STUDY ON THERMAL PERFORMANCE OF THERMOELECTRIC COOLING MODULE

SAFIRUL IKHMAL BIN SAHARUDIN

This dissertation is submitted as partial fulfillment of the requirement for the degree of Bachelor of Mechanical Engineering (Thermal Fluid)

Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka

MAY 2009

‘I hereby declared that I have read through this report and I found that it has comply the partial fulfillment for awarding the degree of Bachelor Mechanical Engineering (Thermal-Fluid)’

Signature : ....

Supervisor : Nazri B. Md Daud

Date : ....

"I declare that this report is done by my own exclude the citation with the mentioned references for each"

Signature:……………………….................

Author : Safirul Ikhmal Bin Saharudin

Date : 18th May 2009

Dedication

This book is especially dedicated to my supervisor, all respective UTeM staffs and friends for their undivided help and guidance in enabling me to gain experience and knowledge in making my final year project a success.

ACKNOWLEDGEMENT

All praises to God for His blessings and guidance. Thanks for giving me the strength and ideas to complete this project report. Without His blessing, I would never complete this report on time.

I would like to thank Mr. Nazri Md Daud, as my supervisor in this project, the most important person with all due respect. I also would like to thank my second panel for his kindness in checking my report. Not to forget, lab technician, Mr. Hairul for all his support, my family that gave me support and motivation during the completion.

Last but not least, bundle of thanks to all people involved directly or indirectly in completing this project report.

ABSTRACT

Thermoelectric module is a device that converts electrical energy to cold and hot temperature and it is called Peltier effect. This cooling system used direct current (DC) as a power supply. Thermoelectric is made from two thin ceramic plates and in the middle of this two plates consist of two semi conductor material in series denoted as P-type and N-type. Current that flow through this thermoelectric will make N-type has an excess of electrons or negative charge, while the P type material has a deficit of electrons or positive charge. The combination of two types of semi conductor will construct an electrical connection in series and thermal connection in parallel. Electrons that moved from P-type to N-type will make one side cooled and vice versa. The main focus in this project is to find the physical properties and performance curve of thermoelectric module. The physical properties and performance curve obtained from this experiment are compared to other journals and previous research. Most of thermoelectric module manufacturer are not concern about this matters. The experiment only focused on the cooling system. The concept of thermoelectric module cooling system is used in various applications such as mobile refrigerator in car connected to automobile cigarette lighter. The cooling capacity of thermoelectric can be determined from the physical properties and the performance curve. The value of physical properties of thermoelectric obtained from this experiment are Seebeck coefficient, $\alpha = 0.0468\ V^{o}C^{-1}$, thermal conductivity, K_t is $0.4074\ W^{o}C^{-1}$, and resistance $R = 2.3603\ \Omega$.

ABSTRAK

Modul penyejuk termoelektrik merupakan satu alat yang menukarkan tenaga elektrik kepada suhu sama ada panas mahupun sejuk. Keadaan ini dipanggil sebagai kesan Peltier. Sistem penyejukan ini menggunakan arus terus sebagai sumber kuasa. Modul termoelektrik diperbuat daripada dua jenis lapisan seramik nipis dan dibahagian tengahnya terdiri daripada kepingan semi konduktor P dan N yang disusun secara selari. Arus yang mengalir menyebabkan lapisan semi konduktor N menerima lebihan elektron atau cas negatif dan lapisan semi konduktor P mempunyai kekurangan elektron atau cas positif. Apabila kedua-duanya di gabungkan, ia akan menjadi sambungan electrik secara sesiri dan sambungan termal selari. Elektron yang bergerak dari P ke N menyebabkan satu bahagian tersebut menjadi sejuk dan sebaliknya. Perkara utama yang akan difokuskan didalam projek ini ialah menyediakan satu eksperimen untuk menentukan ciri-ciri fizikal modul termoelektrik. Ciri-ciri fizikal yang dicari melalui eksperimen ini akan dibandingkan dengan jurnal-jurnal atau kajian-kajian yang dijalankan sebelum ini. Kebanyakan pengeluar modul termoelektrik tidak menyediakan ciri-ciri fizikal yang terperinci untuk produk mereka. Eksperimen yang akan dijalankan hanyalah memfokuskan kepada kesan penyejukan. Prinsip modul termoelektrik ini dalam sistem penyejukan membolehkan ia digunakan dalam pelbagai aplikasi seperti peti sejuk mudah alih yang boleh dimuatkan didalam kereta dan disambung pada palam pencucuh rokok. Sifat-sifat fizikal yang ditentukan didalam eksperimen ini boleh menentukan tahap penyejukan termoelektrik modul yang penting didalam sesuatu aplikasi. Nilai-nilai sifat fizikal thermoelectric yang diperoleh daripada ujikaji ini ialah, pekali Seebeck, $\alpha = 0.0468\ V^{o}C^{-1}$, konduktiviti termal, K_t is $0.4074\ W^{o}C^{-1}$, dan rintangan $R = 2.3603\ \Omega$.

TABLE OF CONTENT

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATION

COP	=	coefficient of performance
I	=	current through the thermoelectric module (amp)
K_t	=	total thermal conductivity of thermoelectric module, (W°C^{-1})
Q_L	=	cooling capacity (W)
P	=	electric power supplied to the thermoelectric module (W)
R	=	total electrical resistance of thermoelectric module (ohm)
T_H	=	hot-end temperature of the thermoelectric module (K)
T_L	=	cold-end temperature of the thermoelectric module (K)
V	=	voltage to the thermoelectric module (volt)
Z	=	figure of merit of thermoelectric module (K^{-1})
α	=	Seeback coefficient of thermoelectric module ($V°C^{-1}$)
ΔT	=	temperature difference
h	=	heat transfer coefficient (30 W/m^2.^{o}C)
A	=	area of the block face (m^2)
T_s	=	surface temperature of aluminum block surface (^{o}C)
T_A	=	ambient temperature or room temperature (^{o}C)

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

1.1 Background

Thermoelectric modules are devices that thermoelectric materials are placed between ceramic plates. They are solid-state, vibration-free, noise-free heat pumps, pumping the heat from one surface to another. If the heat at the hot side is dissipated to ambience by a heat sink, this assembly becomes a cooling unit. Not just being a heat pump, the thermoelectric module also can be used to generate electrical power by converting any source of heat. When direct current (DC) voltage is applied to the module, the positive and negative charge carriers in the pellet array absorb heat energy from one substrate surface and release it to the substrate at the opposite side. The surface where heat energy is absorbed becomes cold; the opposite surface where heat energy is release, becomes hot as shown in Figure 1.

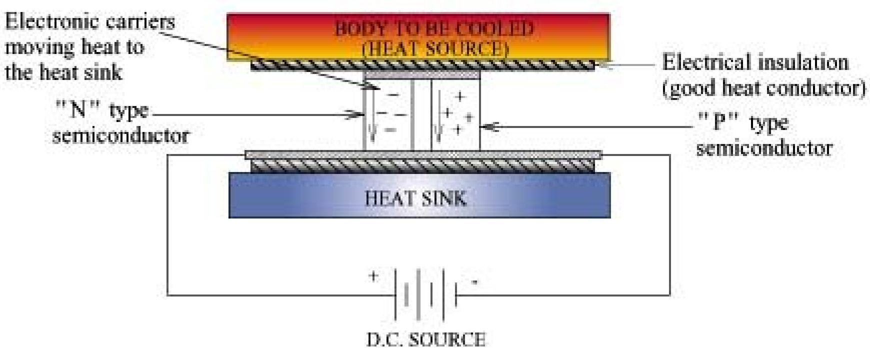

Figure 1.1: Cross Section of a Thermoelectric Module

(Source: http://www.melcor.com/tec.html)

Featured with no moving parts, being small in size and light in weight, the thermoelectric modules have been widely used within the military, medical, industrial, consumer, laboratory, electro-optic and telecommunications areas for cooling, heating and electric power generation. Although thermoelectric phenomena were discovered more than 150 years ago, thermoelectric devices have only been applied commercially during recent decades.

The theories behind the operation of thermoelectric cooling can be traced back to the early 1800s. Jean Peltier discovered there is a heating or cooling effect when electric current passes through two conductors. Thomas Seebeck found two dissimilar conductors at different temperatures would create an electromotive force or voltage. William Thomson (Lord Kelvin) showed that over a temperature gradient, a single conductor with current flow, will have reversible heating and cooling.

1.2 Problem Statement

Thermoelectric devices are widely used in various industries. The manufacturer develops many types of thermoelectric with different features and ability in cooling system. Some manufacturer does not provide physical properties and the performance details of thermoelectric module. The coefficient of performance (COP) for thermoelectric needs to be reviewed by the manufacturer in order to convince customers about the performance of their products. Because of that, a simple test rig needs to be fabricated in order to determine the COP using the Peltier effect and Seebeck coefficient.

1.3 Objectives

The objectives of this project are as follows:

1. To fabricate test rig in order to determine the physical properties and performance curve of thermoelectric module experimentally.
2. Comparison between experimental results that have been obtained with or researcher's data.

1.4 Scope

The scope that focus in this project are:

1. Fabricate an experiment setup of thermoelectric cooling module system model Melcor CP2-127-06L.
2. The performance curve will be determined based on the temperature difference achieved by thermocouple. The temperature difference in thermoelectric is recorded based on temperature in heater that attached to the thermoelectric.
3. Determination of physical properties of thermoelectric based on the experiments which are the total thermal conductivity of thermoelectric, K_t, Seebeck coefficient, α, cooling capacity, Q_L, and coefficient of performance, COP.
4. The performance curve is constructed using the experimental data.

1.5 Project Summary

According to the problem statement, objectives and scope of the project, a simple test needs to be run to obtain several important data. The experiment regarding thermoelectric is fabricated to collect information based on the performance analysis and physical properties. This information must be carried out and proved by the data and graph from the readings in the experiment. The apparatus and instruments need to be prepared to make sure the experiment is running well without damaging the thermoelectric devices. The thermoelectric is very sensitive and easy to get damage so this simple experiment is constructed based on the well prepared procedure. The important data that should be carried out are the performance analysis to get the coefficient of performance and the physical properties.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

A literature review in this section is just a simple summary of the sources, such as journals and papers related to the thermoelectric cooling module. In this chapter, it is also discuss about the fundamental of thermoelectric, experiment of the cooling module and development of thermoelectric. It might give a new interpretation of old material or combine new with old interpretations.

2.2 Fundamental of Thermoelectric Device

According to the Edmund J. Winder and Arthur B. Ellis (1996) from the "Thermoelectric Devices: Solid-State Refrigerators and Electrical Generators in the Classroom", thermoelectric devices are solid-state devices that convert thermal energy from a temperature gradient into electrical energy (the Seebeck effect) or convert electrical energy into a temperature gradient (the Peltier effect). The application of these two effects is described as a thermodynamic principle in a compelling manner. The focus is on the Peltier effect where the application is the portable cooler, which is electrical energy is converted to the temperature.

From this journal, the experiment of cooling module using Peltier effect can be demonstrated using the assembled thermoelectric. The simplest demonstration of the Peltier effect is allows it to establish a temperature difference between the heat sinks. If direct contact by touch is not practical, digital thermometers can be connected to the heat sinks so the temperature between hot and cold can be measured. The experiment of thermoelectric cooling module is related to the thermodynamics theory where the performance of thermoelectrics, is based on the efficiency. The efficiency, η, is defined as the ratio of work output to work input. A device converting electrical work to mechanical work (example, an electric motor) that could theoretically be 100% efficient that is, have an efficiency of one similarly, the reverse process of converting mechanical work to electrical work could theoretically have an efficiency of one. Besides that the theory from the heat pump also has been reviewed, and it is related to the thermoelectric cooling module where the temperature difference from ambient temperature that the two heat sinks reach: the hot side hotter than ambient temperature, while the cold side is colder than ambient temperature. Although resistive heating and transport effects are affecting the temperatures at both heat sinks, ideal thermodynamic effects are also apparent.

Metals typically have thermo powers, which are too small for most practical applications with the exception of thermocouples. Many semiconductors, however, have much larger values of heat transfer, Q. Although metals produce a smaller potential for a given temperature difference, they are good thermocouple materials because they are inexpensive and can easily operate in high temperature environments. The materials used in thermoelectric devices and described herein can be used to introduce a variety of solid-state structures.

2.3 An Experimental Investigation of Thermoelectric

Based on the journal from Yu-Wei et.al (2007), the heat sink on the hot side plays an important role in the overall performance. The selection of heat sink is to be determined, first is to measure the properties of thermoelectric first, and then verify the thermal resistance of heat sink which can meet the thermal design temperature. Theoretically, the thermal resistance of the air-cooling heat sink is constant when dividing the temperature difference by the total amount of heat passing through the heat sink. However, the thermal resistance in this article is only to divide temperature by the heating power of heater. The amount of heat actually passes through heat sink is more than the heat from heater. The influences of heating power and input current are determined. According to the measurement of temperatures, the cooling module includes thermoelectric cooler resistance and heat sink resistance. Thermoelectric cooler resistance stands for the thermal capacity of the thermoelectric cooler, and heat sink resistance for the capacity of the air-cooling heat sink. With increasing input current, thermoelectric resistance decreases and heat sink resistance increases. The opposite trends on input current result in an optimal value in the overall resistance. With increasing heating power of heat source, thermoelectric resistance increases and heat sink resistance decreases. Including these two effects, the overall resistance grows with the increase of heating power.

2.4 Accuracy of the Thermoelectric Module

Reviewed from the Christopher D. Meyer article (2007), an experiment has to be conducted due to the determination of the accuracy of the cooling module. Difference material is used to determine the electrical resistivity and the thermal connectivity. Each material property has to be considered and summarized. Measurement of the internal electrical resistance of thermoelectric materials must always account for the voltage resulting from any difference in temperature between the ends of the material. In thermoelectric materials, current will cause heating and cooling at the ends of the material through the Peltier effect. This effect can be minimized if the direction of current flow alternates quickly so that not enough heat is distributed in one half cycle to create a significant temperature difference within the tested device. Importantly, material properties and parameters can be independently measured by separate experiments and used in the model with reasonable accuracy.

2.5 Advantages of Thermoelectric

Based on the CRC of Thermoelectric handbook by John G. Stockholm (2000), the advantages of thermoelectric can be shown in the industry where the cost has been decreased regularly. The advantages of the thermoelectric in the small system; thermoelectric modules can be the most economic because of the standard off-the-shelf components itself. The operating voltage used by thermoelectric contain series parallel electrical circuitry and this circuitry gives the best and flexible cooling power. Other than that the size of thermoelectric itself made it easy to install or attach to other device. The collaboration of heat exchangers with thermoelectric are widely used in the cooling systems.