Experimental Anaysis of Solar Cooker using Black Coated Box: Review Comparisons of Optimizing Measurements

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Abstract

The need to cook food for sustenance is fundamental to nearly every society and requires the expenditure of energy in some form. Solar energy can be harnessed to meet this need without the environmental and health problems associated with most other fuels. There are a wide variety of devices designed to capture the sun's energy and harness it for cooking food. The experimentation work done by black coated box, is currently used for testing. Based on the input and output energy solar box cooker were performed on their efficiency. This experimental work developed next methods to implement materials, devices and design optimizing with this review. The review conclusions make another experiment to compare the better performance and efficiency to achieve the maximum thermal rate of solar system.

Keywords — *Solar cooker, Black coated box, Thermal efficiency.*

I. INTRODUCTION

Increasing environmental awareness and the growing global need for alternative cooking fuels has spurred solar cooker research and development. Solar cookers represent a simple, low cost, practical and effective application of solar energy. In many developing countries, such as Ethiopia, they can play an important role in improving living conditions among low-income households by lowering exposure to wood-smoke and reducing pressure on firewood resources. It is unlikely that they will substitute for conventional gas or electric cooking in developed countries; however their use could improve safety and protect the environment. In Australia, for example, the cost of cooking a meal with gas or electricity is only a few tenths of a dollar, so financial savings attributable to solar cooking are low (Todd and Miller, 2001) [1]. In Ethiopia, however, many people in rural areas do not have access to electricity. Additionally, other fuels such as gas and paraffin can be difficult to obtain due to the large distances and inadequate road networks. This justifies the deployment of solar cookers and necessitates research into their operation.

II. LITERATURE REVIEW

They are focused on three main areas. Development and solidification of contacts, parametric testing of previously constructed solar ovens, and the development of new solar oven designs. These three methods, majorly concentrated move about parametric testing, because of the research made over by analysis of optimization to implement new design. They tested and designed cooker under identical conditions in natural sunlight outdoor on sunny day and thermocouples were placed on bottom, in the middle, and near top of the cooker. The thermocouple ran visual basic program that recorded and graphed temperature every 30 second. Testing focused on the effectiveness of reflective material. For reflectivity, they designed inside cooker sidewall using single paned door instead of double-paned glass door (Rachel martin) [2]

This project mainly focused on fabrication of solar cooker, major work concentrated to achieve higher thermal efficiency, when thermal efficiency achieved, we definitely get good performance of the solar cooker. Solar radiation concept clearly found followed to complete this project. Based on solar radiation diffuses inside the solar cooker. So, they designed exactly double glazed glass panel inside box blackened by dull black paint and kept good insulation for all side and made air tight. When the solar radiation entered in the box through the glass panel is absorbed by blacked surface and cooking utensils and transformed into thermal radiation. That thermal radiation has longer wavelength, hence it is not possible to pass back to glass. For reducing convection loss the box should be made air tight putting rubber beading. After trail they found difference it is confidently recorded 105 degree to

120 degree in about half an hour time using this type of cooker. (Box type Solar Cooker) [3]

This paper reviewed six different types of solar cookers. Sun stove box cooker, wooden box cooker, and panel cooker, reflector cooker with unpolished aluminium reflectors, reflector cooker with polished aluminium reflector and reflector cooker with glass mirror reflector. The specification should be based on the measured insolation data of the location indication of the direct and diffuse components.

This project reported and conducted at the College of Engineering and Technology, University of Dar of Salaam, Tanzania. This project involved total five students projects (Lissu 2000), (Raphael 2002), (Kikoti 2004), (Kilangi 2005) and (Mwangomba 2006).

They have made three major testing standards for solar cookers. ASAE 80 monitors average temperature. Their studies found tracking procedure, thermal loadings, under condition of high wind, low insolation (or) low ambient temperature and characteristics of solar cooker find how long cooker will take to reach reference temperature. Final results have concluded from under various condition of insolation and wind. Box solar cookers have lower performance compared to the reflector cooker. The reflector cooker with glass reflector achieved highest temperature and according shortest cooking time than any other cooker tested under sunny day with no cloud cover. Results obtained indicate that many of the cooker with medium and high insolation with appropriate selection of type and specification of the cookers. The specification should be based on the measured insolation data of location indicating the direct and diffuse components. (Kimambo CZM) [4]

This research paper has calculated two different method of solar cooker design. Finned and unfinned cooking pot. These investigation for analyse heat transfer from internal hot air used to increase performance of cooking water and rice, finally it demonstrated that fin area increase heat transfer rate compare unfinned area. They have represented 11% reduction in heating time for water heating and boiling test. (Ismail Isa Rikoto) [5]

This paper suggested about Fresnel reflective concentrator to concentrate the solar beam to the bottom of the utensil. This method used to generate axial running tubes. Parabolic concentrator focus the radiation either axial or point. This focusing area covered less than 300 cm^2 most suitable to conventional Indian cookware for concentrated the solar radiation. (Paranthaman) [6]

A. Theoretical Background on Solar Cooking

From a conceptual perspective, solar cooking is relatively simple. However, it is important to have a basic understanding of the underlying principles used by solar cooking devices if an evaluating framework is to be developed for testing these devices.

B. Solar Box Cookers (Solar Ovens)

The Solar Box Cooker (SBC) or Solar Oven consists, largely, of some type of heat trapping enclosure. Quite often, this takes the form of a box made of insulating material with one face of the box fitted with a transparent medium, such as glass or plastic. This allows the box to take advantage of the greenhouse effect and incident solar radiation cooks the food within the box.

The ability of a solar cooker to collect sunlight is directly related to the projected area of the collector perpendicular to the incident radiation. For example, a large box with a glass lid will function as a solar box cooker but the losses due to heat loss over a larger surface area will, at least partially, offset the additional gain through having a larger collector surface.

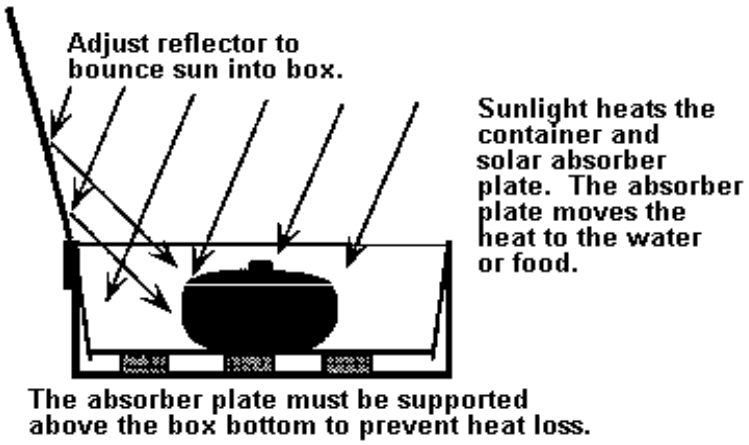

Figure 2.1 is a schematic of the operating simple solar box cooker. Image courtesy of Solar Cooking Archives.

Instead, what is typically done is to create an insulated box with a glazed surface cover and use reflectors to increase the apparent collector area. These reflectors can be made from a variety of materials and their primary purpose is to reflect sunlight through the glazing material and into the cooking space inside of the box. In most cases, these reflectors are planar in geometry, with parabolic and other geometries reserved for the more complicated class of solar cookers that utilize high concentration ratios, as discussed later. While a high concentration ratio allows a potentially higher temperature and flux, high concentration ratio devices generate nearly point source foci, which require regular and frequent tracking to follow the sun. Without this tracking, the focus will quickly deform, resulting in an uneven flux and potentially damaging heat gain. One of the virtues of the solar box cooker is its high acceptance angle and correspondingly high tolerance for tracking error. A Solar Box Cooker will cook meals unattended for long periods of time because the sun is able to remain within the view of the cooker. With some other collector configurations, the sun quickly moves off-axis, causing focus shift that can be highly undesirable or dangerous.

C. Panel Cookers & Concentrating Solar Cookers

The panel cooker is quite similar in operation to the SBC. The same principles are employed but instead of an insulated box, panel cookers typically rely on a large (often multi-faceted) reflective panel. At the focus of the reflector rests the cooking pot contained within a transparent medium, such as an oven bag or a glass bowl (FSEC, 2002). Energy from the sunlight is reflected into the bowl or oven bag, heating up a dark painted pot and whatever may be inside of it. The pot in this case is generally less insulated from the environment than the pot in the case of the SBC. The panel cooker relies much more heavily upon reflected sunlight and less so on heat retention as compared to the SBC. This can make the panel cooker more portable and cheaper to construct but the panel cooker will suffer from generally somewhat poorer performance, particularly on days of marginal insolation or intermittent cloudy conditions.

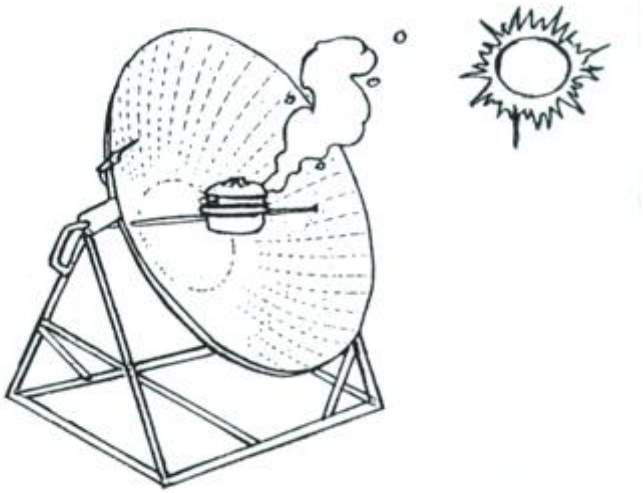

Figure 2.2 Parabolic solar cooker.

The reflector focuses the sunlight on the bottom of the absorber plate, heating the pot in a fashion similar to a traditional electric or gas powered stove. The third major class of solar cooker utilizes concentrating optics. Using mirrors and/or lenses, these cookers can achieve extremely high temperatures. The concentrating cooker is the only class of solar cooker that is truly suitable for frying, as the temperature at the focus can rival that of conventional electric, gas, or wood fired stoves. Similar to the panel cooker, the concentrator suffers from a strong reliance on direct beam insolation. Cloudy conditions and wind combine to make concentrating cookers highly difficult to use. In field studies, the concentrating cooker is not generally chosen due to its need to closely follow the sun (characterized by a low acceptance angle), its relatively high cost, and safety issues as focused sunlight can cause burns or eye damage. Nevertheless, in some applications, solar concentrators can make ideal cookers. So long as direct insolation is readily available and the user is experienced and careful, the concentrator represents a highly useful and powerful cooking tool.

III. TEST EQUIPMENTS & ETHODOLOGY

Solar box cookers were identified for the experiment. Water cups, thermocouples and a multimeter were also used for conducting the load test. Volume of the water was measured with

labelled flask. The solar radiation was recorded by a pynorometer.

Initial Reading was taken for all the thermocouples before setting up the cookers for measurement to calibrate the reading of the thermocouples against with the reading of the ambient thermocouples.

Figure 3 Solar Cooker with black coated box

In test, the cooking cup were filled with 250 grams of water. One type-k thermocouple was immersed centrally in the cup and secured around 40mm below the water level.

Tests were conducted in accordance with the International Standard for Testing Solar Cookers and Reporting Performance.

1. Testing was conducted between 12:50PM and 1:50PM solar time.
2. Ambient temperature was recorded using multi-meter and ambient thermocouples.
3. Wind speed was not measured.

IV. RESULTS & CALCULATION

A. Input Energy

The energy entering the solar box cooker can be computed with the following formula:

$E_{Input} = A_{aperture} I_{solar} \Delta t$
$A_{Aperture} = 0.1626 m^2$
Δt is 10 minutes or 600s

B. Output Energy

The output energy can be gained using the formula

$E_{Output} = mC_p\Delta T$

m = 0.25kg and C_p= 4186 kJ/kgK

Where, ΔT, the change in temperature, is the difference between water temperature and ambient temperature of the successive 10 minute readings.

V. TABLE I - Readings for black coated solar cooker

Black coated solar cooker			
Water temp, T_1	**Water temp, T_2**	**ΔT**	**$E_{Out,i}$**
22.09043	25.93678	3.84635	4025.205
25.93678	30.21659	4.27981	4478.821
30.21659	34.62242	4.40583	4610.701
34.62242	39.09893	4.47651	4684.668
39.09893	43.21476	4.11583	4307.216

These graph represented variation about output energy corresponds to the temperature difference respect to water and ambient temperature. we can find the graph representation about insolation difference associated with the sunlight and wind direction and irradiation of solar cooker. So based on the graphical indication, understood the main objective to execute new method as well recognize the optimization technique.

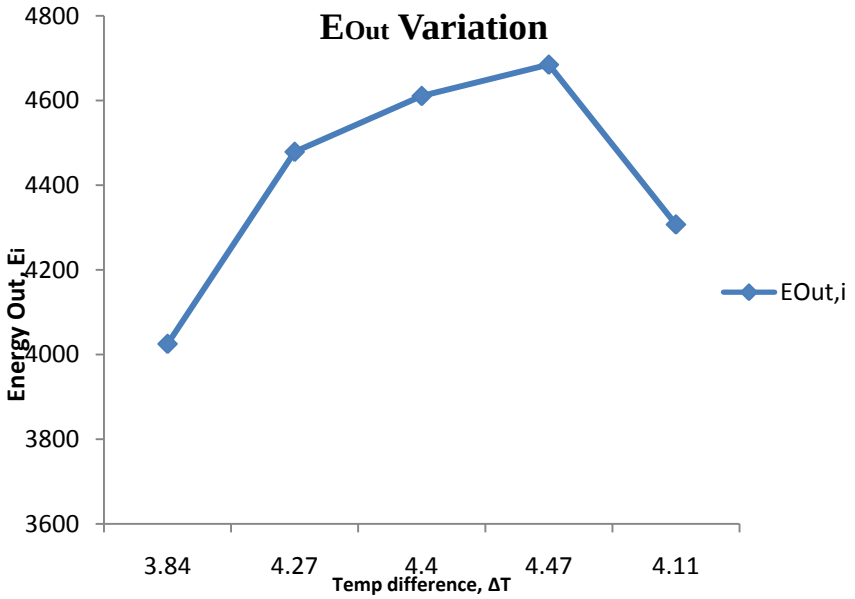

Figure 4 Temp differences vs. Energy out

VI. CONCULSION

Results from the testing showed that the temperature of the water reached maximum of 46.2ºC for black coated solar box cooker. The maximum average ambient temperature during testing was 32.7ºC. The above conclusion given for the black coated box experiment. (Ethiopia)

But this research paper main objective have drawn conclusion from literature review of new method invention for comparison to give better efficiency possible on the system.

[2] has concluded to give more importance about parametric testing. (Nicaragua)

[3] has focused to achieve higher thermal efficiency. For that, they have concentrated on the fabrication technology to diffuses the solar radiation in solar cooker. (India)

[4] Different parameters were used such as thermal loading, insolation and wind based on the environment and inclination of sunlight. (Tanzania)

[5] They were two different methods of solar cooker designed. Finned method performed higher rate of thermal efficiency. (Kano- Nigeria)

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