ENERGY CONVERSION FROM SUSPENSION SYSTEM

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To my beloved wife, **Intan Suraya** who believes in me even though I find it difficult to do so myself, my supervisor and friends who gives me strength to complete this thesis and my parents who always believe in me and guide me in all of my pursuits.

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ABSTRACT

Energy harnessing is the process by which energy is derived from external sources such as solar power, thermal energy, wind energy, kinetic energy, captured and stored for small devices uses. The ambient energy that can be harnessed to generate electricity comes from a wide range of sources but vibration energy shows a promising amount of power generation. In this study, conversion of mechanical vibration into electricity using piezoelectric vibration-to-electricity converter is undertaken with a focus to quantify the amount of power that can be generated and identify electronic devices that can fully utilize this power. The research is divided into two parts, which are simulation from the car suspension data and experimental investigations. An analytical study of the mathematical models of the piezoelectric vibration-to-electricity converter has been conducted and simulations of these models have been developed within Matlab-SIMULINK. The analysis of the harnessing energy from micro-vibration reported in this study will provide useful information for the development of alternative source of energy in the future. The energy collected in this study is an electrical power. The electrical power generated is depend on the length of stroke, which are the length of displacement of vibration. The power generated is also depend on the frequency of vibration. This study shows a result which is the power collected from suspension system.

ABSTRAK

Memanfaatkan tenaga merupakan suatu proses dimana tenaga diterbitkan daripada sumber luar seperti tenaga cahaya matahari, tenaga haba, tenaga angina, tenaga kinetic yang diambil dan disimpan untuk kegunaan peralatan yang kecil. Tenaga daripada persekitaran yang boleh dimanfaatkan untuk ditukarkan kepada tenaga elektrik boleh diambil daripada pelbagai sumber tetapi tenaga daripada getaran dilihat boleh menjana tenaga yang banyak. Dalam kajian ini, penukaran tenaga getaran kepada tenaga elektrik dengan menggunakan piezoelektrik diberi perhatian untuk menentukan amaun tenaga yang boleh dijana dan mengenalpasti alat yang boleh menggunakan membantu supaya tenaga ini boleh dimanfaatkan dengan baik. Kajian ini terbahagi kepada dua bahagian iaitu mendapatkan data daripada kaedah simulasi suspensi kenderaan dan kaedah eksperimen. Kajian analitikal model secara matematik penukar piezoelektrik juga dijalankan dan simulasi model ini dibangunkan dengan menggunakan Matlab-SIMULINK. Analisis hasil daripada kajian memanfaatkan mikro- getaran ini akan memberi maklumat dan membantu dalam kajian menjana tenaga daripada sumber alternatif pada masa hadapan. Tenaga yang dijana dalam kajian ini ialah tenaga elektrik. Kajian ini menunjukkan tenaga yang dihasilkan bergantung kepada jarak ayunan sesuatu suspensi. Jumlah tenaga yang boleh dijana juga bergantung kepada frekuensi ayunan suspensi. Kajian ini menunjukkan amaun tenaga yang boleh dijana oleh sesuatu sistem suspensi.

CHAPTER 1

INTRODUCTION

Introduction

In physics, energy is an indirectly observed quantity that is often understood as the ability of a physical system to do work on other physical systems. Nowadays, harnessing energy has attracted remarkable attention by researchers as a potential source of energy. This is because the energy that already in used today confront with several conflicts such as limited resources, pollution, high cost and also time dependence of the demand (Crawley, 1975).

The field of harnessing energy is growing rapidly with technology innovations today. During this past decade, many researchers have been carried out from different sources of energy to find the most suitable alternative source. These include solar power and wind power (Charters, 1991, Ismail, 2008).

Abdul Rahman (2010) has analyzed scavenging energy from knee motion during walking to produce electrical energy. This useful electrical energy then can be used as a charger to the portable electronic devices. However, this method is only applicable when there is a human motion (Abdul Rahman, 2010).

Vibration is a universal phenomenon and has a very close relationship with human. There are different levels of vibration that will causes different effect on human. Human will face health and safety problem if the level of vibration is higher than the vibration level that human can accept (Bin, 2007). Besides that, vibration can result in noises and it was something unwanted in any operation. It can reduce the system effectiveness and structural fatigue (Mohamed, 2010).

1.1 Research Background

Vibration energy can be converted into electrical energy through piezoelectric, electromagnetic, and capacitive transducers (Muralt et al., 2009, Wang et al., 2010, Mialtu et al., 2009). Among them, piezoelectric vibration-to-electricity converters are the most popular and received much attention from the researchers. This is because they have high electromechanical coupling and no external voltage source requirement (Shu, 2009).

The advancement of current technology has helped to fulfil the demand for self-powered electronics devices by harnessing ambient energy from the environment, thus eliminating the need for batteries and supplying these electronic devices with infinite amount of energy. The ambient energy that can be harnessed to generate electricity is coming from a wide range of sources such as human body (Shenck and Paradiso, 2001; Starner, 1996) and temperature gradient (Stordeur and Stark, 1997).

The driving force to harness ambient energy from the environment is mostly due to the development of wireless sensor and actuator networks where particular research has been conducted for a project named PicoRadios (Rabaey et al., 2002). This project aims to develop a small and flexible wireless platform for ubiquitous wireless data acquisition that minimizes power dissipation. The important specifications for the power system developed by PicoRadios project researchers are the total size and average power dissipation of an individual node. The size of a node must not be larger than 1 cm3 and the target average power dissipation of a completed node is 100 μW.

Car suspension is also producing a vibration. Suspension is the term given to the system of springs, shock absorbers and linkages that connects a vehicle to its wheels and allows relative motion between the two. Suspension systems serve a dual purpose which are contributing to the vehicle's road holding and handling and braking for good active safety and driving pleasure, and keeping vehicle occupants comfortable and reasonably well isolated from road noise, bumps, and vibrations.

These goals are generally at odds, so the tuning of suspensions involves finding the right compromise. It is important for the suspension to keep the road wheel in contact with the road surface as much as possible, because all the forces

acting on the vehicle do so through the contact patches of the tires. The suspension also protects the vehicle itself and any cargo or luggage from damage and wear.

1.2 Research Objectives

The objective of this project is:
To develop instrumentation system for energy conversion from quarter car suspension system.

1.3 Problem Statements

Batteries are type of energy storage devices that commonly used to power hand held and portable electronic devices as well as implanted biomedical systems. However, due to its limited capacity, batteries could possibly supply power only for short lifetime of about one to three years and its significant size and weight has caused problem to the present hand held and portable devices as well as implanted biomedical systems. While researchers continuously developed the technology to increase the energy of storage devices, the solutions are still going to have finite lifetime.

This problem has led to the rising demand for self-powered devices and systems which can be solved by harnessing energy from a wide range of sources using a few technique that have been proven can supply infinite amount of power. In this study, conversion of mechanical vibration into electricity using piezoelectric material is undertaken with a focus to quantify the amount of power that can be generated and identify electronic devices that can fully utilize this power.

1.4 Research Question

Is it possible to collect the energy from car suspension system? How?

1.5 Theoretical Frame Work

This study is to collect the energy generated by car suspension using energy conversion instrumentation method.

1.6 Scopes of research

The scopes of this project are:

1. Literature review of instrumentation of energy conversion, suspension system and vibration energy.
2. Development of energy conversion instrumentation via simulation and experimental validation.
3. Development of storage system for energy collection.

1.7 Research Methodology Flowchart

The methodologies involved in this study are shown in Figure 1.1. The project starts by collecting reading materials such as books, journals and technical papers specifically on sources of vibration, methods of converting ambient vibration energy into electrical energy, types of piezoelectric material, piezoelectric energy harnessing circuit and types of energy storage.

Research has been done continuously throughout this study to get a better understanding on the concept of harnessing energy from ambient vibration using

piezoelectric material. Besides, consultation sessions with the project supervisor and few colleagues who are doing similar research were also held periodically to discuss any arising issues and problems encountered pertaining to this study.

Based on the research conducted, piezoelectric energy harnessing circuit selection process was made in order to get the suitable circuit followed by the selection of a few types of energy storage devices to be used in this study. The study on piezoelectric energy harnessing has been divided into two main parts which are (1) simulation of the vibration environment and (2) laboratory experiment on vibrating mechanical equipments. Both simulation and laboratory experiment will undergo the same process such as piezoelectric vibration to electricity conversion, rectification and energy storage.

The simulation in Matlab SIMULINK has been done using vibration data acquired from experimental study by previous researcher in order to determine the possible amount of power density output that can be produced for the specific acceleration input. With the promising amount of power density output produced during simulation, the laboratory experiment on vibrating mechanical equipments was conducted for the purpose of quantifying the amount of power that can be generated by vibrating mechanical equipment and identifying electronic devices that can fully utilize this power.

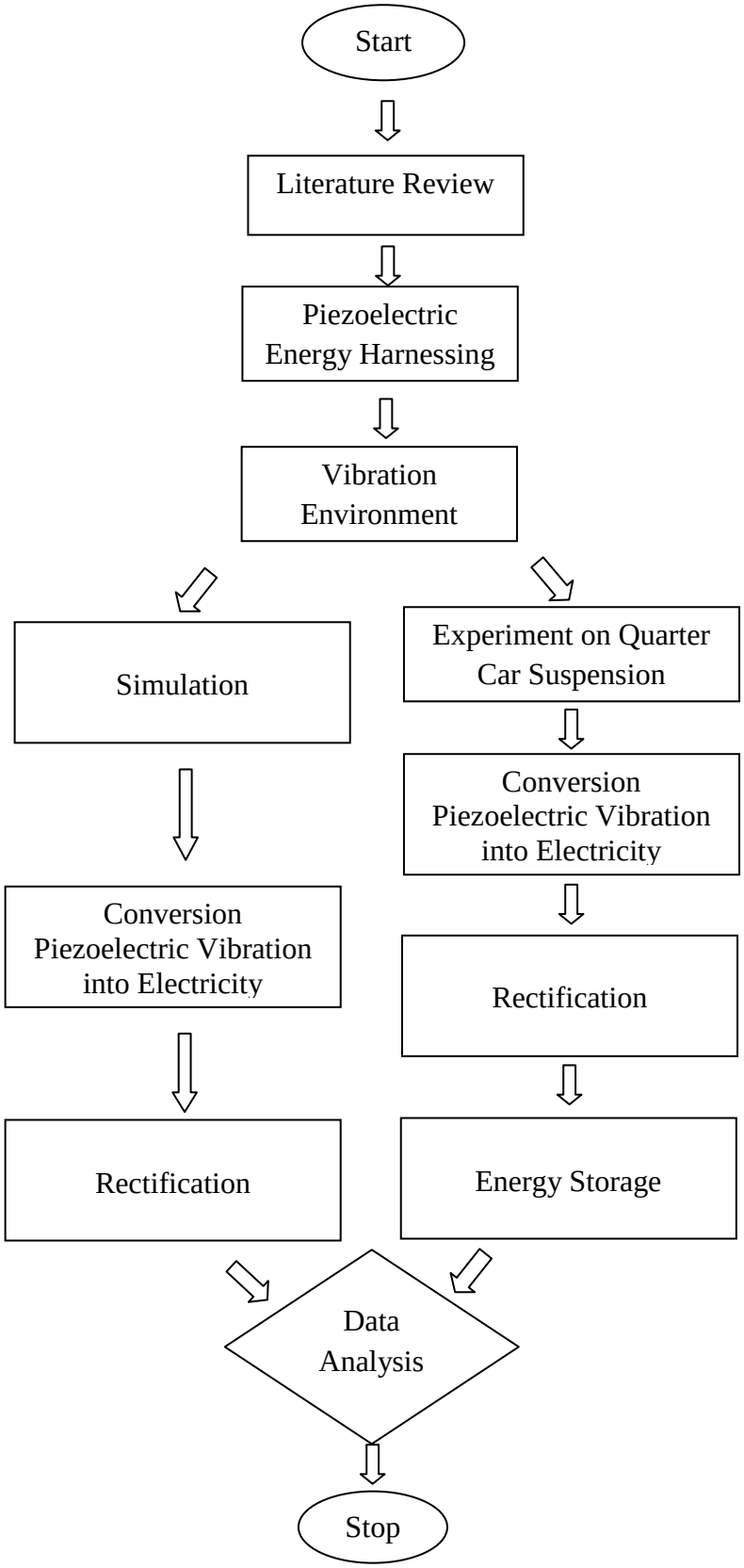

Figure 1.1 : Methodology of the study

1.8 Gantt Chart

Gantt Chart will used in monitoring progress of the project from time to time in order to ensure the project reach its milestone within a specific period of time.

NO.	ACTIVITIES	WEEKS															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Selection of project title																
2	Collecting reading materials																
3	Literature review of previous research																
4	Understanding the concept of piezoelectric energy harnessing from vibration																
5	Familiarization with Matlab SIMULINK																
6	Simulation of vibration environment using data acquired by previous researcher																
7	Simulation of energy harnessing																
8	Analysis of the results from the simulation of energy harnessing																
9	Report writing																
10	Preparation for seminar presentation																
11	Seminar 1																

Figure 1.2 : Gantt Chart for Master Project 1

NO.	ACTIVITIES	WEEKS															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Literature review																
2	Experimental setup: Integration and development of data acquisition and instrumentation system																
3	Experiment on vibrating mechanical equipments (quarter car suspension)																
4	Analysis of the experimental results																
5	Report writing																
6	Preparation for seminar presentation and submission of draft thesis																
7	Seminar 2																
8	Submission of the thesis																

Figure 1.3 : Gantt Chart for Master Project 2

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LIST OF SYMBOLS

°C	-	Celsius
Ω	-	Ohm
ε	-	Induced emf; Dielectric constant
ε_0	-	Dielectric constant of free space, Permittivity of free space
μ_0	-	Permeability of free space
A	-	Ampere
a	-	Acceleration
B	-	Magnetic field
C	-	Capacitance
c	-	Elastic constant
D	-	Electrical displacement (charge density)
d	-	Gap or distance between plates; Piezoelectric strain coefficient
dB	-	Decibel
E	-	Electric field
f	-	Frequency
Hz	-	Hertz
I, I	-	Current
k	-	Coupling coefficient; Piezoelectric constant
l	-	Length of one coil ($2\pi r$); Length of plate
m	-	Meter
N	-	Number of turns in coil

Q	-	Charge on capacitor
R	-	Resistance
s, sec	-	Second
t	-	Thickness
V, Volt	-	Voltage
Vp	-	Voltage peak
Vpp	-	Voltage peak-to-peak
W	-	Watt
w	-	Width of plate
Y	-	Modulus of elasticity (Young's Modulus)
y	-	Distance coil moves through magnetic field

LIST OF ABBREVIATIONS

A/D	-	Analog to Digital
AC	-	Alternate Current
AI	-	Analog Input
AO	-	Analog Output
AEH	-	Acoustic Energy Harvester
BaTiO3		Barium Tinate
D/A	-	Digital to Analog
DAQ	-	Data Acquisition System
DC	-	Direct Current
DIO	-	Digital I/O
fpm	-	feet per minute
HVAC		Heating, Ventilation and Air Conditioning
I/O	-	Input to Output
IEPE	-	Integrated Electronic Piezoelectric
MFC	-	Macro-Fiber Composite
NI	-	National Instrumentation
PI	-	Physik Instrumente
PVDF	-	Polyvinylidene Fluoride
PZT	-	Lead Zirconate Tinate
QP	-	Quick Pack
RFID	-	Radio Frequency Identification

LIST OF APPENDICES