WIDEBAND NON-LINEAR PIEZOELECTRIC VIBRATION ENERGY HARVESTING

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This report is submitted
in fulfillment of the requirement for the degree of
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DECLARATION

I declare that this project report entitled “Wideband Non-linear Piezoelectric Vibration Energy Harvesting” is the result of my own work except as cited in the references.

Signature : .....

Name : .....

Date : .....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

Signature : .....

Name of Supervisor : .....

Date : .....

DEDICATION

To my beloved mother and father

ABSTRACT

Kinetic energy exists in the form of vibrations, forces and any random displacements. Harvesting the kinetic energy is needed in order to generate electricity and prevent it to be wasted. Energy harvesting can be defined as processes that capture the freely available energy in environment and converting it in electrical energy that can be used or stored. Piezoelectric is used to convert mechanical energy to electrical energy. Piezoelectric produces charge when piezoelectric material compressed or mechanically stressed. Basically, energy harvesters are designed as a linear system in order to achieve optimal performance but most ambient energy is sensitive and having different frequency. Due to that, the linear energy harvesters need to tune for every application in order to prevent from narrow bandwidth. To solve this problem, a non-linear mechanism is suggested, which is wider bandwidth can be obtained in one mechanism. In addition, by using non-linear energy harvesting, it able to produce wider bandwidth without any adjustment. A non-linear energy harvester is designed as a cantilever beam with mechanical stopper at upper and bottom side of the beam. The piezoelectric is attached on the beam so that it will deflect along with the beam. The aim of this mechanism is to provide a wider bandwidth with maximum power harvested. The experimental results for the linear and non-linear device are obtained by using quasi-static and dynamic measurement. The quasi-static measurement is used to measure the restoring force against the deflection of beam. Meanwhile, dynamic measurement is used to measure the dynamic response for characterisation of the device. The performance of open circuit and closed circuit of system are also investigated. The system is varied by changing the length of the beam, position of the stopper and input level.

ABSTRAK

Tenaga kinetik wujud dalam bentuk getaran, daya dan sebarang pengalihan secara rawak. Untuk menjana tenaga elektrik, penuaian tenaga kinetik diperlukan atau sebaliknya tenaga kinetik tersebut akan terbuang. Penuaian tenaga boleh ditakrifkan sebagai proses yang menangkap tenaga bebas yang terdapat di persekitaran dan mengubahnya kepada tenaga elektrik yang boleh digunakan atau disimpan. Piezoelektrik digunakan untuk menukar tenaga mekanikal kepada tenaga elektrik. Piezoelektrik menghasilkan caj apabila bahan piezoelektrik dimampatkan atau ditekan secara mekanikal. Pada asasnya, penuai tenaga direka dalam bentuk linear bagi mencapai prestasi optimum tetapi tenaga bebas yang terdapat di persekitaran adalah sensitif dan mempunyai frekuensi yang berbeza-beza. Oleh itu, penuai tenaga linear perlu menyesuaikan diri untuk setiap aplikasi untuk mengelakkan dari lebar jalur menjadi sempit. Untuk menyelesaikan masalah ini, satu mekanisma bukan linear dicadangkan, yang merupakan jalur lebar yang lebih luas boleh diperolehi dalam satu mekanisma. Di samping itu, dengan menggunakan penuaian tenaga bukan linear, ia dapat menghasilkan jalur lebar yang lebih luas tanpa sebarang pelarasan. Penuai tenaga bukan linear direka sebagai rasuk penyangga dengan penahan mekanikal di sebelah atas dan bawah rasuk. Piezoelektrik dipasang pada rasuk supaya ia memesong bersama rasuk. Matlamat mekanisma ini adalah untuk menyediakan jalur lebar yang lebih luas dengan kuasa maksimum dituai. Keputusan eksperimen untuk peranti linear dan bukan linear diperoleh dengan menggunakan pengukuran kuasi statik dan dinamik. Pengukuran kuasi statik digunakan untuk mengukur daya pengembalian terhadap pesongan rasuk. Sementara itu, pengukuran dinamik digunakan untuk mengukur tindak balas dinamik untuk pencirian peranti. Prestasi litar terbuka dan sistem litar tertutup juga disiasat. Sistem ini diubah dengan mengubah panjang rasuk, kedudukan penahan dan tahap input.

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CHAPTER 1

INTRODUCTION

1.1 Background

Energy is the capacity to do work. It may appear in many forms such as potential energy, thermal energy, kinetic energy and more. Basically, energy is associated with motion and can be converted to another form in various ways. For example, kinetic energy generators able to convert energy in the form of mechanical movement present in application environment into electrical energy. Kinetic energy exists in the form of vibrations, forces and any random displacements. Kinetic energy could produce motion, sound, thermal energy and electrical energy. In order to generate a clean electricity, harvesting the kinetic energy are needed or otherwise it be wasted.

Energy harvesting can be defined as the sum of all those processes that allow capturing the freely available energy in environment and converting it in electrical energy that can be used or stored. Harvesting energy is one of the most promising techniques in response to global energy problem. Nowadays, most vibration-based energy harvesters are designed as linear resonators that only work efficiently with limited bandwidth near their resonant frequencies. Unfortunately, in the vast majority of practical scenarios, ambient vibrations are frequency-varying or aimless with energy distributed over a wide frequency range. Therefore, increasing the bandwidth of vibration energy harvesters has become one of the most critical issues before these harvesters can be widely deployed in practice.

1.2 Problem Statement

In linear energy harvesting system, maximum power can be obtain when device is operated at the natural frequency of the system, ($\omega_{system} = \omega_n$). But, if the harvester is mistuned, a slight shift of excitation frequency will drop the performance of the system. Most ambient energy is frequency-varying and sensitive. Due to that, the linear energy harvesters need to adjust for every application in order to prevent from narrow frequency range. To solve this problem, a non-linear mechanism is suggested, which is a wide frequency range can be obtained in one mechanism. Furthermore, by using non-linear energy harvester, there is no need to adjust or tune towards wider bandwidth. So, the device can cover the bandwidth and optimize the performance. The harvester should be carefully designed in accordance with prescribed procedure.

1.3 Objectives

The objectives of this project are:

a) To characterise the linear and non-linear mechanism in energy harvesters.

b) To design and develop the non-linear energy harvester.

c) To investigate the performance of the non-linear piezoelectric energy harvester.

1.4 Scope

This research is studies the effect of non-linear energy harvester with appearance of piezoelectric. A non-linear energy harvester can be simply design as a cantilever beam with rectangular cross-section. A pair of mechanical stopper is added at upper and bottom side of the beam. The gap between stopper and beam is expected to inherit the features of resonant peaks and hardening dynamics for bandwidth widening. The experiment will be conducted by two types of measurement, which are quasi-static measurement and dynamic measurement. The system is varied by changing the length of the beam, position of the stopper and the input level.

CHAPTER 2

LITERATURE REVIEW

There is energy in everything and energy is used in everything. Energy is the ability to do work and it fall in two categories: non-renewable and renewable. Non-renewable energy is energy that comes from the ground and it is not replaced in relatively short amount of time. For examples, energy generated from combustion of fossil fuels, coal, natural gas and etc. Most of fossil fuels such as oil, natural gas and coal are considered as non-renewable resources. Their used is not sustainable because their formation takes a billion years. The term of non-renewable resources also refers to minerals and metals from the earth, such as gold, silver and iron, which is similarly formed as long-term results of geological processes such as plate tectonics. These resources often cost to mine, as they are usually deep within the earth but there are more abundant than fossil fuels. Some types of groundwater are considered as non-renewable resources, if the aquifer is unable to be replenished at the same rate at which it is drained. Also, nuclear materials such as uranium are referring as non-renewable resources. Meanwhile, renewable energy can be generated continuously practically without of decay of source. Some of examples are solar energy, wind energy, hydro energy, geothermal energy and kinetic energy. Renewable sources of energy are better than non-renewable sources because they refill themselves over a short period time while non-renewable resources have a limited quantity and it will be run out. The world is taking a serious look at ways to make a renewable source of energy.