DESIGN OF CAR COOLING DEVICE FOR CAR PARK IN HOT WEATHER CONDITION

CHOO HAE LING

A report is submitted
in fulfillment of the requirements for the degree of
Bachelor of Mechanical Engineering (Hons)

Faculty of Mechanical Engineering

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2018

DECLARATION

I declare that this project report entitled “Design of Car Cooling Device for Car Park in Hot Weather Condition” is the result of my own work except as cited in the references.

Signature : .....

Name : CHOO HAE LING

Date : .....

APPROVAL

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (Hons).

Signature	:.	.....
Name of Supervisor	:	Mr. Mohd Nazim bin Abdul Rahman
Date	:	.....

DEDICATION

To my beloved parents, Choo Ah Yoong and Chia Bak Kiau.

ABSTRACT

Car is commonly parked under exposure of sunlight directly. Increasing of air temperature in cabin vigorously due to heat trapped and transferred within the cabin causes thermal uncomfortable, heat stroke, and deformation of material within cabin. Therefore, a cooling device for car park under sunlight exposure is designed following engineering design process. Method of temperature reduction selected is the combination system of ventilation and thermoelectric Peltier cooling module. Prototype is fabricated to test the method selected and experiment is conducted from 11am to 3pm at same day and same venue by using three similar cars without tinted in three conditions: fully sealed cabin, cabin with prototype, cabin with single window gap of 4cm opened. Result showed that cabin with prototype has lowest average air temperature in cabin (41.25 ˚C), then cabin with single window gap opened (50.45 ˚C) and fully sealed cabin showed highest average air temperature in cabin (54.75 ˚C). The objective of this research is achieved with average air temperature reduction of fully sealed cabin that is 13.5 ˚C (24.66%) and cabin with window gap opened which is 9.2 ˚C (18.24%) when compared to the average temperature of cabin with prototype. Peltier module's cooling efficiency is 25.21% and 21.74% when compared to fully sealed cabin and cabin with window gap opened respectively.

ABSTRAK

Kereta sentiasa dijemur bawah matahari semasa diletakkan di parkir yang tidak berbumbung. Kepanasan yang terperangkap di dalam kereta akan menyebabkan ketidakselesaan, kematian, dan kerosakan komponen dalam kereta. Oleh sedemikian, sebuah penyaman udara untuk kereta yang diletakkan di parkir tidak berbumbung telah direkabentuk mengikut proses rekabentuk kejuruteraan. Cara yang terpilih untuk mengurangkan suhu di dalam kereta merupakan kombinasi sistem pengudaraan dan kepingan Peltier. Sebuah prototaip dibina bagi mengkaji rekabentuk yang dicadangkan. Ujikaji dijalankan dari pukul 11 pagi hingga 3 petang pada hari dan tempat yang sama dengan menggunakan tiga kereta yang serupa dengan tingkap tidak berwarna dalam tiga keadaan iaitu kabin bertutup penuh, kabin dengan prototaip, dan kabin dengan satu tingkap terbuka sedikit dengan jarak 4cm. Keputusan menunjukkan kabin dengan prototaip mengalami purata suhu terendah (41.25 ˚C), kabin dengan satu tingkap terbuka sedikit mengalami purata suhu 50.45 ˚C, manakala kabin bertutup penuh mengalami purata suhu tertinggi (54.75 ˚C). Suhu purata yang dikurangkan sebanyak 13.5 ˚C (24.66%) dan 9.2 ˚C (18.24%) berbanding kabin tingkap bertutup penuh dan kabin dengan satu tingkap terbuka sedikit. Kecekapan kepingan Peltier merupakan 25.21% dan 21.74% berbanding kabin tingkap bertutup penuh dan kabin dengan satu tingkap terbuka sedikit.

ACKNOWLEDGEMENTS

I would like to express my outmost gratitude to Universiti Teknikal Malaysia Melaka for providing me an opportunity to conduct the research studies as a partial fulfilment of the requirement for the degree of Bachelor of Mechanical Engineering. It has gave me a chance to learn independent by handling project individually and also a chance for me to solve the problem that I never met.

Besides that, I would like to express my deepest appreciations to my supervisor, Mr. Mohd Nazim Bin Abdul Rahman for consultants and guidance throughout the studies. I am glad that Mr. Nazim willing to spend his free time always to meet with me and always provides useful and helpful information and tips for me to accomplish the project. I am sincerely thankful to the patience of him throughout the project. Other than that, I would like to thank my second examiner, Dr. Faiz Redza Bin Ramli, for giving advice during presentation.

Throughout this research studies, I am very fortunate to be blessed with the guidance and encouragement from my parents, especially the supportive and helpful during in needed. They always giving advice, support morally to make me keep going whenever I face problems. I would like to thank all the staffs and technician of the laboratory Universiti Teknikal Malaysia Melaka, who have assisted me in several small matters and also getting along with me very well. Nevertheless, I would also like to express my deepest gratitude to my friends and respondent for giving me the help and advice during the experiment, data collection, information collection and prototype manufacturing.

Last but not least, I would like to take immense pleasure of thanking who are always give me advice as well as encouragement whenever I face obstacles throughout the studies. I will never forget the help that I got from throughout the project, it would always be my motivation to fight for future.

TABLE OF CONTENTS

			PAGE
DECLARATION			
APPROVAL			
DEDICATION			
ABSTRACT			**i**
ABSTRAK			**ii**
ACKNOWLEGDEMENTS			**iii**
TABLE OF CONTENTS			**iv**
LIST OF FIGURES			**vii**
LIST OF TABLES			**x**
LIST OF ABBREVIATIONS			**xi**
LIST OF APPENDICES A			**xii**
CHAPTER			
1.	**INTRODUCTION**		**1**
	1.1	Background	1
	1.2	Problem Statement	4
	1.3	Objective	5
	1.4	Scope of Project	5
	1.5	General Methodology	5
2.	**LITERATURE REVIEW**		**8**
	2.1	Air conditioning system	8
	2.2	Ventilation	9
	2.3	Ventilation concept	9
	2.4	Cooling	11
	2.5	Solar Reflective Shell	11
	2.6	HVAC Blower	11
	2.7	Opening of Window	12
	2.8	Air Movement	13
	2.9	Heat Pipe	13
	2.10	Light Colour Exterior and Interior	14
	2.11	Infra-Red Glazing (IRG)	14
	2.12	Privacy Glazing	15
	2.13	Modified Blower	15
	2.14	Phase Change Material (PCM)	15
	2.15	Product Filled with PCM	17
	2.16	Compressed Liquid Air	17
	2.17	Thermal Comfort	19
	2.18	Power System	19
	2.19	Thermoelectrically Module	19
	2.20	Heat Sink	20
	2.21	Spray Cooling	21
	2.22	Thermal Load	21
	2.23	Cooling Device	23
3.	**METHODOLOGY**		**26**
	3.1	Define Problem	26
	3.2	Gather Information	29

	3.3	Concept Generation	29
	3.4	Concept Selection and Evaluation	30
	3.5	Product Architecture	31
	3.6	Configuration Design	32
	3.7	Parametric Design	33
	3.8	Detail Design	33
	3.9	Design Testing and Analysis	34
	3.10	Report Writing and Oral Presentation	34
	3.11	Methodology Flow Chart	35
4.	**CONCEPTUAL DESIGN**		**36**
	4.1	Survey Questionnaire Analysis	36
	4.2	House of Quality	44
	4.3	Product Design Specification	47
	4.4	Morphological Chart	48
		4.5.1 Concept Design 1	51
		4.5.2 Concept Design 2	53
		4.5.3 Concept Design 3	55
		4.5.4 Concept Design 4	57
	4.6	Weighted Decision Matrix	59
	4.7	Final Concept Design (Modified)	62
5.	**PRODUCT ARCHITECTURE**		**63**
	5.1	Arrangement of Functional Element	63
6.	**CONFIGURATION DESIGN**		**66**
	6.1	Material Selection	66
	6.2	Manufacturing Process Selection	67
	6.3	Device Operation Hour	67
7.	**PARAMETRIC DESIGN**		**69**
	7.1	Dimension and Tolerance	69
	7.2	Failure Mode and Effect Analysis (FMEA)	69
8.	**DETAIL DESIGN80**		**72**
	8.1	View of product	72
9.	**COSTING**		**77**
	9.1	Costing of Prototype	77
	9.2	Costing of Product	79
10.	**TESTING AND RESULT**		**81**
	10.1	Prototype	81
	10.2	Experiment	82
	10.3	Result	84
11.	**DISCUSSION AND ANALYSIS**		**94**
	11.1	Prototype Discussion	93
	11.2	Experiment Discussion	94
	11.3	Result Discussion	95

11.4	Peltier Module Efficiency	97
11.5	Ventilation Blower	98
11.6	Concept Design	100
11.7	Maximum Temperature Differences	100
12. CONCLUSION AND RECOMMENDATION		**101**
12.1	Conclusion	101
12.2	Recommendation	103
REFERENCES		104
APPENDICES		10

LIST OF FIGURES

FIGURE	TITLE	PAGE
1.1	Thermal Distribution of Car Parked Under Sunlight	2
1.2(a)	Car Parked at Outdoor Exposed under Sunlight Directly	4
1.2(b)	The Indication of Temperature Inside Cabin and Outside the Car	4
1.3	Flowchart of Methodology	7
2.1(a)	Mixing Ventilation (MV)	10
2.1(b)	Cabin Displacement Ventilation (CDV)	10
2.1(c)	Low Momentum Ceiling Ventilation (LMCV)	10
2.1(d)	Hybrid Ventilation (HV)	10
2.2	Arrangement of Heat Pipe	14
2.3	Thermal Distribution in Car Cabin with PCM and without PCM	16
2.4(a)	Air Conditioning Rear Vents	18
2.4(b)	Designated Location for the CLAC	18
2.4(c)	Valve	18
2.5	Temporal Variation of Vehicle Cabin Average Temperature	18
2.6	Peltier Module	20
2.7	Thermal Distribution of Heat Sink	21
2.8	Temperature Distributions in the Car Cabin at Different Times (left) and Temperature Distribution on the Car Interiors at 3 p.m. (right).	23
2.9	Solar Powered Car Ventilator	24

2.10	The Contours of the Temperature Distribution at Different Cross Sections (left) and Contours of the Velocity Magnitude at Different Cross Sections (right)	25
2.11	Temperature Distribution inside the Car Cabin for both Systems On and Off	25
3.1	Template of House of Quality	28
3.2	Template of Schematic of Product	32
3.3	Template of Failure Mode and Effect Analysis	33
3.4	Methodology flow chart	35
4.1	Gender	37
4.2	Age Category	37
4.3	Living Place	38
4.4	Income	38
4.5	Reasonable Price	39
4.6	Durability	39
4.7	Simple and User Friendly	40
4.8	Affordable Price	40
4.9	Easy Maintenance	41
4.10	Portability	41
4.11	Reliability	41
4.12	Aesthetic Value	42
4.13	Small Size and Space Saving	42
4.14	Robustness	43
4.15	Functionality	43
4.16	Concept 1	51
4.17	Concept 2	53
4.18	Concept 3	55
4.19	Concept 4	57

4.20	Exploded View of Concept 4	57
4.21	Finalized Concept Design of Car Cooling Device and Design of Car Roof	62
5.1	Schematic of Product	64
5.2	Rough Geometric Layout	65
6.1	Electrical System of Cooling Device	68
8.1	Isometric, Top, Front, Side View of Device	73
8.2	Assembly View with Bill of Material	74
8.3	Exploded View with Balloon Generated	75
8.4	Isometric View and Exploded View	76
9.1	Prototype Costing Model	78
9.2	Product Costing Model	80
10.1	Prototype (a)Back view, (b)Front view, (c)Side view, (d)Top view, (e) (f)Isometric view	82
10.2	Similar Car with Condition (1)Fully Enclosed Cabin, (2)Cabin Installed with Prototype, (3)Cabin with Single Window Gap of 4cm Opened	83
10.3	Prototype Hanging on Window Gap Viewed from (A) External, (B)Internal	83
10.4	Position of Thermocouple Thermometer when Taking Reading Of (A)Surrounding Temperature, (B)Air Temperature in Cabin	84
10.5	Air Temperature of Different Condition (˚C) against Time (Minutes)	86
10.6	Temperature Differences (˚C) against Time (Minutes)	88
10.7	Temperature Differences (˚C) against Time (Minutes)	90
10.8	Temperature Differences (˚C) against Time (Minutes)	92
11.1	Dimension of Perodua Myvi in mm	99

LIST OF TABLE

TABLE	TITLE	PAGE
3.1	Template of Product Design Specification	29
3.2	Template of Morphological Chart	30
3.3	Template of Weighted Decision Matrix	31
4.1	House of Quality	46
4.2	Product design specification (PDS)	47
4.3	Morphological Chart	49
4.4	Weighted Decision Matrix	59
7.1	Failure mode and effect analysis (FMEA)	70
10.1	Air temperature from time to time for three kind of condition and surrounding temperature	84
10.2	Temperature differences from time to time between condition of fully enclosed cabin and cabin with prototype	87
10.3	Temperature differences from time to time between conditions of cabin with window gap opened and cabin with prototype	89
10.4	Temperature differences from time to time between conditions of cabin with prototype and surrounding temperature	91
11.1	Summarize table for Peltier cooling efficiency when different average temperature of cabin condition used as initial temperature	98
12.1	Summarize table of result specification compared to earlier specification	103

LIST OF ABBREVIATIONS

MV	Mixing Ventilation
CDV	Cabin Displacement Ventilation
LMCV	Low Momentum Ceiling Ventilation
HV	Hybrid Ventilation
IRG	IR Reflective Glazing
PCM	Phase Change Material
PV	Photovoltaic Panel
HOQ	House of Quality
PDS	Product Design Specification
DC	Direct Current

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Survey form	108
B1	Side polystyrene insulator	111
B2	Housing	112
B3	Cold side heat sink	113
B4	cold side TEC insulator	114
B5	Front polystyrene insulator	115
B6	Hot side heat sink holder	116
B7	Switch	117
B8	Hot side heat sink	118
B9	TEC Peltier module	119
B10	Fan cover	120
B11	Fan	121

CHAPTER 1

INTRODUCTION

1.0 Introduction

In this section, background regarding to the study is briefly described. The problem statement is stated and the objective and scopes of this project are listed. General methodology to conduct the project is briefly explained.

1.1 Background

Nowadays, car is one of the main transportation for human to move from one place to another. Air conditioner as built in system of car is important for thermal comfort especially during hot and sunny day (Maan Al-Zareer et al, 2017). The solar radiation from the direct exposure of sunlight caused the increasing of air temperature inside an enclosed volume or sealed car cabin. Especially for windows and windshield parts that being clear and transparent allowed the transmission of solar radiation. The solar radiation on the roof of car transmits heat via convection to the other parts in car cabin. The parts such as dashboard absorbed heat and then transmit via conduction and convection in the cabin. The heat trapped inside the sealed car cabin has increased the air temperature inside car cabin easily (C. Y. Tseng et al, 2014). The increasing of the air temperature has caused the thermal uncomfortable to human. It also destroys the materials of parts in car cabin and some of the materials might emit poisonous substances. In order to maintain the thermal comfort of

human, air conditioning system is widely used to regulate and reduce the air temperature inside of car cabin. Figure below shows the thermal distribution of the car parked under sunlight.

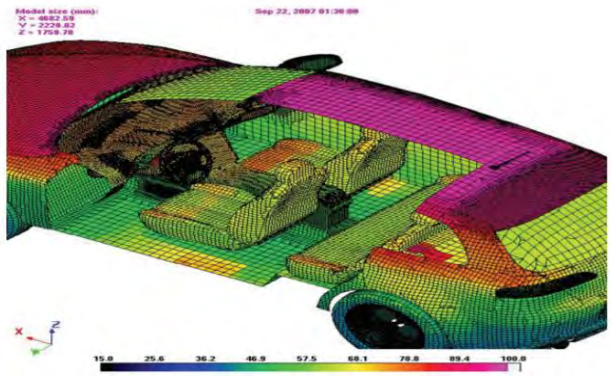

Figure 1.1: Thermal Distribution of Car Parked Under Sunlight (C. Y. Tseng et al, 2014).

Whilst the car parked statically under sunlight exposure directly without shading is unable to initiate and maintain the air conditioning system. The air temperature inside car cabin increased tremendously and heat being trapped until the re-entry of drivers and the initiation of ventilation and air conditioning system. Immediate cooling requirement needed more fuel consumption and also promoted the emission of harmful substances. The solar radiation and the increasing of air temperature inside the car cabin can be described as the greenhouse effect. The extremely high temperature inside the car has raised some issues such as the thermal comfort, colour fading and seat upholstery wear and tear, death of children and animals that unintended left inside the car and so on. The number of children in USA left unintended in car cabin parked under sunlight and died of heat stroke in 2003 and 2004 was 42 and 35 respectively (Sudhir, Jalal, 2015). It shows the importance of air ventilation system and reduction of temperature inside car cabin.

In order to reduce the transmission of solar radiation into the car cabin, variety of external methods such as tinted, sunscreen, sunshade, curtain, car ventilator has been implemented mostly to the car. The shading is used to prevent the solar radiation as much as possible. The Road Transport Department Malaysia stated that the visible light transmission of front windshield is at least 70%, rear and side windows at least 50% (Jabatan Pengangkutan Jalan Malaysia, 2017). The control of the translucence level makes restriction to the prevention of solar radiation transmission. The heat transferred via convection and conduction through the solar radiation onto the roof of cabin still existed even though all cars' windows are shaded.

Somehow the window is rolled down to a gap distance for ventilation purpose. The ventilation system is done by movement of air in and out of the car where hot air escaped to the surrounding meanwhile ambient air is introduced into the car cabin (Tobias D. et. al, 2017). Subsequently, the air temperature inside of the car cabin can be reduced due to the ambient air has lower air temperature than the air temperature inside meanwhile increased the indoor air quality. However, there is no cooling or reduction of temperature inside car cabin when the ambient air temperature is higher than the air temperature inside. The ventilation system is not effective enough due to the natural ventilation and small gap opening available. The window gap opening is limit due to the security issue.

Sometimes, driver and passengers are forced to enter the car cabin that higher in temperature or forced to wait outside the car and open the door while initiate the air conditioning system to wait for the cooling of car cabin. As a result of solar radiation to the car that parked under direct sunlight exposure, it is very important to remove and minimize the unwanted temperature rise inside the car cabin. Solution is required not only to reduce the air temperature inside the car cabin anytime but also convenient and secure the car and passengers.

1.2 Problem Statement

Car is frequently used to be the transportation vehicle that assists human from moving one place to another. During hot and sunny day, the solar radiation from sunlight transmitted to the unshaded object is unavoidable. Parking lot inside the building or parking lot with cover roof is rarely found and does not in demand due to its costly development fees. Most of the car drivers are forced to park their car at outdoor parking lot. The outdoor parking lot does not prepare covered place where the entire car parked under direct exposure of sunlight without any shelter. The heat transmitted to the car and trapped inside the car cabin has increased the air temperature inside car cabin tremendously. The air temperature inside car cabin is higher than outside temperature. Driver felt uncomfortable and hot once they entered into the car parked under the sunlight exposure. They are forced to open windows, initiated air conditioning system and wait outside the car for cooling of cabin before re-entry of car. The air conditioning runs at high energy and fuel consumption in order to cool rapidly. The hotness of the cabin also been found that destroy the materials of the car cabin and even emit poisonous substances.

(a) (b)

Figure 1.2: (a) Car Parked at Outdoor Exposed under Sunlight Directly (b): The Indication of Temperature inside Cabin and Outside the Car (Eduard et al, 2016)

1.3 Objective

The objective of this project is shown as follow:

1) To design a cooling device for car that parked in hot weather condition.

1.4 Scopes

This project is subjected to focus mainly on:

1) Only passenger car type is used to implement the cooling device

2) Reduction of the temperature in cabin of car installed with cooling device for at least 5 ^{o}C compared to car without cooling device

3) Prototype is fabricated to test the function of the method selected

1.5 General Methodology

1. Define problem

Problem given according to the topic. Problem details will be inspected via survey questionnaire. The result of survey questionnaire will be analysed. The product design specification will be listed. Customer requirements and engineering characteristics will be generated and grouped into house of quality. The importance of customer requirements will be given based on the result of survey questionnaire. Relationships among engineering characteristics and customer requirements will be rated. The rank of engineering characteristic will be rated for further development of conceptual design.

2. Gather information

Reviews, journals, articles, internet, consultant, products regarding to the project will be referred and read through to gather the information. Previous result will be reviewed as to further understanding and guideline of the topic.

3. Concept generation

Design of functional models will be generated via brainstorming and creativity. The alternative design of the functional parts will be classified into morphological chart. Conceptual design will be generated from the combination of different type of alternative functional parts in morphological chart.

4. Concept selection and evaluation

Weighted decision matrix will be conducted to select the most concern criteria and to select the most suitable concept of design. The conceptual design generated will be evaluated based on each of the criteria. The rank of the conceptual design will be rated to proceed for further development. Redesign and design modification will be carried out to confirm last design concept.

5. Product architecture

Physical elements will be arranged in blocks to decide the arrangement of the parts in the assembly of the product.

6. Design configuration

Materials will be selected and the manufacturing process will be decided. The size and dimension of parts will be generated according to real vehicles dimension.

7. Design parametric

Tolerance of dimension will be set. Design robustness, assembly, manufacturing will be explained.

8. Detail design

Engineering drawing for every part design will be produced by using software Catia in real dimension. Assemblies of parts will be produced with material applied. The drafting of every parts and assembly of product will be generated.

9. Design testing and analysis

The prototype will be fabricated and experiment will be carried out to show the function of the method selected. Result will be analysed and discussed.

10. Report writing and oral presentation

A report on this study will be written in the end of project. Presentation slides will be prepared for oral presentation.

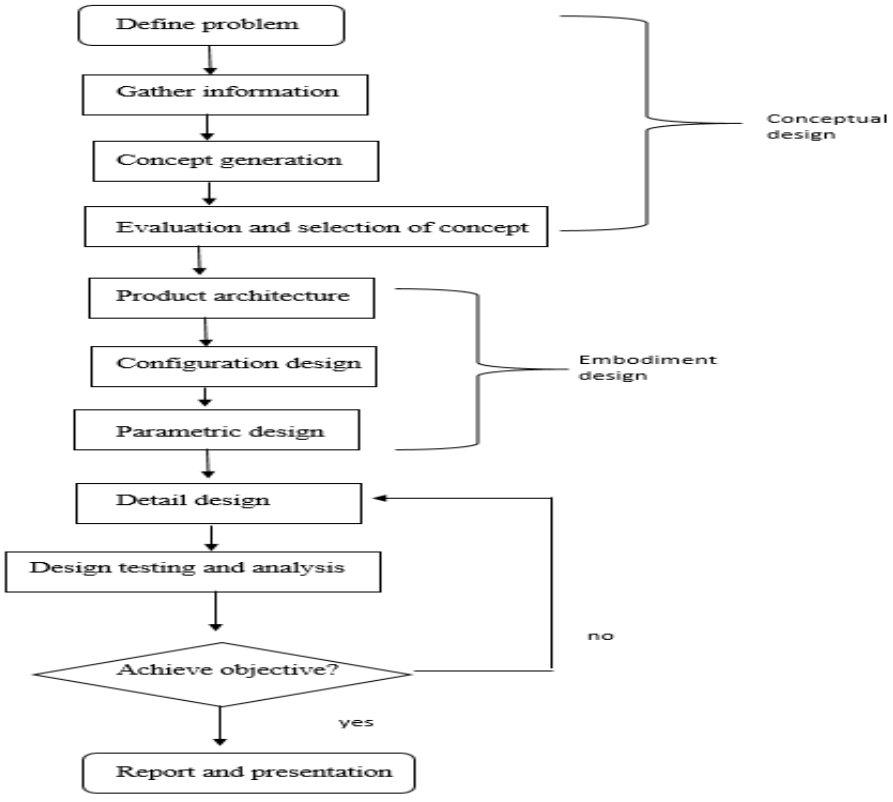

Figure 1.3: Flowchart of Methodology (Ertas and Jones, 1996)

CHAPTER 2

LITERATURE REVIEW

2.0 Introduction

A literature review is defined as an evaluative report of information found in the literature related to selected area of study. It did not include the primary sources where all are secondary sources. All of the literature has been reviewed, evaluated, analysed and summarized which give theoretical base for the research and help in determine the nature of research. The literature established gives ideas and knowledge on the research topic selected. As the problem met is the higher temperature of car cabin when the car is parked under direct sun exposed without shading, the objective is to resolve this problem by design a cooling device. Hence, the literature reviewed is regarded more to cooling or method that would assisted in reduction of temperature. Other related information also reviewed.

2.1 Air conditioning System

Air conditioning system is used to alter and remain the temperature, relative humidity, the velocity of air flow, and so on inside the car cabin effectively as well as to build better thermal comfort environment inside the car cabin. The air conditioning system required 70% of overall train energy and up to 15% of petrol consumption. (Jianghong Wu et al., 2017, Abbas Z. Kouzani et al, 2011). The usage of air conditioning system depleted battery which leads to the cruising range reduced up to 33% (Tobias D, 2017). The air conditioning system is said that energy was used to cool down the vehicles more than to the passengers. The