A DEVELOPMENT OF SOLAR DRYER USING PARABOLIC MIRROR PLATES

[1]K. NARANCHALA, [2]N. SENANGKANIKORN, [3]U.KRAWKLOM, [4]C.CHOOMFON

Rajamangala University of Technology Rattanakosin, Nakhon Pathom, 73170, Thailand
E-mail: [1]naranchala.khu@rmutr.ac.th, [2]numfon.sen@rmutr.ac.th, [3]uthai.kra@rmutr.ac.th, [4].cho@rmutr.ac.th

Abstract - Utilization of solar energy has been encouragedin many parts of the world in order to delay the arrival of energy crisis. In tropical countries, like Thailand, open sun drying of foods is traditionally used in household but there are some disadvantages of this method such as contamination and no protection from rain or dew that wets the product. This study aims to develop a new solar dryer using parabolic mirror plates as solar collector and other materials readily obtained in community. The performance of the new dryer was evaluated both in the closed and open systems by measuring the temperature inside the cabinet every ten minutes during 9 a.m. to 4 p.m. on sunny day. The results reveal that the new dryer can heat the temperature inside the cabinet from 33 up to 120 °C with the average of 90.8°C for the closed system and from 33 up to 90 °C with the average of 67.0 °C for the open system. The developed dryer can be used as a pilot for everyday use in community and its performance can serve for drying common foods, such as fish and agricultural products.

Keywords - Solar Dryer; Parabolic Mirror Plate; Renewable Energy

I. INTRODUCTION

It has been generally known that the causes of energy crisis in Thailand are the increase of population, the economic and social development, and the increasing consumption of technology. These all multiply the people's need for energy and the government is responsible to supply the energy to appropriately satisfy the people's need while the crude oil and natural gas's prices have continuously increased. Moreover, the use of energy for different activities may cause air pollution and global warming which greatly affect their people's life quality as well as the country's economic and social development.

Now, both sustainable energy and stability have considerably been important to many countries' economic growth. Many factors are required in order to achieve this issue and these factors include the sufficiency and renewability of energy as well as the effective energy conservation system. Thanks to advanced technology, "renewable energy" has gained more attention and it is now possible to produce energy for commercial purpose; therefore, many countries have paid their attention to renewable energy as it can replace the decreasing petroleum. One of the most common renewable energies for Thai people is solar energy, the fundamental energy that everyone acknowledges its benefits. Most energy we get is from the sun as it generates around 178,000-trillion watts per day for the earth and around 35 percent of that amount returns to the space. Then the atmosphere of the earth absorbs approximately 43 percent of the energy and about 22 percent returns to the aerospace.

Thailand receives about 4.7 kilowatt-hour or 16.92 megajoules of solar radiation intensity per square meter per day: therefore, the unlimited energy can be produced by using the processing equipment and different types of energy in the forms of heat and solar cell.

The energy crisis has, and will, affected people's life at the present time and in the future because living requires energy. The energy problems we are facing now include the lack of energy and the decrease of fossil energy. Also, the cost of electrical energy is getting too high, if compared with the average income of Thai people, especially those agriculturists who live out of town, have low income, and have high cost for energy used in processing. Therefore, this study is conducted as the researchers realize the usefulness of the sunbeam that Thai people have been familiar with as can be seen from the traditional method of food and agricultural products preservation. Consequently, the researchers have developed the solar dryer, based on scientific theories. This dryer collects solar energy from the mirrors connected in a parabolic shape.

The mirrors are used as the main material because they are inexpensive and prevalent. These mirrors and scientific principles are combined to create the beneficial innovation for people in the community. Moreover, this dryer will make local agricultural products more valuable and create more non-polluting jobs. Run by the renewable energy, the dryer can help to reduce a product's cost which will allow the community to be able to compete with large manufacturers. In addition, this innovation will provide local small manufacturers the chance to improve their product and business in the future.

The researches on solar energy concerning the radiation concentration on parabolic dish have been studied by many Thai and international researchers, for example, [1] BunchaKongtrakul who studied the size, shape, and optimum of parabolic dish collectors as the thermal energy resource, [2] PrakobSurawattanawan and TeerapathLimboonruang who presented the mathematical model and the design of parabolic trough solar radiation collectors, [3] HarirakKuanpradit who studied the development of solar parabolic concentrators in drying process for

agricultural products, and [4] WatcharinDongbang and With aya Puangsombat who developed parabolic trough solar water heater. [5] Fareed M. Mohammedstudied Design and Study of Portable Solar Dish Concentrator [6] Ibrahim Ladan Mohammed who studied Design and Development Parabolic Dish Solar Water Heather [7] Lifang Liwho studied A New Design Approach for Solar Concentrating Parabolic Dish Based on Optimized Flexible Petals [8]Saad D. Odeh & Hosni I. Abu-Mulawehwho studiedDesign and development of an educational solar tracking parabolic trough collector system

II. CALCULATION AND DESIGN

2.1 Analysis of sun movement

The declination angle is the angular position of the sun at solar noon with respect to the plane of the equator.

$$\delta = 23.45\frac{\pi}{180}\sin\left[2\pi\left(\frac{284+n}{36.25}\right)\right](\text{rads}) \quad (1)$$

n = no. of day suchast n = 1 means the experimental study start on January 1th, $-23.45^0 \le \delta \le 23.45^0$

The hour angle of the sun is calculated from:

$$\omega = 15(12 - st) \quad (2)$$

St is the local standard time with respect to solar noon.

2.2 Analysis of parabolic dish size [2]

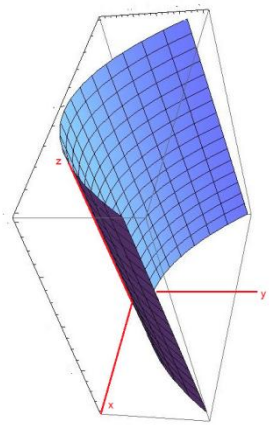


Figure1 Appearance of dish

The reflective parabola dish is in the cylindrical parabolic shape that can defined bythe equation $x^2 = 4ay$andthe cylindrical surfaceis crosswise with axis xyatZ = 0 andZ = k There was a parabolic curve on axis xy. This is consistent with the equation$x^2 = 4ay$,a > 0

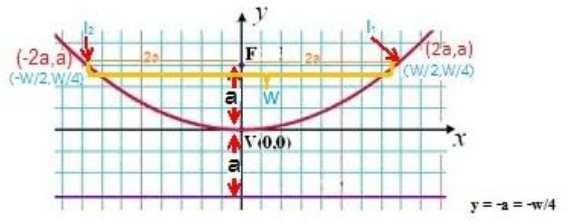


Figure 2 Components of aparabola

When the vertical distance of parabolic mirror plate is $a = \frac{w}{4}$can be used in all designs if

1. The vertex at the origin v(0,0)
2. The focus at F (0,a) or F $(0,\frac{w}{4})$
3. The directrix is Y line=$-\frac{w}{4}$
4. The parabola axis isaxisY
5. 5.Thelatusrectum is |4a |= $|4.\frac{w}{4}|$= |w| (w=the width distance of mirror plates in the parabolic dish)
6. The focus length is $|\frac{w}{4}|$

The equation of parabola is

$$y = \frac{x^2}{4a} = \frac{x^2}{w} \quad (3)$$

For find the width of the plate and focal length , it's necessary to find the relationship of the width of the plate and focal length ;

$$\frac{\text{the focus lengt h}}{\text{the width of parabolic dish}} = \frac{\frac{w}{4}}{w} = \frac{1}{4} = 0.25$$

The focus length is = 0.25 the width of the plateWhen the relationship between the focal length and the width of the plate. Analyzed the length of the parabolic curve touch $linel_1$andl_2

$$\delta = 2\int_a^b \sqrt{1 + [f'(x)]^2}dx(4)$$

$$\delta = 2\int_{-\frac{w}{2}}^{\frac{w}{2}} \sqrt{1 + [f'(x)]^2}dx(5)$$

$$f'(x) = y = \frac{x^2}{4a} = \frac{x^2}{w}(6)$$

$$f'(x) = \frac{1}{w}.2x = \frac{x}{w/2} = \frac{x}{2a}(7)$$

(7) into (5)

$$\delta = 2\int_{-\frac{w}{2}}^{\frac{w}{2}} \sqrt{1 + (\frac{x}{2a})^2}(8)$$

With concept hyperbolic function

$$f'(x) = \frac{dy}{wdx} = \frac{x}{w/2} = \sinh t(9)$$

(8)and(9);

$$\delta = 2\int_0^{\frac{w}{2}} \sqrt{1 + \frac{x^2}{2a}}dx(10)$$

$$\delta = 2(\int_0^{\frac{w}{2}} \sqrt{1 + (\sinh t)^2}\frac{w}{2}\cosh t\, dt)(11)$$

$$\delta = w\left[\int_0^{\frac{w}{2}} \frac{(\cosh 2t+1 dt}{2}\right](12)$$

$$\delta = w\left[\frac{1}{4}\sinh 2\,(0.75049) + \frac{0.75049}{2}\right]^{\frac{w}{2}}(13)$$

$$\delta = w\left[\frac{1}{4}\sinh 1.50098 + 0.375245\right] \quad (14)$$

(14)A long arc

$$\delta = 4\left[\frac{1}{4}\sinh 1.50098 + 0.375245\right](15)$$

To find S-curvature or the width distance of mirror plates in the parabolic dish can be used in all designs if

$$\frac{f}{w} = 0.25 \text{ ซึ่ง} s = 4f\left(\frac{\sinh(1.764)}{4} + \frac{0.882}{2}\right)(16)$$

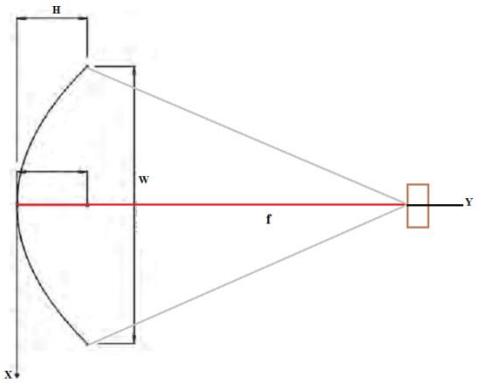


Figure 3 Dimension of parabolic dish

III. TESTING EQUIPMENT

3.1 Mirrors Parabola Plate)



Figure 4 Mirror solar concentrator set



Figure 5 Back frame of mirror plate

3.2 Stove receiving the heat from solar concentration



Figure 6 stove receiving the heat

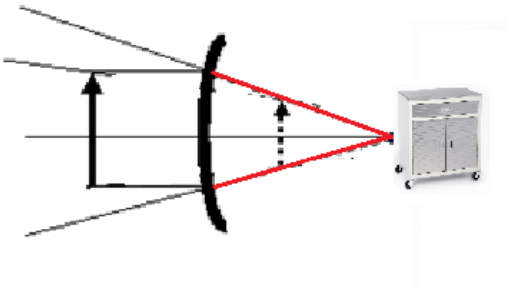


Figure7 Solar concentration and collection



Figure 8 Thermometer for taking temperature in the stove

IV. TESTING METHOD

The efficiency of parabolic mirror solar dryer was tested by placing the parabolic mirror dish to receive solar energy and adjusting its degree to produce the radiation concentration at the focus (focal point) on the back of the stove. The focus plate is made of 2 mm-thick stainless metal. The parabolic dish was adjusted to move 15 degrees per hour in order tofollow the solar angle. The sample products used in the test were local products such as fish, banana, and cashew nut. The testing hours were 9 a.m. – 4 p.m. and during this period, the temperature in the stove was taken every hour.



Figure9Thefresh-water fish were drying by the opened oven



Figure 9 Thefresh-water fish were drying by the closed oven

V. RESULTS

The test was conducted on the sunny day in March 2013. The information was collected every 5 minutes and there was the calculation for an average every hour, from 9 a.m. to 4 p.m., for 7 hours. The average temperatures taken in the stove are as follows:

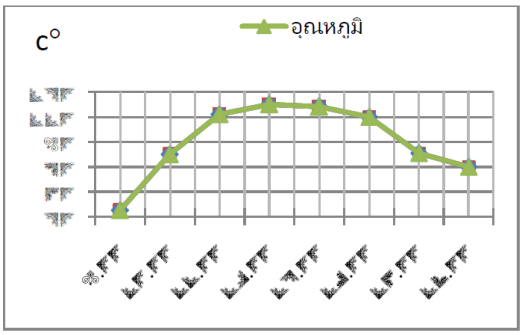


Figure 10 Relation Between Temperature in closed oven and time

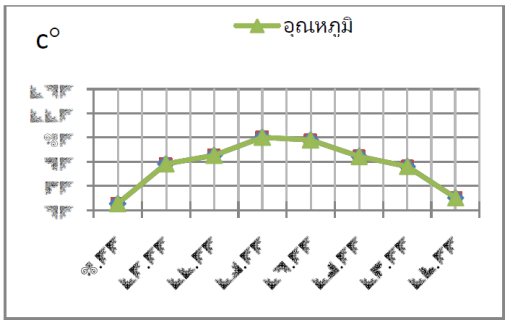


Figure11 Relation Between Temperature in opened oven and time

It is found that while the temperature of the location where the equipment was placed was 28-33°C, the temperature in the stove got higher during 9 a.m. - 1 p.m. After that, from 1 p.m. to 4 p.m., the temperature gradually decreased. In addition, when there were clouds, the temperature was stable for 10 minutes before decreasing.

The temperature in the stove (in closed system) was at the lowest which was 33°C at 9 a.m. and at the highest which was 120°C at noon. The average temperature (in closed system) equaled 90.75°C. However, in the open system the lowest temperature was at 33°C at 9 a.m. and the highest temperature was at 90°C at noon. The average temperature (in open system) was 67°C.

VI. CONCLUSION

The study on parabolic mirror solar dryer involves the development of the equipment that allows the community to use and apply renewable solar energy in processing. The equipment's materials can be found in the community, for example, mirror plate, steel frame, and stainless cabinet. After the test, it is found that in the sunshiny condition, in 7 working hours the stainless stove which is the receiver of solar concentration could generate up to 105 degrees Celsius in the closed system and approximately 80 degrees Celsius in the open system. Therefore, this equipment can be used properly in drying local foods such as fish, banana, herb, and other agricultural products.

Symbol List
δ = declination angle degree
ω = hour angle of the sundegree
f = focal distance m
x = horizontal position m
y = vertical position m
u = heat loss coefficient W/m2.K
n = number of days per year
S = curvature of parabolic mirror dishm
W = parabola aperture m

ACKNOWLEDGEMENT

The authors would like to thanks Rajamangala University Rattanakosin (RMUTR) andThe Thailand Research Fund (TRF) for financial support for this research.

REFERENCE

[1] BanchaKongtrakul(2008). Mathematical Modeling of a Parabolic Concentrator for a Solar –Power Stering Engine. The 4th Conference on Energy Network of Thailand. Silpakorn University.
[2] PrakobSurawattanawan&TeerapathLimboonruang. (2011). Mathematical Modeling and the Design of Solar Parabolic Trough. The 25th Conference of the Mechanical Engineering Network of Thailand. Kasetsart University and Thai Society of Mechanical Engineers.
[3] HarirakKuanpradit. The Development of Solar Parabolic Concentrators in Drying Process. Srinakharinwirot University.
[4] WatcharinDongbang&WithayaPuangsombat. (2009). Parabolic Trough Solar Water Heater. The 5th Conference on Energy Network of Thailand. Naresuan University.
[5] Fareed M. Mohammed.(2012)Design and Study of Portable Solar Dish Concentrator. International Journal of Recent Research and Review, Vol. III. Tikrit University, Iraq
[6] Ibrahim Ladan Mohammed (2012) Design and Development Parabolic Dish Solar Water Heather ,International Journal of Engineering Research and Applications (IJERA) Vol.1 Issue 1
[7] Lifang Li (2011) A New Design Approach for Solar Concentrating Parabolic Dish Based on Optimized Flexible Petals ,Accept for publication in the Journal Mechanism and Machine Theory, Harbin, China.
[8] Saad D. Odeh & Hosni I. Abu-Mulaweh(2013) Design and development of an educational solar tracking parabolic trough collector system. Global Journal of Engineering Education, University of South Australia

★★★