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Final Year Project Report

Mobile Air Conditioning Device

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2014/2015

“ I hereby declare that I have read through this report entitle “Mobile Air Conditioning Device” and found that it has comply the partial fulfilment for awarding the degree of Bachelor of Electrical Engineering (Mechatronic)

Signature : …….....

Supervisor’s Name : ……..

Date : ……..

MOBILE AIR CONDITIONING DEVICE

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A report submitted in partial fulfilment of the requirements for the degree

of Bachelor of Mechatronic Engineering, BEKM

Faculty of Electrical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014/2015

I declare that this report entitle “Mobile Air Conditioning Device” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidate of any other degree.

Signature : …….

Name : ……

Date : …….

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ABSTRACT

The motivation behind this project is to design a portable cooling system that able to control temperature in a jacket at a certain degree. In the present extreme heat situation, portable cooling system is a solution to compromise the high temperature especially during daytime. The problem to realize is how to maintain temperature underneath the jacket while minimizing the weight of the equipment and reducing power consumption upon completing this project. It is proposed that water is used as medium to transfer coldness in this project. In order to control the temperature, sensor will be installing on the system as the feedback loop so that the controller can decide an action to overcome the change in temperature. Component is compared so that the smallest size of component will use for this project in order to minimize the weight problem. A 12V thermoelectric cooler is applied as main actuator to produce cooling. Hence, the objectives of this project are to design a system that able to control temperature accurately which is light in weight for portability purpose and is less in power consumption. Two experiments test is carried out in order to achieve the objectives of the project. Experiment 1 is to test the accuracy level of feedback loop in order to maintain temperature. Experiment 2 is separate into two parts which the first part is carried out using Scilab to analyse the efficiency of the system in term of rate of heat transfer. Prototype is needed in order to analyse the efficiency of the system in term of power consumption for second part. Result shows that this cooling system have a temperature difference of 0.7 ◦C in 600s and for experiment 4.3.1 and 2.5◦C in 300s for experiment 4.3.2; while the power consumption is 11.5 watts per unit thermoelectric cooler experiment 4.3.1 and 37.85 watts per unit thermoelectric cooler for experiment 4.3.2.

ABSTRAK

Motivasi di balik projek ini adalah untuk mereka bentuk sistem penyejukan mudah alih yang dapat mengawal suhu dalam jaket pada tahap tertentu. Dalam keadaan panas yang melampau pada masa ini, sistem penyejukan mudah alih adalah satu penyelesaian untuk mengatasi suhu tinggi terutama pada waktu siang hari. Masalah yang wujud adalah bagaimana untuk mengekalkan suhu di bawah jaket dan pada masa yang sama meminimumkan keberatan system serta mengurangkan penggunaan kuasa. Adalah dicadangkan air sebagai medium untuk memindahkan kesejukan untuk projek ini. Dalam usaha untuk mengawal suhu, sensor akan memasang pada sistem sebagai gelung maklum balas supaya pengawal dapat memutuskan suatu tindakan untuk mengatasi perubahan suhu. Komponen dibandingkan sehingga saiz yang paling kecil komponen akan digunakan untuk projek ini untuk mengurangkan masalah berat badan. A 12V sejuk termoelektrik digunakan sebagai penggerak utama untuk menghasilkan penyejukan. Oleh itu, objektif projek ini adalah untuk mereka bentuk satu sistem yang dapat mengawal suhu dengan tepat yang ringan mudah dibawa untuk tujuan dan kurang penggunaan kuasa. Dua eksperimen ujian dilakukan bagi mencapai objektif projek. Eksperimen 1 adalah untuk menguji tahap ketepatan gelung maklum balas bagi mengekalkan suhu. Eksperimen 2 adalah terpisah kepada dua bahagian yang bahagian pertama dilakukan dengan menggunakan Scilab untuk menganalisis kecekapan sistem dari segi kadar pemindahan haba. Prototaip yang diperlukan untuk menganalisis kecekapan sistem dari segi penggunaan tenaga untuk bahagian kedua. Keputusan menunjukkan bahawa sistem penyejukan ini mempunyai perbezaan suhu 0.7 ◦C dalam masa 600s untuk percubaan 4.3.1 dan 2.5◦C dalam masa 300s untuk percubaan 4.3.2; manakala penggunaan kuasa adalah 11.5 watt per unit termoelektrik eksperimen sejuk 4.3.1 dan 37,85 watt per unit lebih sejuk termoelektrik untuk percubaan 4.3.2.

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CHAPTER 1

INTRODUCTION

1.1 Motivation

Climate changed a lot in recent few years' time. This changes has indirectly brings other bad influence to human or World. Extreme weather is one of the influences that give so much of effect to human. As the climate has warmed, some type of extreme weather will become more frequent. Extreme hot, cold, sudden flood, storms and lightning are the examples of extreme weather [14]. Heat-related illness is a public health problem that usually happen when someone expose to extreme heat for too long. Examples of illness are heat stroke, heat cramps and heat syncope.

The issue of extreme weather is not only happen to western country, but it also happen in local, Malaysia. According to the Health Ministry, director-general Datuk Dr Noor Hisham Abdullah, March 2014, a person will also face the signs of muscle pain, spasms, and vomiting, dry and reddish skin before the serious consequence approached-coma or death. There is also a report by The Meteorological Department, announced that the hot weather was worse than previous year [20].

These illnesses will result in death and there is a research about deaths attributed by heat, cold and other wealth events in United States, 2006-2010 [14] with data shown in Figure 1. By focusing to heat-related death, data shown death rate increased from age 45 and above where this can be explain by healthy level is not strong as people at age less than 45 years old. There is actually a way to reduce the death rate which is by controlling

body temperature to prevent changes in large scale especially when a person move from surrounding with low temperature into a surrounding that have very high temperature.

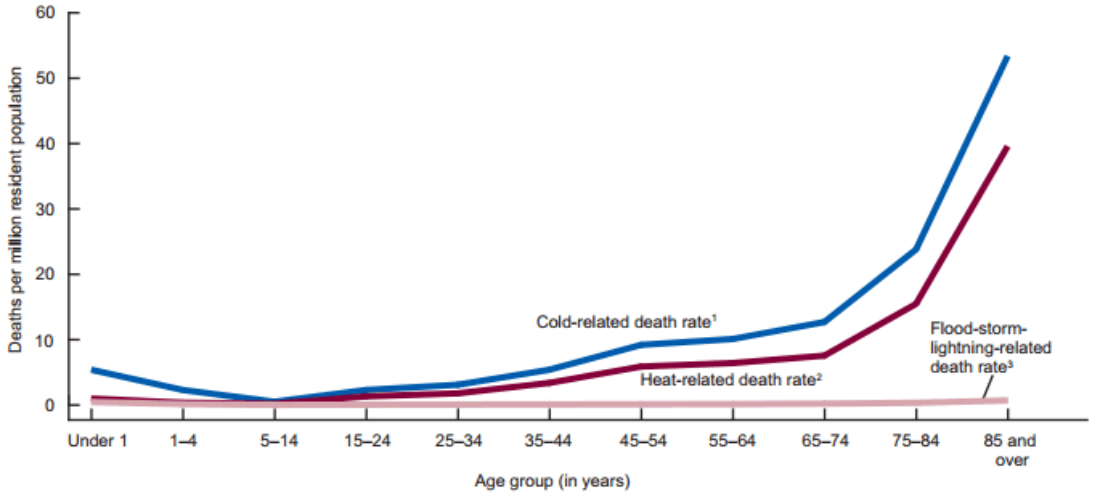

Figure 1: Death rates for extreme weather related to age: United States, 2006-2010

Source: http://www.cdc.gov/nchs/data/nhsr/nhsr076.pdf

Air conditioner is to compromise with the hot weather. Refrigeration cycle is typically used in air conditioner equipment in order to achieve the cooling purpose. Besides that, there are other method used in cooling purpose like evaporation, natural cooling and so on. There was a significant of transformation in air conditioner history where it started with a rotary fan as air conditioning in 2nd century. However, Wills Carrier had successfully invented the first modern air conditioning unit for a plant in 1902 where he applied the knowledge of reversing heating using steam into his invention. The air was send through a cold coil that fills with cold water then produce moisture air. The main purpose of his invention was to control the temperature as well as the humidity of surrounding.

Wills invention was big in size and usually for plant sector. David St. Pierre DuBose has developed a network of ductwork to control the air conditioning in private home in 1933. However, there is still an improvement can be done on current air conditioner status which make it become portable. A portable, in-window air conditioner has designed and invented by Robert Sherman in 1945 which this invention upgraded the previous air conditioner function to another level by combining cooled, heated, humidified,

dehumidified and filtered air. The present of air conditioner has indirectly introduced refrigerant development where it contains a complex construction like compressor, filter, blower, evaporator coil, condenser coil and fan.

There is now greater expectation from the public about the portability. There is a need on making the portable become a complete mobile air conditioner device. This requirement is not impossible but actually there is already have inventions on it to solve hot weather during outdoor activity. Invention of cooling jacket will grab attention where it gives the exactly solution to the expectation as a fully portable cooling system which consume less power [4].

1.2 Problem Statement

In developing a mobile cooling jacket, there are few requirements that are needed in order to complete this project. The first requirement in this cooling system is the control system must able to maintain temperature below threshold; second requirement is to make sure the weight of the prototype to be as light as possible while the last requirement is to minimize power consumption.

In this project, the idea in designing the cooling system is by using thermoelectric cooler as the cooling actuator while the medium selected to transfer the coldness is by water or usually called as coolant. However, there are other methods of cooling like ventilation and melting of ice. Ventilation helps the air flow process, how about if the air is hot. In addition, the ice has to supply from time to time if applying the method of ice melting.

In order to solve the first requirement, cold water able to absorb heat from hot object which make it to be chosen as the medium to transfer coldness in this cooling jacket. However, the distribution streamline has to be design well so that the coldness can be transfer equally over the entire jacket. The cooling system should have the ability to stop actuated thermoelectric cooler at temperature threshold and re-actuate it when temperature rise. In addition, consideration of the jacket design to making it seal so that it able to trap coldness for longer time.

The solution for the second requirement is by comparing few components in term of mass, and chooses the component that has less weight for the prototype. Mass distribution is important in order to arrange components equally, so, method of centre of mass can be applied to find out the best position for components arrangement.

Nowadays almost every kind of electric device is implemented to save energy. Hence, components are also being compared in term of power consumption in solving second requirement before finalised.

In addition, basic knowledge of thermodynamic and heat transfer is required in order designing this mobile cooling jacket. It is required to identify which mode is applied within three modes of heat transfer. Basic concept of a cooling system in thermodynamic is important where it helps to design own cooling system and decide what components are needed.

It is proposed that by using thermoelectric cooler with a feedback loop controller, it could optimize the problem of temperature changes which gives a lot of bad influence to human during extreme weather.

1.3 Objective

The objectives of this project are:

1. To design and develop an AC system that able to control temperature accurately while considering light in weight
2. To analyse the efficiency of the cooling system in term of the rate of heat transfer and power consumption while considering the pipe arrangement pattern

1.4 Scope

Several scopes had been outlined in order to achieve the objectives. The scope of this project referring to the two objectives stated in previous section.

- Finding a suitable cooling method
  i. Two type of cooling methods are being compare
  ii. Comparing components for cost saving
- Only experimental testing is carry out to test the accuracy of the cooling jacket
  i. To test the accuracy of feedback loop controller at outdoor
  ii. Surrounding temperature within range of 25 – 38 ˚C
- Only simulation is carry out to test the efficiency of the system in term of power consumption
  i. Graph of rate of heat transfer against thickness is tabulated
  ii. Power consumption will be analyse in watt unit

CHAPTER 2

LITERATURE REVIEW

2.1 Overview

This section describes some of the important aspect in cooling methods characteristic used to cold down a body temperature so that a desired cooling method can be select to fulfil the requirement of a portable cooling jacket. The first part in this chapter is description of the fundamental knowledge that will apply in this project. The second part is the description of cooling methods that exist in nowadays. The third part is to describe the problems and compare the existing cooling jacket invented in other country. The fourth part is to identify the solutions related to the problems. The last part in this chapter is to discuss the selection in terms of performance.

2.2 Fundamental Knowledge

Coefficient of performance (COP) is a type of calculation where we can know the efficiency of the system. COP is usually measure for refrigerator, however, it can also apply for cooling system as well [4]. In addition, COP is also applying on finding the efficiency of thermoelectric cooler. Coefficient calculation for refrigerator or cooling system and heat pump are as below [4]:

$$COP_R = \frac{Q_L}{W_{net,in}} \quad (1)$$

$$COP_{HP} = \frac{Q_H}{W_{net,in}} \quad (2)$$

Where

Q_L = desired output for refrigerator, watt

Q_H = desired output for heat pump, watt

$W_{net,in}$ = energy needed for the system, watt

A piping streamline that filled with liquid or air is commonly applied in heating and cooling applications. This type of application basically needs external force to complete the works like pump for liquid system and fan for air system. Flow rate is constant regardless diameter of pipe when all pipes are connected in series. For parallel pipes, a junction is joining with two or more piping where flow rate total is the sum of the flow rate in the individual pipes. By limiting the consideration to incompressible flow, an equation can be used to calculate the volume flow rate of a flow as below [15]:

$$\dot{v} = vA_c \quad (3)$$

Where

$\dot{v}$ = volume flow rate, m^3/s

v = flow velocity, m/s

A_c = cross-sectional area of flow, m^2

Depending to the direction of current flow, heat will flow from one side to the other side of thermoelectric cooler, thus making a cool and a hot at both sides. The power used when performing can be calculated using equation as below:

$$W = PIt \quad (4)$$

Where

W = power usage of thermoelectric cooler

P = Peltier coefficient

I = current

t = time

Heat can be transfer in three different modes: conduction, convection and radiation. Heat transfer rate is different in every mode and also depending to the thermal conductivity of the material [9]. Only convection mode is applied in this paper.

Mode 1: Conduction

$$\dot{Q_{cond}} = kA\frac{T_1 - T_2}{\Delta x} = kA\frac{\Delta T}{\Delta x} \quad (5)$$

Where

$\dot{Q_{cond}}$ = rate of heat conduction, watt

k = thermal conductivity, W/mK

A = cross-sectional area, m^2

ΔT = temperature different, K

Δx = thickness, m

Mode 2: Convection

$$\dot{Q_{conv}} = hA_s(T_s - T_\infty) \quad (6)$$

Where

$\dot{Q_{conv}}$ = heat transfer rate, watt

A_s = heat transfer area, m^2

h = convective heat transfer coefficient, W/m^2K

T_s = surface temperature, K

T_∞ = fluid temperature away from the surface, K

Mode 3: Radiation

$$\dot{Q_{rad}} = \varepsilon\sigma A_s(T_s^4 - T_{surr}^4) \quad (7)$$

Where

$\dot{Q_{rad}}$ = heat transfer per unit time, W

ε = emissivity

σ = Stefan-Boltzmann constant, $5.67 \times 10^{-8}\ W/m^2K^4$

T_s = absolute temperature of surface, K

T_{surr} = absolute temperature of surrounding, K

2.3 Type of Cooling Methods

Weather of nowadays has change a lot where this lead a serious problem to all living creatures which is hot weather. However, there is also a solution that engineers have comes out to solve this problem and it is what we called it as 'Air Conditioner'. Majority of cooling equipment exist in this world mainly with compression as well. Actually, there is several type of cooling that do have and also being applied by human in daily life in order to lower down the surrounding temperature which are natural cooling, compression cooling [11], evaporative cooling [16], fan and ventilation cooling [12], and thermoelectric cooler [1][10].

2.3.1 Natural Cooling

A cooling method whereby using natural resources from surrounding to cool up a place instead of using passive methods like air conditioner. There are force convection and free convection.

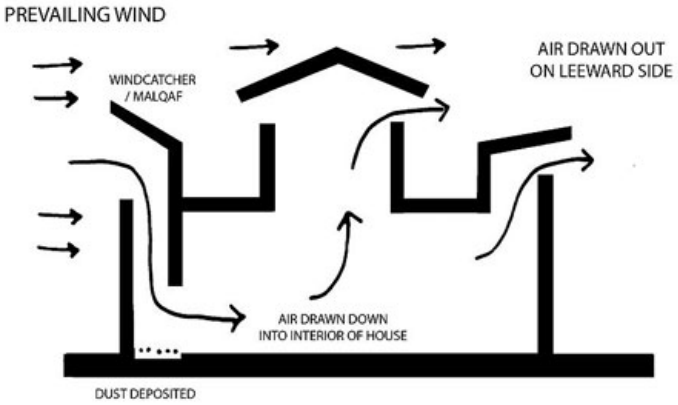

Figure 2: Natural cooling

Source: http://www.alternativebuilder.com/natural-air-conditioning.html

Convection is a mode where energy transfers between a solid surface and adjacent liquid or gas that is in motion. It can be categorised into force convection and free convection. First, force convection or also called as passive convection is where air is blow over a surface by external force like wind, fan and pump. Second, free convection, use of prevailing winds and natural, gravity-induced convection to ventilate an object, a straight forward convective method is cool night air to drive hot air out.

Equation related and used in convection calculation is:

$$Q_{conv} = hA_s(T_s - T_\infty) \quad (8)$$

where,

h= convection heat transfer coefficient, W/m^2, ˚C

$\boldsymbol{A_s}$ = surface area where heat transfer takes place

$\boldsymbol{T_s}$ = surface temperature