Chapter 56

Toward Energy Saving Thermoelectric Refrigeration for System Efficiency

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Abstract

A prototype thermoelectric system integrated with portable refrigeration unit using Peltier for space cooling act as a heat pump has been introduced in this work. In today's scenario, due to the development of production, the home appliances such as refrigerator is the most energy consuming and disposal of refrigerants. It is consequently release a lot of unneeded gas all over the world that contributing the factor of global warming on climate change. Additional, the normal refrigeration system use high power consumption than this development of thermoelectric refrigerator. A simplified analytical model for the thermoelectric module has been adopted to investigate the efficiency of this thermoelectric refrigeration which is based on the parameter of the result taken and evaluation on performance of thermoelectric refrigeration. The experimental test in a reduced-scale polystyrene ice box has achieved temperature at average 17^{o}C in minutes of 120 and realized an average energy usage this system only uses about 251.85 kW/h per year that half energy usage than the typical mini refrigeration system with vapor compression system. Plus, this experiment was improved by Arduino UNO microcontroller to ensure the system of this thermoelectric refrigeration system cut off automatically when the Arduino detected the gradient of temperature for power save. The thermoelectric Peltier was attached with the heat sink and CPU fan for the force convection to release the cold and hot air into the refrigeration box. This thermoelectric system can continuously improve the previous research to ensure the thermoelectric refrigeration can continually develop in market value.

Keywords- ***Peltier Effect, Thermoelectric Module, Heat Sink, Refrigerator System.***

Introduction

Thermoelectric cooling technologies have proven themselves as reliable alternatives for laboratorial applications and small home appliances. They consists of an assembly of Peltier modules and heat sinks, which in the scope of this work, are air cooled. Design and developmental methodology of thermoelectric refrigeration has been explained in detail of thermoelectric cooling module used in this research work have been investigated.

In this project, thermoelectric Peltier encompasses the advantages such as quiet operation, lower power consumption usage, more compact, lower budget than typical air conditional and refrigeration system using compressor that have higher price in market.

Literature Review

a) Refrigeration

Table 1
Comparison between TEC System and VCR System

Parameter	TEC	VCR
Cooling method	Non-cyclic refrigeration	Vapor compression cycle
Cooling/heating capacity	Low	High
Electricity consumption	Less	High
COP	0.38-0.45	2.6-3.0
Noise level	Quiet	Noisy
Working Fluid	Electrons	Refrigerant (R-134a)

Refrigeration is the process of heat-removal from a space in order to bring it to a lower temperature than surrounding temperature. In this context, "Peltier cooling module" which works on thermoelectric refrigeration, aims to provide cooling by using thermoelectric effects rather than the more prevalent conventional methods like 'vapour compression cycle' or the 'vapour absorption cycle'.

Before conducted experiment this projectprovides understanding to select suitable refrigeration system according to its applicable application. Table 1 shows that the comparison between thermoelectric cooling (TEC) system and vapor compression refrigeration (VCR) system according to theparameter(Gaikwad et. al, 2016). According to the research, they found that COP for TEC is lower than VCR. Due to lower COP for Peltier coolers, usually are used in small applications where the cooling demand are not too great and has low efficiency. Thus, thermoelectric refrigerator should be chosen when a low cooling capacity is needed.

b) Thermoelectric Peltier Module

Thermoelectric refrigeration system is used Peltier cooling device that able to convert the heat or electricity directly or vice versa (Patil et. al, 2017). Thermoelectric effect is from the fundamental properties between the thermal properties of system and the electronic itself. All of this effect can be measure by the total number of voltage and current produce in the system. Thermoelectric device gives the different temperature of two side which is cold and hot by creating the voltage.

In the term of atomic scale, the apply temperature cause the charges carries into material that diffuse from hot to cold side. The heat flow can be induced by the electrical voltage and current. He et al.(2015) find that Seebeck effect,Thomson effectand Peltier effect are the three primary thermoelectric effect where it can be combined by using thermodynamic effect and then can be derive all the thermoelectric effect as shown in Fig. 1.

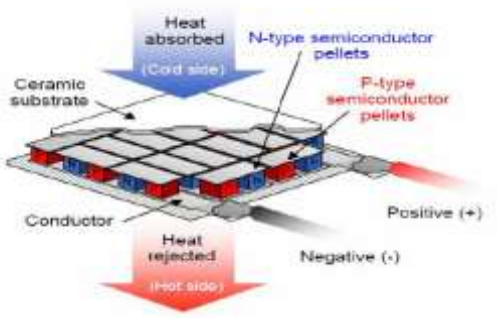

Fig. 1 Principle Operation of Peltier

Methodology

a) Experimental Setup

This project focusses on the Thermoelectric Cooler Peltier (TEC), heat sinks and blower fan construction and using 12V Direct Current (DC) power supply that connected to the system. In Fig. 2, the TEC has been attach in between small heat sink and big heat sink. The big heat sink is the hot side, ambient air removes heat by using blower fan. The forced convection systems are using in this thermoelectric refrigeration system. After the cold side are enough cold, the heat will remove out by the small heat sink with the aid of the blower fan into the box, so the cold air will flow into the box as the refrigeration system. Heat transfer in the system produce equivalent thermal equilibrium which is the cold air circulated within the enclosure.

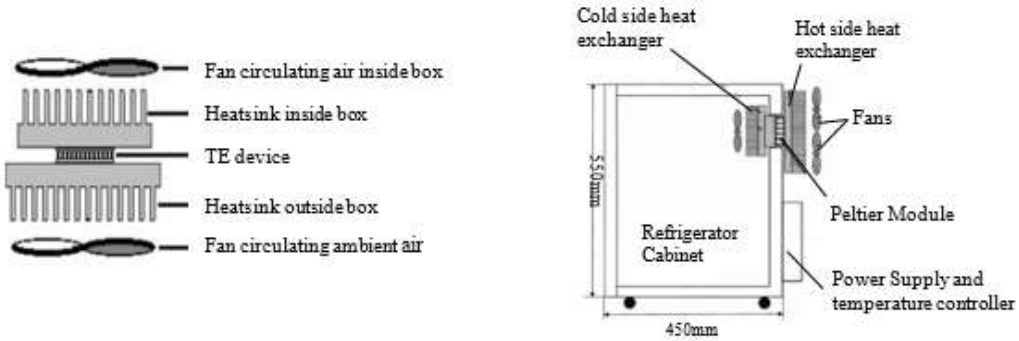

Fig. 2 Schematic Diagram of Peltier Cooling System

TEC refrigerator are simple and there is no moving part in this system, there are using direct current power supply because direct current could not easily be changing to high voltage. The thermoelectric refrigeration produces reliable refrigeration by incorporating environmental friendly form, energy saving and stable. This system can be further improved by utilization of smart temperature controllerinterpreted by LabVIEW software and measured by Arduino UNO microcontroller using transistor LM 35, to vary the power supply within specified range of temperature as shown in Fig. 3. This immensely decreases the working cost of the refrigerator and burden on the earth. Then, as the output, CPU cooler fan, TEC Peltier and LED light was added to shows the current flow across the system.

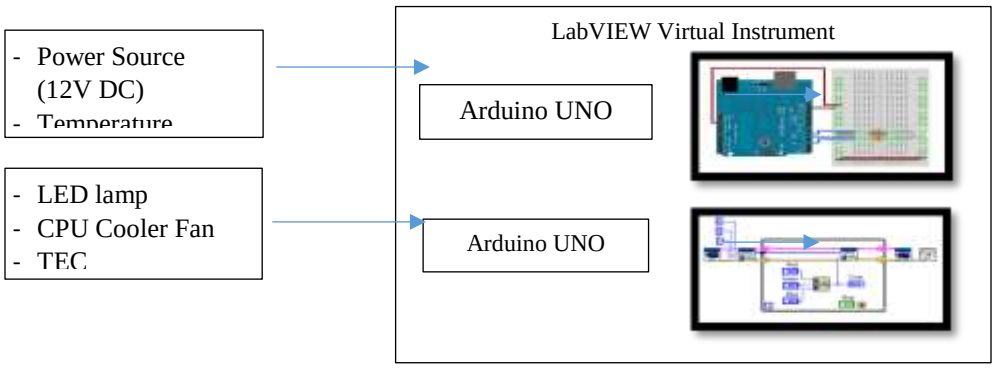

Fig. 3 Process Block Diagram

Result and Analysis

The investigation on the temperature of this system was conducted by using ice box refrigerator size at (13.5cm x 13.5cm x 20cm). Using of two TEC1-12706 Peltier module have their specification which is one

module of Peltier are only allow maximum 60 watts of power on it system with I max is 6 Amp only. The Fig. 4 shows that the experiment for the temperature degradation and power consumption inside the refrigeration. Data are taken every 15 minutes with room temperature at 30 ℃

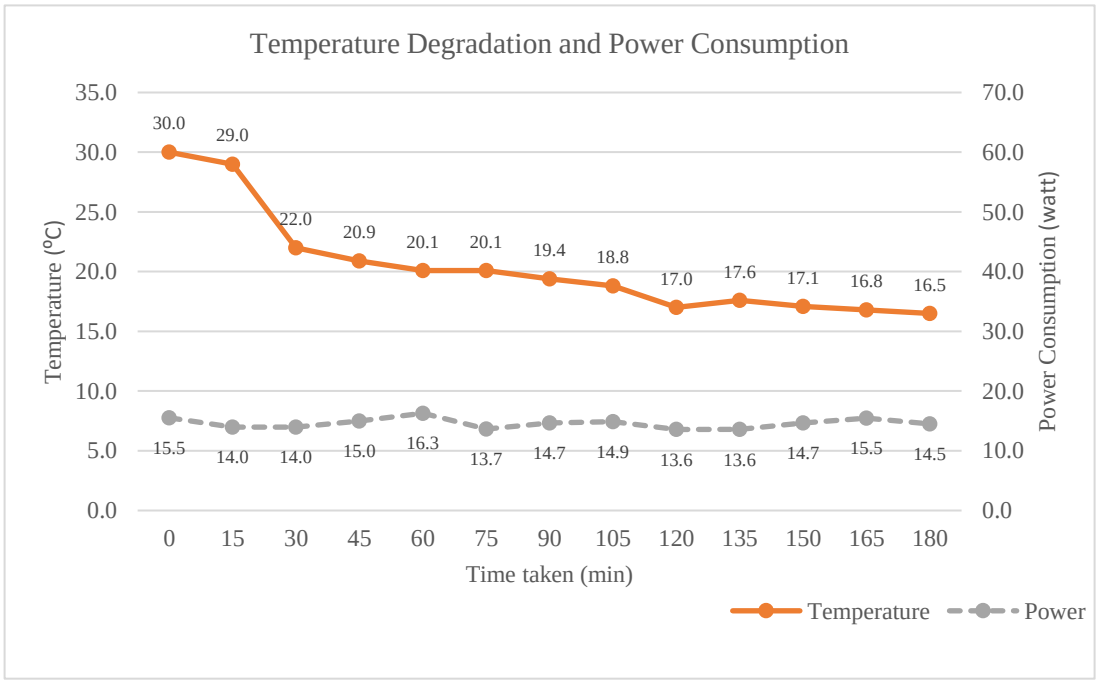

Fig.4Temperature Degradation and Power Consumption

Regarding Fig. 4, at room temperature 30℃, the refrigerator take 2 hours to achieve the optimum temperature at 17°C and constant at it range temperature with the use of two thermoelectric Peltier. Next, it is clear shows that the thermoelectric refrigerator system is using average power per hour at 14.59 watt to reach until 16°C just only use the lowest energy in power consumption.

Table 2
Normal Refrigeration System vs Thermoelectric Refrigeration System

Thermoelectric Refrigeration System (TER)	Normal Mini Refrigeration System
(Kilowatt-hour per year) (120-watt Peltier System)	(Kilowatt-hours per year) (1000-watt Rankine Cycle system)
Power Consumption 0.69Kw/h per day	Power Consumption 1.5Kw/h per day
251.85 kW/h per year	547.5 kW/h per year
RM 54.90 per year	RM 119.40 per year

By comparing TER and normal mini refrigeration system in Table 2, the optimum cold temperature can achieve until 16°C in two to three hours of operation and use less energy than the normal mini refrigerator. Moreover, the average power use is half of the normal mini refrigerator system. TER system can operated 18-19 hours in a day, because the Arduino system can detect the temperature, when its detected low temperature, the system will be stop duty (auto cut off system) and stop within 15 minutes to 20 minutes and vice versa. The results indicate the cost for TER system RM 54.90 per year. In term of utility bill saving,

(based on the residential electricity tariff at 21.80 cents per kWh), the thermoelectric system is able to save a lot of energy uses.

Conclusion

Thermoelectric cooling are being studied exhaustively for the past several years and various conclusions have been conceived regarding the efficient functioning of thermoelectric refrigerators. Thermoelectric refrigerators are greatly needed, particularly for developing countries, where long life, low maintenance and clean environment are needed. In this aspect thermoelectric cannot be challenged in spite of the fact that it has some disadvantages like low coefficient of performance. These contentious issues are the frontal factors hampering the large scale commercialization of thermoelectric cooling devices. The solution to above problems can only be resolved with the development of new techniques.

For further improvement, replacing the power plug with the use of solar can help to reduce the energy consumption in house to use the refrigeration system. The Peltier block also must be attach and easily remove by user when this product need to be commercial because the Peltier are very sensitive that easily to broken. In conclusion, thermoelectric system is a potential energy method that can be used as an alternative source of cooling system.

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