

MODIFICATION AND FABRICATION OF A HYBRID SOLAR PELTIER-ADSORPTION COOLER

Tie Soon Hieng

Bachelor of Engineering with Honours (Mechanical and Manufacturing Engineering) 2008

UNIVERSITI MALAYSIA SARAWAK

Judul:	MODIFICA	TION AND FAB	RICATION OF A HYBRID SOLAR
		PELTIER-ADS	SORPTION COOLER
		SESI PENGAJ	IAN: 2007/2008
Saya		MR. T	IE SOON HIENG
			DLSAR)
menga dengar	ku membenarkan tesis * 1 syarat-syarat kegunaan	ini disimpan di Pusat Kl seperti berikut:	hidmat Maklumat Akademik, Universiti Malaysia Sarawał
1. 2. 3. 4. 5.	Tesis adalah hakmilik Pusat Khidmat Maklu tujuan pengajian sahaj Membuat pendigitan u Pusat Khidmat Maklu sebagai bahan pertuka ** Sila tandakan (✓)	Universiti Malaysia Sara mat Akademik, Univers a. ntuk membangunkan Par mat Akademik, Universi ran antara institusi penga di kotak yang berkenaa (Mengandungi mal Malaysia seperti ya	wak. iti Malaysia Sarawak dibenarkan membuat salinan untul ngkalan Data Kandungan Tempatan. ti Malaysia Sarawak dibenarkan membuat salinan tesis in jian tinggi. n slumat yang berdarjah keselamatan atau kepentingan ang termaktub di dalam AKTA RAHSIA RASMI 1972)
	TERHAD	(Mengandungi mal badan di mana pen	klumat TERHAD yang telah ditentukan oleh organisasi/ yelidikan dijalankan).
	✓ TIDAK TERHAI)	
			Disahkan oleh
-	(TANDATAN)	GAN PENULIS)	(TANDATANGAN PENYELIA)
Al	amat tetap: BATU 9, J	ALAN HENG HUNG	
	96000 SIBU, SARAWA	AK	DR MOHAMMAD OMAR BIN ABDIILLAH
-			Nama Penyelia

CATATAN

* Tesis dimaksudkan sebagai tesis bagi Ijazah Doktor Falsafah, Sarjana dan Sarjana Muda.
** Jika tesis ini SULIT atau TERHAD, sila lampirkan surat daripada pihak berkuasa/organisasi berkenaan dengan menyatakan sekali sebab dan tempoh tesis ini perlu dikelaskan sebagai SULIT dan TERHAD.

Approval Sheet

The project report attached here to, entitle "Modification and Fabrication of A Hybrid Solar Peltier-Adsorption Cooler" prepared and submitted by Tie Soon Hieng, 13133, in partial fulfillment of the requirement for Bachelor of Engineering with Honours in Mechanical and Manufacturing Engineering in hereby read and approved by:

Dr. Mohammad Omar bin Abdullah Supervisor

Date

MODIFICATION AND FABRICATION OF A HYBRID SOLAR PELTIER-ADSORPTION COOLER

TIE SOON HIENG

Thesis Is Submitted To Faculty of Engineering, Universiti Malaysia Sarawak In Partial Fulfillment of the Requirements For the Bachelor Degree of Engineering with Honours (Mechanical and Manufacturing Engineering) 2008 For my Father and Mother And My beloved family

ACKNOWLEDGEMENT

I would like to take this opportunity to express my sincere appreciation to all people that had helped me to accomplish my Final Year Project successfully.

First of all, I would like to thank my supervisor, Dr Mohammad Omar Abdullah, head of the Department of Chemical Engineering & Energy Sustainability for giving me the valuable advices, his patience and full support throughout the project and willingness to assist me in completing this report. The moral and idea support brings an encouragement to me in accomplishing the project. The project is also supported by ASHRAE Senior Project Grant 2005.

Besides it, I also thank to S.L. Leo for giving me his valuable advice and help me solving some problems during accomplishing the project. Thanks also to Mechanical's Department technician; Mr Masri, Mr Rhaiya and Mr Ruzaini for their help and guidance throughout my final year project works.

Thanks also to JKR for borrowing me solar panel to help me to complete my Final Year Project. I would like thanks to Sidney Wee for his valuable advice.

I would like to thank my father and mother for giving continues support and encouragement in finishing my study and guiding my life. I will be forever grateful for their love and kindness.

Lastly, special thanks to my friend, Teh Hieng Hua, Tian Chuan Ming and Chong Sia Onn for assisting me during the fabricating process of the device.

ii

ABSTRACT

Modification of Solar Peltier-Adsorption cooler has been done and fabricated during the Final Year Project. The main purpose of the project is to improve the performance of the Solar Peltier-Adsorption cooler. The device is using solar radiant to produce power from photovoltaic panel for generating the thermoelectric device in the daylight. Then, the device using adsorption and desorption theory to generate cooling effect during the night time. The device consists of a few main parts assembly which is solar collector, adsorber box, condenser, reservoir, evaporator and support frame. Solar flat plate collector type has been used for the system which can support an adsorber bed charcoal capacity of 5 kg. The adsorption cycle operates intermittently where provide only one cycle per day. The cooling effect occurs during the adsorption process at night. Photovoltaic panel provides electricity to peltier cooler to produce cooling effect during the day time. Therefore the cooling effect of the hybrid device can produce cooling effect continuously for day and night time period. Experimental results show that lowest temperature achieves is 9.3°C in Peltier during daylight and 13.6°C during the night by using 300ml load of water.

ABSTRAK

Penambahbaikan alat Peti Sejuk Suria telah dilakukan dan siap dibina. Tujuan utama projek ini ialah memperbaiki sistem ini. Alat ini menggunakan radiasi dari cahaya matahari pada waktu siang untuk menghasilkan kuasa elektrik untuk menghidupkan peti sejuk. Pada waktu malam, alat ini menggunalan teori menyerap dan memeluwap untuk menghasilkan kesejukan dalam peti sejuk. Alat ini terdiri daripada beberapa cantuman bahagian-bahagian kecil seperti penyerap matahari, kotak penyerap, pemeluwap, tangki pengumpul, penyejat, and rangka sokongan. Pengumpul cahaya matahari jenis rata dan berkotak telah digunakan untuk sistem ini yang mana ianya boleh memuatkan tiub penyerap yang boleh menampung kapasiti karbon aktif sebanyak 5kg. Proses penjerapan di dalam sistem berlaku dalam satu kitaran dalam sehari. Oleh itu, proses penjerapan yang berlaku pada waktu malam memberikan kesan penyejukan di dalam peti sejuk. Panel 'photovoltaic' berupaya membekalkan tenaga elektrik untuk menghasilkan kesan penyejukan pada waktu siang. Oleh yang demikian, kombinasi alat ini menghasilkan kesan penyejukan yang berterusan pada waktu siang dan malam. Hasil daripada eksperimen menunjukkan suhu terendah yang dicapai ialah 9.3°C di dalam "Peltier" pada waktu siang and suhu 13.6°C pada waktu malam dengan menggunakan 300ml air.

TABLE OF CONTENT

	Page
ACKNOWLEDGEMENTS	ii
ABSTRACT	iii
ABSTRAK	iv
TABLE OF CONTENT	v
LIST OF TABLE	Х
LIST OF FIGURE	xii
NOMENCLATURE	xiv

CHAPTER 1: INTRODUCTION

1.1	Introduction	1
1.2	Overview of research	2
1.3	Problem Statement	2
1.4	Objectives of Project	3

CHAPTER 2: LITERATURE REVIEW

2.1	Introd	uction	4
2.2	The B	enefits Gained from Solar Energy	5
2.3	Adsorption Cycle		6
	2.3.1	Adsorption Refrigeration	7
	2.3.2	Principles of Adsorption Refrigeration	8

	2.3.3 Performance of V	arious Solar Adsorption	
	Application		13
2.4	Peltier Cooler		14
	2.4.1 The Working Prin	ciples of Thermoelectric	15
	Cooler		
2.5	Combination of Peltier Co	ooler and Adsorption	
	Cooler		16
2.6	Material Properties		17
	2.6.1 Activated Carbon		17
	2.6.2 Copper		19
	2.6.3 Methanol		20
2.7	Coefficient of Performance	ce (COP)	21
2.8	Specific Cooling Power (SCP)	21

CHAPTER 3: METHODOLOGY

3.1	Introd	uction	22
3.2	Construction and Analysis of the Device		
	Specif	lications	
	3.2.1	Construction of the Adsorber Bed	23
		3.2.1.1 Analysis of the Adsorber	
		Bed Specifications	24
		3.2.1.2 Analysis of Adsorbents and	
		Refrigerant Specification	25
	3.2.2	Construction of the Heat Trap Collector	26

		Specifications	27
	3.2.3	Construction of the Reservoir	28
		3.2.3.1 Analysis of Reservoir Specifications	29
	3.2.4	Construction of Reservoir Support Frame	30
		3.2.4.1 Analysis of Reservoir Support	
		Frame Specifications	30
	3.2.5	Construction of Condenser	31
		3.2.5.1 Analysis of Condenser	
		Specifications	32
	3.2.6	Construction of Support Frame	33
		3.2.6.1 Analysis of Support Frame	
		Specifications	34
	3.2.7	Construction of final design layout hybrid	
		solar peltier-adsorption cooler	35
3.3	Const	ruction of Hybrid Solar Peltier Adsorption	
	Coole	r	36
3.4	Inspec	ction Test	
	3.4.1	Leakage test	37
	3.4.2	Vacuum test	38
3.5	Syster	m Properties and Characteristics	39
3.6	Expec	cted Results	
	3.6.1	Introduction	41
	3.6.2	Expected Results	42

3.2.2.1 Analysis of the Heat trap Collector

CHAPTER 4: RESULTS, ANALYSIS AND DISCUSSION

4.0	Introd	uction	43
4.1	Solar	peltier-adsorption cooler	43
4.2	Hybri	d solar peltier-adsorption cooler test	
	4.2.1	Hybrid solar peltier-adsorption cooler 1 st	
		operation	44
	4.2.2	Hybrid solar peltier-adsorption cooler 2 nd	
		operation	49
	4.2.3	Hybrid solar peltier-adsorption cooler 3 rd	
		operation	55

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1	Concl	usion	61
5.2	Proble	ems and limitations	62
	5.2.1	Leakage	62
	5.2.2	Quantity of activated carbon is not enough	62
	5.2.3	Manual valve operation	63
	5.2.4	Sensor equipments	63
5.3	Recon	nmendations for future work	64
	5.3.1	Heater integration	64
	5.3.2	Solar vacuum collector	64
	5.3.3	Data logger	64
	5.3.4	Solar radiation equipments	65

REFERENCES

APPENDIX

66 68

LIST OF TABLE

Table		Page
2.1	Performance of Adsorption Systems for Different	13
	Application	
2.2	Specification for Palm Shell Activated Carbon	18
2.3	Specific Properties of Copper	19
2.4	Specification of Methanol	20
3.1	Analysis of Adsorber Bed Specifications	24
3.2	Analysis of Adsorbents (activated carbon) and refrigerant	
	(methanol) Specifications	25
3.3	Analysis of Heat Trap Collector Box Specifications	27
3.4	Analysis of Reservoir Specification	29
3.5	Analysis of Reservoir Support Frame Specification	30
3.6	Analysis of Condenser Specifications	32
3.7	Analysis of Support frame specifications	34
3.8	State point properties, temperature and pressure	40
4.1	Hybrid Solar Peltier-Adsorption Cooler 1st Operation	
	(Morning)	44
4.2	Hybrid Solar Peltier-Adsorption Cooler 1 st Operation	
	(Night)	45

Х

4.3	Hybrid Solar Peltier-Adsorption Cooler 2 nd Operation	
	(Morning)	49
4.4	Hybrid Solar Peltier-Adsorption Cooler 2 nd Operation	
	(Night)	51
4.5	Hybrid Solar Peltier-Adsorption Cooler 3 rd Operation	
	(Morning)	55
4.6	Hybrid Solar Peltier-Adsorption Cooler 3 rd Operation	
	(Night)	57

LIST OF FIGURE

Figur	Figure		
2.1	Simplified absorption cycle	6	
2.2	Clapeyron Diagram of Ideal Adsorption Cycle	9	
2.3	Peltier Effect Thermoelectric Cooler	14	
2.4	Peltier Effect Flow	14	
2.5	Oil Palm Shell Activated Carbon	17	
3.1	Construction of Adsorber Bed	23	
3.2	Heat trap Collector Box	26	
3.3	Reservoir Tank	28	
3.4	Reservoir Support Frame	30	
3.5	Condenser	31	
3.6	Adsorber Box Support Frame	33	
3.7	Final Design Layout of Hybrid Solar Peltier-Adsorption		
	Cooler Device	35	
3.8	Schematic Diagram of the System	39	
3.9	The expected result for the conceptive modifying hybrid		
	solar peltier-adsorption cooler	42	
4.1	Hybrid Solar Peltier-Adsorption Cooler Device	43	
4.2	Hybrid Solar Peltier-Adsorption Cooler 1 st Operation-		
	Morning	45	
4.3	Hybrid Solar Peltier-Adsorption Cooler 1 st Operation-		
	Night	46	

4.4	Hybrid Solar Peltier-Adsorption Cooler 2 nd Operation-	
	Morning	50
4.5	Hybrid Solar Peltier-Adsorption Cooler 2 nd Operation-	
	Night	52
4.6	Hybrid Solar Peltier-Adsorption Cooler 3 rd Operation-	
	Morning	56
4.7	Hybrid Solar Peltier-Adsorption Cooler 3 rd Operation-	
	Night	58

NOMENCLATURE

COP	Coefficient of performance		
Psia	Absolute pressure [Pa]		
Psi	Pressure [pa]		
G	Global irradiance, [J Kg ⁻¹ K ⁻¹] [Wm ⁻²]		
L	Evaporation latent heat for water [J kg ⁻¹]		
Q	Heat quantity [J]		
N	Number		
А	Area [m ²]		
Т	Temperature [K]		
t	Time [s]		
\overline{m}	Mass flow rate [kg s ⁻¹]		
ΔT	Changes of temperature [K]		
Q	Heat energy		
\overline{Q}	Input energy rate [KJ s ⁻¹]		
Р	Power [Watt]		
R	Specific gas constant [J/gK]		
ρ	Density [kg m ⁻³]		
v	Volume		
m	Mass [kg]		
η	Efficiency		
k	Thermal conductivity [W/m K]		
С	Specific heat capacity [J/kg K]		
d	Diameter [m]		
PV	Photovoltaic		
W	Work		
SCP	Specific ice production		
τ	Cooling power		

Indexes

c	Condenser	L	Liquid
d	Day	S	Solar
ev	Evaporator	tl	Thermal losses
g	Generating	р	Peltier
ad	Adsorption	rej	Rejection
1	Load	Н	Hybrid

CHAPTER 1

INTRODUCTION

1.1 Introduction

In today's climate of growing energy needs and increasing environmental concern, alternatives to the use of non-renewable and polluting fossil fuels have to be investigated. One such alternative is solar energy. Solar energy is the cleanest and most inexhaustible of all known energy sources. Solar radiation is the heat, light and other radiation that is emitted from the sun. Solar radiation contains huge amounts of energy and is responsible for almost all the natural processes on earth. In this study, a hybrid solar peltier-adsorption cooler was constructed and it could reduce power and utilising the solar as a renewable energy.

Peltier cooler is a solid-state active heat pump which transfers heat from one side of the device to the other side against the temperature gradient which is from cold side to hot side, with consumption of electrical energy. [1] Absorption cooler is a device that involves the absorption of a refrigerant by a transport medium. The adsorption cooler mainly consists of a collector box which containing absorbers, a condenser, an evaporator and a reservoir. Combination of those two devices can obviously save non-renewable energy and reduce the hazardous to the environment.

1.2 Overview of research

The research is based on the hybrid solar peltier-adsorption cooler which was modified and built by Muhamad Zuhairi bin Sulaiman (2007). The coefficient of performance (COP_H) of the hybrid solar peltier-adsorption cooler was calculated as 0.05, i.e. cooling effect of 5%.

1.3 Problems statement

According to Muhamad Zuhairi bin Sulaiman (2007), there are several problems identified on the previous fabricated device. During the project, leakage was found on the system and caused the efficiency of the device decreased. Besides that, unsuitable sensor also stated as the problem because large amount of heat loss from the peltier cooler due to bigger thermocoupler. The amount of activated carbon is believed not sufficient. [2]

Inconstant schedule of the open-close valves also will affect the measurement taken during the testing operation. Muhamad Zuhairi bin Sulaiman (2007) recommended using vacuum collector is better than solar flat plate collector. He also advised using boiled water in order to provide constant heat. He also suggested that use automated data logger to record the data more efficiency. The Pyranometer is suggested for determine the solar radiation for the day. [2]

1.4 Objectives of project

Objectives have been identified in this research which is stated below:

- To study the working principle of hybrid solar peltier-adsorption cooler.
- To modify and improve the functional of the device.
- To analyse and determine the new coefficient of performance (COP) of the new modified device
- To increase the efficiency of the device.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Solar energy had been proven that bring greater benefits to the cooling application. Solar cooling is important to our daily life application because it is friendly to environment by reducing the use of non-renewable energy. Researchers over the past few decades have developed and invented a number of additional solar thermal applications, such as industrial process heat, refrigeration and airconditioning, drying and curing of agricultural products and electric power production by solar thermal conversion.

Normally there are two ways to achieve refrigeration by using of solar energy. One of the methods are by converting the solar energy to electricity which by means of photovoltaic cells to provide electricity to run the domestic refrigerator. Another one is using the solar thermal radiation directly to make refrigeration by adsorption and desorption systems. The one that are being studied in this project is combination of both of the methods by hybridisation peltier cooler by using photovoltaic power source in daylight and solar radiation for desorption and adsorption operation.

2.2 The benefits gained from solar energy

In today's climate of growing energy needs and increasing environmental concern, alternatives to the use of non-renewable and polluting fossil fuels have to be investigated. One such alternative is solar energy.

Solar energy is quite simply the energy produced directly by the sun and collected elsewhere, normally the Earth. The sun creates its energy through a thermonuclear process that converts about 650,000,000 tons of hydrogen to helium every second. [3] The process creates heat and electromagnetic radiation. The heat remains in the sun and is instrumental in maintaining the thermonuclear reaction. The electromagnetic radiation (including visible light, infra-red light, and ultra-violet radiation) streams out into space in all directions.

Much of the world's required energy can be supplied directly by solar power. More still can be provided indirectly. The heat energy from solar radiant promise a good alternative to be utilise in cooling technologies especially in solid adsorption technology and photovoltaic technology.

2.3 Adsorption cycle



Simplified absorption cycle

Figure 2.1: Simplified absorption cycle [4]

The basic absorption cycle employs two fluids, the absorbate or refrigerant, and the absorbent. The most commonly fluids are water as the refrigerant and lithium bromide as the absorbent. These fluids are separated and recombined in the absorption cycle. In the absorption cycle the low-pressure refrigerant vapor is absorbed into the absorbent releasing a large amount of heat. The liquid refrigerant/absorbent solution is pumped to a high-operating pressure generator using significantly less electricity than that for compressing the refrigerant for an electric chiller. [4]

Heat is added at the high-pressure generator from a gas burner, steam, hot water or hot gases. The added heat causes the refrigerant to desorb from the absorbent and vaporize. The vapors flow to a condenser, where heat is rejected and condense to a high-pressure liquid. The liquid is then throttled though an expansion