Undergraduate Research Symposium 2k20

MURS 2020 Mahindra University Research Symposium

Solar Cooker with Low Cost Sensible Heat Storage Medium

Anil Kumar B C[1] , Ranjith Maniyeri[2] , Anish S[3]

Introduction:

- Solar energy as an inexhaustible source for cooking has been the primary interest of many researchers for the past four to five decades.
- To extend the usability of Solar cooker in the late evening hours, different sensible and latent heat storage materials are used.
- The primary objective of this work is to determine the optimum surface area of absorber plate in solar box cooker (SBC) with the aid of analytical heat loss and design equations using an iterative solution procedure.
- The second objective is to identify the optimum mixture of low-cost sensible heat storage materials so that the device can perform effectively in the evening hours also.
- A performance evaluation has been carried out experimentally using the optimum mixture of heat storage materials such as iron grits, brick powder, sand and charcoal powder.

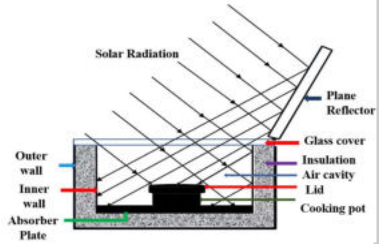

Figure 1. *Solar box cooker.*

Literature Review:

- Basic working principle of all kinds of SBC is similar but their performance will be different by the design modifications in external or internal part such as:
  - Reflector, absorber plate, cooking vessel etc. (Aramesh et al. 2019)
- Proposed various test procedures and performance assessment parameters:
  - First and second figure of merit, cooking power, energy and exergy efficiency, effects of instrumentation for testing, revised testing procedure and new figure of merit, effective concentration ratio, heat retention time.
- Use of sensible and latent heat storage materials in SBC include (Nkhonjera et al. 2017)
  - Sand, engine oil, vegetable oil, carbon etc.
  - Phase change materials (stearic acid, Magnesium nitrate hexa-hydrate, acetamide, acetanilide, paraffin wax, erythritol).
- Numerical analysis: Thermal balance equations at each component.

Methodology:

- The overall heat loss coefficient and absorber plate area are found out by solving the heat loss and energy balance equation using iterative procedure.
- The area of absorber plate in SBC is calculated based on the mass of water to be boiled (m_w =1.5kg) using the energy balance equation as:

$$A_p = \frac{m_w c_w (T_f - T_i)}{t(I_{av}\alpha_p \tau_g - U_L(T_p - T_a))} \quad (1)$$

- Overall heat loss coefficient (U_L) which involves heat losses through bottom, top and remaining four sides which is given by,

$$U_L = U_T + U_B + U_S \quad (2)$$

Figure 2. *Experimental setup.*

- Heat storage materials are kept above the absorber plate in different trays. The peak stagnant temperature of different composition is measured by using a thermocouple. The mixture composition which gives maximum temperature is selected as the optimum proportion of storage materials.

- Stagnation test: First figure of merit, (Mullick et al. 1987)

$$F_1 = \frac{T_{ps} - T_{as}}{H_s} \quad (3)$$

- Sensible heat test: Second figure of merit, (Mullick et al. 1987)

$$F_2 = \frac{F_1 m_w c_w}{At} \ln\left[\frac{1 - \frac{1}{F_1}\left(\frac{T_{w1} - T_a}{H}\right)}{1 - \frac{1}{F_1}\left(\frac{T_{w2} - T_a}{H}\right)}\right] \quad (4)$$

Results:

- An optimal mixture of iron grits, sand, brick powder and charcoal are obtained as 1:2:2:3
- First and second figures of merit (F_1 and F_2), thermal and exergy efficiency are found to be 0.085, 0.319, 16.1% and 0.61% respectively.
- Water temperature in the developed SBC is maintained above 70°C till 6 PM in a day.

Table 1. *Design parameters*

Specifications	
Top heat loss coefficient, U_T (W/m^2K)	3.65
Side heat loss coefficient, U_S (W/m^2K)	0.48
Bottom heat loss coefficient, U_B (W/m^2K)	0.59
Overall heat loss coefficient, U_L (W/m^2K)	4.72
Absorber plate area, A_p (m^2)	0.36

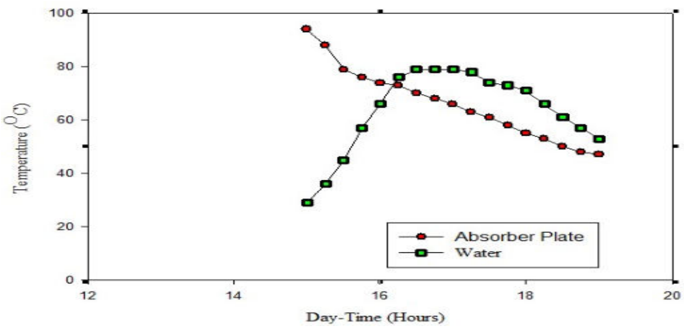

Figure 3. *Variation of absorber plate and water temperature with time during heat retention test*

Conclusions:

- For an anticipated average solar irradiation of 800W/m² and for boiling 1.5 kg mass of water, the cooker surface area is found to be 0.36 m² and fabricated accordingly.
- An optimal mixture of four sensible heat storage materials namely iron grits, sand, brick powder and charcoal in the ratio 1:2:2:3 is used to store heat in the cooker.
- The indoor cooking with more than 100°C may be possible by the use of optimum mixture of phase change materials and low cost sensible heat materials in solar cookers of optimum design.

Important References:

- Aramesh M, Ghalebani M, Kasaeian A, Zamani H, Lorenzini G, Mahian O, Wongwises S (2019) A review of recent advances in solar cooking technology. Renewable Energy 140: 419-435.
- Mullick SC, Kandpal TC, Saxena AK (1987) Thermal Test Procedure for Box-Type Solar Cookers. Solar Energy 39(4):353-360.
- Nkhonjera L, Bello-Ochende T, John G, King'ondu CK (2017) A review of thermal energy storage designs, heat storage materials and cooking performance of solar cookers with heat storage. Renewable and Sustainable Energy Reviews 75 (2017) 157–167.

anilkbc20031@gmail.com
mranji1@nitk.edu.in
anish@nitk.edu.in

National Institute of Technology Karnataka, Surathkal