



A POTENTIAL STUDY OF PIEZOELECTRIC ENERGY HARVESTING IN CAR VIBRATION

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ABSTRACT

Micro Generating System Using Piezoelectric for Low Energy System is a system that provides the user with free flowing energy that can be used without any consequences to the environment. This system enables users to generate low energy for their uses by transforming the mechanical energy produced by the car engine vibration into electrical energy. This project is generally about designing and developing the circuit and its charging system for piezoelectricity. The electrical energy harvested is then charged the capacitor after passing through full wave rectifier. The harvesting system is made up of piezoelectric cantilever that will convert vibration to electrical energy and the charging system is made up of capacitor and known as capacitor banks. The system is then installed at a car engine to generate energy from the car vibration when the engine is switched on. The energy is then being directly used or stored in the capacitor bank for future uses.

Keywords: piezoelectric, renewable energy, vibration.

INTRODUCTION

The process of acquiring the energy surrounding system and converting it into usable electrical energy is termed power harvesting. In the last few years, there has been a surge of research in the area of power harvesting (Verbelen, Y.; Touhafi, A., 2013). This increase in research has been brought on by the modern advances in wireless technology and low-power electronics such as micro-electromechanical systems. The advances have allowed numerous doors to open for power harvesting systems in practical real-world applications (Amirthalingam, M., 2010). The use of piezoelectric materials to capitalize on the ambient vibrations surrounding a system is one method that has seen a dramatic rise in use for power harvesting. Piezoelectric materials have a crystalline structure that provides them with the ability to transform mechanical strain energy into electrical charge and, vice versa, to convert an applied electrical potential into mechanical strain (Wang Hongjin; Meng Qingfeng; Zhang Kai, 2013). This property provides these materials with the ability to absorb mechanical energy from their surroundings, usually ambient vibration, and transform it into electrical energy that can be used to power other devices. While piezoelectric materials are the major method of harvesting energy, other methods do exist; for example, one of the conventional methods is the use of electromagnetic devices (Turkyilmaz, S.; Muhtaroglu, A.; Kulah, H., 2011).

Many researches that has been performed in the area of power harvesting and the future goals of the research that must be achieved in the field of power harvesting systems is to find their way into everyday use (Shukla, R *et al*, 2010). Piezoelectric materials belong to a

larger class of materials called ferroelectrics. One of the defining traits of a ferroelectric material is that the molecular structure is oriented such that the material exhibits a local charge separation, known as an electric dipole. Throughout the material composition the electric dipoles are orientated randomly, but when the material is heated above a certain point, the Curie temperature, and a very strong electric field is applied, the electric dipoles reorient themselves relative to the electric field; this process is termed poling. Once the material is cooled, the dipoles maintain their orientation and the material is then said to be poled. After the poling process is completed the material will exhibit the piezoelectric effect. (Henry A. S; Daniel J. I. and Gyuhae, P., 2004.)

PIEZOELECTRIC

Fundamentals of Piezoelectric material

According to E. Minazara, D. Vasic and F.Costa in their paper entitled "Piezoelectric Generator Harvesting Bike Vibrations Energy to Supply Portable Devices", piezoelectricity is a physical phenomenon that convert mechanical movements into electricity. There are two types piezoelectric effect, firstly, the material's ability to transform mechanical strain into electrical charge known as the direct effect, and secondly, the ability to convert an applied electrical potential into mechanical strain energy or the converse effect (Rahib, A.A.M *et al.*, 2013). The effect of the piezoelectric fundamentals is shown in Figure-1 for direct piezoelectric effect and reverse piezoelectric effect. Piezoelectric sensors exhibit the direct piezoelectric effect whereas actuators use the converse piezoelectric effect (Tabesh, A.; Frechette, L.G, 2010).

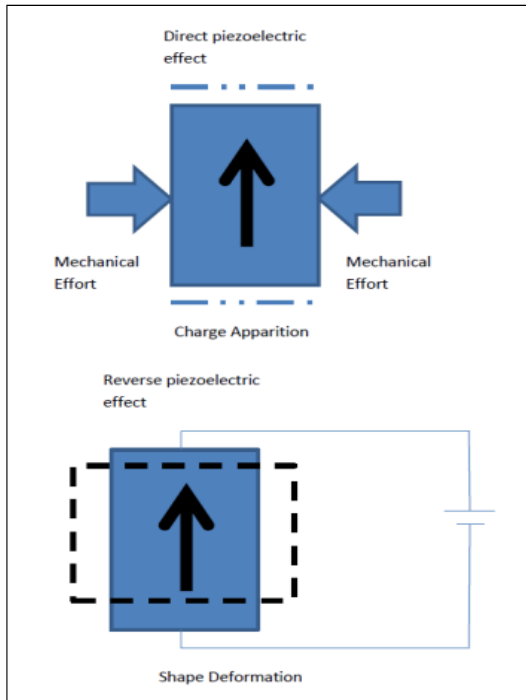


Figure-1. Piezoelectric fundamentals.

Piezoelectric generator

C. R. Saha explains the usefulness of most high technology devices such as cell phones, computers, and sensors is limited by the storage capacity of batteries. In the future, these limitations will become more pronounced as the demand for wireless power outpaces battery development which is already nearly optimized (C. R. Saha *et al*, 2008). Thus, new power generation techniques are required for the next generation of wearable computers, wireless sensors, and autonomous systems to be feasible (Magno, Michele *et al*, 2013). Piezoelectric materials are excellent power generation devices because of their ability to couple mechanical and electrical properties (E. Bouendeu *et al*, 2009). For example, when an electric field is applied to piezoelectric a strain is generated and the material is deformed (J. C. Park *et al*, 2009). Figure-2 shows the piezoelectric generator principle.

Consequently, when a piezoelectric is strained it produces an electric field; therefore, piezoelectric materials can convert ambient vibration into electrical power. Piezoelectric materials have long been used as sensors and actuators; however their use as electrical generator is less established. A piezoelectric power generator has great potential for some remote applications such as in vivo sensors, embedded MEMS devices, and distributed networking (Lopes, C.M.A.; Gallo, C.A, 2014). Developing piezoelectric generators is challenging because of their poor source characteristics that are high

voltage, low current, high impedance and relatively low power output

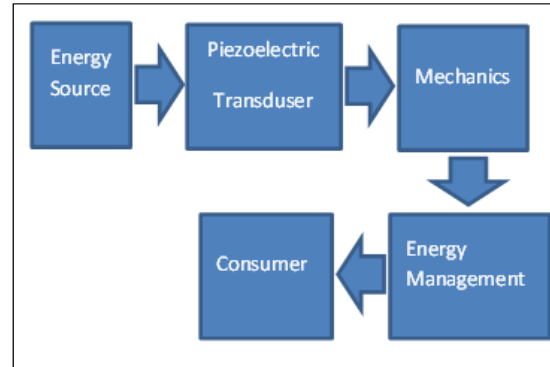


Figure-2. Piezoelectric generator principle.

Piezoelectric Cantilever

A piezo cantilever beam is a common design configuration for piezo film technology since the film produced its highest output per unit strain when elongated. It is also particularly well-suited for use within high-fidelity transducers, such as microphones, due to its wide operating range, from low frequency (<100 Hz) up to ultrasonic (>100 MHz). Figures 3 and 4 below shows two types of piezoelectric cantilever used in this project.



Figure-3. Piezoelectric cantilever with mass.

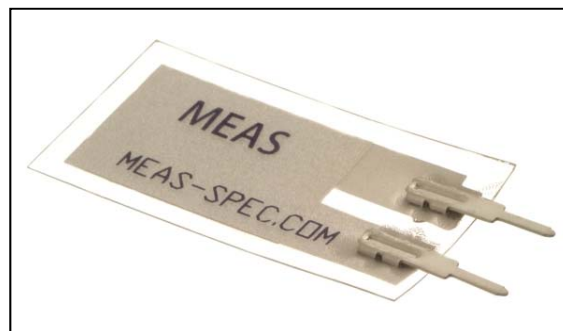


Figure-4. Piezoelectric cantilever without mass.



RESULT AND DISCUSSIONS

Output characteristics of Piezoelectric Cantilever

An initial experiment is conducted in order to understand the basic characteristic of the cantilever piezoelectric. The piezoelectric is tested by using a vibration source. The output comparison of both piezoelectric type is compared for Piezoelectronic cantilever with mass and Piezoelectronic cantilever without mass.

The result for both fundamental characteristic of the piezoelectric is shown in Figures 5 and 6. The output of both of the piezoelectric can be distinguished where compared both of the output voltage of the piezo for the same group of vibration, the piezoelectric cantilever with mass and piezoelectric without mass show almost the same output characteristic.

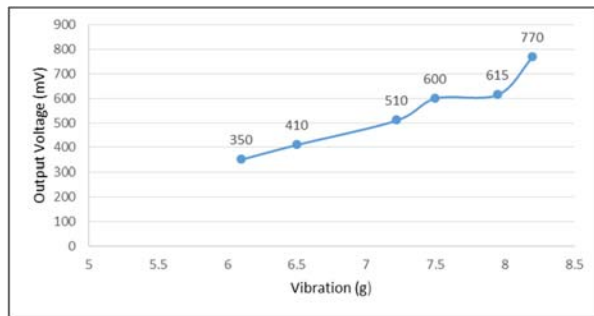


Figure-5. Piezoelectronic cantilever without mass.

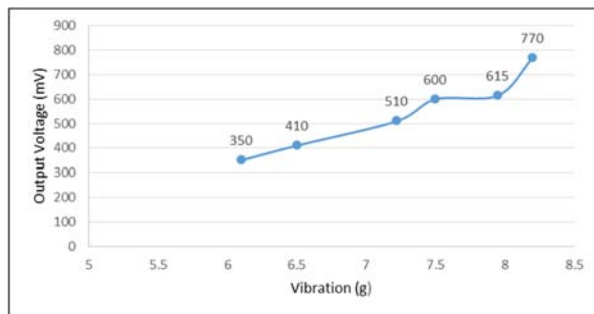


Figure-6. Piezoelectric cantilever with mass.

Second experiment is done to study the effect of based on the piezoelectric cantilever. A base is design for the piezoelectric cantilever to study the output relationship and the distance with base and without base. The relationship of the base and distance is as shown in Figure-7.

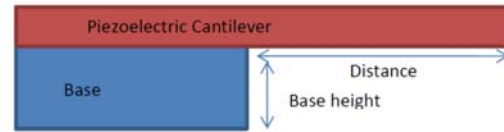


Figure-7. Relationship of piezoelectric, base and distance.

Based on the experiment, it found out that from the results obtained in the Figure-8, it is shown that the piezo cantilever with mass is more sensitive to the vibration at car engine compared to the piezo cantilever without mass. The output voltage produced by the piezo cantilever with mass is also higher than the piezo cantilever without mass. Next, the varied distance also contributes to the output voltage produced. The graph shows that the distance of 1.5 cm is the best distance of piezo cantilever used to generate energy from vibration in this project. This is because the output voltage produced is higher compared to other distances. Thus, harvesting energy circuit for this project is using the piezo cantilever with mass and the distance is 1.5cm.

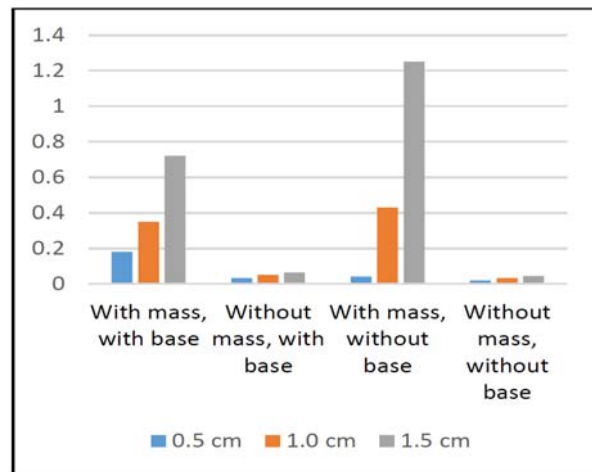


Figure-8. Relationship of output voltage with based and varied distance.

Experimental work of Piezoelectric Cantilever

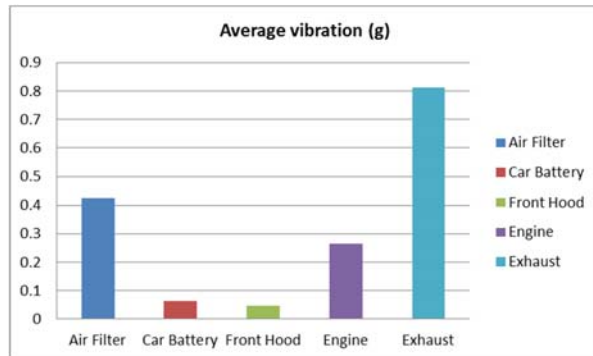
In order to study the most significant placement of piezoelectric output at a car, a results was obtained from measuring the vibration at several point at the car, it is shown that the vibration at exhaust is the highest compared to the other. But it is not possible to generate energy from vibration at the exhaust due to several limitations. First of all, the temperature of exhaust will become hot and may affect the piezo cantilever performance.

The value of the maximum vibration generated at different point of the car is shown in the Table-1.

**Table-1.** Vibration produced at each point of the car.

Location	Maximum vibration (g)
Air Filter	0.46
Car Battery	0.07
Front Hood	0.05
Engine	0.24
Exhaust	0.79

In order to determine the best position for the placement of the piezoelectric based on the vibration, the average vibration for each of the selected point is studied. The average vibration produced for each selected point is as shown in Figure-9.

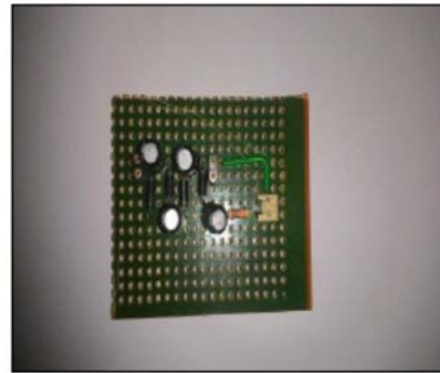
**Figure-9.** Average vibration produced on different point of car.

Based on the average vibration produced on the selected point, the highest point is the exhaust followed by the air filter and the engine. However, two points of the engine that is the car battery and front hood only give minimum output of vibrations, therefore this point is neglected as potential installation for piezoelectric generation system. Another potential area is in the exhaust system, but due to the heat emitted and the exposed condition of the exhaust system this point also been neglected as the installation of point of piezoelectric. Based on this condition two points were selected as the experimental point for the piezoelectric that is the air filter and the engine point.

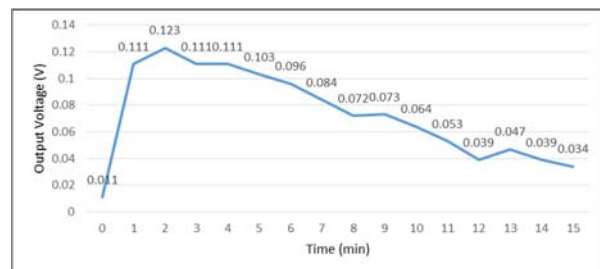
Output voltage of Piezoelectric in different point of car

Next, the piezoelectric micro generating system is tapped at selected points at the car engine. The two points that are air filter and engine where these two points produce the suitable vibration needed for the piezoelectric micro generating system. This is because the output voltage generated from the circuit depends on the vibration produced.

In order to give load for the measurement of the output given by the piezoelectric, a capacitor was designed and used as the load for the piezoelectric micro generating system. The complete circuit of the capacitor bank is shown as in Figure-10.

**Figure-10.** Capacitor bank as output load for piezoelectric.

The first that been tested on the piezoelectric output is that engine of the car. The resultant of the output can be seen from the graph in Figure-11, the output voltage generated by the system increased drastically from initial time to 1st minute. This is because the car engine is being started up and the vibration produced by the engine is at the highest. Then, the output voltage increased slightly before starting to decrease from the 3rd minute onwards due to stable vibration produced by the engine because the car is static and there is small amount vibration produced. The system does not utilise enough vibration from the engine to harvest energy. For a car in static condition, this is not the suitable point to install the system because the system only utilised the vibration produced at the moment the car engine started and cannot generate sufficient energy after the engine has been stable and onwards.

**Figure-11.** Output of Piezoelectric in Engine vs Time.

The second point of the piezoelectric placement is on the air filter. For this point we can see from the graph in Figure-12 shows that the output voltage generated increase linearly with time from the beginning of



experiment until 6th minute. This is because the engine of the car was just starting to run and air filter begins to allow air-intake, resulting in drastically increasing output voltage generated. This is the period where the vibration produced at the air filter at the highest. However, the output voltage generated starting to remain constant after the 6th minute due to the engine has been stable and the air-intake at air filter for non-moving car is the same as before, resulting in vibration produced also remains the same. Thus, the output voltage generated remains constant.

Hence, this is the best point to install the system for a car that is not moving because the system generate energy at the moment the car engine is starting up and after the engine has been stable, the output voltage remains the same and there is no significant increase for the interest of this project.

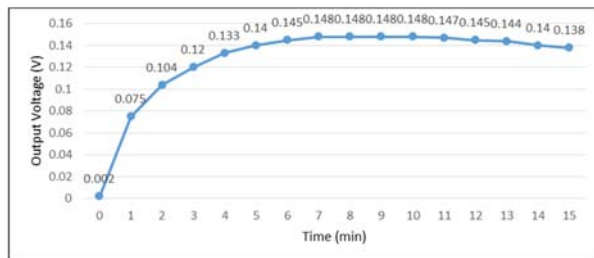


Figure-12. Output of Piezoelectric in Air Filter vs Time.

CONCLUSIONS

There are various source of renewable energy that can be harvested from the environment. Piezoelectricity, by the mean of vibration is one of the most conventional because the source of vibration is present almost everywhere. Furthermore, it is environmental friendly and does not pollute the environment.

For this project, Micro Generating System Using Piezoelectric for Low Energy System, car engine has been chosen as the source of vibration. The experiment was conducted at several point at the engine to obtain various result of energy harvesting. However, not all vibration level can be used as source due to several limitations.

The circuit for this project consists of a full-wave bridge rectifier, and charging and discharging capacitor. The function of full-wave bridge rectifier is to convert the alternating current (AC) from the output of piezo cantilever to direct current (DC). Charging and discharging capacitor is used to store the energy generated from the circuit for future uses. The system is installed at car engine because it produces optimum vibration and does not affect the performance of piezoelectric cantilever. Piezoelectric cantilever with mass is used in this project because it is more sensitive to the vibration produced at the car engine compared to piezoelectric cantilever without mass.

The best location to install the system is at air filter or the air outflow of the car air filter because the system can generate continuous energy. This is due to the vibration produced is sufficient even when the car is in static condition. Based on the initial finding the piezoelectric output, it seem that piezoelectric is having a potential in generating micro energy especially for the electronic system in the hybrid cars.

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