A REVIEW ON VIBRO-WIND FOR BLUFF BODY AND PIEZO-ELECTRIC MATERIAL

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ABSTRACT

The field of renewable power generation has attained a significant growth over the past few years. This is to satisfy the needs of the growing population and due to the degrading resources. Though the non-renewable harvesting methods satisfy the current needs, they are against green environment. Portable power sources such as electro-chemical batteries are very much convenient for our current society, but due to their limited life-span and periodic replacement, there is a need to provide a portable harvesting technology which are non-replaceable, having extended life-span and support green environment and the growing demand and not affected by weather change and satisfy the rural needs. Though there are renewable power harvesting done via wind-mill, turbine, bio-gas and solar. They are big and heavy in construction and low in power generation which can't afford the growing demand. Thus due to the above drawbacks, the standard biological communities here placed an emphasis on scavenging vibrational energy with piezo-electric material. This article will review the recent articles and literatures based on power harvesting, vibrational energies and provide the best suitable self-powered technology for current trend.

KEYWORDS: Piezo-electric material, portable power, vibrational energy, renewable source

I.INTRODUCTION

The ultimate goal of designing an energy harvester is to produce a geometrical shape and size that reduces the critical wind speed for the cause of instability, minimizes hysteresis and increases the sensitivity of amplitude corresponding to wind velocities beyond the critical speed.

The Cornell University has conducted a harvesting research based on vibration known as vibro-wind harvester in which arrays of cantilevered bluff bodies are assembled in a panel (Moon, 2010b).This experiment is based on power generation due the effect of aerodynamic forces. The principle behind the power generation is Piezo-electric effect. This effect is based on power generation due to change in motion. Here foam pads are used as bluff body (a body which alters it's position due to aerodynamic forces) which provides motion when it is subjected to aerodynamic forces. When the setup is exposed to wind flow, the bluff bodies provides the necessary motion (This motion produced by the bluff bodies is an example of transverse aerodynamic galloping) which is then transmitted to the beam and due to beam's vibration the piezo-electric material is excited. Thus the power is generated. This power generation is then measured by the voltmeter and the corresponding vibration is measured by the vibrometer and the wind flow by anemometer. Here, the oscillations are produced at approximately the natural frequency of the structure.

This setup leads to a power generation even in wind speeds as low as 3 m/s which is very much less than the 9 m/s start-up velocity of wind turbine. A one square meter vibro-wind panel operating at 10% efficiency in just 10 m/s is capable to generate 54W of electricity.

As per previous researches the amplitude produced by the galloping oscillators with both translation and rotational movements is comparatively less than oscillators providing pure translation.

This oscillation motion may vary depending on the energy harvesting devices such as resistor, capacitor or battery. A relative example to this is the coupling of a piezo-aeroelastic oscillator with a resistor. Erturk et al. (2010) decreases the critical wind speed. Thus, this research is starting point for understanding the role of oscillator’s geometry in a piezo-aeroelastic energy harvester’s performance.

Thus, there is a growing needs in the number of applications to powered devices which do not require physical connection of wires. This uses embedded wireless sensors which are flexible, easy to implement and can fit in certain previously inaccessible locations.

II.PIEZO-ELECTRIC MATERIAL

Piezo-electric materials are used as energy harvesters to capture all the waste vibrations from the surroundings and convert it into useful energy.

There are two types of commonly used piezo-electric material available. They are zirconate titanate(PZT) and PVDF(PZT).Among this the zirconate titanate material is subjected to fatigue crack growth when exposed to high frequency cyclic loading, where-else the PVDF is a polymer that exibits good flexibility on comparison. Hence PVDF is preferred.

TABLE 1: NORMALISED OUTPUT POWER FOR PARALLEL AND SERIES CONNECTION

Layers	**Series**		**Parallel**	
	Case 1	**Case 2**	**Case 1**	**Case 2**
Single	1	1	1	1
Double	1.37	2.22	1.17	3.42
Triple	1.18	4.56	1.4	6.63

Dibin Zhu et al. / Procedia Engineering 25 (2011) 199 – 202 suggested a way to improve the output efficiency of the piezo electric material i.e) by using multilayer structures with different connections. The research deals with single, double and triple layer structures with different series and parallel connections. The table 1 shows the variations in the normalized output power for different layers and connections. From the table 1 it is clear that for both the series and parallel connections in both the cases the output power is increased as the number of layers increases except for the series double layer connection. Thus he concluded that this type of structures and combinations pave way to improve the efficiency.

R. Patel et al done an experiment on finding the difference between placing the piezo-electric material above and below the cantilever beam. A graph was plotted for the data gained from the experiment for output voltage against the frequency. From the graph it was found out that the data collected by placing the piezo-electric material below the beam attains a maximum output voltage for smaller frequency as compared to the data collected by placing the piezo-electric material above the beam.

TABLE 2: AUTHORS AND THEIR RESEARCHES TOWARDS THE PIEZO-ELECTRIC CONFIGURATION

AUTH ORS	**CALEN DAR YEAR**	**PIEZO ELECTRIC CONFIGURA TION**	**RESULT S**

Ng and Liao	2004,2005	Unimorph, Series triple layer bimorph, Parallel triple layer bimorph	Unimorph exibits good under low excitations and loads. The triple layer series is good under high excitations and the Parallel triple layer series is good under medium excitations and loads
Mateu and Moll	2005	Homogeneous bimorph, heterogeneous bimorph, heterogeneous unimorph	The conclusion of the research was the Heterogeneous unimorph series has generated more power
Platt et al	2005a	145 stacked PZT wafers, solid monolithic PZT cylinder	Matching resistance is in Grange for monolithic type and in k range for stacked type

The table2 shows the details related to certain authors and their researches towards different piezo-electric configuration.

III.DESIGN OF BLUFF BODY

TABLE 3: PARAMETERS FOR DESIGNING THE BLUFF BODY DESIGN

A^,B^,C^,D^	coefficients of polynomial approximation to CFY
C_{fy}	lateral aerodynamic force coefficient

The target is to design a bluff body that possess high amplitude sensitivity, low hysteresis, low critical wind speeds. These properties depends on lateral aerodynamic force coefficients A^, B^,C^,D^ which are shown in the table3. Thus for this there is a need to identify A^, B^,C^,D^ for different bluff body shapes. Such data has been collected by Luo et al. (1993)

J.M. Kluger et al (2013) just made a comparison over the Oudheusden-cornell and Parkinson and smith models for both the square and trapezoidal section. It was found that the data collected from the experiment for the square section has a qualitative shape that agrees with the curves made by simulating Oudheusden-cornell and Parkinson and smith models and also the trapezoid section has a qualitative shape and also the data collected for it also agrees with the curves for less than 5 m/s. In addition their research says that the square section exhibited hysteresis for wind speeds greater than critical wind speed and the trapezoidal section exhibited hysteresis wind speeds starting at the critical wind speed. Thus the hysteresis factor is found in both the Oudheusden-cornell and Parkinson and smith models.

IV.LITERATURE REVIEW

1. Piezo ceramic materials are subjected to fatigue crack growth under high frequency cyclic loading Lee *et al* (2005). Their research also suggested that by using a more durable electrode layer, the device can operate under strenuous condition and can harvest more output.
2. The amount of energy harvested can be increased by using a more efficient coupling mode Sodano *et al* (2005a) 31mode and 33mode are the two practical coupling mode used. Among this the 31mode configuration cantilever has proved to be efficient under

low vibration level environment while the 33mode configuration cantilever is suitable in high vibration level sectors.

3. The above suggested result is also presented by Roundy *et al* (2003)and concluded that the resonant frequency of a system that operates at the 31mode is much lower and leading the system to drive in the natural environment at resonance and thus providing more power.
4. The harvested output power is directly proportional to the coupling coefficient k and dielectric constant ε. Yang *et al* (2005). The research concludes that the device having high coupling coefficient produce more power and that have nearer driving frequency to resonant frequency will leads to more power generation.
5. Cho *et al* (2005a) predicted that by increasing the stiffness of the passive elastic layer will simultaneously increase the coupling coefficient which in-turn leads to more output and at the end his research it was found that the residual stress plays a key role in decreasing the coupling coefficient and concluded that reducing this residual stress will show significant gain in coupling coefficient.
6. Later in his research Cho *et al* (2005a) proved that an electrode coverage of about 60% gives the best coupling. Also by increasing the PZT thickness by 1-3μm for a substrate of thickness 2μm increases the coupling coefficient by a factor of 4. And finally the coupling coefficient is increased by 150% by reducing the stresses for a membrane of having 80MPa of residual stress.
7. Another effective way of increasing the output power is proposed by Jiang *et al* (2005).His research states that a stack configuration that contains a large number of thin piezo ceramic wafers as stack with the electric field applied along it's length provides an increased output and concluded that both the resistive load and the voltage output are much more manageable in a PZT stack than a monolithic configuration
8. Experimental verification of the above research is carried out by Baker *et al* (2005) by testing a same volume triangular trapezoidal cantilever beam with a rectangular cantilever beam and determined that the power produced by the trapezoidal beam is 30% more than that of the rectangular beam. Finally the research concluded that the trapezoidal beam is smaller and economical to satisfy the power requirements.

Apart from these there are also several authors and researchers over the piezo-electric materials. Some of them and their researches are listed below in the table 4

TABLE 4: AUTHORS AND THEIR RESEARCHES TOWARDS PIEZO-ELECTRIC MATERIAL

AUTHORS	CALENDER YEAR	TYPE OF MATERIAL	RESULTS
Lee et al	2004,2005	PVDF film coated with PEDOT/PSS electrodes	Acts as a resistance and prevents fatigue crack growth in electrode
Mohammadi et al	2003	piezofiber composite	More flexibility
Churchill et al	2003	piezofiber composite	More flexibility

V.FUTURE SCOPE

- Normally power generation systems are usually large in size and heavy in construction. Thus they occupy a lot of floor space. Our Vibro-wind power generator overcomes these difficulties. They are compact and light in construction and satisfy the power requirement
- In our current scenario in-order to generate power, lot of investments are required. Factors such as site rate, labour etc. are to be considered. On this economy point of view Vibro-wind power generator is cheap and

occupy smaller area. Hence investment is less and power requirement will be satisfied.

- Unlike the other power generating systems this device free from pollution and is much more eco-friendly. Vibro-wind power generator does not provide any noise or polluted air and hence they can be placed within the city limit even for roof-top applications and it is a green method of producing power.

- Vibro-wind power generator is a hazard free device. Unlike the other generators like nuclear power reactor, thermal power plant this does not produce any hazardous waste or gas. Hence there is no health hazard for living organisms.

- As a developing nation there is a high demand in power generation and due to which our natural resources gets depleted. Hence there is a need to look for the renewable energy power generation. Though there are wind turbines, solar panel, bio gas, they are heavier in construction and cannot satisfy the needs. This drawback is rectified in our Vibro-wind power generator.

- This Vibro-wind power generator is suitable for all weather climates and will be very much helpful for the remote areas.

VI.CONCLUSION

Thus the main aim of this article is to provide a best cross-section of bluff body with low critical wind speed, high amplitude sensitivity and minimal hysteresis loss during galloping which can be used to harvest energy from wind even at low speed and techniques to improve the efficiency by comparing the recent reviews and researches. So far from our references we can conclude that using different mechanical structures, multilayer structures, multilayer connections with series and parallel connections, by varying the thickness of the layers, using more efficient piezo-electric layers (Macro-Fiber composites), by varying the piezo-electric configuration(mode31 and mode33) one can increase the overall efficiency of the system. Power can also be increased by mounting the piezo-electric material nearer to the clamping end of the beam.

Thus, the mechanical design of bluff bodies plays a major role in in the resonant frequency characteristic of a system and therefore in-order to increase the power density, it is important for a designer to consider the above said factors and optimize the design that satisfy the target needs.

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REFERENCE

1. J.M. Kluger , F.C. Moon, R.H. Rand "Shape optimization of a blunt body Vibro-wind galloping oscillator", Cornell University, Ithaca, NY 14850, USA,Journal of Fluids and Structures ,vol-40(2013) pg:185-200.
2. Moon, F.C., 2010b. Vibro-wind energy technology for architectural applications. Accessed 04/28/2013 (http:// www.windtechinternational.com/articles/ vibro-wind-energy- technology- for- architectural-applications).
3. Erturk, A., Vieira, W.G.R., De Marqui Jr., C., Inman, D.J., 2010. On the energy harvesting potential of piezo aeroelastic systems. Applied Physics Letters 96, 184103.
4. Dibin Zhu*a, Steve Beeby, John Tudor, Neil White and Nick Harris,"Improving Output Power of Piezoelectric Energy Harvesters using Multilayer Structures",School of Electronics and Computer Science, University of Southampton, UK,vol-25(2011)pg:199-202.
5. R.Patel[a,*], Y.Tanaka[b], S.McWilliam[a,c,**],H.Mutsuda[b],A.A.Popov[a]"Model refinements and experimental testing of highly flexible piezo-electric energy harvesters", Journal of Sounds and Vibration(2016)
6. Churchill D L, Hamel M J, Townsend C P and Arms S W 2003 Strain energy harvesting for wireless sensor networks Proc. Smart Struct. and Mater. Conf.; Proc. SPIE 5055 319–27
7. Lee C S, Joo J, Han S and Koh S K 2004 Multifunctional transducer using poly(vinylidene fluoride) active layer and highly conducting poly(3,4-ethylenedioxythiophene) electrode:

actuator and generator Appl. Phys. Lett. 85 1841–3

8. Lee C S, Joo J, Han S, Lee J H and Koh S K 2005 Poly(vinylidene fluoride) transducers with highly conducting poly(3,4-ethylenedioxythiophene) electrodes Proc. Int. Conf. on Science and Technology of Synthetic Metals vol 152 pp 49–52
9. Ng T H and Liao W H 2004 Feasibility study of a self-powered piezoelectric sensor Proc. Smart Structures and Materials Conf.; Proc. SPIE 5389 377–88
10. Ng T H and Liao W H 2005 Sensitivity analysis and energy harvesting for a self-powered piezoelectric sensor J. Intell. Mater. Syst. Struct. 16 785–97
11. Mohammadi F, Khan A and Cass R B 2003 Power generation from piezoelectric lead zirconatetitanate fiber composites Proc. Materials Research Symp. p 736
12. Mateu L and Moll F 2005 Optimum piezoelectric bending beam structures for energy harvesting using shoe inserts J. Intell. Mater. Syst. Struct. 16 835–45
13. Platt S R, Farritor S and Haider H 2005a On low-frequency electric power generation with PZT ceramics IEEE/ASME Trans. Mechatronics 10 240–52
14. Baker J, Roundy S and Wright P 2005 Alternative geometries for increasing power density in vibration energy scavenging for wireless sensor networks Proc. 3rd Int. Energy Conversion Engineering Conf. (San Francisco, CA, Aug.) pp 959–70
15. Cho J, Anderson M, Richards R, Bahr D and Richards C 2005a Optimization of electromechanical coupling for a thin-film PZT membrane: I. modeling J. Micromech. Microeng. 15 1797–803
16. Jiang S, Li X, Guo S, Hu Y, Yang J and Jiang Q 2005 Performance of a piezoelectric bimorph for scavenging vibration energy Smart Mater. Struct. 14 769–74
17. Yang J, Zhou H, Hu Y and Jiang Q 2005 Performance of a piezoelectric harvester in thickness-stretch mode of a plate IEEE Trans. Ultrason. Ferroelectr. Freq. Control 52 1872–6
18. Roundy S, Wright P K and Rabaey J 2003 A study of low level vibrations as a power source for wireless sensor nodes Comput. Commun.26 1131–44