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Dual-harvester energy (type3)

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Abstract

In this paper, we describe a multifunctional energy harvesting device that uses both magneto electric and piezoelectric processes in order to harvest energy from stray magnetic and mechanical fields. The device consists of a magneto electric laminate attached to the center of a with a mass at the tip. It was discovered that the system generated output voltage of Vp.p. also manuscript shows that both mechanical and magnetic energies can be summed up using an equivalent circuit model.

Keywords: Energy Harvesting; Piezoelectric Materials; Magnetoelectric Laminates; Stray Magnetic

1. Introduction

Popularity has grown in the society for non-conventional sources of energy. Various approaches have been found to cater the power supply needs of portable devices used by humans which they include piezoelectric and magnetoelectric materials. In certain cases, such as when replacing batteries in distributed sensor networks, which require periodic maintenance, or when operating underwater vehicles or industrial machinery, there is a possibility that these systems can be deployed.

Piezoelectric: The word Piezoelectric is derived from the Greek root "piezein", which means press and the Latin root "Electrum" which means Electricity. The concept of the piezoelectric effect is a mechanical stress response that can generate an electric charge in certain materials. Basically, piezoelectricity occurs when a material physically deforms due to an electric field. This phenomenon can be observed in a wide variety of materials which we can find in quartz and some artificial piezoelectric materials like BaTiO3, Lead Zirconium Titan ate etc. There are many types of piezoelectric materials that have the same single crystal which is PZN-PT and PMN-PT. Also, PZT had a ceramic shape.

Magnetoelectric: Whenever materials have magnetic and electric properties coupled together, they have a magnetoelectric effect. In 1888, Wilhelm Röntgen discovered that dielectric materials become magnetized when they are subjected to an electric field. Materials with intrinsic couplings such as these are referred to as magneto electric.

Magnetostriction: refers to the effect of magnetic fields on ferromagnetic materials. Observing a sample of iron in 1842, James Joule identified the effect for the first time. The magnetic effect of magnetostrictive materials allows electromagnetic energy to be converted into mechanical energy and vice versa. This effect can be used to develop magnetic field sensors or force sensors. When a magnetic field or force is applied to a material, strain is created. Fe-Si-B-C-Sn alloy having a high saturation magnetic flux density and excellent thermal stability are used for magnetic cores for transformers. Our device is made from magnetostrictive /Fe-Si-B-C/ alloy ribbons laminated with piezoelectric /Pb (Zr, Ti) O3 / PZT fibers.

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2. The Characterization Of Eh (Designing)

A schematic illustration of the energy harvester (EH) that the magneto electric (ME) lamination configuration was four magnetostrictive Fe-Si-B-C ribbons laminated onto two PZT fiber layers with push-pull units of symmetric polarization. It is possible to use two mechanisms simultaneously with this design:

- By using the magnetostrictive effect of Fe-Si-B-C, stray magnetic fields (H) can stimulate longitudinal strain through the magneto electric effect then give electricity (magnetoelastoelectric)
- By piezoelectric effect causes strain through mechanical vibrations and generate electricity.

When combined, these two responses will result in generating electricity from composite strain. Due to the elastic interactions that occur during the conversion, there is the possibility of an additive effect.

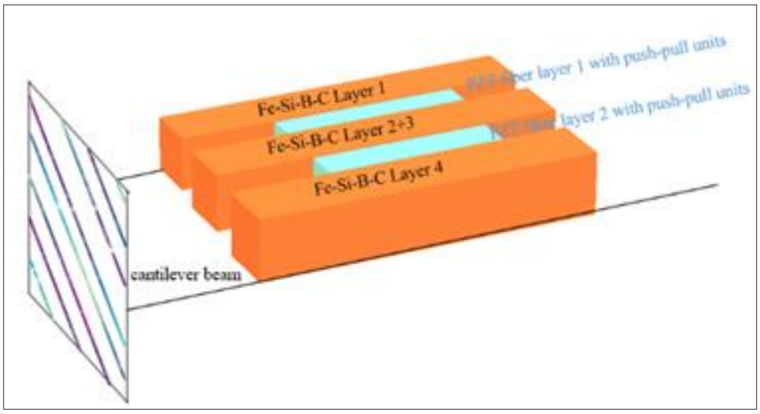

Figure 1 Prototype of EH

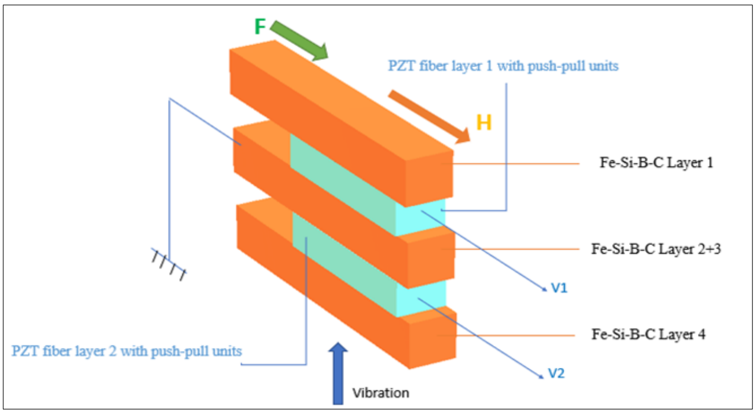

Figure 2 Schematic Illustration of EH

A magnetic field (Hac) and a force (F) of frequency are applied to the laminate synchronic, Essentially, vibrations longitudinally and bendingly will be created. Accordingly, the induced voltage across the dielectric layer can be calculated by using the following formula:

$$U^{ind} = -\varphi_e \left(\frac{Zc}{Z_m}\right)(F + \varphi_m H) \ldots \ldots (1)$$

- φ_e : Electromechanical coupling factor.
- φ_m : Magnetostrictive coupling factor.
- Zc : Capacitance impedance.
- Z_m : Mechanical impedance.

The equation (1) can write as follows:

$$U^{ind} = -\varphi_e \left(\frac{Zc}{Z_m}\right) F - \left(\frac{Zc}{Z_m}\right) \varphi_e \varphi_m H \ldots\ldots (2)$$

A negative (-) indicates the reverse phase between the (F and H) and the induced voltage induced. It is evident that the induced voltage is the result of two contributions:

- **F-induced voltage:** as a result of a mechanical-to-electric conversion (φ_e).
- **H-induced voltage:** as a result of a magnetoelastoelectric conversion ($\varphi_e . \varphi_m$).

The equation (2) refers that the (F or H) induced voltage comparing the capacitance impedance (Zc) of a piezoelectric layer with the mechanical impedance (Z_m) of the layer the entire ME laminate. An appropriate mechanical impedance should be adjusted in a laminate in order to achieve effective stress transfer to the vibration source. Therefore, high coupling factors, a low damped capacitance that is a high piezoelectric voltage coefficient, and a high coupling between the laminate and the vibration source are the variables that can result in large induced voltages.

With the use of Helmholtz coils powered by a function generator and with Fe-Si-B-C ribbons, an alternative magnetic field was created (H_{ac}) as figure (3) & (4).

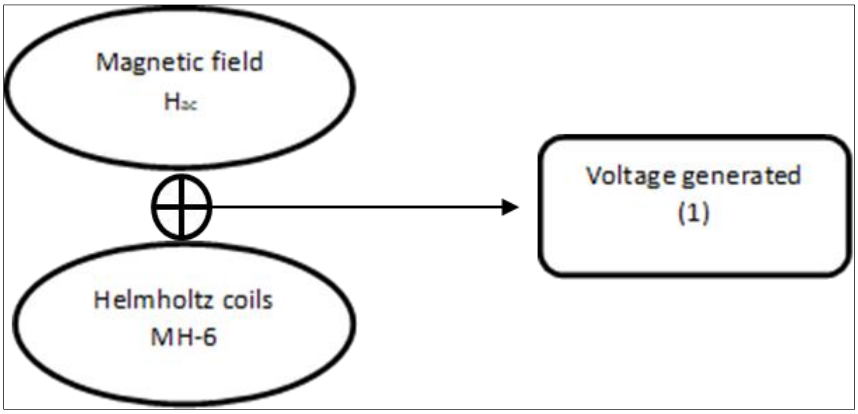

Figure 3 Schematic diagram of the first voltage generation

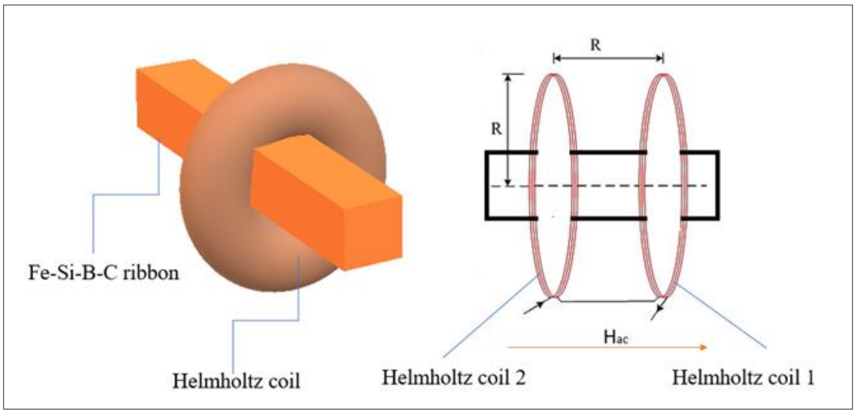

Figure 4 Illustration of first generation

Here is a graph (5) of the H-induced voltage and power based on ($P=V^2/R$) as follow

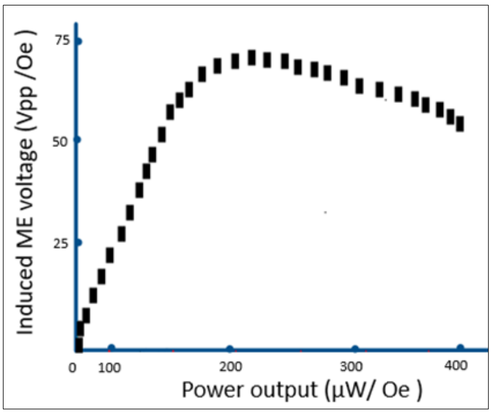

Figure 5 Relation between power and voltage for First generation

Vibration testing was performed using shakers of wheel to exert mechanical excitation on ME laminates and it monitored by PCB Piezotronics Accelerometer Model number U352C22 / meter 482A16. Piezoelectricity is the result of mechanical vibration causing a voltage to be generated and showed in figure 7 for V1 (first layer) & V2 (second layer) as the free end of the cantilever was attached to a mass of 1 g on top of a shaker of whee.

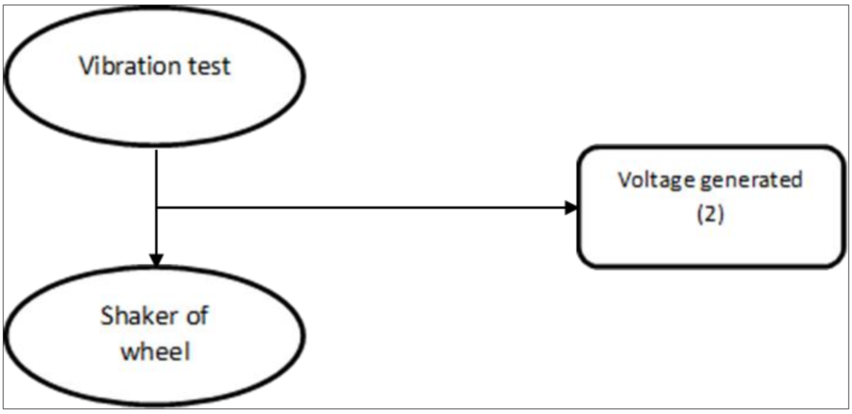

Figure 6 Schematic diagram of the Second voltage generation

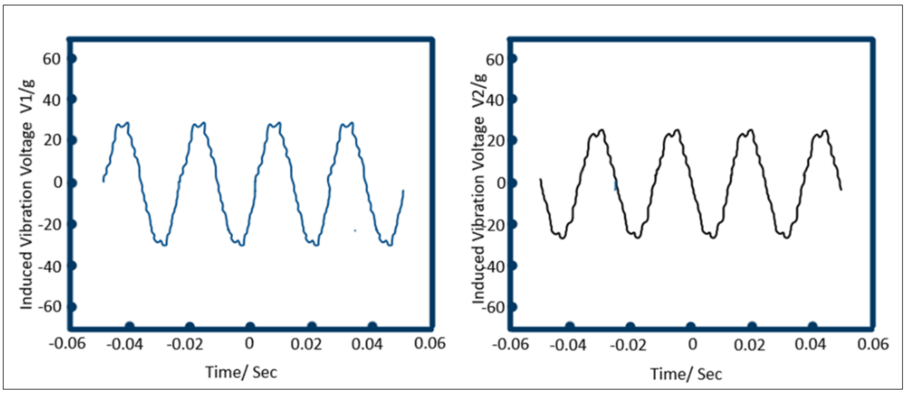

Figure 7 Induced Voltage generate per first layer V1 and second layer V2

3. Results and discussion

The following table summarizes the results

Table 1 Summary of final results

System	Voltage	Power
First system	~ 64 Vp.p./Oe	422 µW/Oe for 49 KΩ load
Second system (V1+V2)	~ 60 Vp.p./g	404 µW/g across 3.2 MΩ

According to Figures 5 and 7, the first system's and second systems voltages are around 124 V and 826 µW (power) for resonance frequencies of 20 kHz, 1/Oe and 1/g respectively. These results show that both the magnetic field and mechanical vibrations affect laminates. Two external inputs were applied at the same frequency in our case, doubling the generated electric charge due to bending stress on the composites.

4. Conclusion

Overall, we describe a multimodal system that can simultaneously harvest both mechanical vibrations and magnetic energies. The electric energy is generated when a magneto elastic contribution is combined with a piezoelectric contribution. In the future, this design may prove valuable for creating EH components for underwater vehicles, industrial machinery, or automobile wheels.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors agree no conflict of interest.

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