

Solar Cooker for Night Cooking

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ABSTRACT: A novel design of a solar cooker for night cooking is proposed in this project. The solar heat energy is utilized to cooking food. To use the energy emitted by the sun for cooking reduce the other fossil fuel usage for cooking. The heat storage system is a well-insulated container made of clay and coconut husk. Dry sand is used for store the heat in the form of sensible heat. The system was designed to achieve maximum amount of heat store and which is used for the night cooking purpose. The theoretical calculation showed a good efficient results. The proposed solar cooker design is economically viable and environmentally friendly. The design of this solar cooker is very simple and the majority raw materials of this solar cooker is easily available and low cost. This solar cooker is mainly applicable in domestic use.

KEYWORDS: Parabolic dish, Solar heat storage system, heat storage system calculation, Parabolic dish calculations

I. INTRODUCTION

Wood, biomass and fossil fuels are being used as cooking fuels worldwide on large scale. These elements not only cause environmental hazards but also lead to rapid deforestation, global warming, and depletion of natural resources. To resolve these issue, environmental agencies are working hard in searching climate friendly solutions. Even the top energy consumption countries proposed to utilize renewable energy sources instead of fossil fuels.

Various studies of solar cookers, some have focused on local applications and one type of cooker, while, various on thermal storage unit and on structure of cooker. Recently, studies have been conducted on economic aspects of solar cooking system in specific region such as Lebanon and India. Also, many studies analysed and compared various types of solar cookers conducting energy and exergy analysis for evaluating their thermal performances. In this project a solar thermal heat storage system is used for night cooking.

Designs of solar thermal energy storage system need to consider three important factors: technical properties, cost effectiveness and environmental impact. Thermal energy researches of latent heat storage with Phase Change Materials (PCM) have drawn attentions of solar power generation and other applications due to their high phase transition enthalpy and high working temperature. Sometimes, it is good to use a combination of latent and sensible thermal storage for optimal utilization of the available energy.

The main focus of this project was to investigate if heat was transported from receiver to storage without major heat loss.

II. RELATED WORK

The concept of parabolic dish solar cooker get from Muhammad Nomana [1]. The design and focal point c is calculated using the paper by Berryman [3]. And the construction of parabolic dish, the concept taken from the paper by Jorge Alexander Alarcon [5]. The heat storage system design concept get from the paper Asfaw Haile Selassie [2]. The main component used to make the heat storage system is clay/mud. The idea about Heat Transfer Characteristics of soil thermal storage in the non-heating get from the paper Cang Tong [4].

III. METHODOLOGY

A schematic illustration of a solar cooker for night use is shown in Fig. The dimension of the solar cooker was also plotted in the figure. During the sunshine hour of the daytime, the parabolic dish directly reflects solar radiation and supplied to the solar heat storage system. The heat storage system have two similar lids one is lower lid and other is upper lid. The lower lid is attached to the focal point of the parabolic dish. During day time the lower lid is opened and the upper lid is closed. During day time the solar radiation is reflected with the aid of parabolic dish solar concentrator. The energy stored in the form of sensible heat by the solar heat energy storage system. At night time the lower lid is closed and upper lid is opened and the container placed in the upper lid position. The stored heat is coming out through the upper lid and that heat is used for night cooking purposes.

The heat storage system have two similar type frustum it have three layer, one is dry sand and other two are coconut husk and clay. The outer most layers clay and coconut husk are using for insulation it have low thermal conductivity so it prevent the heat transfer which is stored by the solar thermal storage system. The inner layer is made with an aluminium sheet and which is filled with dry sand. The dry sand have high thermal conductivity and heat storage capacity.

The dimensions of the heat storage system is a frustum which base diameter is 600mm and the upper side diameter is 150mm. the height of the frustum is 400mm.

The parabolic dish solar concentrator dimensions are, the diameter of the dish is 1000mm and the depth is 150mm.

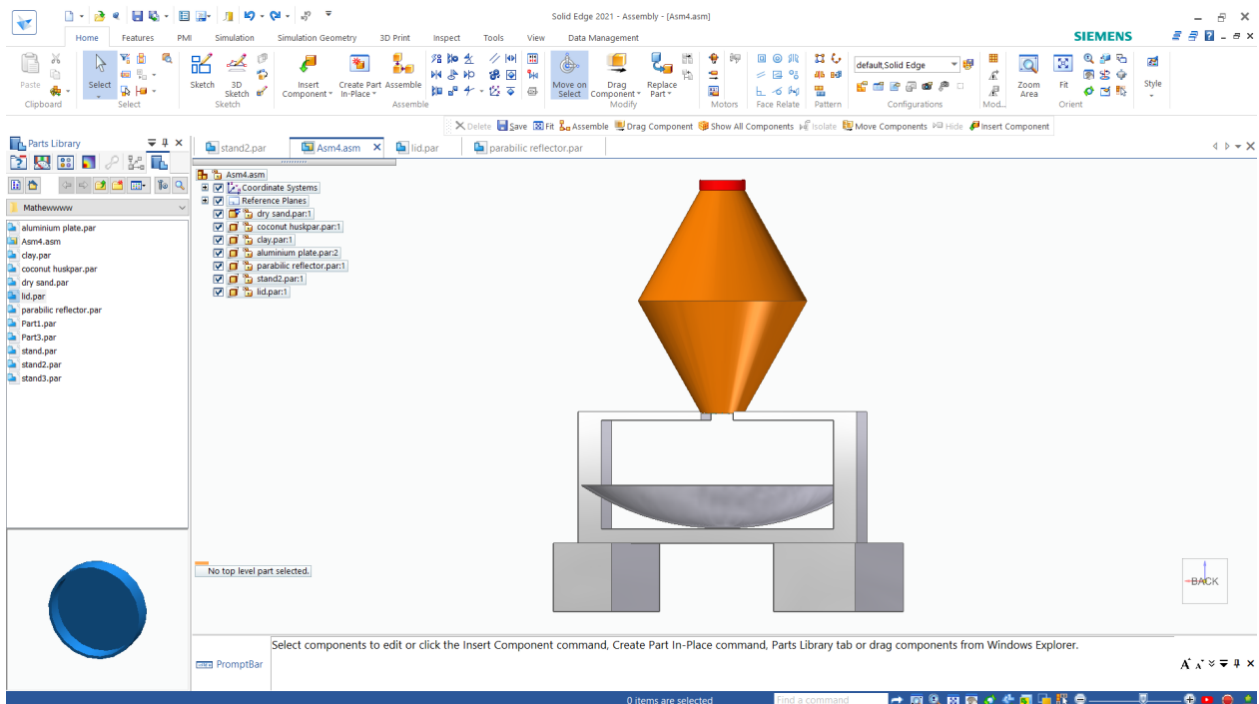


Fig.1. 3D drawing of solar cooker for night cooking

ANALYTICAL WORK

Solar heat storage system calculation,

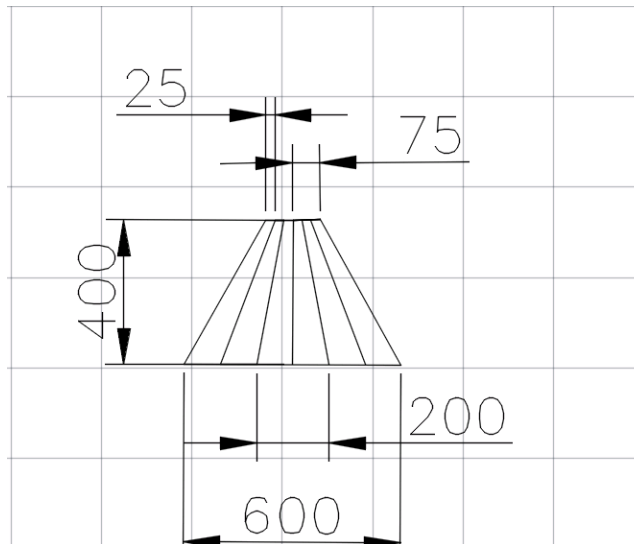


Fig.2. CAD drawing of frustum

The solar heat storage system contain two similar type of frustum.

$$\text{Volume of frustum, } = \frac{h}{3} \times (A_1 + A_2 + \sqrt{A_1 \times A_2})$$

$$\text{Area of circle} = \pi r^2$$

$$\text{Volume of frustum (dry sand)} = \frac{400}{3} \times \pi \times 25^2 + \pi \times 100^2 + \sqrt{\pi \times 25^2 \times \pi \times 100^2} = 5.5 \times 10^6 \text{ mm}^3$$

$$\begin{aligned} \text{Volume of frustum (coconut husk)} &= \frac{400}{3} \times (\pi \times 50^2 + \pi \times 200^2 + \sqrt{\pi \times 50^2 \times \pi \times 200^2}) - 5.5 \times 10^6 \\ &= 22 \times 10^6 - 5.5 \times 10^6 = 16.5 \times 10^6 \text{ mm}^3 \end{aligned}$$

$$\begin{aligned} \text{Volume of frustum (clay)} &= \frac{400}{3} \times (\pi \times 75^2 + \pi \times 300^2 + \sqrt{\pi \times 75^2 \times \pi \times 300^2}) - 22 \times 10^6 \\ &= 49.5 \times 10^6 - 22 \times 10^6 = 27.5 \times 10^6 \text{ mm}^3 \end{aligned}$$

$$\text{Total volume (dry sand)} = 2 \times 5.5 \times 10^6 = 11 \times 10^6 \text{ mm}^3$$

$$\text{Total volume (coconut husk)} = 2 \times 16.5 \times 10^6 = 33 \times 10^6 \text{ mm}^3$$

$$\text{Total volume (clay)} = 2 \times 27.5 \times 10^6 = 55 \times 10^6 \text{ mm}^3$$

$$\text{Total volume of the heat storage system} = 11 \times 10^6 + 33 \times 10^6 + 55 \times 10^6 = 99 \times 10^6 \text{ mm}^3$$

The total specific heat storage capacity by the solar heat storage system,
(Assume at 1800 seconds the $dt = 100 - 25 = 75^\circ\text{C}$)

$$q = V\rho cp dt$$

$$= 0.011 \times 1600 \times 2000 \times 100 = 2.64 \times 10^6 \text{ J}$$

$$(W = J/s)$$

There for, $2.64 \times 10^6 = 2.64 \times 10^6 \times 1800 = 1466.6 W$

Focal point calculation,

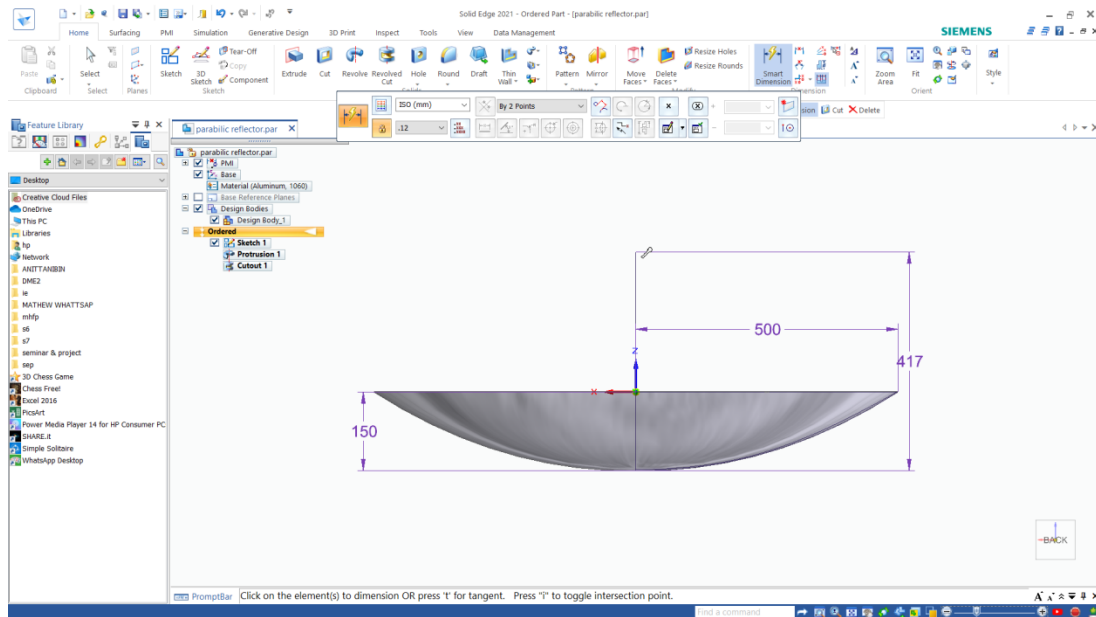


Fig. 3. 3D drawing of parabolic dish

$$\text{Focal point distance} = \frac{x^2}{4a} = \frac{500^2}{4 \times 150} = 417 \text{ mm}$$

Surface area calculation,

$$\text{Surface area} = \pi \times \left(\frac{c^2}{4} + a^2 \right) = \pi \times \left(\frac{1000^2}{4} + 150^2 \right) = 856 \times 10^3 \text{ mm}^2$$

Calculation for energy received by the parabolic dish,

Total energy emitted by the sun,

$$Eb = \sigma A_{sun} T^4$$

$$= 5.67 \times 10^{-8} \times (4\pi \times r_{sun}^2) \times 5775^4 = 5.67 \times 10^{-8} \times (4\pi \times (0.7 \times 10^9)^2) \times 5775^4 = 3.8833 \times 10^{26} W$$

The emission received Per m^2 ,

The sun may be assumed as a point source at a distance of $15 \times 10^{10} m$ from earth. The mean area just outside the earth's atmosphere over which the radiation will fall is,

$$= 4 \pi R^2 = 4\pi \times (15 \times 10^{10})^2 = 2.8274 \times 10^{23} m^2$$

So the emission received per m^2 ,

$$= \frac{3.8833 \times 10^{26}}{2.827 \times 10^{23}} = 1373.44 W/m^2$$

The energy received by the earths,

Assume the earth is a spherical body. The energy received by it will be proportional to the projected area.

ie. Area of earth = πr_{earth}^2

There for , Energy received by the earth = $1373.44 \times (\pi \times (6.4 \times 10^6)^2) = 1.7673 \times 10^{17} W$

The energy received by the solar collector,

The direct energy reaching the Earth = $(1-0.4) \times 1373.44 = 824.064 W/m^2$

(Atmospheric loss is 40%)

The diffuse radiation (20%) = $0.2 \times 824.064 = 164.813 W/m^2$

Total radiation reaching the collector, = $824.064 + 164.813 = 988.88 W/m^2$

The projected area of parabolic dish = $0.856 m^2$

Energy received by the solar collector, = $988.8 \times 0.856 = 846.41 W$

IV. CONCLUSION

Now days the energy consumes level increases so the total fossil fuel energy level decreases. So many countries are use solar energy for many purposes. Solar energy also used for cooking purposes because solar energy is green energy source, economic and environment friendly etc.

Using the solar cooker for night cooking, the main drawback of the solar cooker will solved.

The effective design of solar cooker will reduce the time for cooking. In India around 5 crores domestic parabolic cookers are worked. Crores of tons of biomass and wood fuel can be saved and CO₂ pollution can be avoided.

Through this project we are proposed an efficient method of the solar cooker which is also used for night cooking purposes.

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