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JUDUL: DESIGN, CONSTRUCTION AND PERFORMANCE OF ANGULAR REFLECTIVE PANEL SOLAR COOKER

Ijazah: BACHELOR OF SCIENCE WITH HONOURS

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DESIGN, CONSTRUCTION AND PERFORMANCE OF ANGULAR REFLECTIVE PANEL SOLAR COOKER

BENEDICT ONG YUN WUI

THIS DISSERTATION IS SUBMITTED IN PARTIAL FULLFILMENT OF THE REQUIREMENT FOR BACHELOR OF SCIENCE WITH HONOURS

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APRIL 2011

DECLARATION

I certify that this thesis does not incorporate without acknowledgement any material previously submitted for bachelor degree in any university; and that to the best of my knowledge and it does not contain any material previously published or written by another person where due reference has not made in the text.

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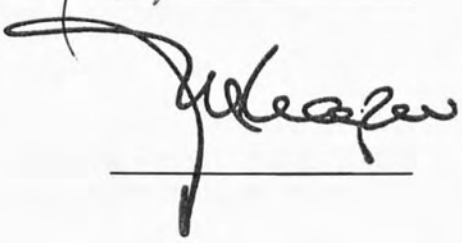

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REKAAN, PEMBINAAN DAN PRESTASI DAPUR SURIA *ANGULAR REFLECTIVE PANEL*

ABSTRAK

Satu kajian telah dijalankan mereka, membina dan menguji prestasi dapur suria *angular reflective panel*. Kajian terhadap dapur suria dijalankan sebab Malaysia menerima radiasi suria yang banyak sepanjang tahun. Radiasi suria adalah penting untuk pemasakan suria. Di samping itu, dapur mempunyai kemampuan untuk menyediakan satu alternatif memasak yang lebih sihat dan lebih mesra alam sekitar berbanding dengan memasak menggunakan kayu api yang mana masih diguanakan oleh beberapa masyarakat luar bandar. Rekaan dapur suria ini telah dilakukan dengan bantuan program rekaan komputer. Dapur suria ini dibina dari keluli tahan karat dengan bantuan templat yang dibuat menggunakan bantuan program rekaan komputer. Ujian prestasi dilakukan menurut piawaian *American Society of Agricultural Engineers* dalam pengujian dan pelaporan prestasi dapur suria. Selain itu, ujian kesan terhadap perstasi dapur suria di bawah tetapan yang berbeza dan prestasi memasak dapur suria turut dilakukan. Hasil ujian menurut piawaian *American Society of Agricultural Engineers* mendapati kadar kehilangan haba dapur suria ini adalah tinggi iaitu, 4.04 W/°C. Ini menandakan bahawa dapur suria ini menpunyai kekurangan dari segi penebatan. Kekurangan dari segi penebatan akan melembapkan prestasi dapur suria terutama apabila masakan cara perlahan, iaitu memasak dengan suhu konsisten pada satu tempoh masa yang panjang, diperlukan. Ujian dapur suria di bawah tetapan yang berbeza menunjukkan bahawa kadar peningkatan haba menurun dengan peningkatan isipadu air. Ujian juga menyimpulkan bahawa dari semua bekas memasak, penggunaan bikar memberikan prestasi terbaik. Ini adalah kerana kebanyakan gelombang dari Matahari boleh melalui bikar maka memanaskan air itu secara langsung. Dari segi prestasi memasak pelbagai makanan, didapati bahawa satu enam hidangan boleh dimasak dalam masa 4 h dari 1000 hr ke 1400 hr waktu suria. Prestasi dapur suria ini masih boleh peningkatkan terutama dari segi penebatan.

ABSTRACT

A study was carried out to design, construct and test the performance of the angular reflective panel solar cooker. The reason study on solar cooker was conducted is because Malaysia receives abundant solar radiation throughout the year which is important for solar cooking. In addition to that, solar cooker is also seen as being able to provide a healthier and environmental friendlier alternative to cooking as oppose to cooking using firewood which is still practice by some rural communities. The design of the solar cooker was done with the aid of computer-aided design programs. The solar cooker was constructed from stainless steel with the aid of templates made with the aid of the computer-aided design programs. The performance test was done according to American Society of Agricultural Engineers' standard of testing and reporting solar cooker performance. In addition, test on the effect of the solar cooker under different configuration and the cooking performance of the solar cooker was also carried out. Test result according to the American Society of Agricultural Engineers' standard shows that the solar cooker lack proper insulation as the rate of heat loss was found to be high, *viz.* 4.04 W/°C. The lack of proper insulation would dampen the solar cooker's performance especially when slow cooking, *viz.* cooking at consistent temperature over a long period of time, is required. The test of the solar cooker under different configuration showed that the rate of heat gain would decrease with the increase in load volume. The test also concluded that out of all the cooking vessels used, the beaker provided the best performance. This is because the beaker allowed most of the wavelength that is emitted by the Sun to penetrate it thus heating the water directly. In terms of cooking performance of various foods, it was found that a meal of six dishes can be cooked within the 4 h of the 1000 hr to 1400 hr solar time. Further improvement can still be made on the solar cooker especially in terms of its lack in proper insulation.

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LIST OF UNITS, SYMBOLS AND ABBREVIATIONS

°	degree
°C	degree Celsius
cm	centimetre
ft	feet
g	gram
G	gauge
h	hour
J/kgK	joules per kilogram Kelvin
K	Kelvin
kg	kilogram
L	litre
m	metre
m/s	metre per second
MJ/m^2	mega joules per metre square
min	minute
mL	millilitre
W	watt
W/m^2	watt per metre square
Cr	chromium
Ni	nickel
α	angle of reflectance
θ	angle of incidence
π	pi constant (3.14159)
A_I	intercept area
C_v	heat capacity of water
I_i	interval average solar radiation
M	water mass
P_i	cooking power
P_s	standardised cooking power
r	aperture radius
T_1	initial water temperature
T_2	final water temperature

T_a	ambient air temperature
T_d	temperature difference
T_w	water temperature
V	volume of water load
ARP	angular reflective panel
ASAE	American Society of Agricultural Engineers
ASAE S580	American Society of Agricultural Engineers' standard of testing and reporting solar cooker performance
BIS	Bureau of Indian Standards
ECSCR	European Committee on Solar Cooking Research
CAD	computer-aided design

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CHAPTER 1

INTRODUCTION

Since the early years of human life, all forms of energy have been used to help in the daily routines of life. One of the earliest forms of energy known is fire by wood, in which it was used for cooking and lighting. As the life of humans developed so did the use of energy. Energy in the form of wind were use to aid travelling, *viz.* sail boats. In our modern society today, we depend highly on all forms of energy. We need it in terms of entertainment, for example in powering electrical entertainment device such as television. We use it for our daily routines such as work through the use of computers and even providing food through cooking with gas stove or even electrically powered induction cookers. We are lucky that these form of energies are readily available to us and ways of attaining it is just as simple as paying the companies providing the service at affordable prices.

But let us now imagine how our life would be if we were stripped of all these forms of energy and its easy of attaining it and go back to the time where our main source of energy is fire by wood. That would not be an easy life to live. In the modern society today where we can enjoy the necessity of life at easy, many of us forget that there are still people all around the world who live the life mention before. Where by living can sometimes be tough and even the most basic routine in life, *viz.* cooking can be a challenge. This is the life that most people in rural areas experience. Where they live much like humans in the early year, where fire by wood is the main form energy used and are without electricity. This is experience by people even in Malaysia, for example in the village of Sonsogon Mogis, located in the

state of Sabah; the villagers are without the supply of electricity, phone service, and piped water (Golingai, 2010).

Those living in those conditions have to suffer from finding the firewood to starting the fire everyday to cook their daily meals. That is not the end of it, because as they use wood as the source of fire, they are also susceptible to respiratory problems, *viz.* from inhaling smoke from the burning of the wood. The smoke produce also pollutes the environment. The smoke produce from biomass is estimated to contain about 180 polar, 75 aliphatic and 225 aromatic hydrocarbons (Sharma, 2004).

Solar energy can be used to solve the problem of cooking in these rural areas (Schwarzer, 2008). The development on the use of solar energy has be on-going throughout the world much of it for the generation of electric. Instead of always concentrating in developing technology for enhancing the lives of the modern society, we should take a brief moment to think on ways to help those living in rural areas. One of it is by utilising solar energy to enhance their lives. The use of solar energy to provide them electric can be a long term project. However, the utilisation of solar energy for its basic use, heating, is more achievable. Solar energy which is a source of heat can be used to aid them in their daily cooking activity.

1.1 Problem Statement

Certain rural areas in Malaysia are in need of help as they lack access to certain commodities such as electric and cooking gas. Solar cookers can help people in these rural areas with their daily cooking activities. The construction of a solar cooker must first involve the review of previous designs of solar cooker to understand the strength and weaknesses of each design. It is not enough just to construct a solar cooker. In order to know how well a solar cooker functions, performance testing on the solar cooker must be carried out.

1.2 Objectives

This study is carried out to accomplish two objectives. These objectives are to (i) design and construct an angular reflective panel (ARP) solar cooker and (ii) to test and report the angular reflective panel solar cooker's performance.

CHAPTER 2

LITERATURE REVIEW

2.1 SOLAR COOKING SYSTEMS

Generally, solar cookers are divided into three types of categories based on their designs. These categories are concentrating solar cookers, box solar cookers and indirect solar cookers (Sharma, 2004). In reviewing the different categories of solar cooker, the researcher also carried out patent search whereby the researcher reviewed patented solar cookers in the United States of America to understand their strengths and weaknesses to help in the designing of the solar cooker.

2.1.1 Concentrating Solar Cookers

Concentrating solar cookers are solar cookers that utilise reflectors to focus and concentrate sunlight's heat onto the cooking vessel. Concentrating solar cookers usually fall into one of three subcategories. These subcategories are parabolic solar cookers, cylindrical solar cookers and Fresnel solar cookers.

a. Parabolic Solar Cookers

Parabolic solar cookers are solar cookers that utilise a parabolic shaped reflector to focus sunlight's heat onto the cooking vessel. Depending on the shape of the parabola, the focus of the solar cooker can either be inside out outside the rim of the solar cooker. Parabolic solar cookers are one of the most well known and used solar cooker because of its better focus (Muthusivagami *et al.*, 2010). The better focus allows it to attain high temperature relatively quick.

The ability of the parabolic cooker to achieve better focus is also responsible for its disadvantage, in the sense that it requires constant solar tracking. Besides that, parabolic solar cookers are also sensitive to change in the environment, for example cloud cover (Sharma, 2004).

An example of a parabolic cooker is one invented by Jackson in 1977. His design (Figure 2.1) allowed for the solar cooker to be folded up much like an umbrella in order for storage purposes. The design however did not address problems such as stability and thermal cooling by wind.

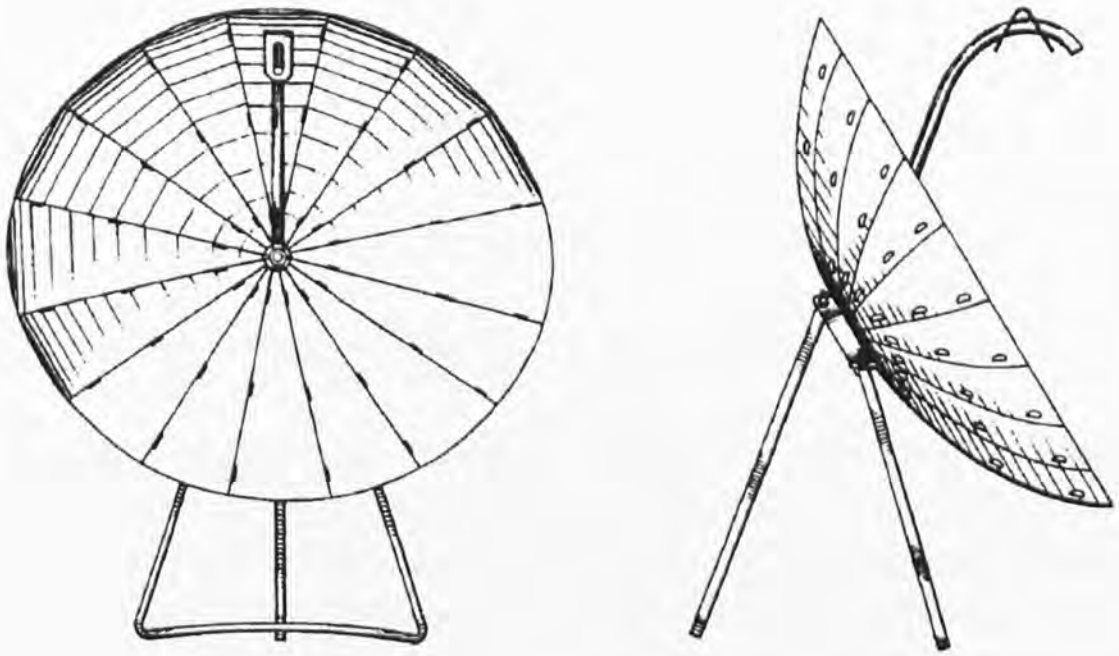

Figure 2.1 Foldable parabolic solar cooker (Source: Jackson, 1977)

Another design of a parabolic solar cooker (Figure 2.2) is one invented by Essig, Jr. and Essig in 2005. It was design with a sphere structure encasing the parabolic reflector and the entire structure is supported by a toroidal ring. This unique design enabled for easy solar tracking. This feature is important for parabolic solar cookers as they require constant solar tracking. The design however, did not address the problem of thermal cooling by wind as no proper insulation or wind shield are used in the design.

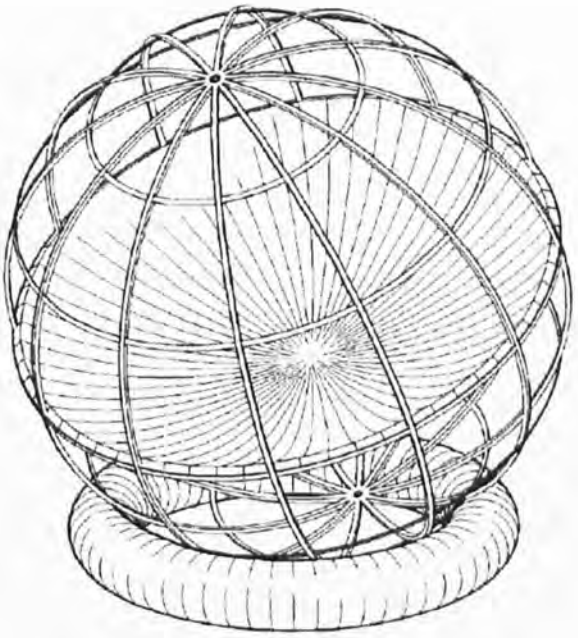

Figure 2.2 Solar cooker with globe shape (Source: Essig, Jr. and Essig, 2005)

b. Cylindrical Solar Cookers

Cylindrical solar cookers or better known as trough solar cookers is different from parabolic solar cookers in the sense that they focus sunlight in a line instead of a spot. Cylindrical solar cookers also only require one axis solar tracking as compared to parabolic solar cookers which require two axis tracking. However, because of its line focus, cylindrical solar cookers falls behind parabolic solar cookers in term of heat gain capabilities.

An example on a cylindrical solar cooker is shown in Figure 2.3. This solar cooker was invented by Fischer in 1978. Fischer designed the solar cooker in a way that solar tracking could be carried out easily and also the cooking vessel was able to maintain its upright position even when tracking is done. In order to minimise heat loss, the cooking vessel was design in a shape of a cylinder which has a transparent bottom half and an inner reflective top half. The cooking vessel encases the food and allows heat to be trap within it.

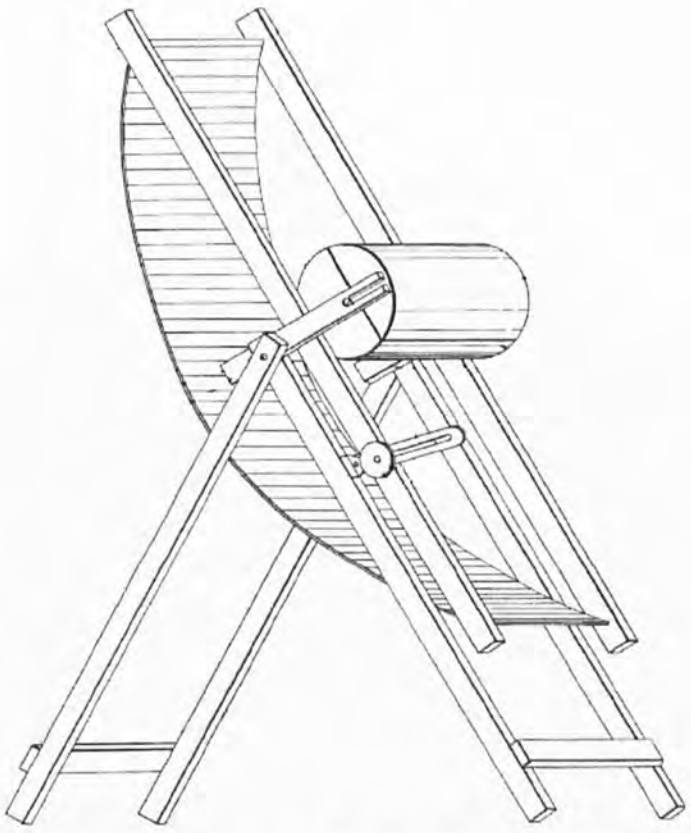

Figure 2.3 Cylindrical solar cooker with its cooking vessel (Source: Fischer, 1978)

About three years after Fischer's invention, another inventor patents a slightly different version of a cylindrical solar cooker (Ilich, 1981). Ilich version of the cylindrical solar cooker (Figure 2.4) is smaller in size and has a smaller cooking vessel. Ilich design his solar cooker so that it can be kept easily. The reflector and cooking vessel is design in such a way that it can be dissembled and stored in the box shaped supporting body below it.

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