UNIVERSITI TEKNIKAL MALAYSIA MELAKA

IMPROVEMENT OF THE EFFICIENCY OF MINI THERMOELECTRIC REFRIGERATOR BY USING PELTIER MODULE

This report is submitted in accordance with the requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor of Mechanical Engineering Technology (Refrigeration and Air-Conditioning Systems) with Honours

by

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SESI PENGAJIAN: **2015/16 Semester 1**

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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 of Mechanical Engineering Technology (Refrigeration and Air-Conditioning Systems) (Hons.). The member of the supervisory is as follow:

……………………………….

(Project Supervisor)

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ABSTRACT

The human activity of releasing chlorofluorocarbons (CFCs) and hydrofluorocarbons (HCFCs) from vapour compression refrigeration systems have caused adverse impact to the environment. This phenomenon leads to the necessity of developing air-conditioning and refrigeration technologies which are more environmentally friendly and energy-efficient. Thermoelectric refrigerator is one of the most promising devices that suit this requirement. This device consists of Peltier module as one of its vital components. Since it is not driven by compressor, thermoelectric refrigerator offers several advantages such as light weight, easy maintenance and less noisy as compared to conventional compressor-driven vapour compression refrigerator. When electric current applied to a Peltier module, the hot side of the module becomes very hot, thus it needs a heat sink to dissipate the heat to the surrounding. In this study, several prototypes of mini thermoelectric refrigerators were fabricated by using Peltier module as its main components. This study aims to improve the dissipation of the heat at the hot side of Peltier module in order to achieve lower cooling temperature of the mini refrigerator. The effects of several parameters on the temperature of the hot side of the Peltier module were investigated. These parameters are ambient temperature, insulation materials, design of heat sink, the direction of air flow by fan, quantity of electric current and the effect of using paraffin Phase Change Material (PCM) as a cooling source. The result showed that the main parameters affected the temperature of the Peltier module was the quantity of electric current. This is because the more electric current supplied, the greater the temperature difference between the hot and cold sides of the Peltier module. The design of heat sink is also very important in order to dissipate the heat efficiently. The lowest cooling temperature of the mini refrigerator was 11℃ and the thermal efficiency was 5.79%. With further improvement especially in the techniques of reducing the temperature of the hot side of the Peltier module, thermoelectric refrigerator can be developed further to achieve lower cooling temperature and more energy-efficient. Thus, thermoelectric refrigerator would provide an alternative technology to replace the conventional compressor-driven vapour compression refrigerator for some applications.

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ABSTRAK

Aktiviti manusia yang melepaskan klorofluorokarbon dan hydrofluorocarbons daripada sistem penyejukan telah memberi kesan negatif kepada alam sekitar. Fenomena ini melahirkan konvensional keperluan untuk membangunkan teknologi penghawa dingin dan penyejukan yang lebih mesra alam dan cekap tenaga. Peti sejuk termoelektrik adalah salah satu peranti yang paling sesuai untuk memenuhi keperluan ini. Peranti ini terdiri daripada modul Peltier sebagai salah satu komponen yang utama. Disebabkan ia tidak mengguna pemampat, peti sejuk termoelektrik mempunyai beberapa kelebihan seperti ringan, mudah diselenggara dan kurang bising berbanding dengan sistem penyejukan yang menggunakan pemampat konvensional. Apabila arus elektrik mengalir ke modul Peltier, bahagian panas modul akan menjadi sangat panas, oleh itu pelepas haba diperlukan untuk melepaskan haba ke persekitaran. Dalam kajian ini, beberapa mini prototaip peti sejuk termoelektrik telah direka dengan menggunakan modul Peltier sebagai komponen yang utama. Kajian ini bertujuan untuk meningkatkan pelepasan haba di bahagian panas modul Peltier untuk mencapai suhu penyejukan yang lebih rendah. Beberapa parameter yang memberi kesan kepada bahagian suhu panas modul Peltier itu telah dikaji. Parameter tersebut ialah suhu persekitaran, bahan-bahan penebat peti sejuk, reka bentuk pelepas haba, arah aliran udara oleh kipas, kuantiti arus elektrik dan kesan bahan perubahan fasa parafin sebagai sumber penyejukan juga telah dikaji. Hasilnya menunjukkan bahawa parameter utama yang mempengaruhi suhu modul Peltier itu ialah kuantiti arus elektrik. Ini disebabkan semakin tinggi arus elektrik dibekalkan, semakin besar perbezaan suhu di antara bahagian panas dan sejuk modul Peltier. Reka bentuk pelepas haba juga ialah parameter yang penting dalam kajian ini. Ia menjadi salah satu komponen yang utama untuk menyebarkan haba dengan cekap. Suhu penyejukan terendah yang dicapai oleh mini peti sejuk ialah 11℃ dan kecekapan tenaga ialah 5.79%. Dengan penambahbaikan terutamanya dalam teknik-teknik mengurangkan suhu bahagian panas modul Peltier, peti sejuk termoelektrik boleh ditambah baik lagi untuk mencapai suhu penyejukan yang lebih rendah dan kecekapan tenaga yang lebih tinggi. Oleh itu, peti sejuk termoelektrik boleh menawarkan suatu teknologi alternatif untuk menggantikan sistem penyejukan konvensional yang menggunakan pemampat bagi aplikasi tertentu.

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DEDICATIONS

This thesis is dedicated to my beloved parents, supervisor and friends for their help and guidance to complete the final year project successfully.

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LIST OF SYMBOLS AND ABBREVIATIONS

A	=	Ampere
AC	=	Alternating Current
AIN	=	Aluminium Nitride
Bi_2Te_3	=	Bismuth Telluride
Bi-Sb	=	Bismuth-Antimony
CFCs	=	chlorofluorocarbons
COP	=	coefficient of performance
DC	=	Direct Current
EMF	=	electromotive force
HCFCs	=	hydrochlorofluorocarbons
n	=	Neutron
p	=	Proton
PbTe	=	Lead Telluride
PCM	=	Phase Change Material
SiGe	=	Silicon Germanium
T_c	=	Temperature of cold side
T_h	=	Temperature of hot side
V	=	Voltage

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CHAPTER 1

INTRODUCTION

1.0 Introduction

Refrigeration is a process where the work is done to remove the heat from cold medium to hot medium. The work of the heat transfer is driven by the mechanical work. A thermoelectric refrigerator functions the same way as a conventional compressor refrigerator. Thermoelectric device provides a promising alternatives refrigerator system due to the compressor which is consuming a lot of electricity and adverse impact to the environment. The thermoelectric refrigerator is using the Peltier module to function it which also known as thermoelectric module. It works as a solid state active heat pump which transfers the heat from one side to another side, with consumption of electrical energy and depending on the direction of the current.

1.1 Project Background

Recently, the activity of releasing chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) to the atmosphere from the vapor compression refrigeration systems has raised the awareness towards environment. It has become a great concern among researchers, technologist, businessman and politician that leads to develop of environmentally friendly refrigeration technologies. Hence, many researches have been conducted to find alternative refrigeration technology in replacing the old refrigerator system. Nowadays, modern refrigeration system does not use CFC because CFCs are harmful to the atmosphere and caused the green house effect which shown in Figure1.1. Instead, the refrigeration system now is using less harmful HFC which is compressed by compressor in the refrigeration cycle.

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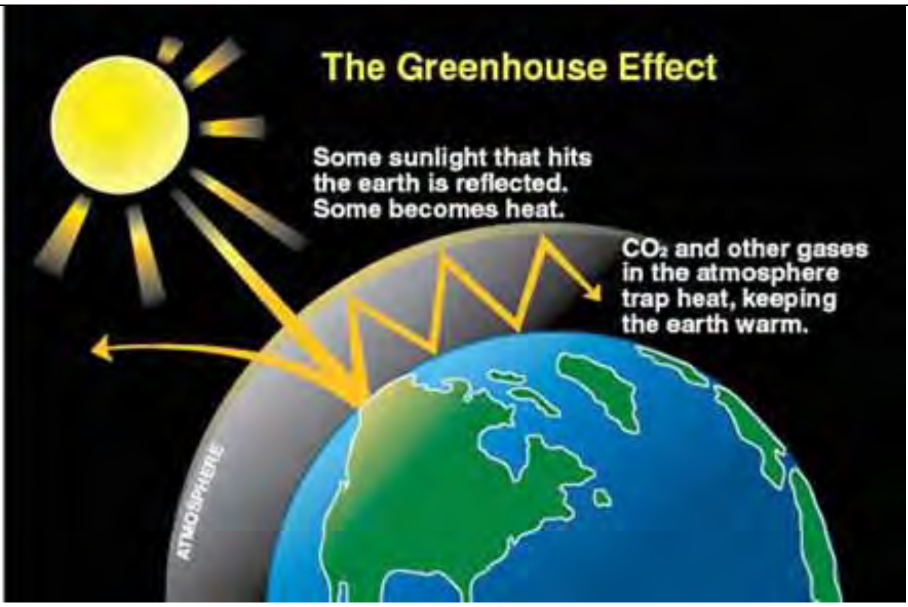

Figure 1.1: Green House Effect

Vapor compression refrigeration system, as shown in Figure 1.2, has compressor as one of its main component. This system, in which the refrigerant undergoes phase change, is one of the most widely used systems for air-conditioning of building and household refrigerators.

Figure 1.2: Vapor Compression Refrigeration System

One of the disadvantages of the compressor is they are very big and heavy. In this system, liquid refrigerant circulate the system while changing its phase. If any leakage occurs, the refrigerant might harm the environment. Besides that, it is expensive to change a new compressor if it is damaged and it is also hard to maintain

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the system well. The compressor also produces annoying noise and consumes a large amount of electricity during operation.

Thermoelectric device provides a promising alternatives refrigeration system as compared to compressor which is consuming a lot of electricity and an adverse impact to the environment. Thermoelectric cooling has many advantages such as compact in size, no mechanical moving parts and thus no noise, no working fluid that make it more environmentally friendly. Seebeck effect is the direct conversion of temperature differences to electric voltage and vice versa.

Seebeck effect as shown in Figure 1.3 is discovered by Thomas Johann Seebeck in 1821. The experiment was carried out when a temperature difference between the junctions was deflecting the compass needle by two metals joined in two points. Hence, Seebeck effect is defined as a phenomenon in which a temperature difference between two dissimilar metals or materials produce a voltage between the two points.

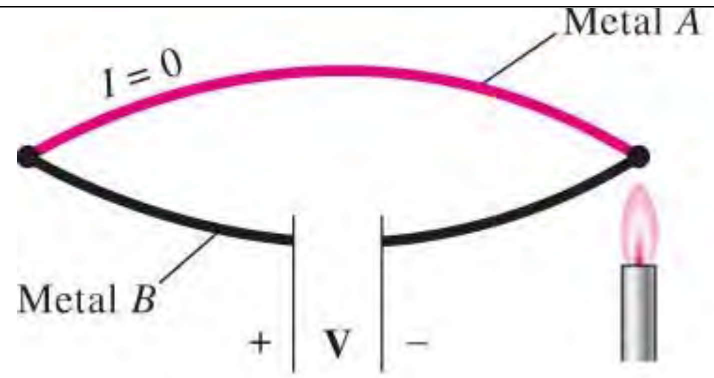

Figure 1.3: Seebeck Effect

French physicist Jean Charles Athanase Peltier (1785-1845) discovered another type of the thermoelectric effect. The physicist observed the reversed effect, the temperature difference was produced at the two different electrical conductors when the flow of an electric current was passed through. The effect is called Peltier effect, as shown in Figure 1.4. In simple words, when there are temperature gradient is applied to Peltier module, current electric is generated and can be stored.

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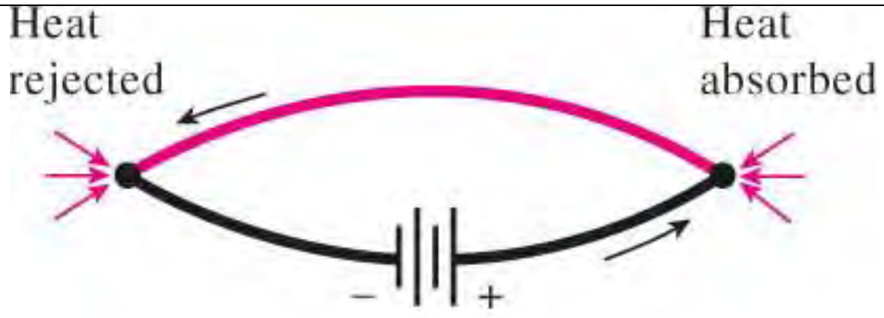

Figure 1.4: Peltier Effect

Peltier module is a device that implies Peltier effect which works as a heat pump which transfers the heat from one side to another side. It consumes electrical energy and also depending on the direction of the current when it transfers the heat. This Peltier device functions as heat pump because it does not create heat or cold. It simply transfers the heat from one side to another side. A Peltier consists of two plates, that is, one cold side and hot side. Several of the thermocouples are connected to each other together with two wires as shown in Figure 1.5. When voltage is applied to both of the wires, the cool side becomes cool whereas the hot side becomes hot. Peltier is usually made of semiconductor materials.

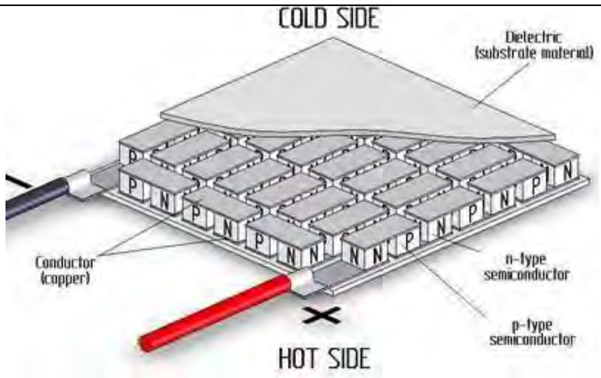

Figure 1.5: Peltier Module

The hot side becomes very hot after a few minutes of running. Therefore, the hot side is connected to the heat sink to dissipate the heat to the surrounding.

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1.2 Problem Statement

In this study, a mini thermoelectric refrigerator was fabricated by using Peltier module. The Peltier module generates hot side and cold side after applying electrical current to it. The main problem is the hot side of the Peltier module. This is because the hot side of the Peltier module generally apply the thermo equilibrium principle with the cold side of the Peltier module, thus affects the cooling temperature of the mini refrigerator. The hot side of the Peltier module becomes very hot after a few minutes of running. Instead, the hot side is connected to the heat sink by dissipating the heat to the surrounding. However, the cooling temperature of refrigerator using Peltier module is relatively low. Therefore, in order to increase the cooling temperature of a mini refrigerator, the effect of the ambient temperature, insulation material, design of the heat sink, Phase Change Material (PCM), the direction of the fan air flow and quantity of electric current have to be studied.

1.3 General Objective of Research

To improve the cooling temperature of a mini thermoelectric refrigerator by several techniques in order to reduce the temperature of the heat sink of the Peltier module

1.3.1 Specific Objectives

i. To design and fabricate a mini thermoelectric refrigerator by using Peltier module
ii. To study the effect of ambient temperature, insulation material, design of the heat sink, Phase Change Material (PCM), the direction of the fan air flow and quantity of electric current on the cooling temperature of the mini thermoelectric refrigerator
iii. To calculate the coefficient of performance (COP) of the mini thermoelectric refrigerator

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1.4 Scope of Research

In this project, the aim is to design a mini thermoelectric refrigerator which uses Peltier module and improve its efficiency by several techniques by changing the insulation material, design of the heat sink, the direction of the air flow, quantity of electric current and by applying the Phase Change Material (PCM) as a cooling source. In this research, the efficiency of the mini refrigerator was evaluated mainly based on the cooling temperature of the mini refrigerator and the coefficient of performance (COP).

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CHAPTER 2
LITERATURE REVIEW

2.0 Introduction

This chapter discusses mainly on the history of the thermoelectric and the application of the Peltier module. The main components of thermoelectric refrigerator such as Peltier module, design of heat sink and the Phase Change Material (PCM) have been reviewed in this chapter.

2.1 A Brief History of Thermoelectric

In the year 1822, the study of thermoelectric began when Thomas Johann Seebeck (1821) as shown in Figure 2.1, a German physicist found that a circuit made from two different types of metals, with junctions at different temperatures would deflect a compass magnet, shown in Figure 2.2. This showed that an electric field was created between the two metals. This was due to magnetism induced by the temperature differences which deflected the needle.

Figure 2.1: Thomas Johann Seebeck

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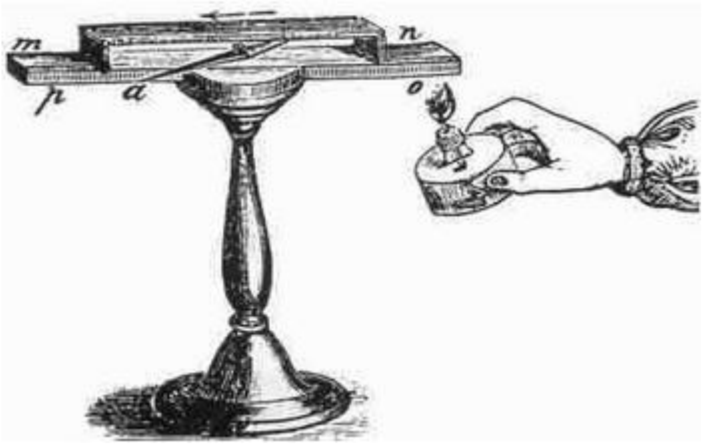

Figure 2.2: Instrument Used by Seebeck

The temperature difference produces an electrical potential which can drive an electric current in a closed circuit. Today, it is known as the Seebeck effect. Seebeck then discovered that some metals can create stronger fields with the same temperature difference and the amount of deflection in the needle was proportional to the temperature difference between two conducting metals. These principles provided the foundations of thermoelectric. Later, the Seebeck coefficient was discovered which means that the voltage was produced between two points of a conductor where a uniform temperature difference of 1K exists between those two points. The discovery of the Seebeck coefficient was named after the founding father of thermoelectric, Thomas Johann Seebeck.

In the year 1834, the thermoelectric materials could also work in reverse and this was discovered by a French watchmaker named Jean Charles Athanase Peltier (1834). Peltier found that an electric current would produce heat at the junction of two different dissimilar metals. Although the discovery of the thermoelectric cooling is generally credited by Peltier, he did not understand the physics of the phenomenon. In 1838, Emil Lenz (1838) gave the full explanation by showing him the heat could either removed from a junction to freeze water into ice, or by reversing the current, heat can generated to melt ice depending on the direction of the current. The heat absorbed or created at the junction is proportional to the electric current which is known as Peltier coefficient.

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