APPLICATION OF ENERGY HARVESTING OF VIBRATIONS CAUSED BY PASSING TRAINS

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Abstract. *Vibration is a source of energy that can be recycled and used to power some specific devices. This work presents an experimental case of energy harvesting of vibrations caused by passing trains. The main goal is to evaluate the possibility of storage the low energy produced into a battery and capacitor for reutilization. To that end, piezoelectric devices were attached to a train line prototype and connected to the storage elements and rectifier circuits. A plain machine with a steel wheel provided the impact input form to the prototype (simulating the train moving on the line) and the vibrations caused were converted to electric energy. Although has relative low power production, the amount of energy converted from the vibrations caused by the train movement, the vibrations can be considerable as font due to the cycle and continue movement of the passing train.*

Keywords: *Energy Harvesting 1, Piezoelectric ceramic 2, Vibration 3, Passing Train 4.*

Resumo. *A vibração é uma fonte geradora de energia reciclada, que pode ser utilizada para alimentar alguns dispositivos específicos. Este trabalho apresenta um caso experimental de captação de energia através de vibrações causadas pela passagem de trens. O objetivo principal é avaliar a possibilidade de armazenamento da baixa energia produzida em bateria e capacitor para reaproveitamento. Para tanto, pastilhas piezoelétricas foram acopladas a um protótipo de linha de trem e conectadas aos circuitos retificadores e elementos de armazenamento. Uma plaina com um dispositivo contendo uma roda de aço, aplicou impactos e movimentos contínuos ao protótipo (simulando o movimento do trem sobre a linha) e as vibrações causadas foram convertidas em energia elétrica. Embora tenha uma relativa baixa produção de potência ou quantidade de energia convertida, a partir das vibrações causadas pelo movimento do trem, as vibrações geradas podem ser consideráveis fonte de energia, devido ao ciclo e movimento contínuo da passagem dos trens.*

Palavras chaves: *energia recuperável 1, cerâmica piezoelectrica 2, Vibração 3, Vibração induzida 4.*

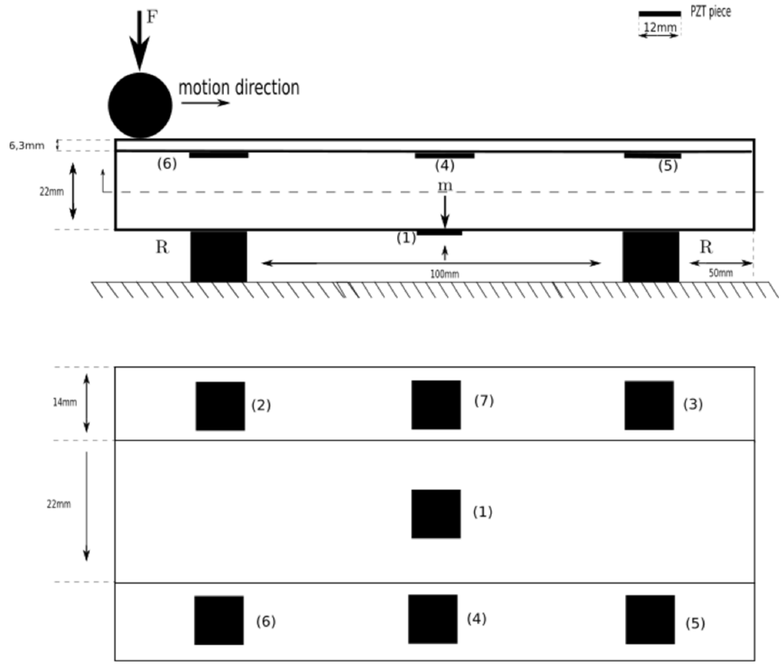
1. INTRODUCTION

Mechanical vibrations showed to be a very rich source of energy that in many cases can be converted to useful electrical energy (Energy Harvesting). Piezoelectric devices are widely used as transductor of energy combined to vibration. Studies of the applicability and energy-efficiency with diverse piezoelectric interfaces and piezoelectric material as transductors of kinetic energy had been performed to investigate the pertinency of harvesting energy to supply wireless systems [1]. The applications of combination between piezoelectric and vibration has advantages and challenges. Gljuscic et al. [2] analysed power requirements for sensors associated data logging and circuit transmission. The majority of studies in literature used electromagnet transformer or electric generator through vibration caused by passing train, as this kind of devices are able to amplify the energy produce from (μ)microwatts to (m)milliwatts. The utilization of piezoelectric devices for harvesting energy showed be suitable to devices developed to have an ultra-low energy consumer behaviour. Nelson et al. [3] presented an investigation using a piezoelectric transducer attached to the bottom of the rail to scavenge energy from vibration induced by loaded and unloaded freight trains.

In this scenario, this work presents an experimental case of energy harvesting of vibrations caused by passing trains in which piezoelectric devices were attached to a train line prototype and connected to different storage elements: capacitor and cell phone battery. A plain machine with a steel wheel provided the impact input form to the prototype (simulating the train moving on the line) and the vibrations caused were converted to electric energy.

2. EXPERIMENTAL CONFIGURATION

Many experiments have been performed to evaluate the interaction between wheel-track and impact forces [4]. Some have the intention do predict the security by delimitation of those dynamic forces. In order to simulate the impact caused by the wheels train at the train line, a train line model was built and mounted on a planer Zocca 550. The energy harvester prototype consists of a two different steel beam welded on a steel plate in order to simulate the sleepers and the trail line. The train wheels movement were simulated by a steel wheel fixed to the plain. The continues movement of the steel wheel on the prototype and its constant return represents impact forces caused by the passing trains. The piezoelectric elements were connected to a rectifier circuit and then to a charging capacitor and battery (separately). The capacitor and battery voltages were measured by a multimeter in order to verify the electrical energy being harvested by the storage elements. The actual test setup can be seen in Fig. (1b).



(a)

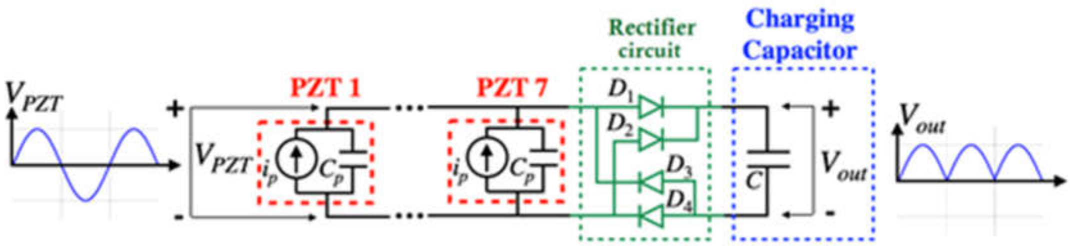
(b)

Figure (1). (a) Simplified trail line model showing the position of the piezoelectric elements and (b) Experimental setup used in the Energy Harvesting process

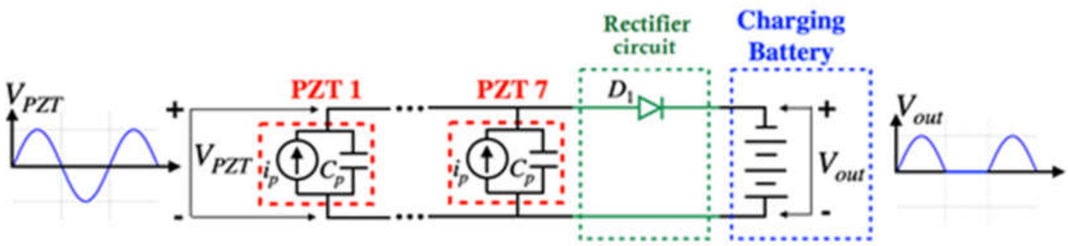
As harvester producer is used lead zirconate titanate Pb(ZrTi)O3 (PZT). This ceramic has a relatively low hydrostatic piezoelectric coefficient and piezoelectric voltage coefficient (*g*33) because of their negative *d*31 and high dielectric constant respectively that properties give to these ceramic good piezoelectric features [6]. Piezoelectricity is the characteristic that is present in materials that become polarized when a homogeneous deformation occurs. Plates with 1 mm thickness was cut in pieces square 12x12mm dimensions [5]. This PZT's pieces were sticked under the model of train line, along to the 7 positions described on the Fig. (1a). Electric cables were welded on the PZT's pieces (positive) and on metallic leaf was sticked on opposite side of PZT and weld on the model of train line as well. The primary tests were made with oscilloscope (Tektronix TDS 1012B) to be sure that all PZT's were working well by production of energy.

The piezoelectric ceramics can be electrically represented by a current source (i_p) in parallel configuration with its internal capacitance (C_p) [7]. Many electrical circuits have been done to apply the poor electrical current and high electrical voltage, generated by the PZT, in diverse system [8]. According to the Fig. (2), it's possible to observe that the 7 piezo ceramics were connected in parallel to the rectifier circuit and the current will run throughout only of positive part after both rectifiers. The harvested energy has a range of frequencies. The circuit will convert it to be stored and used as a continuum electric power.

Two different storage elements were used: a capacitor (HITANO 470μF25V) and a cell-phone battery (SAMSUNG 3,7V Li-ion 5,55Wh – 1500mAh). In order to obtain an output voltage signal necessary to perform the harvested energy, two different rectifier circuit were used considering a combination of Zenner diodes.



(a)



(b)

Figure 2 Rectifier circuits set for charging (a) capacitor and (b) battery

3. RESULTS AND DISCUTIONS

Two different sets of experimental tests were conducted during 3 hours each set and 4 measurements for set were performed considering one hour interval between measurements. The planer provided a periodic impact input to the simulated track. An example of the signal obtained by the piezoelectric material is shown in Fig. (3). This signal was repeated in time, and two sets of measurements were performed in different days.

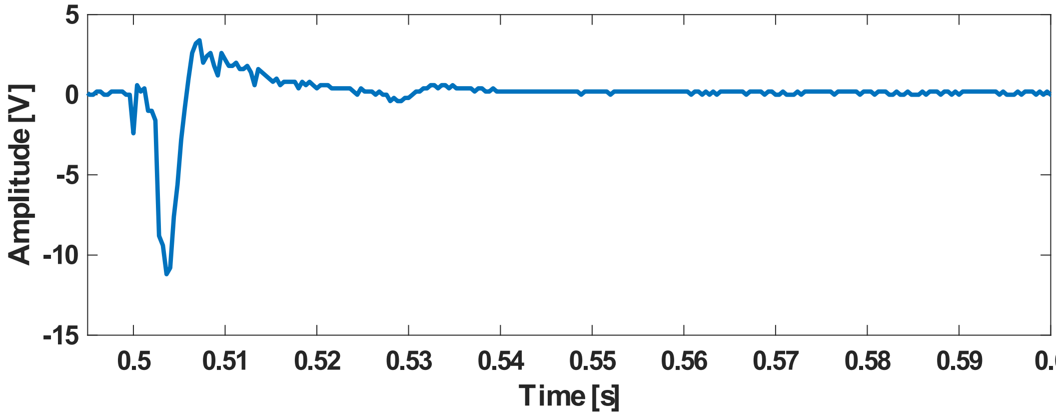
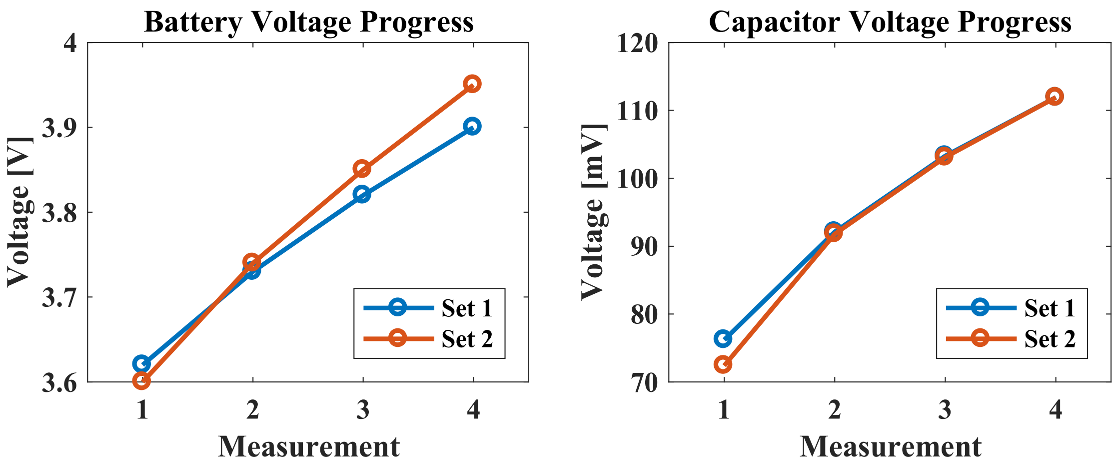


Figure 3. Voltage signal captured by the piezo ceramic.

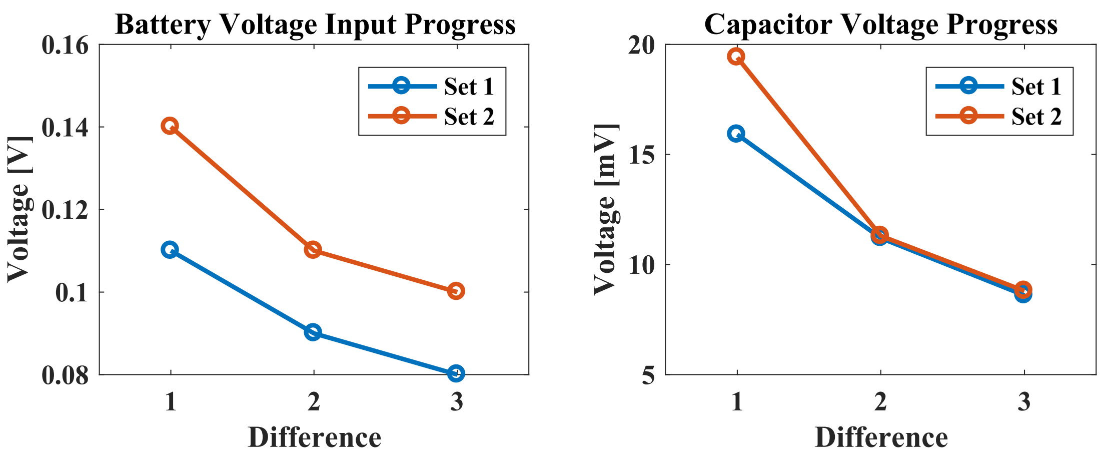
Fig. (4) shows the output voltage progress obtained for the battery and the capacitor. As can be seen, the voltage increased confirming that the harvested energy was stored by both elements. The vibration caused by the passing trains can be harvested by the piezoeletric elements and the energy can be possible used to power some specific devices.



(a) (b)

Figure 4. Voltage measurements showing the (a) battery and (b) capacitor charging

Although the measurements were carried out in the same time interval (1 hour), the progress of the captured energy decreases, although both the battery and the capacitor continue to accumulate energy, this amount of stored energy becomes smaller and smaller. As shown in Fig (5).



(a) (b)

Figure 5. Difference of voltage input in consecutive measurements for (a) battery and (b) capacitor.

4. CONCLUSIONS

The extracted of energy from PZT cells still be very low but these paper shows that is possible to storage it into battery and capacitor for re utilization. The analyzing of figures 7 and 8 is possible to recognize that how much closer to the highest capacity, less is the charge voltage storage, although it still happens until stability. Because of this for future researcher is recommended to looking for a modern and market actually devices battery and capacitor that can bring better results of amount of energy harvested and timeless to get it.

The circuit can be as well a focus of new research, as it had an important part of the results and can have influence on results of energy harvested.

The goal of this paper has been accomplished and shows that many small cells along a train line can produce energy that can be stored to be used in situations like blackouts, when security signals must be activated, wireless information can be sent or only security neon lights can be turned on.

5. REFERENCES

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6. RESPONSABILITY NOTICE

The authors are the only responsible to the information presented in this work.