremely durable
- Low magnetic permeability
- Retention to corrosion and many more.

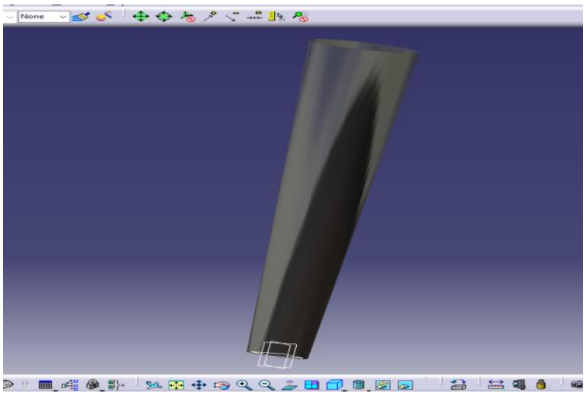

Fig- 5: Material Selection of Mast.

STEP 3: The next step is applying constraints to the system. As we know mast will behave like a cantilever beam so accordingly it is clamped from one end (end with smaller radius). Now using the result which we got from numerical analysis i.e. **Force applied by the wind on the projected area = 11.93 N.** This force is applied in the Z direction and it is considered that the applied force behaves like continuously varying load. In Figure 6, the arrow shows the direction of the applied force.

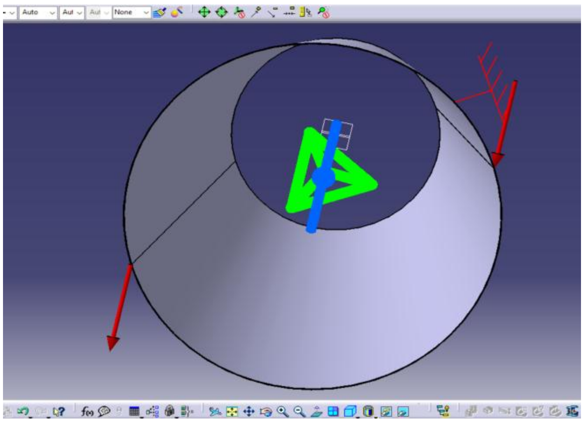

Fig- 6: Applying constraint to the system.

STEP 4: Meshing is a necessary part of the designing process where complex geometries are broken into simpler components that can be used as a discrete and smaller part of a larger domain. By doing so, we get a better result as it impacts the accuracy, union, and speed of simulation. As it is the main step in structural analysis, time taken by meshing is significantly higher than any other process. Now, as we know a mast is a 3-dimensional object, tetrahedral meshing is done so that more accurate results can be calculated.

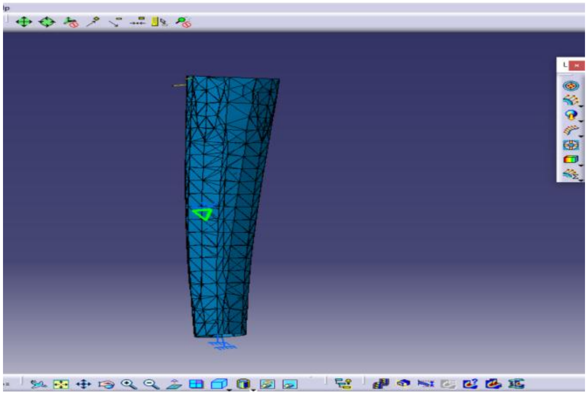

Fig- 7: Meshing of Mast.

STEP 5: This step comprises of the main result for which this whole structural analysis is done i.e. stress analysis for this, we use **Von mises criteria** which is best suited for a ductile material. Figure 8 shows the graphical result for this analysis. The red zone indicates that maximum stress is generated at the fixed end and the blue zone shows minimum stress is generated at the free end.

STEP 6: This final step of structural analysis shows the translational displacement of the particle when force is applied. Maximum particle displacement is at the top end (free end) of the mast and the minimum is at the fixed end.

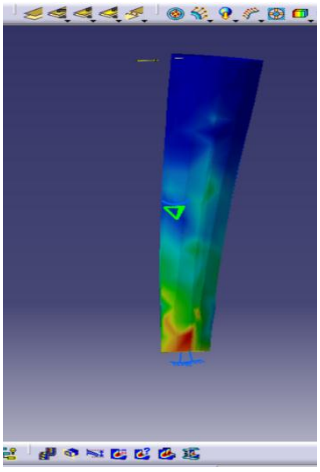

Fig- 8: Stress Analysis

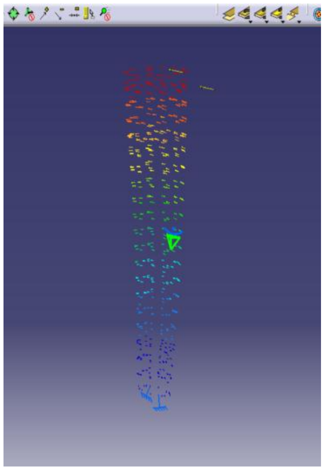

Fig- 9: Translational Displacement of particles.

5. RESULT AND DISCUSSION

The result from the numerical analysis shows that net force acting on the mast is **11.93 N** acting in Z-direction.

For this calculation, the maximum average wind speed was taken i.e. 40 km/hr.

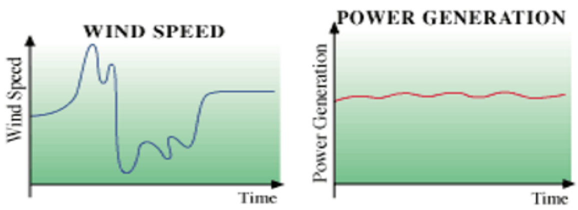

Chart- 1: Variation of Wind Speed and Power Generation with time.

As shown in the above chart, variation in wind speed is very much, and due to this net force applied on the mast varies, generating oscillations of different frequencies. Due to these random oscillations, stress applied on the piezoelectric chips is of varying magnitude, which later generates an alternate current. So, for steady power output, we have used a full-wave rectifier, which helps in producing this steady power flow as shown in the above figure.

Also, by our structural analysis, we came up with a conclusion that maximum stress is generated by the flowing wind at the lower end of the mast. But due to the geometry and material chosen of the mast, our structure can sustain this generated stress making in more economic than a conventional wind turbine.

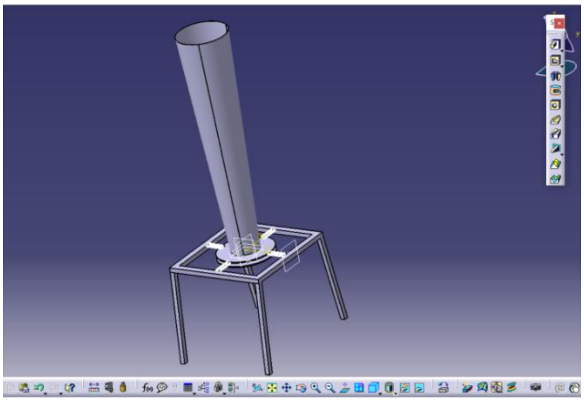

Fig- 10: Structural Analysis Of Mast.

The other major benefit of a piezoelectric wind turbine is that the only input required to start the turbine is wind-blown with a certain velocity making the mast of the turbine resonate. As the components are less in number making the turbine light weighted and reducing the chances of wear and tear as there are less moving parts. Due to the compact size of the turbine, transportation can be effectively done, making electricity generation possible in secluded areas. Because of simple design, its installation cost is less. Also, it doesn't require lubrication reducing the maintenance cost by 52.7% as compared to the traditional wind turbines. It can easily convert 39.8% of wind energy into free energy. Another fact in favor of piezoelectric wind turbines is that with no sharp blades around the mast makes the environment a bit safer for birds and as these blades acquire more space as compared to the bladeless mast, the area for its installation is 30% than that required in conventional turbines. By reducing the area required per unit, more turbines can be installed in a given field increasing the amount of energy generation. As the installation cost, maintenance cost is less, the overall cost of the project is 25% less expensive than the conventional wind turbines for the same power output.

All we can say is that piezoelectric wind turbine has all the advantage to be the better alternative of the conventional wind turbine and with its installation in large numbers, overall efficiency can be increased.

6. CONCLUSION

Conversion of renewable energy into a useful form is the new approach which is gaining momentum in the past few years. The purpose of this project is to find an alternative for the traditional wind turbine. As we have used piezoelectric sensors in place of alternator and generator, the cost of this turbine is very much less than that of the normal bladeless turbine. Also, we have kept the size of this turbine compact, so we can easily install it in households, schools, and any rural area. Another advantage of our turbine is that it has less moving parts so the wear and tear will be less and hence the maintenance cost will get reduced. Overall our piezoelectric bladeless turbine is economic, eco-friendly, and new innovation to the old approach.

7. FUTURE SCOPE

As we know, non-renewable energy resources are limited that's why bladeless turbine can be a better alternative for free energy generation through wind energy. This project mainly focuses on the generation of free energy which can be efficiently used in the industrial sector, lowering the cost of the project. As it is very handy and its installation is easy, the problem of electricity in rural areas can be resolved. The use of piezoelectric bladeless wind turbines can be beneficial in the agricultural sector as the energy generated can be used to supply power to water pumps, fencing, and can easily be stored for later use. It can be used to provide power to transmission equipment in telecom industries so that they can easily expand to the rural area where power supply is the major problem. It can provide a small contribution to supply free energy to railway stations, airports, or other public places. By using this technology in the future, the percentage of usage of renewable energy for electrical power consumption will increase. It will work effectively in numerous spots like businesses, hospitals, schools, and so on. All this makes it very economical and furthermore, research on it can help us to reduce the cost and increase its efficiency

8. REFERENCES

- Prof. Harshith K, Blayan Santhosh Fernandes, Shreerama P R, Thilak Raj | Bladeless wind power generation | IJSRD - International Journal for Scientific Research & Development| ISSN (online): 2321-0613 | Vol. 4, Issue 03 | Page 1897 | 2016.
- Abhijit Mane, Manoj Khaeade, Pravin Sonkambale, Shubham Tapase, Sachin S. Kudte | Design & Analysis of vortex bladeless Turbine with Gyro e-generator| International Journal of Innovative Research in Science and Engineering| Vol. No.3, Issue 04 | Page 445 | April 2017.
- Akshay Agrawal, Aditya Sheth, Prof. Ankit Dandiwala, Prof. Subhasis Sarkar | Bladeless windmill based on the principle of vibration | International Journal of Scientific Research | ISSN: 2277-8179, IF: 4.176 | Volume- 6, Issue-5 | Page 13 | May- 2017.
- Shubham S. Davang, Sunil K. Manade, Ganesh Kumar Patil, A.M. Bhandari | Bladeless Wind Turbine | International Journal of Innovations in Engineering Research And Technology [IJIERT] | Novateur Publications |ISSN: 2394-3696 | Volume 5, Issue 4| Page 36 | Apr- 2018.
- Pratik Oswal, Abhishek Patil | Bladeless wind Turbine | International Journal for Research in Applied Science & Engineering Technology (IJRASET) | ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887 | Volume 6 Issue III | Page 2549 | March 2018.
- Vaibhav Aru, Narendra Chavan, Uday Chaudhari, Chaitanya Dange | Design & Analysis of vortex bladeless | International engineering Research journal | ISSN: 2395-1621
- R. Haridass, K.S. Jayaram Singh, T. Ramesh Kumar, B. Sabarish Kumar, L. Thamarai Kannan | Design and Fabrication of bladeless windmill | International Journal of Pure and Applied Mathematics | ISSN: 1311-8080 (printed version) | ISSN: 1314-3395 (online version) | Volume 118 No. 11 2018, 557-561 | Page 557.
- Conference Paper in Proceedings of SPIE - The International Society for Optical Engineering · March 2013 DOI: 10.1117/12.2009551, piezoelectric wind turbine.

9. BIOGRAPHIES

I, **Sumit Upadhyaya** was born and brought up in Gwalior. I am currently a final year student pursuing a Bachelor of engineering in Mechanical branch from Madhav Institute of Technology and Science. I had done courses in designing software like AutoCAD and CATIA v5. My areas of interest include 3D simulation and designing.

I, **Radhika Agrawal** was born and brought up in Gwalior. I am currently a final year student pursuing a Bachelor of engineering in Mechanical branch from Madhav Institute of Technology and Science. I had done courses in designing software like Solidworks and AutoCAD. I aim forward to my career in the Designing Department. My areas of interest are Machine Design, Strength of Materials, and Heat Transfer.

I, Nishant Baish was born and brought up in Gwalior. I am currently a final year student pursuing a bachelor of engineering in Mechanical branch from Madhav Institute of Technology and Science Gwalior, Madhya Pradesh, India. I aim to pursue a Masters in Dynamics of Machines field and further researching for Ph.D. My areas of interest are Dynamics of Machine, Automobile Engineering, and Power plant.

I**, Adarsh Shivhare** was born and brought up in Gwalior. I am currently a final year student, pursuing a Bachelor of Engineering in Mechanical branch from Madhav Institute of Technology and Science, Gwalior, Madhya Pradesh, India. I aim to pursue a Master's degree in Thermal engineering from an IIT. My areas of interest are Thermodynamics, Heat transfer, the strength of the material, and fluid mechanics.