DEVELOPMENT OF HEAT-BOX TYPE SOLAR COOKER AS EDUCATIONAL MATERIAL

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ABSTRACT

Our box type solar cooker named "AIT-Educooker" was produced in order to complete the lineup of Japanese solar cookers as educational materials. Now we have concentrator type, panel type, and heat box type low-priced solar cookers on the market. Japanese sunlight is satisfactory but not as abundant as other countries suitable for solar thermal applications. Therefore all the educational solar cookers have to be effective enough to persuade the students of the validity of them throughout the year. Our box type solar cooker is designed through the ray tracing technique to have both the high cooking power when adjusted to the sun frequently and high robustness of up to four hours when left unadjusted.

Keywords: Box-type, educational material, adjust-free, ray tracing.

1. INTRODUCTION

Commercial solar cookers in Japan are categorized into two main groups. One consists of the industrial products at relatively high prices which are mostly regarded as devices for leisure hours. The others are educational materials aimed at the school children. In many cases they are low priced in order to distribute one solar cooker to each person or to a small group. In Japan solar cookers are still not very popular but some of them are introduced in the science textbooks used in elementary schools. In spite of their low saturation level, many educators think solar cookers are ideal tools to enlighten children on fundamental physics and renewable energy. In this study, we report on the kit of a box type solar cooker newly developed by Ashikaga Institute of Technology as an educational tool.

Figures 1 through 3 shows three different kinds of solar cookers produced in Japan on a commercial basis. Asagao in Fig. 1 representing the concentrator type solar cookers is designed by Mitsuko Karino of Japan Solar Cooking Association and produced by Jukankyo-Kobo in 2003. The price is less than four dollars. A portable solar cooker, Sola-range in Fig. 2 represents the panel type solar cookers and the basic shape is designed by Yasuko Torii who has been devoting herself to the dissemination of solar cooker in Japan since 1991. "Sola" in Japanese means sky. Finally it was brought to market by Eco-club Suginami (present Japan Solar Energy Education Association) in 2004. To date, more than 600 sets are sold at the price of less than five dollars a set.

Fig. 1 Asagao (meaning morning glory) produced by Jukankyo-Kobo.

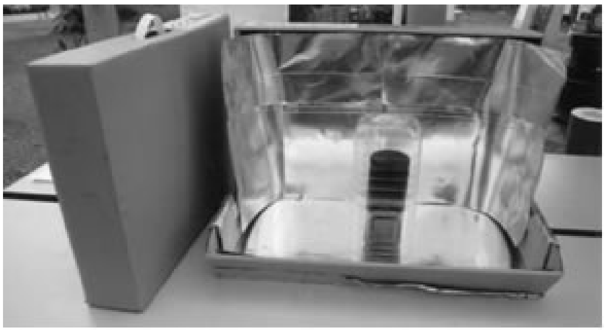

Fig. 2 A portable solar cooker produced by Japan Solar Energy Education Association.

Fig. 3 Newly developed AIT-Educooker.

2. <u>BACKGROUND</u>

The history of solar cooker in Japan dates back to 1947 when Saizo Goto, the president of Goto Optical Mfg. made the first Japanese solar cooker subsidized by the Japanese government. He made two solar cookers and brought one of them to the first ISES symposium held at Phoenix, Arizona in 1955. Goto Optical Mfg. is a long-established company manufacturing optical devices and especially famous for planetariums and telescopes but few Japanese remember that they also made solar cookers because they were not commercialized.

The first solar cooker on the market in Japan is probably "Sunchef" designed by CLEVELAB Inc. It was similar to the present model "Sunspot". A Japanese cardboard company got the license to manufacture it in Japan and started selling it as camping item around 1990. People who are concerned about environmental problems or renewable energy found it interesting, but the business was far from successful. However, it was just then that we experienced the collapse of Japan's overheated bubble economy and many of us began to turn our attentions to the energy efficiency and finally to the sustainable energy systems. Some researchers including myself started studying solar cookers as a form of solar thermal application at this time.

The pure Japanese first solar cooker on the market is "Kirapika", a parabolic concentrator type solar cooker designed and manufactured by Motoharu Takizawa at Kobo-Amane. Up to now (2006.3) the sales totaled above 600 units since it was first brought to the market in 2002. When he designed Kirapika, he did not limit its usage to a particular purpose. As a result, some are used for leisure items, some are for daily cooking tools, the others are bought by teachers for educating school children and this purpose has an increasing percentage these days. Additionally there are many inquiries from developing countries but the price is not affordable enough for them to buy large quantities.

As can be seen from Kirapika's case, many educators are aware of the potentialities of solar cooker as a teaching material, and in 2005 one of the science textbooks for the third grade pupils of primary school employed a solar cooker to explain about the sun's energy. In 2003 the Solar Energy Education Association of Japan was founded. Although the name of their association covers a wide area, large part of their work is assigned to the support of teachers in science classes of primary schools giving outdoor lessons on solar energy using solar cookers. In 2004 the Japan Solar Cooking Association started their systematic activities after a few years preparation. The members are spread all over Japan and include most active persons on solar cooker despite the small size of the organization.

In Ashikaga Institute of Technology, we have "Wind and Sun Square" which was established in 1995 to enlighten people to the renewable energies and sustainable systems. As for wind part, small and micro wind turbines mainly feature our square. The total number of installation is more than 30 and is increasing every year. In the exhibition hall, old Japanese wind turbines as historical materials, models, toys, pictures, books, and other items relating to wind turbines and windmills are displayed. In another room, we exhibit many solar cookers collected inclusively from the Japanese market. In the field of the square, we undertake many outdoor classes concerning natural energy requested by various schools ranging from fundamental schools to universities.

Through our activities concerned with solar cookers, we are strongly convinced that it is an effective tool to educate youngsters and enlighten people of all ages.

Fig. 4 Wind and Sun Square at AIT.

Fig. 5 Examples of outdoor classes for high school students at AIT.

3. THIS PROJECT

Convinced that the solar cookers are good teaching tools, we realized the strong necessity for a box type solar cooker as an educational tool to complete the variety. It has to be effective enough to completely cook within assigned school hours which are in most cases 90 minutes or two successive school hours. It should have both the merits and demerits of box type solar cookers clearly because some teachers may want to explain the difference between the various kinds of solar cookers. Additionally it has to work through the year in Japan when it is clear.

3.1 Design Concept

The desired specifications to fulfill our needs are as follows.

i) It is made of cardboard to make modification by students easy.
ii) It is compact when folded but large enough for practical cooking.
iii) It is easy to use and robust for the adjustment to represent the box type solar cooker, but powerful enough to complete the cooking within the limited school hours.
iv) The price is reasonable enough for the limited budget of public schools.
v) It comes with a fully self-contained manual friendly to the people of all ages.

3.2 Design

To enforce the power we employ two booster mirrors and a narrow complementary mirror as shown in Fig. 6. Because of this arrangement, the front of the cooker is facing the diagonal direction of the box and the sun receiving area increases 40% comparing with the conventional box type cooker and the ratio of the light hitting the pot to the received amount of light also improves from 14% to 20% in the winter season in Japan as shown in Fig. 6. For the better reflection of the light to the center of the inner box, we use asymmetric truncated pyramid for the shape of inner box and reverse the direction according to the seasons. (See Fig. 7.)

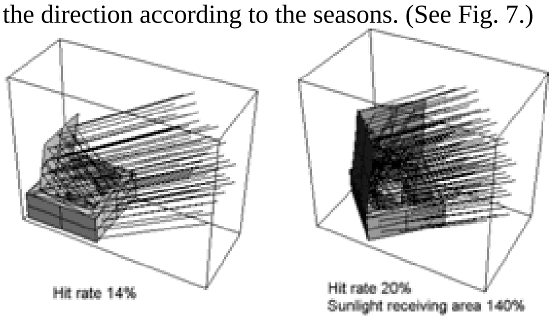

Fig. 6 Improvement by using two booster mirrors.

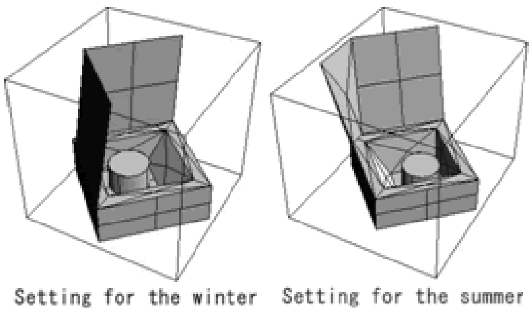

Fig. 7 Setting of the Educooker in different seasons.

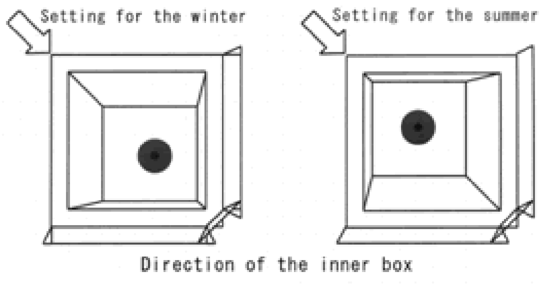

Fig. 8 Direction of the inner box in different seasons.

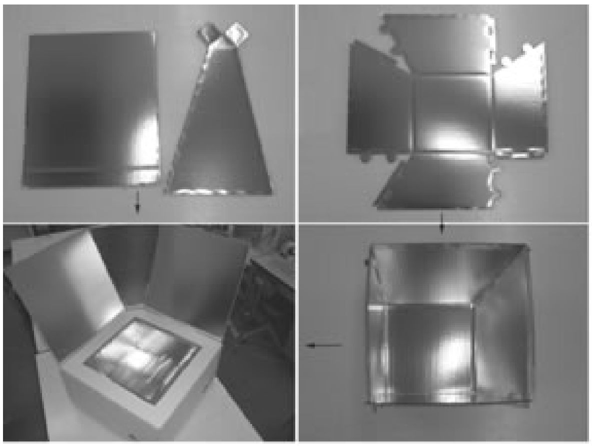

Fig. 10 Parts and assembly of the AIT-Educooker.

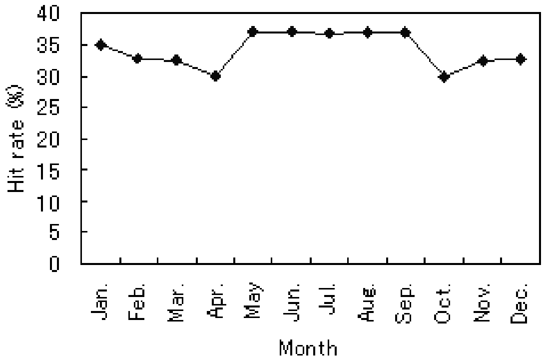

Fig. 12 Ratio of the light hitting the pot at noon through a year.

3.3 Estimated performance

Fig. 11 shows that the optimally designed inner box shape gives consistently stable cooking power through a year where the empirically determined shape gives higher performance in summer and poor performance in winter. Fig. 12 shows the effect of the method to reverse the direction of the inner box according to the season. The ratio of the light hitting the pot at noon (when the sun elevation is highest) is quite constant through the year. The Japanese sun elevation at noon through the year varies approximately from 30 degrees in winter to 75 degrees in summer. Because the Educooker is designed to sit on the ground horizontally for the ease of construction by children and stableness during the cooking, it is very difficult to obtain a constant concentration of light around the pot. The figures show that it can collect enough sun light into the box even in winters. This also means versatility of the Educooker when used in different countries where the sun elevation differs from Japan.

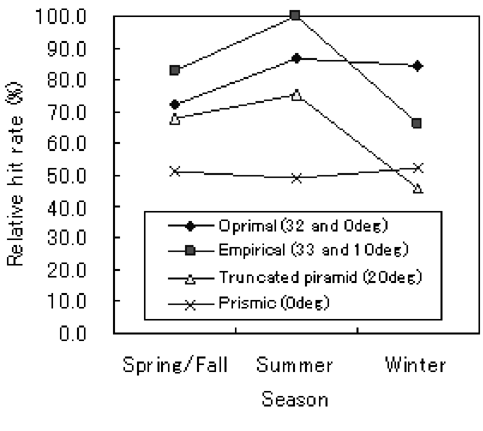

Fig. 11 Ratio of the light hitting the pot for various inner box shapes.

Fig. 13 shows the robustness of the cooker. The ratio of the light hitting the pot is calculated assuming that it is directed to the South and other settings are fixed for the sun elevation at noon. Even if it is left unadjusted, it can lead the light to the pot for nearly four hours in both seasons. Even if unadjusted, a pot of rice which is enough for three to four people can be cooked in two hours and stews can be made extraordinarily tender if left it in sunshine for four hours.

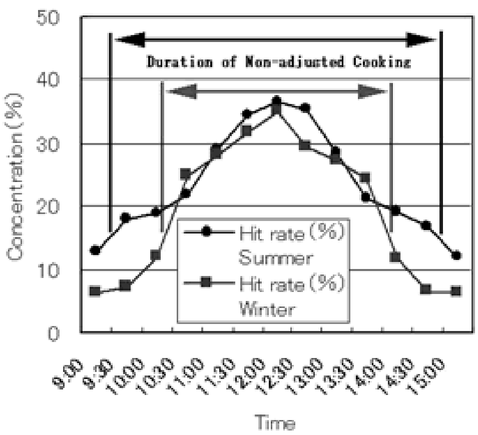

Fig. 13 Ratio of the light hitting the pot when it is directed to South and left unadjusted.

TABLE 1 SETTING OF THE BOOSTER MIRROR.

Month	Angle of the center booster mirror	Direction of the inner box
Jan.	-8	Winter setup
Feb.	-5	Winter setup
Mar.	0	Winter setup
Apr.	5	Summer setup
May	10	Summer setup
Jun.	15	Summer setup
Jul.	21	Summer setup
Aug.	15	Summer setup
Sep.	10	Summer setup
Oct.	5	Summer setup
Nov.	0	Winter setup
Dec.	-5	Winter setup

3.4 Assembly and operation manual

In the manual, assembly, settings, and cooking tips are explained graphically with a lot of illustrations. (See Fig. 14 and 15.) Total number of pages is eight including a page of two recipes. All illustrations are drawn by a student of AIT. We have both Japanese and English versions.

Fig. 14 The cover and the examples of cooking.

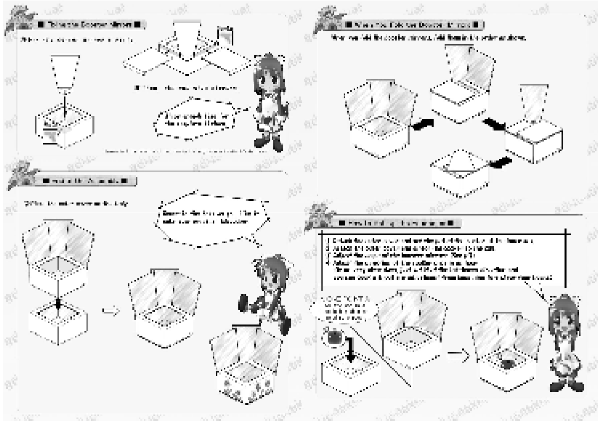

Fig. 15 An example of a page in the manual.

3.5 Example of cooking

Japanese live on rice, so it is a good material for demonstrations of solar cookers. Although we cook rice everyday, few of us know that rice can be cooked without a rice-cooker. Actually most of us rely on electrical rice-cookers to cook rice and we do not even use ordinary pots or pans. Because the rice is too common to us, you can deeply impress the people by cooking rice with solar cookers. Fig. 16 shows a cup of rice cooked in 90 minutes in the winter season in Japan.

Fig. 16 Cooked rice.

4. CONCLUSIONS

Our box type solar cooker, "AIT-Educooker" was developed in order to complete the lineup of Japanese solar cookers as educational materials. Now we have concentrator type, panel type, and heat box type low-priced solar cookers. It was designed through the ray tracing technique to have both the high cooking power when adjusted to the sun frequently and high robustness of up to four hours when left unadjusted. The kit comes with a tools, a pot, and a comprehensive instruction manual. We are ready to sell it at 40 dollars including shipping charge in Japan.