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Performance of Elliptical Solar Cooker Suitable for Baghdad Environment

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ABSTRACT

In this research, a solar cooker was manufacture from the scrap of an elliptical satellite dish, the dish was covered with reflective layer of aluminum that reflects up to up to 85% of solar radiation. This solar cooker has the ability to move horizontally in 360 degrees and vertically in 90 degrees, which makes it easier to follow the movement of the sun. Experimental investigation was carried out on this solar cooker in January, March, June, September between the hours of 9:00 AM. to 3:00 PM local time in Baghdad city in year 2020, by heating 1 L of water at every experiment, the results showed the best month for testing is June, due to the increase in the intensity of solar radiation and the reduced influence of weather factors, wind speed and cloud cover. this changing environmental conditions led to an instability in energy efficiency. The results also showed that the thermal efficiency is correlated inversely with solar radiation. This means that whenever the quantity of solar radiation was high, we need less energy to raise the temperature of the water, because the thermal efficiency is the ratio of the sensible energy required to heat the mass of water in the pot when the solar energy falls on the dish at the same time, and is correlated inversely with temperature and wind speed.

KEYWORDS: Solar energy; elliptical solar cooker; Energy Efficiency.

الخلاصة

في هذا البحث تم تصنيع طباخ شمسي من طبق قمر صناعي بيضاوي الشكل ، وقد تم تغطية الطبق بطبقة من الألومنيوم تعكس 85٪ من الاشعاع الشمسي ، وهذا الطباخ الشمسي له قابلية على التحرك أفقيًا بزاوية 360 درجة وعموديًا 90 درجة مما يتيح تتبع الشمس بسهولة. وتم اجراء الاختبار على هذا الطباخ من خلال غلي 1 لتر من الماء في الأشهر كانون الثاني ، اذار، حزيران، ايلول في سنة 2020 من الساعة 9:00 صباحا الى الساعة 3:00 مساءاً. واوضحت نتائج الاختبار ان الكفاءة كانت افضل في شهر حزيران وذلك بسبب ان شدة الاشعاع الشمسي تكون اكبر مقارنة بالاشهر الاخرى وقلت تاثير سرعة الرياح والسحب وهذه التغيرات البيئة أدات الى عدم الاستقرار في الكفاءة و كما أوضحت النتائج أن الكفاءة الحرارية ترتبط عكسياً بالإشعاع الشمسي وهذا يعني أنه كلما كانت كمية الإشعاع الشمسي عالية، نحتاج طاقة أقل لرفع درجة حرارة الماء لأن الكفاءة الحرارية هي نسبة الطاقة اللازمة لتسخين الماء في الوعاء والطاقة الساقطة على الطبق خلال نفس الفترة، وكذلك ترتبط عكسيامع سرعة الرياح ودرجة الحرارة المحيطية.

INTRODUCTION

Sun is the main source of energy for Earth and inexhaustible, and the power from the sun intercepted by earth is approximately 1.8 x 10^{11} MW per second.

This is equivalent to thousands of times the world's energy consumption. Cooking and heating smoke is one of the main causes of environmental pollution and it is the direct cause of many heart and lung diseases also, more than 15 million hectares of forest have been lost in developing countries due to the use of firewood. Therefore, human societies decided to confront this matter by being attracted to solar energy, which is considered new technologies that reduce pollution processes and in response to the growing shortage of firewood resulting from chronic deforestation [1]. Cooking is one of the examples of using solar energy, as many attempts have been made to replace traditional cooking with a technology that is less polluting to the environment and less expensive. This technology also has disadvantages such as the cooking time is relatively long compared to conventional cooking appliances, especially at a time when the solar radiation is relatively low and for overcoming this problem, many solar stoves have been successfully designed and expensive, many solar stoves have been

successfully designed and developed by many researchers in this field, and some of these devices are still used all over the world. n finding a way to boost the performance of parabolic concentrators, Dandakouta et al., designed and constructed a Compound Parabolic Concentrating (CPC) solar cooker fitted with a booster mirror whose angle can be adjusted. After experimental evaluation of the system, it was observed that the fitting of booster mirror led to an increase in solar irradiance which produced 2.36% and 8.75% increase in the absorber and water temperature respectively [2]. Around the word commonly, here are three types of solar cookers; first one which is a concentrating type cooker and required a tracking sun for effective cooking and generates higher temperatures compared to others cookers. Second is non-concentrating cooker box type solar cooker, and third is Indirect type [3, 4].
concentrating-types cooker are more common because it's used the dish focus the sun's rays on the base of the cooking pot is often placed in the focus that can reach higher temperatures and can cook more quickly [5, 6]. which is preferred to be coated by a thin layer of black paint; to decrease the reflection of the solar rays [7].

DISH GEOMETRY

The elliptical used when the locus of a point have the capacity to realign itself that its space from a fixed point and a constant line is always the same. This is shown in Figure 1, [8].

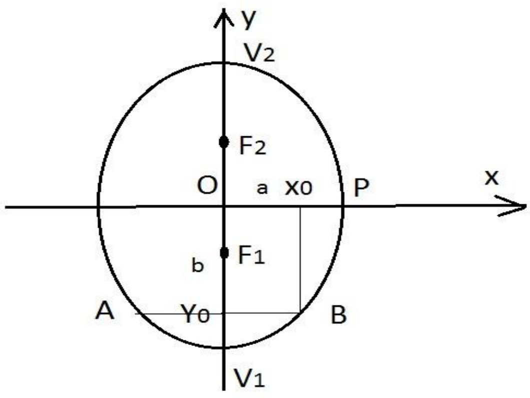

Figure 1 . The elliptical diagram.

The mathematical modelling that represents the elliptical dish solar concentrator in the cartesian coordinates, which are defined as [8].

$$\frac{x^2}{a^2}+\frac{y^2}{b^2}=1 \quad (1)$$

a and b are the semi-minor axis and the semi-major axis of the ellipse respectively. The points V_1 and V_2 are the vertexes, F_1 and F_2 is the focal point of the reflector, X0 and Y0 the coordinates of B. The focal length (f) is expressed as [8].

$$f = b - \sqrt{b^2 - d^2} \quad (2)$$

and the depth of Concentrator follows is given as [8].

$$h = 0.13397b \quad (3)$$

DESCRIPTION OF THE DESIGN

Figure 2, shows different views of the design of the elliptical -type solar cooker which is use for this study. The design mainly consists of the following parts.

Figure 2. The solar cooker.

1- Dish: The elliptical TV satellite dish was a metal scraps that were recycled and used in manufactured the solar cooker in this study has a diameter of 90 cm, depth of 13.3 cm and a focal point of 56.4 cm and surface area 1.473 m^2. the dish was covered with a reflective layer of aluminum that reflects up to 85%. Aluminum sheets were divided into small pieces in the form of squares to facilitate the manufacturing process as shown in Parts (a,b) of Figure 2.

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2- Control arm: By this design the control arm of the cooker has the ability to move horizontally in 360 degrees and vertically in 90 degrees to allow easy follow up the movement of the sun as well as to make the focus in the most suitable place to get the best results as shown in Part (c) of Figure 2.

3- Cooking pot: made of steel and coated with a matte black color and the cover of the cooking pot is glass to received more solar radiation. The cooking pot put on special base connected with control arm that connected to the back of the dish which used to central the focus point in the base of the pot, as shown in part (d) of Figure 2.

ENERGY EFFICIENCY OF THE SOLAR COOKER

Energy analysis is based on the first law of thermodynamics which is concerned only with the amount of energy use and the efficiency of energy processes. To perform energy of the solar cookers, the input and output quantities of energy must be evaluated. the total energy equilibrium of the solar cooker could be written as follow:

Energy Input =Energy Output +Energy Loss

Energy input to the solar cooker is the total solar energy that falls on the solar cooker per unit of time per unit area. The energy inputs of the solar cooker can be calculated as follows is given as [9].

$$E_i = I_b * A_{SC} \quad (4)$$

where; E_i is energy input to the solar cooker in (Watt), I_b the average solar intensity (W/m^2) during time interval t, A_{SC} surface area of the solar cooker is gotten as follow:

$$A_{sc} = \pi\left(\frac{(a^2.d^2+1)^{3/2}}{6\alpha}\right) \quad (5)$$

$$\text{where; } a = \frac{1}{4f} \quad (6)$$

d = diameter; f =The focal length

Energy output (heating power) from the solar cooker is given as:

$$E_0 = [M_w C_{pw}(T_{wb} - T_{wa})]/t \quad (7)$$

E_0 is energy output (watt); M_w, mass of water (kg); C_{pw}=specific heat of water=4186 J/Kg.K T_{wa} is the initial temperature of the water (K); T_{wb} is the final temperature of the water (K) [10].

Energy efficiency equation is follows given as

$$\eta = \frac{E_0}{Ei} \quad (8)$$

RESULTS AND DISCUSSION

After constructing of the solar cooker, it is tested boil 1 liter of water, the test was conducted period (9:00 AM-3:00 PM). The Results of the test are show in the following Figures:

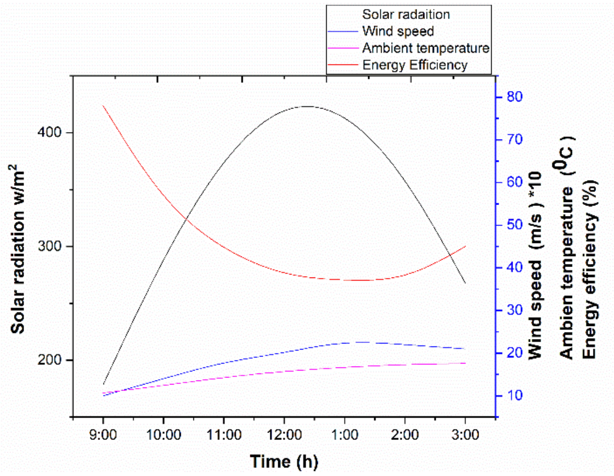

Figure 3. Efficiency versus time.

Figure 3, indicate how the efficiency of the solar cooker is affected by the intensity of solar radiation, ambient temperature and wind speed in January. It's seen that when the intensity solar radiation is low (178.41 w/m^2) efficiency is high 78 %. After that energy efficiency decreases with the increase in the intensity of solar radiation and ambient temperature with time, this means the energy required to raise the water temperature from the surrounding temperature to the boiling point is low. So, energy efficiency is less (37%) when intensity solar radiation large (421.16 w/m^2) after that then the energy efficiency is higher due to the decrease in the intensity of solar radiation, and the increase in the wind speed, this means the energy required to raise the water temperature from the surrounding temperature to the boiling point is large. Although the ambient temperature continues to rise. And because the thermal efficiency increases with increasing ambient temperature so the ambient temperature is more influential in morning hours ambient temperature affects its performance but at sunshine hours less affects due to high surrounding temperature and decrease the difference between the surrounding and the cooker.

Figure 4, indicate how the efficiency of the solar cooker is affected by the intensity of solar radiation, ambient temperature and wind speed in March. when the solar radiation is low (501 W/m^2) efficiency is high 30 %. after that energy efficiency decreases with the increase in the intensity of solar radiation and Ambient temperature with time, this means the energy required to raise the water temperature from the surrounding temperature to the boiling point is low.

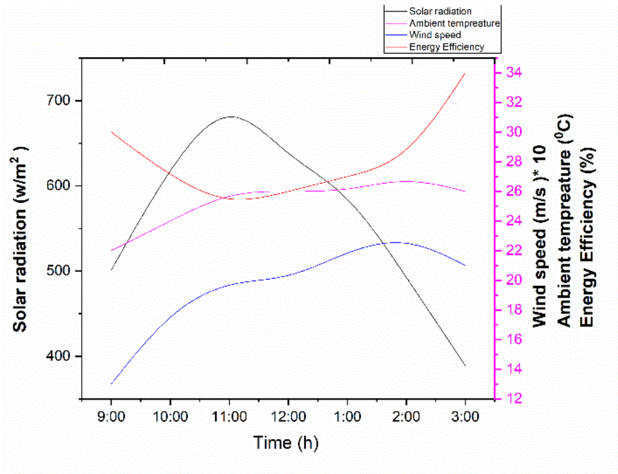

Figure 4. Efficiency versus time.

So, energy efficiency is less (25%) when intensity solar radiation large (707.16 W/m^2) after that the energy efficiency is higher due to the decrease in the intensity of solar radiation, and the increase in the wind speed, although the ambient temperature continues to rise. So, the ambient temperature is more influential in morning hours ambient temperature affects its performance but at sunshine hours less affects due to high surrounding temperature and decrease the difference between the surrounding and the cooker.

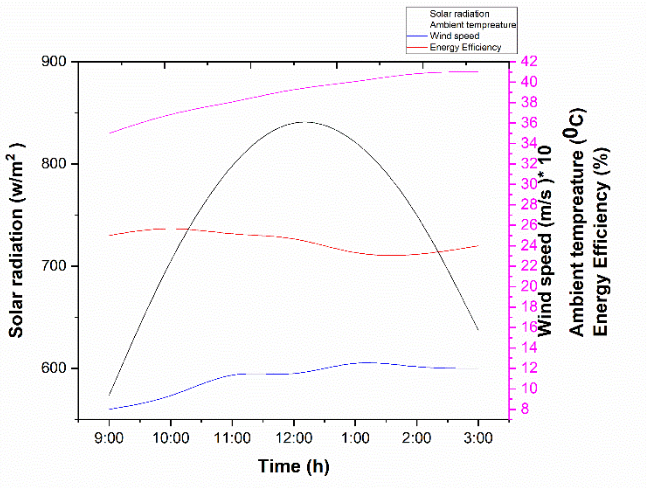

Figure 5. Efficiency versus time.

Figure 5, indicate how the efficiency of the solar cooker is affected by the intensity of solar radiation, ambient temperature and wind speed in June. when the solar radiation is low (574.95 W/m^2) efficiency is high 25 %. After that energy efficiency decreases with the increase in the intensity of solar radiation and ambient temperature with time, this means the energy required to raise the water temperature from the surrounding temperature to the boiling point is low. The efficiency continues at this value up to until hour (1:00 PM) , and the value reaches 34%, And then it keeps getting increase And the effect of the ambient temperature on the performance of the cook in the summer season is less than in the winter , and also in the morning hours it affects his performance, but in the hours of sunshine it is less affected due to the high difference between the surrounding and the cooker, in this month the energy efficiency are better than all test months due to the increase in the value of intensity solar radiation compared to the all months and the influence of other weather factors such as wind speed and the effect of cloud cover.

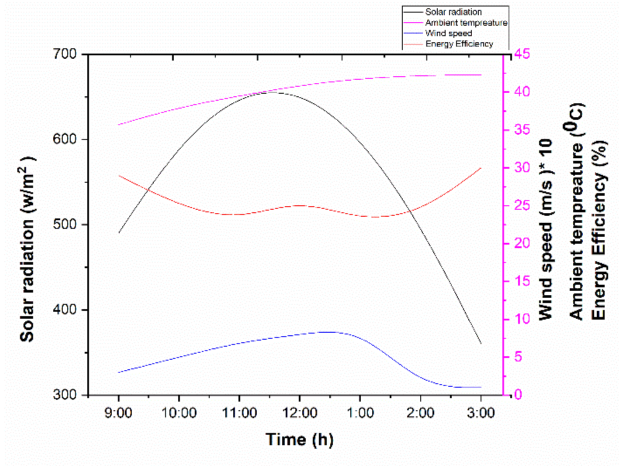

Figure 6. Efficiency versus time.

Figure 6, indicate how the efficiency of the solar cooker is affected by the intensity of solar radiation, ambient temperature and wind speed in September. when the solar radiation is low (490 W/m^2) efficiency is high 29 %. After that energy efficiency decreases with the increase in the intensity of solar radiation and ambient temperature with time, this means the energy required to raise the water temperature from the surrounding temperature to the boiling point is low. so energy efficiency is less (23%) when intensity solar radiation large (655 W/m^2) after that, the efficiency increased, although the intensity of solar radiation was high, but the value decreased due to cooker calibration errors and solar tracking

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inaccuracy in this hour. After that, decreased because the intensity of solar radiation is large, and then the efficiency increased due to the intensity of radiation low until it reached the highest value (30 %) during the month at hour (3:00 PM) at intensity solar radiation (360.55 W/m^2). And ambient temperature (26 ℃).

CONCLUSIONS

A television cable dish was adapted into A television cable dish was adapted into elliptical concentrator solar cooker using readily available and cheap material, and the determination of the dish's focal point so as to locate the pot or any other heat output element. The performance of the elliptical solar cooker was investigated in terms of testing boiling 1 liter of water For the months January, March, June, and September. Also, the results showed that solar radiation, wind speed and ambient temperature have a great effect on energy efficiency of the solar cooker. The best month for testing is June, due to the increase in the intensity of solar radiation and the reduced influence of weather factors, wind speed and cloud cover., it can be concluded that the dishes used are good for the solar thermal application. And this method can be used as a solar water heat and cooking.

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