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DEVELOPMENT AND PERFORMANCE TESTING OF A LIGHT WEIGHT PORTABLE SOLAR RICE COOKER IN RURAL AREAS OF BANGLADESH

R. Ahamed[1], M. A. Kader[2], M.M.Rashid[1] and M.M. Ferdaus[1]*
[1]Department of Mechatronics Engineering, International Islamic University Malaysia
[2]Department of Mechanical Engineering, Rajshahi University of Engineering and Technology
Rajshahi-6204, Bangladesh
E-mail: mahbub@iium.edu.my, talhame07@gmail.com

ABSTRACT
Generally sunlight is one of the most potential sources of energy on earth. Among the total energy consumption, energy consumption for cooking is a leading component in developing countries. Most of the rural people in Bangladesh use biomass fuel for cooking such as wood, cow dung, jute sticks or other agricultural wastes. Hence, there is an attentive necessity for the improvement of alternative, suitable, cheap mode of cooking in Bangladesh. This paper presents the thermal performance of a light weight Portable Solar Cooker (PSC) using parabolic shaped umbrella with aluminum foil coating. An umbrella of 125 cm diameter was used as a frame of the portable cooker because it is more convenient to transport and its surface area is almost parabolic. The aluminum foil was attached to the inner side of the umbrella with white glue which acts as reflector plate. The focal length of the parabolic surface was 26.16 cm. The maximum temperature of the experimental water recorded was 98˚C at around 12 PM. The investigational time was from 10:00 AM to 01:00 PM. The cooking power and energy efficiencies of the PSC were in the range 37W to 149.3 W and 2.8 % to 11.59%, respectively.

Key words: Solar cooker, portable cooker, temperature and aluminum foil.

Glossary

T_a Ambient Temperature (ºC)
T_w Water Temperature (ºC)
I Solar radiation in W/m^2
A Inside surface area of umbrella in m^2
C_p Specific heat capacity at constant pressure in J/ (kg)
ΔT_w Is the water temperature difference in k
Δt Is the duration of time
P Average heating power of a solar cooker
η Eenergy efficiency of the solar cooker
PSC Portable solar cooker

1. INTRODUCTION

Cooking rice in house is one of the old-style culture and vital events of Bangladesh. It is a staple food in most of the South Asian countries and a big part of energy is spent for cooking (Anoopa et al. 2012; Roy et al. 2011). Solar cooking is the easiest, harmless, furthermost appropriate way to cook rice without consuming fuels in recent conventional fuel crisis situation (Pillai et al. 2009; Lior, 2010). Cooking with solar energy has extensive been offered as a good-looking solution for reducing fuel wood sources, time saving and additional ecological difficulties (Wentzel et al. 2007). Bangladesh is a perfect place for solar energy application and regular solar radiation differs among 4.1 to 6.5 kWh each square meter (Rofiqul Islam et al. 2008; Alam Hossain Mondal et al. 2010). Extreme amount of solar intensity is existing on March - July and lowest on December-January. The climate conditions of Bangladesh are promising for solar energy applications and solar cooking is a good possibility for general use. Many researchers have developed different types of simple solar cooker. Al-soud et al built and tested a portable cooker and three days performance result presented that the water temperature reached 90 ˚C in typical sunlight days (Al-Soud et al. 2010). Badran et al (2010) designed, built and verified a parabolic solar water heater. The authors found that, the water heater was capable to heat 30 kg of water from 22 °C to 50 °C in 2½ h in the collector mode. The peak efficiency found for this parabolic solar water heater was 77% and the gradient of the efficiency curve was 10.63 W/m^2 °C. Ozturk designed and built a PSC and calculated its energy efficiencies (Ozturk et al. 2004). The cooking power of the PSC varied from 20.9 to 78.1 W and the energy efficiencies of the PSC varied from 2.8 to 15.7 respectively. Notwithstanding their capability to offer suitable temperatures required for boiling and cooking, all the above mentioned categories of concentrating solar cookers suffer outstanding to some drawback. The main drawbacks of these previous works are heavy weight of the cooker, complexity in construction and comparatively high cost.

In this research a light weight umbrella have been used to construct the portable solar cooker. So, the presented work is able to resolve the abovementioned limitation.

2. EXPLANATION OF THE METHOD

The tests were guided on July 2012 in behind the Mechanical Heat Engine Lab, Rajshahi University of Engineering and Technology (RUET) in Bangladesh.

2.1. The Portable solar cooker

The photograph of the investigational set-up has been shown in Fig. 2. The main components of the developed

PSC were (1) An Umbrella (16 segment) (2) Aluminum foil (reflection index: 85%) (3) Cooking pot (locally available which height 10cm, diameter 16cm, thickness 1.5 cm) known as a saucepan and (4) Stand.

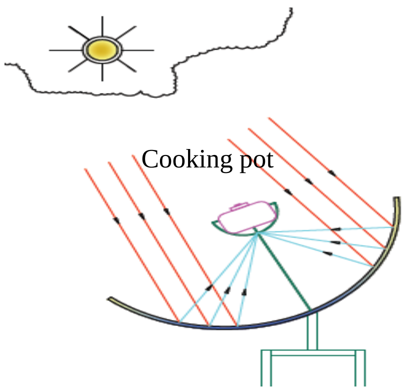

Figure 1 Schematic of portable solar cooker

The portable solar cooker was designed to be together adaptable and dismountable, by a display and heat concentrator thru from reflective aluminum foil. The support is a stand made of iron (angle bar) and G.I. pipe in which the whole arrangements are mounted by screw mechanism. An umbrella of 125 cm diameter was used as a frame of the presented portable solar cooker because it was more convenient to transport and its surface area was almost parabolic. The aluminum foil was attached to the inner side of the umbrella with white glue which acts as reflector plate. The reflector surface was faced towards the sun, such that the most shining zone was located on the handle with permanent leveler that was obviously on the focal point of the reflection surface. The focal length of the parabolic surface was 26.16 cm. The umbrella can be tightly attached by the screw to give a constant stability on irregular ground and permitting any essential feeling for the reflector. The pressure cooker stand must be fixed on the point of most shining zone. The sunlight was reflected from the inner surface of the umbrella and reflected heat will fall to the bottom and surface of the saucepan.

2.2 Performance tests of the solar cooker

To determine the performance of a solar cooker, characteristics (power, energy efficiency) values need to be defined. The typical cooking power of a solar cooker is calculated as:

$$P = mC_p \Delta T_w / \Delta t$$

Where m is the mass of water in kg, C_p is the specific heat capacity at constant pressure in J/ (kg), ΔT_w is the temperature difference in k, Δt is the duration of time (Schwarzer et al. 2008).

The ratio of the energy output (water increasing temperature) to the energy input (solar radiation) is known as energy efficiency of the solar cooker (Hasan et al. 2004).

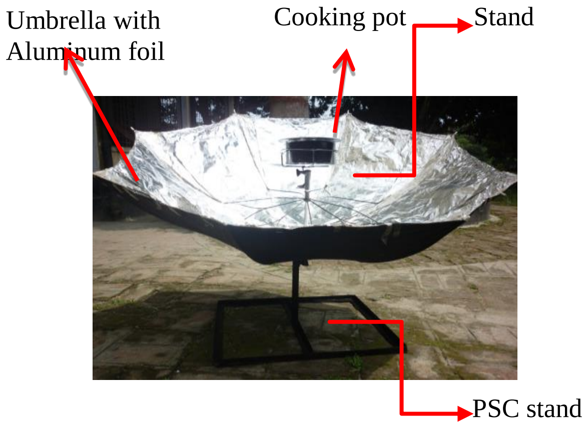

Figure2 Photograph of the portable solar cooker

Hence the instant energy efficiency of the solar cooker is calculated as follows:

$$\eta = \frac{\frac{mc(T_{wf} - T_{wi})}{\Delta t}}{IA}$$

Where I is the solar radiation in W/m^2, A is the surface area in m^2.

The formula of the equation of the parabola: $x^2 = 4ay$, and its focus is at (0, a).

3. MODELING OF THE SYSTEM

The experiments for the PSC were accompanied in 5 days. In the experimental period, the subsequent amounts were measured: T_a, T_w and I on a parallel surface. The water temperature inside the pan was measured by using ordinal thermocouples which have suitable precision and rapid reply and solar intensity was measured by the sensor which is known as solar sensor. Solar intensity on a parallel surface, ambient air temperature and water temperature were noted after every 15 min through the tests. The amounts of 1 kg water was taken inside the cooking pot and the PSC experiments were conducted between 10.00 to 13.00 solar times. In the period of test the ambient temperature was varied from 30 to 37℃ and solar intensity was in 1160 W/m^2. Water temperature inside the pot was recorded and it was increased from 32 to 98℃. After every 30 min the PSC direction was adjusted to retain the solar intensity fixated on the pot.

4. RESULTS AND DISCUSSION

Fig. 3-5 are displayed the investigational effects of the PSC. Fig. 3 displays the change of the water temperature Tw in the cooking pan with time t. The water temperature in the pot increased from 32 to 98℃ with increasing solar radiation. This extreme water temperature 98℃ was touched after 1.5 h. The ambient air temperature increased from 32 to 34℃, but the solar intensity increased from 550 to 1420 W/m2.

Fig. 5 shows the cooking power and cooking efficiencies of PSC in different times. PSC cooking efficiency varied from 2.8% to 11.59% and the regular typical cooking efficiency was 7.2%. The PSC cooking power varied from 37 to 149 W and the usual day-to-day coking power was found to be 93 W. Cooking power and cooking efficiencies are exaggerated mostly by some reasons; the level of water temperature, solar intensity energy and ambient temperature. The efficiencies increase as the time of the day passes and showed its peak of energy efficiency at 12 pm and continuously diminish after the noon.

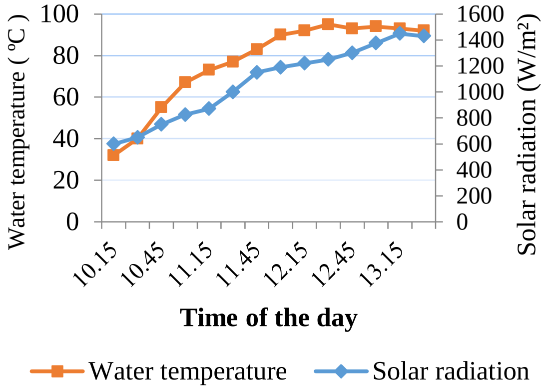

Figure3 Change of water temperature and solar radiation with time of day.

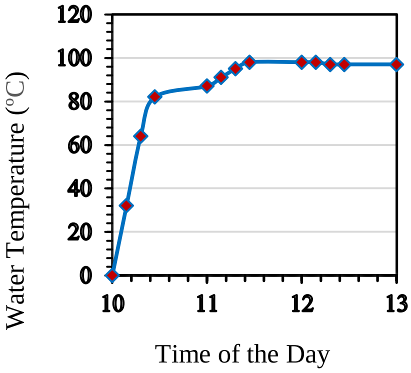

Figure4 Change of water temperature with time of the day.

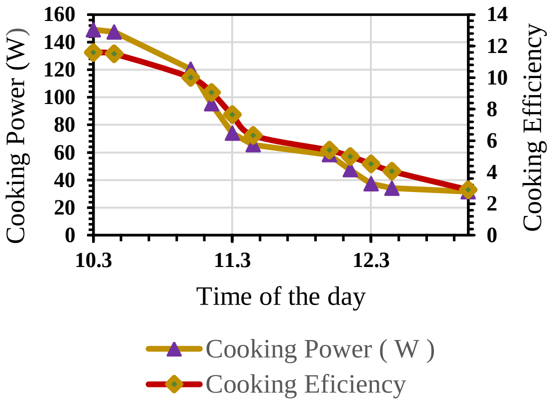

Figure5 Change of the cooking power and cooking efficiencies of PSC in different time

5. CONCLUSION

The specialty of this PSC is the circular folding of its heat concentrator, whereas another mechanisms can simply be accumulated and dis-accumulated. After opening the diameter of the heat concentrator is 1.25 m and solar assembly area is 1.11 m^2. The use of convenient umbrella frame have shortened the design of the solar cooker for the operator, decreasing the accumulated (2 min) and dis-accumulated (1 min) times. The little mass (4 kg) and capacity of this PSC make it simple to take somewhere. Experiments have determined that the solar cooker touches a typical power of 100W on a sunshiny day. This stores adequate energy can cook an artless meal for two persons in an ordinary interval of 1 h. This PSC consequently delivers a portable, low-cost, and ecologically friendly cooking, food heating, and water heating.

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