UNIVERSITI TEKNIKAL MALAYSIA MELAKA

DEVELOPMENT OF PORTABLE MINI THERMOELECTRIC GENERATOR FOR OUTDOOR ACTIVITIES AND EMERGENCY SITUATIONS BY USING PCM-COOLED THERMOELECTRIC MODULE

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Engineering Technology (Automotive Technology) with Honours

by

MUHAMMAD ZAKI BIN ZAHRI
B071310576
940110-10-6317

FACULTY OF ENGINEERING TECHNOLOGY
2016

APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor Degree of Engineering Technology (Automotive Technology) with Honours. The member of the supervisory is as follow:

……

(Project Supervisor)

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **Development of Portable Mini Thermoelectric Generator for Outdoor Activities and Emergency and Emergency Situations by using PCM-cooled Thermoelectric Module**

SESI PENGAJIAN: **2016/17 Semester 1**

Saya **MUHAMMAD ZAKI BIN ZAHRI**

mengaku membenarkan Laporan PSM ini disimpan di Perpustakaan Universiti Teknikal Malaysia Melaka (UTeM) dengan syarat-syarat kegunaan seperti berikut:

1. Laporan PSM adalah hak milik Universiti Teknikal Malaysia Melaka dan penulis.
2. Perpustakaan Universiti Teknikal Malaysia Melaka dibenarkan membuat salinan untuk tujuan pengajian sahaja dengan izin penulis.
3. Perpustakaan dibenarkan membuat salinan laporan PSM ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. **Sila tandakan (✓)

☐ SULIT (Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia sebagaimana yang termaktub dalam AKTA RAHSIA RASMI 1972)

☐ TERHAD (Mengandungi maklumat TERHAD yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)

☐ TIDAK TERHAD

Disahkan oleh:

_____ _____

Alamat Tetap:

C-4-10 Jalan Putra Perdana 5F

Taman Putra Perdana

47130 Puchong, Selangor

Cop Rasmi:

Tarikh: _____ Tarikh: _____

** Jika Laporan PSM ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh laporan PSM ini perlu dikelaskan sebagai SULIT atau TERHAD.

DECLARATION

I hereby, declared this report entitled Development of Portable mini Thermoelectric Generator for Outdoor Activities and Emergency Situations by using PCM-cooled Thermoelectric Module is the results of my own research except as cited in references.

Signature : …….

Author's Name : ……

Date : ……

ABSTRAK

Penjana termoelektrik (TEG) adalah alat yang menukarkan tenaga haba kepada tenaga elektrik berasaskan prinsip kesan Seebeck. Komponen utama TEG adalah modul termoelektrik. Apabila terdapat perbezaan suhu antara permukaan panas dan permukaan sejuk modul termoelektrik, tenaga elektrik akan terhasil. Jumlah tenaga elektrik yang terhasil amat dipengaruhi oleh perbezaan suhu antara permukaan panas dan permukaan sejuk modul termoelektrik. Semakin tinggi perbezaan suhu, semakin tinggi tenaga elektrik yang dihasilkan. Bagaimanapun, apabila permukaan panas termoelektrik dipanaskan, permukaan sejuk turut menjadi panas disebabkan oleh pemindahan haba daripada sumber haba. Oleh itu, permukaan sejuk modul termoelektrik perlu disejukkan dengan berkesan. Objektif projek ini adalah untuk mengkaji kesan penggunaan bahan perubahan fasa (PCM) sebagai medium penyejukan pada permukaan sejuk modul termoelektrik. Prototaip TEG telah direka menggunakan perisian CATIA. Pada dasarnya, TEG dibuat dari modul termoelektrik, plat aluminium, penyingkir haba aluminium dan pendawaian elektrik. Sumber haba ialah api lilin. Sebagai tambahan pada penyingkir haba aluminium, parafin PCM telah digabungkan dengan penyingkir haba sebagai medium penyejukan pada permukaan sejuk modul termoelektrik. Hasil kajian menunjukkan bahawa PCM berkesan mengurangkan suhu permukaan sejuk sebanyak 2~3 ^{0}C dan menyebabkan penjanaan voltan yang lebih tinggi berbanding tanpa PCM. Voltan dan arus tertinggi yang dijana masing-masing adalah 1.70 V and 259 mA. Penukaran haba kepada tenaga elektrik oleh TEG telah disahkan kerana ia boleh mengecas peranti elektrik seperti telefon pintar dan alat penyimpan kuasa. TEG ini mampu untuk mengecas alat penyimpan kuasa pada kadar 1% bagi setiap tiga minit dan ia dijangka mengambil masa kira-kira lima jam untuk mengecas penuh alat ini. Dengan penambahbaikan selanjutnya, penjana termoelektrik mini ini mempunyai potensi besar untuk menjadi alat yang menarik dan praktikal yang boleh menjana tenaga elektrik semasa aktiviti luar dan situasi kecemasan iaitu keadaan apabila bekalan elektrik tidak boleh diakses dengan mudah.

ABSTRACT

Thermoelectric generator (TEG) is a device that convert heat energy to electrical energy based on the principles of Seebeck effect. The main component of thermoelectric generator is thermoelectric module. When there is difference in temperature between the hot side and cold side of thermoelectric module, electricity is generated. The amount of electricity generated is greatly influenced by the temperature difference between the hot and cold sides of the thermoelectric module. The higher the temperature difference, the higher the amount of electricity produced. However, when the hot side of the module is heated, the cold side tends to become hot too due to heat transfer from the heat source. Therefore, the cold side of the thermoelectric module needs to be cooled effectively. The objective of this project is to investigate the effectiveness of using paraffinic Phase Change Material (PCM) as a cooling medium at the cold side of thermoelectric module. Prototype of TEG were designed by using CATIA software. TEG basically made of thermoelectric module, aluminium plate, aluminium heat sink and electrical wiring. The heating source was candle flame. In addition to aluminium heat sink, paraffinic PCM was incorporated into the heat sink as a cooling medium for the cold side of the thermoelectric module. The results shows that PCM effectively reduced the temperature of the cold side by 2~3 ^{0}C and resulted in higher voltage generation by the TEG as compared that of without PCM. The highest voltage and current generated were 1.70 V and 259 mA, respectively. The conversion of heat to electrical energy by TEG was verified since it can charge electrical devices such as smartphones and power bank. This TEG is able to charge a power bank at a rate of 1% for every three minutes and it is expected to take about five hours to fully charge the power bank. With further improvement, this mini thermoelectric generator (TEG) has great potential to become an attractive and practical device that can generate electricity during outdoor activities and emergency situations - the situations in which electrical supply cannot be accessed easily.

DEDICATION

This project and research work is dedicated to my beloved parents for their enthusiastic caring throughout my life, my loving siblings and also my friends for their encouragement and love

ACKNOWLEDGEMENT

My deep appreciation goes first to Mr. Aludin Bin Mohd Serah, who expertly guided me and constant supervision as well as providing necessary information regarding the project and also support in completing this project. I would like to express my gratitude towards my parents and member of Universiti Teknikal Malaysia Melaka for their kind co-operation and encouragement which help me in completion of this project. My thanks and appreciations also go to my colleague in developing the project and people who have willingly helped me out with their abilities.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS AND SYMBOLS

A	-	Cross-sectional Area
ATGs	-	Automotive Thermoelectric Generators
Bi_2Te_3	-	Bismuth Telluride
C_nH_{2n+2}	-	Paraffin
$CH_3(CH_2)_n COOH$	-	Fatty Acids
c	-	Specific Heat
DSC	-	Differential Scanning Calorimetry
E	-	Intensity of the Electric Field
FTP	-	Federal Test Procedure
I	-	Current
J	-	Current Density
L	-	Length
LHS	-	Latent Heat Storage
M_nH_2O	-	Salt Hydrates
n	-	Negative type
PCM	-	Phase Change Material
Pd	-	Palladium
p	-	Positive type
S	-	Seebeck Coefficient
TEG	-	Thermoelectric Generator

TEM	-	Thermoelectric Module
T_1	-	Temperature 1
T_2	-	Temperature 2
t	-	Time
V	-	Voltmeter/Voltage
W	-	Thermal Power
zT	-	Figure of Merit
α	-	Thermal Diffusivity
σ	-	Electrical Conductivity
κ	-	Thermal Conductivity
η	-	Efficiency
ΔV	-	Thermoelectric Voltage
ΔT	-	Temperature Difference
T_H	-	Hot Side Temperature
T_C	-	Cold Side Temperature

CHAPTER 1
INTRODUCTION

1.0 Introduction

This chapter explains the background of this study. The explanation is then extended to the problem statement, objectives and scope which clarifies the main concepts in designing portable mini thermoelectric generator.

1.1 Project Background

Nowadays, outdoor activities such as mountain climbing, camping in the forest, lake or waterfall and island hoping are very popular among teenagers. This adventurous activities motivate them to boost their physical and mental strength.

During these activities, modern gadgets such as smart phones and high resolution camera are used frequently to take photos of beautiful sceneries or their activities as their life-time memory. The smart phone also can function as a compass to know direction of a place or to determine the kiblah to perform Solah for the Muslims. Figure 1.1 shows some basic functions of smartphones.

Figure 1.1: Basic functions of smartphones

The basic function of smartphones is to ease of communication especially in getting the information from various sources such as the internet, phone call and text messages. Thus, in many situations these communication gadgets are important for people to get information and to make contact with others in various ways.

However, the electrical source of these gadgets need to be recharged from time to time due to weakening of battery life. In order to solve the problem of accessing electricity during outdoor activities, a power bank, an electrical energy storing device is used to charge the gadgets. Yet, the power bank also needs to be charged. Figure 1.2 illustrates the importance of accessing source of electricity during outdoor activities.

Figure 1.2: Necessity of electricity source during outdoor activities

Source of electricity is extremely important during outdoor activities to supply energy to electricity-operated devices such as hand phones, torch light, fan and many others. In fact, this requirement is crucial in preventing difficulties that may happen in the future.

Source of electricity is also indispensable during or after the natural disaster such as flood, earthquake, typhoon and hurricane in which the electrical supply

possibly will be cut off. An electrical energy is needed to get assistance from the outside. Big flood which frequently attacks many areas in Malaysia cause many adverse effects including the shut-down of electricity supply.

In the end of December 2015, a heavy raining fall in Kelantan for a several days. Figure 1.3 shows the photo of Stadium Muhammad IV that had been immersed in water caused by the big flood attack.

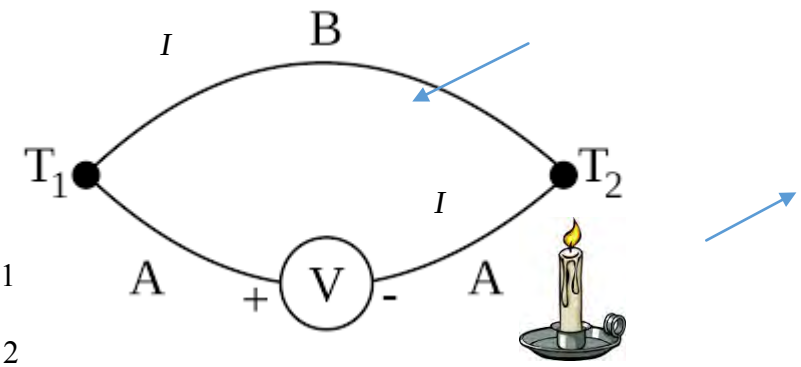
Figure 1.3: Big flood in Kota Bharu, Kelantan in 2015

In this kind of situation, it is crucial for the flood victims to contact the outsiders for helps and to exchange the latest information. Therefore, people need to find a way to generate an electricity from the source that can be easily generated from the surrounding. One of the promising electricity-generation device is thermoelectric generator which can convert heat to electricity.

1.2 Thermoelectric Effect

Thermoelectric generator is a device that convert heat energy to electrical energy through a phenomenon known as Seebeck effect. It is based on the principle that a temperature difference across thermoelectric material can be converted directly into electrical power.

When two different metal wires are connected at both ends (junctions) ordinarily nothing will happen. After one of the junction end is heated, a current is produced continuously in the circuit. This phenomenon is called as Seebeck effect. The circuit that incorporates both thermal and electric effect is called thermoelectric circuit. As shown in Figure 1.4, when one of the junctions of two dissimilar metals is heated, a current *I* flows through the closed circuit.



T_1: Temperature 1

T_2: Temperature 2

Figure 1.4: Basic principle of Seebeck effect

When heat is supplied from a candle to one junction of metal A and metal B, a current is produced flowing through the connection of the closed circuit. Nowadays, scientists are developing thermoelectric modules that can generate electricity by applying the same principle.

1.3 Thermoelectric Module

Thermoelectric module is the main component of thermoelectric generator. It consists of two sides; a hot side and a cold side. When heat is applied to the hot side of the thermoelectric module, electricity will be generated. The cold side is the side of thermoelectric module that is needed to be cooled effectively. The amount of the electricity generated are greatly affected by the temperature gradient between the hot

side and cold side of the module. The higher the temperature gradient, the more electricity is generated. Figure 1.5 shows the photo of a thermoelectric module.

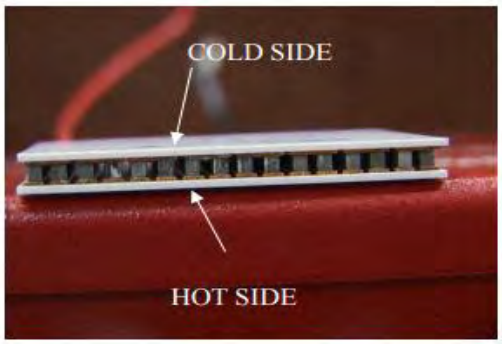


Figure 1.5: A thermoelectric module

In order to generate the electricity, heating and cooling sources need to be supplied to the hot and cold sides of thermoelectric module.

1.3.1 Heating and Cooling Source

Heating and cooling sources are important to thermoelectric module in generating electricity since it depends on temperature differences between the hot and cold sides of the thermoelectric module. Examples of heating sources are lighting candle, hot water, solar heat and many others. In automotive vehicles, there are also several potential heating sources such as heat from the car engine and hot exhaust gas. Meanwhile, the cooling sources are metal heat sink, ice pack, cold water, paraffin and several others.

1.3.2 Phase Change Material (PCM)

In order to cool the cold side of thermoelectric module, in this study, paraffinic phase change material was used as the cooling medium as an attempt to increase the temperature difference between the hot and cold sides of the module. It is expected that the thermoelectric module generates more electricity as the temperature difference increases. Phase Change Material (PCM) is a material that capable to absorb, store and release large amount of energy at a relatively constant temperature through melting and freezing

processes. Figure 1.6 illustrates the change in PCM phases when it experiences melting or freezing processes.

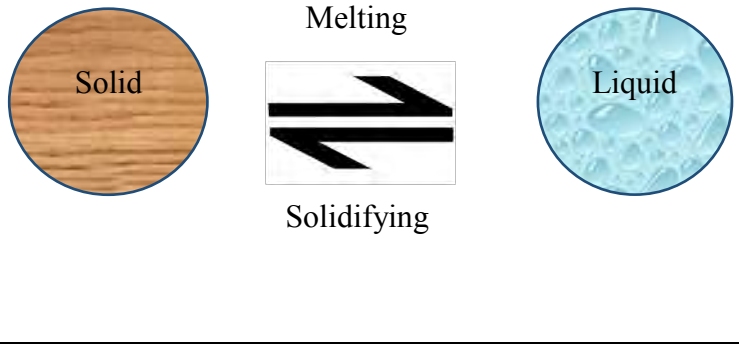


Figure 1.6: Phase change of PCM

PCM change their state from solid to liquid when heat energy is provided, which means it act as heat energy absorber. Meanwhile when PCM undergoes cooling process, it will change to solid from liquid state while releasing the same amount of heat energy.

1.4 Problem Statement

During camping in jungles, people are normally at remote areas where there is no source of electricity to recharge their electrical gadgets. Similar situations can happen during natural disasters such as flood or earthquake in which the affected areas may experience electricity shut down. In these situations, electricity is extremely important to contact outsiders for assistance. Thus, a portable mini thermoelectric generator should be developed to ease people to get access to electricity in these situations.

The main component of the thermoelectric generator is thermoelectric module. The hot side of the module is where heat sources is supplied to while the cold side is supposed to be cooled. The problem is, however, when heat is applied to the hot side of the thermoelectric module, the electricity will be produced but the cold side of the module also tends to get hot. This will reduce the temperature difference between the hot and cold sides of the thermoelectric module which in turn reduce the amount of electricity generated. This problem is illustrated in Figure 1.7.

Note that the cold side thermoelectric module also getting hotter due to the heat transfer from the hot side of the module.

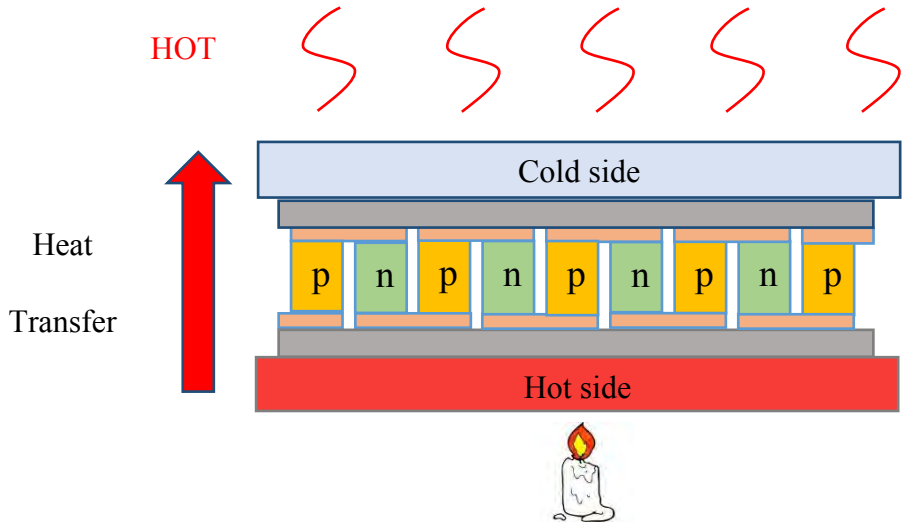


Figure 1.7: Thermoelectric module problem

Due to the heat transfer, thermoelectric module become less efficient in generating electric current. This is due to the low temperature difference between the hot side and cold side of the module. This phenomenon can simply verified by touching by bare hand the cold side of the module. When the hot side is heated, the cold side also getting hotter. Therefore, in this study, paraffinic PCM was used (in addition to aluminium heat sink) as a cooling medium to the cold side of thermoelectric module to create high temperature difference between the both sides of the module and keep the cold side at low temperature.

1.5 Objectives

In order to achieve this project successfully, several objective were established.

1.5.1 General Objectives:-

To develop a portable mini thermoelectric generator for outdoor activities and emergency situations by using phase change material (PCM)-cooled thermoelectric module.