UNIVERSITI TEKNIKAL MALAYSIA MELAKA

POTENTIAL STUDY OF PIEZOELECTRICITY GENERATION SYSTEM FROM VEHICLE VIBRATION

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Electrical Engineering Technology (Industial Power) (Hons.)

by

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DECLARATION

I hereby, declared this report entitled "Potential Study of Piezoelectricity Generation System from Vehicle Vibration" is the results of my own research except as cited in references.

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Date : 13th January 2016

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfilment of the requirements for the Degree of Bachelor of Electrical Engineering Technology (Industrial Power) (Hons.). The member of supervisory is as follow:

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Syahrul Hisyam bin Mohammad @ Abd Rahman

(Project Supervisor)

ABSTRACT

The purpose of the study is to study and investigate the potential power produce by using the vehicle vibrations energy harvesting using technique from piezoelectric. This new method of harvesting itself will be used and expected to generate a low voltage output. The piezoelectric sensor is the main component in the design. It works with the vibration placed on it by converting mechanical energy into electrical output. The study involved on investigation of vibration from different point within the car and choosing the best point. The piezoelectric device is then mounted near the selected vibration source from the vehicle. The outcomes will be contributed by vibrations in the vehicle, thus vibrates and displacement to the piezoelectric device to produce electricity. Then, the electricity generated in voltage. The voltages that are generated maybe one of the new ways to produced hybrid cars or recharging the battery that is used by hybrid cars in future. The project is an effective to be used as a method to conserve the wasted energy as well as to reduce the dependencies on fuel. The positive side to take as the main advantage is that the electricity will remain generated as long as the vehicles vibrations are available. Besides, the project is taking into account of the green technology device as recommended and all daily users who are using the cars can get benefits by the system.

DEDICATION

I dedicate my dissertation to my family and many friends. A special feeling of gratitude to my be loving parents whose give me endless support throughout my studies and to my family whose never left me alone and are very important to me.

I also dedicate this dissertation to my special friends, especially my supportive classmate of BETI for helping me through the process of completing this thesis. A special thanks to my supervisor who always guide and help me to develop this project as well as this report. Thank you for everything.

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INTRODUCTION

1.1 Introduction

Sustainable energy is an energy that can be can be produce without destroying or causing harmful to the nature. This energy also has the unlimited sources which could potentially persist into the future. This sustainable energy is also known as green energy. Today, we can see that the energy consumption around the world is increasing due to a massive development around the world including vehicle industries. The usages of fuels are also increases as the demand from the people to have their own vehicle are increase. Nowadays, green energy became so popular especially to the countries that were still developing around the world. Green energy are renewable energy resources that actually came from sunlight, wind, rain, tides, plants and more. Compare to fossil fuels, it does take a millions of years to develop into a fine fuel and at the same it also a finite sources of energy.

This green energy has been widely developed to ensure that it's not just sustainable but also can deliver a good amount of power it can produce, more efficient and cheap. This development of green energy also saves the earth from heating, exceeding carbon oxide in the air as well as to keep the air more cleanly. Green energy can replace fossil fuels in all major areas of use including electricity, water and space heating and fuel for motor vehicles. We can see some of motor vehicle started to use battery as their energy instead of fuel to move the vehicle. Hybrid vehicle are the vehicle that using both battery and fuel at the same time. Since that battery has limited usage, this type of car is not suitable to travel for a long distance.

1.2 Problem Statement

Electrical motor vehicles are the type of vehicles that are using battery as their energy sources to move the vehicle. This type of vehicle is good as it reduce the carbon emission in the compared to a fuel vehicle used on the road. It also does not make a loud sound as a normal vehicle do. Some of this vehicle are fully operated using battery but some of it are using both battery and fuel. The battery must be charging every time it run out of power, thus this indicates that the battery has a certain limited of usage. Besides, to replace a battery if the battery is damage is quite expensive and this battery also has a short lifespan.

Since that most of population in the world are having their own vehicle, there are abundant alternative methods to generate energy from the vehicle. As we can see when the car is igniting, the vehicle will produce some sort of vibration. This vibration can be used as an energy harvester. Harvesting electrical energy from vibration is of great interest, particularly for generating voltage, due to the ubiquitous presence of environmental motion that can be transformed into useful electrical power through several methods of electromechanical transduction.

Piezoelectric materials have received the most attention due to the ease of direct conversion from kinetic to electrical energy achieving high power densities and ease of integration into a system. As we can see, the vehicle is the best source to produce the vibration where it is suitable to study the potential piezoelectric to generating voltage. The vehicle is the best source because most of the transportation is one of the human needs. By doing this study, there is a potential that the piezoelectric will become a suitable source of generating system in vehicle.

1.3 Project Objective

The objectives of this research study are listed as follows:

a) To study the potential of a piezoelectric as an energy harvesting from vehicle.
b) To develop and testing a piezoelectric energy harvesting system from vehicle.
c) To analyse a small voltage from vehicle vibration by using piezoelectric.

1.4 Project Scope

In order to achieve the stated objectives, several work scopes had been identified. This scope is to make sure that this project is not out of the studies and investigation that will be conduct. The work scopes are listed as below:

a) To identify the sources of vibration on selected vehicle.
b) To measure the vibration value on the vehicle.
c) To compare and select the suitable piezoelectric to generate electricity through vehicle vibration.
d) To record and analyse the generated voltage from piezoelectric.

CHAPTER 2
LITERATURE VIEW

This chapter provides the preliminary reviews for the piezoelectric background. Literature reviews will explain about the history of the piezoelectric and type of materials that are used in manufacturing this project. Besides, the discussion about the piezoelectric that will be used in this project will be listed out and explain. Hence, this chapter will start with the explanation of the history of the piezoelectric in the next section.

2.1 History of Piezoelectric

In 1880, Jacques and Pierre Curie were working as a researcher in the mineralogy laboratory at Sorbonne, Paris in France. Both of them demonstrated that when crystal of quartz is applied with stress in form of weight, a proportional electrostatic polarisation was generated along an axis at an angle to the direction of the stress to a sufficient magnitude that the charge on the surface could be detected by an electrometer. This phenomenon was called piezoelectricity which is taken from the Greek word which means pressure. This phenomenon has the similar to Lenz's law, which the existence for this inverse effect has to do with induced current and magnetic field.

Hankel, Lord Kelvin and Voigt have developed the relevance of geometrical theory of crystals in 1894. They shows that how the atomic structures of the materials were affecting each other's and how does the atomic phenomenon could be related to Lenz's law. According to A.J. Pointon (1982), during the First World War, Langevin has developed a practical device which is the first application of the piezoelectric effect. His devices known as 'Langevin's sandwich' are used as an originator for the sonar system as well as the science of ultrasonic. He has the idea by envisaged the high frequency sound wave which is generated in the water as a means of detecting the submerged object, for example submarines

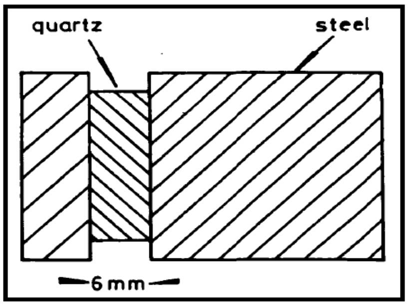

Figure 2.1 Langevin's sandwich

In 1920's the quartz material that are functions for the oscillators stabilization were now becoming as a field of frequency control. This make the quartz resonator become more precise in any applications especially in we known as a timekeeping. Thus, this make the frequency become the most entity known that we are used to know today. There are a lot of applications that used the piezoelectric such as telephone speakers, sonar arrays, mechanical actuations and even sensing microstructures which can be implement into electronic chips.

Arthur Ballato (2001) stated that the piezoelectric cantilever bimorph consist of two layer laminate which are silicon with thin patches. This patch contains active film materials such as aluminium nitride or zinc oxide that can drive the piezoelectric patches into flexural motion. This bending mode delivers the greatest possible displacement for generating voltage. The bimorph Micro-Electro-Mechanical-Systems (MEMS) devices provide otherwise unavailable capabilities and require piezoelectricity as the transduction mechanism. An alternative configuration for the piezoelectric are laminated plate, where aluminium nitride or zinc oxide thin-film layers drive silicon plates in resonant thickness modes for integrated frequency control devices.

Today the modern applications for piezoelectric were becoming more immediacy and simplicity as a transduction mechanism. Elastic field/mechanical considerations are therefore incorporated into the operations of modern electronic components in a clean, efficient, and very direct manner, by making use of the voltages resident on the chips, via the piezo-effect.

2.2 Piezoelectric Effect

Piezoelectric Effect is the ability of certain materials to generate an electric charge in response to applied mechanical stress. The words Piezoelectric were actually derived from the Greek language, piezein, which means to squeeze or press, which is Greek for “push”. One of the unique characteristics of the piezoelectric effect is that it is reversible, meaning that materials exhibiting the direct piezoelectric effect (the generation of electricity when stress is applied) also exhibit the converse piezoelectric effect (the generation of stress when an electric field is applied). When piezoelectric material is placed under mechanical stress, a change in positive and negative charge centres in the material takes place, which then resulting the external electrical field. But when it is reversed, an outer electrical field will either stretches or compresses the piezoelectric material.

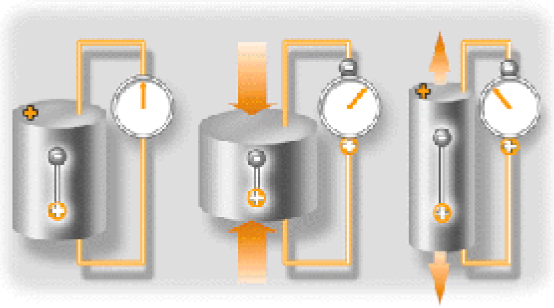

Figure 2.2 Piezoelectric produced electricity when stress is applied

Antoine Ledoux (2011) stated that the piezoelectric creates a voltage is because when the mechanical stress is applied, the crystalline structure is disturbed and it changes the direction of the polarization of the electric dipoles. In order for the material to be polarized, it is exposed to a strong direct current electric field whose goal is to align all dipoles in the material. He also stated that as the mechanical stress increase, the bigger the change in polarization and the more electricity is produced.

The piezoelectric crystal actually generates both DC and AC parameters where the DC flow of current is unidirectional while the AC is bidirectional. The DC current can be explained by connecting a small piezoelectric crystal to an external load and squeeze it. It can be briefly described that the current that flows in one direction through the load will stop the moment the squeezing is stopped. This basically can be called a DC. The DC can be created only for a moment because the piezoelectric crystal cannot be indefinitely compressed to keep the current flowing in one direction because of the compression that would destroy it. In other hand, the AC is produced when the piezoelectric crystal being compressed and released alternately which may leads the current to flow in both direction. Basically, the output of a piezoelectric crystal is an alternating signal and must be converted first into digital signal to use the voltage for low power consuming electronic devices (Dikshit et al, 2010).

2.3 Piezoelectric Materials

There are many types of piezoelectric that can be used to build a piezoelectric that can react when the mechanical stress is applied. These materials might be different but it has the same functions. Satoru Fujishima (2000) said that Rochelle salt was used for underwater tranducers and phonograph pickups while barium titanate is used for communications devices, underwater transducers and dielectric components such as capacitors. Meanwhile quartz crystal was used for underwater transducers during World War I. During 1954, PZT ceramics is discovers and by that time all the piezoelectric applications that used barium titanate ceramics are being replaced. But the most commonly known piezoelectric material is quartz. According to Antoine Ledoux (2011) the most commonly use materials piezoelectric are:

a) Quartz (SiO_2)

- Quartz shows a strong piezoelectricity due to its crystalline structure, meaning that when a pressure is applied on a quartz crystal an electrical polarization can be observed along the pressure direction.

b) Gallium Orthophosphate (($GaPO_4$)

- It has almost the same crystalline structure as quartz that is what it has the same characteristics. However its piezoelectric effect is almost twice important as the one for the quartz, making it is a valuable asset for mechanical application. It is not natural element, it has to be synthesised.

c) Barium Titanate ($BaTiO_3$)

- This element is an electrical ceramics; it is usually replaced by lead zirconate titanate (PZT) for piezoelectricity. It is used for microphones and transducers.

d) Lead Zirconate Titanate (PZT)

- It is considered one of the most economical piezoelectric elements; hence it is used in a lot of applications.

e) Tourmaline

- This crystal is commonly black but can range from violet to green and pink.

f) Berlinite ($AlPO_4$)

g) Zinc Oxide

h) Aluminium Nitrade (AlN)

i) Polyvinylidene Fluoride (PVDF)

2.4 Energy Harvesting From Vibration Absorber (EHVA)

This device is develops for passive attention of surface vibration. R.L. Harne (2012) stated that the cantilevered piezoelectric beam harvester employs a piezoelectric spring with inertial mass which is also known for its classical vibration absorber construction. A reactive moment working on a vibrating structural panel may be useful in supressing vibration, where substantial forces would be more practical if a suitable design may be devised to yield a distributed forced over the vibrating surface. The Figure 2.3 shows the design of the EHVA.

Figure 2.3 EHVA design

The design has been tested on a city bus structural panel which is partially suspended and supported by several bolts as a safety guards for passenger that is near to the rear door. The panel is outlined by a green dash while some of the mounting bolt are indicated with the yellow arrows. Figure 2.4 shows the EHVA that is mounted ate the rear door.

Figure 2.4 The EHVA is mounted at rear door

2.5 Piezo Bending Actuator

According to Yi Pu et al. (2014) an electromechanical actuator can become the more efficient energy harvesting system, which can improving the efficiency usage of the fuel. If two piezoelectric ceramic plates are bonded together with a supporting material and counter-actuated, this results in a pronounced deformation of the composite similar to the case of a bimetal. These bending actuators are design so it can deflects for several millimetres, withstands several Newton forces and achieve short deflection times. Therefore, the piezo bending actuator is one of the highest performance and fast-reacting control element.

Due to the high speed of deflection, piezoelectric productivity is increased many times over compared to the use of electromagnets. Because of its compact design, the piezo bending actuator only required less space compare to other generating devices. Its energy requirement compared to that of the electromagnets is also considerably lower. One advantage is its high reliability - downtime periods become a rare exception. The piezo bending actuator is modifiable to suit the application and is therefore an extremely versatile control element. Figure 2.5 shows that the piezo bending actuators, where yellow is resemble its electrode, orange for piezo ceramic and purple resembles its centre vane.

Figure 2.5 Piezoelectric bending actuator structures

2.6 Piezoelectric Bending Type

In this section, there are a few piezoelectric bending types which can generate electricity. One of the bending types is the piezo film types. The piezo film is a flexible, lightweight, tough plastic film which is available in a variety of thicknesses and in large areas. These piezo films do have its advantages. According to D.L. Halvorsen (1986) the advantages of piezo film includes high voltage output, high dielectric strength and mechanically strong and impact resistant. Piezo film develops a voltage (potential difference) between its upper and lower surfaces when the film is stressed. This voltage arises from generation of charge within the material. If this charge is removed by the external circuit, no further charge is generated until the stress is changed. Therefore the piezoelectric film does not produce any current, even though the voltage (with no load) may be very high.

For this project purposed, there are 3 piezoelectric films that will be review in this section. These piezoelectric films will compare based on its voltage output and tip deflections. The basic characteristic for each piezoelectric film is briefly reviewed so that it is suitable for generating the voltage from vibration.

2.6.1 Piezoelectric Ceramic EB-T-320

Figure 2.6 Piezoelectric ceramic EB-T-320

This piezoelectric is a versatile piezoelectric with low power electromechanical transducer. This piezoelectric is capable of converting mechanical energy to electrical energy when the element is stressed or subjected to vibration, the, minute movement causes one layer to be under tension while the under compression. Since the two layers are polarised in opposite directions, the opposite stresses in each layer will produce an electrical output or charge. The Figure 2.7 shows the shape and dimension of this piezoelectric.

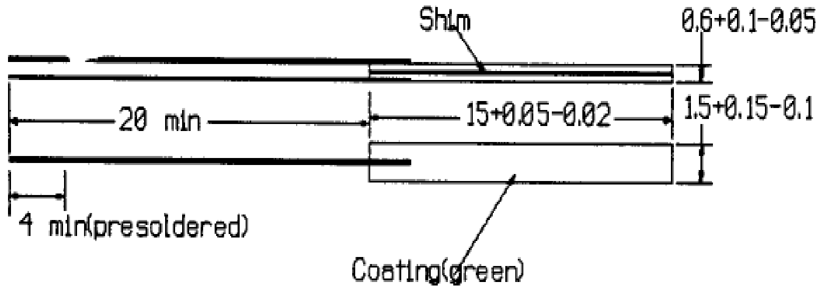

Figure 2.7 Piezoelectric ceramic EB-T-320 dimensions

This piezoelectric has high compliance, low mass, high efficiency as well as high capacitance which mean it has low impedance. Besides having the ability to generate electricity, it also can be used as vibration or stress sensors, phonograph cartridges and micro-positioners. This piezoelectric can operate in high temperatures environment which is up to 60˚C. The Table 2.1 shows the technical specification for this piezoelectric.

Table 2.1 Piezoelectric ceramic EB-T-320 technical specification

Dimensions	15mm x 1.5mm x 0.6mm
Capacitance	750 pF ± 170
Tip Deflection	50µm ~ 5mm
Voltage Output	$4V_{p-p}$
Impedance, Z	1 MΩ
Operating Temperature	-20˚C – 60˚C
Frequency, Hz	1 kHz

2.6.2 Piezoelectric LDT0-028K

Figure 2.8 Piezoelectric LDT0-028K

This piezoelectric is a flexible piezo film that comprises a 28µm thick piezoelectric PVDF polymer film with screen-printed Ag-ink electrodes, laminated to a 0.125 mm polyester substrate, and fitted with two crimped contacts. When this piezo film bends, it creates a high strain within the piezopolymer and as a result it generates the voltages. These device acts as a flexible "switch" when the assembly is deflected by direct contact, thus trigger MOSFET or CMOS stages directly due to sufficient generated output. The Figure 2.9 shows the added mass piezoelectric dimension.

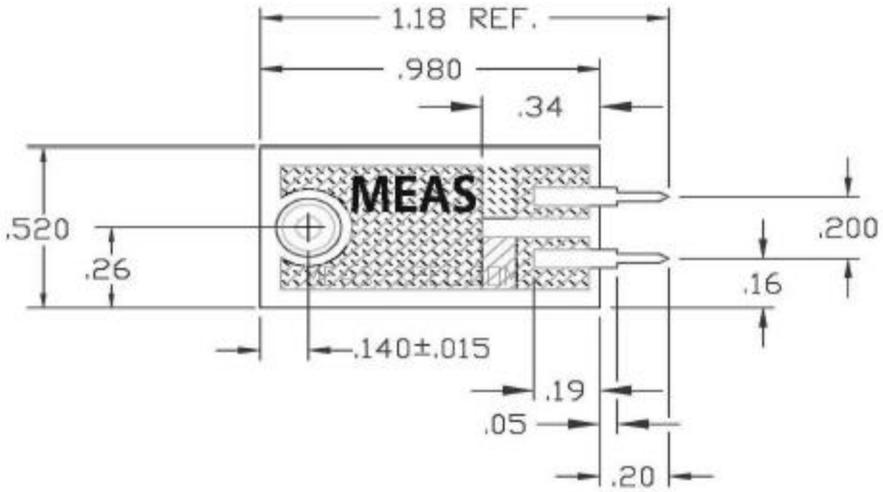

Figure 2.9 Piezoelectric LDT0-028K dimension

By adding mass or clamping the altering of the free length of the element the resonant frequency and sensitivity of the sensor may vary, to suit specific applications. By positioning the mass in the centre of the piezo film, multi-axis