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No Load and Load Test of Black Nickel Coated Solar Cooker Without using reflector in Surat, India and Validating against Indian standards

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Abstract
Solar cooking is a form of out door cooking and is often used in situations where minimal fuel consumption is important, or the danger of accidental fires is high. Solar cookers are available in many variations, but the main type is concentrating solar cookers and box type solar cooker which is collector solar cooker. Parboiled cooker is developed for kitchen and community purpose.But it is costly as compared to box type solar cooker The aim of this project is to design and develop a low cost box type solar cooker that can be used for cooking food for four persons Black nickel coated MS plate has a very less value of emissivity which provides more energy for cooking. Use of this coated plate eliminates the need of reflector system and thus makes it to be much simpler. Further, for the cooking need of a family of a four person, the new model offers better performance in terms of reduced cooking time as compared to the standard BIS model. Encouraged through this performance, the cooking period for the major cities of India is predicted for the whole year with this new optimal solar cooker

1. Introduction

In 2010 renewable energy accounted for 16.7% of total energy consumption, and of that wind power provided 0.51%, and photovoltaic 0.06% of the total.

The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 3,850,000 exajoules (EJ) per year.

The Earth receives 174 petawatts (PW) of solar radiation at the upper atmosphere. 30% of that is reflected back to space and the rest is absorbed by clouds, oceans and land masses. Humans harness solar energy in many different ways: space heating and cooling, the production of potable water by distillation, disinfection, lighting, hot water, and cooking

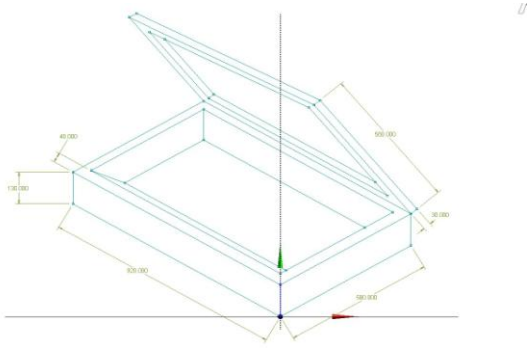
Box-type solar cookers/ovens use the greenhouse effect to cook food. A transparent glass or plastic cover over the insulated box allows short-wave radiation to pass through. The black-coated inner box absorbs this radiation. With the increase in the temperature of the inner tray, energy is re radiated at longer wavelengths. The glass cover does not allow long-wave radiation to pass through it. The temperature of the box increases and an equilibrium temperature is reached, where the input of solar energy is balanced by the heat losses.

2. Black Nickel Coated Solar Cooker

Solar cooking provides a very cost-efficient and environment-friendly solution foremost to rural communities of developing countries. There are various types of solar cookers available in market for cooking purpose. Some models are community type and some portable model for family purpose. BIS (Burea of Indian standards) model of solar cooker is one of the most widely used model to fulfill the cooking need of four persons. This cooker is chosen for further improvement and reduce the cost This parameter provides the option to select the combination of materials for components of solar cooker which is optimised. Thermal performance of this new solar cooker is then evaluated and compared with the thermal performance of standard BIS solar cooker to establish its superiority.

From energy balance, less heat loss from top and sides of cooker results improved performance and less time required for cooking. The emissivity of absorber plate is the most dominating factor. Combination of material with different coating gives different emissivity value. MS sheet with black nickel coating, combination give less emissivity.

The present cooker as well as the standard BIS model solar cooker are designed to meet the cooking need of a family of four persons. The cost of materials in both the cookers have been estimated based on present material cost prevailing in the market



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3. Specifications Of New Model

Area of tray shape absorber plate at the top (Ac) = 0.42m^2
Area of tray at its bottom (Ap) = 0.3192m^2
Depth of tray (Xm) =70 mm
No. of glass covers: 2
Thickness of glass cover: 3mm each
Spacing between glass cover: 15 mm
Bottom insulation (x_b): 60 mm
Side insulation (x_s): 60 mm
Emissivity of cover system: 0.88
Absorptivity of absorber plate: 0.95
Emissivity of absorber: 0.12
Thermal conductivity of insulating glass wool: 0.0484 W/m K

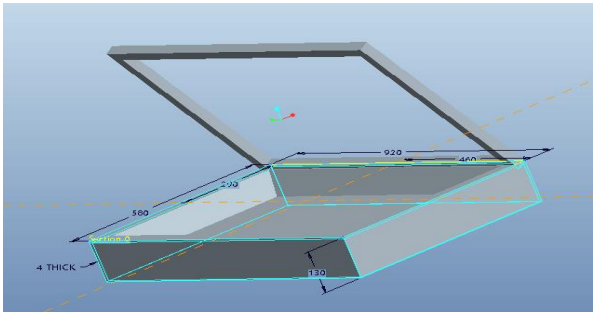

Fig: 2. 3D Model of Solar Cooker

4. Instrumentation

To measure mean plate temperature , glass covers temperature , inside air temperature and cooking food/ water temperature.

Type T (copper–constantan) thermocouples are suited for measurements in the range of 200°C to 350 °C range. Since both conductors are non-magnetic, there is no Curie point and thus no abrupt change in characteristics. Type T thermocouples have a sensitivity of about 43 µV/°C and offers quite linear characteristics.

Fig 5.3 shows the thermocouples location in plate and glass cover. The e.m.f. generated by thermocouple is measured correlated with temperature as:

$$e.m.f. = 0.038906666T + 0.0000383333T^2$$

Where e.m.f. in mV and= temperature in °C

Fig: 3. Thermocouples Positions in Plate and Glass Coves

Abbreviations and Acronyms

Tp absorber plate temperature (K)
Tps absorber plate temperature at stagnation (K)
Tw water temperature (K)
U_L cooker heat loss factor
*F*1 first figure of merit for cooker performance rating (m^2 kW^{-1})
*F*2 second figure of merit for cooker performance rating (dimensionless)
F heat exchange factor (dimensionless)
Fgs view factor of the glazing and sky
Frg reflector-glazing exchange factor
I isolation (Wm^{-2})
Iav average total insolation incident on cooker surface (Wm^{-2})
Ib Instantaneous beam insolation incident on cooker surface (Wm^{-2})
Ibr instantaneous beam insolation incident on reflector surface (Wm^{-2})
Id instantaneous diffuse insolation incident on cooker surface (Wm^{-2})
Ir instantaneous reflected beam insolation incident on cooker surface (Wm^{-2})
Is insolation incident on cooker surface at stagnation (Wm^{-2})
I_T instantaneous overall insolation incident on cooker surface ((Wm^{-2})
K thermal conductivity of the fibre glass wool insulation (Wm^{-1} K^{-1})
M mass of water (kg)
Q rate of energy absorbed by the cooker (W)
q_L desired maximum rate of heat loss from cooker walls (W)
q_u rate of useful heat gain by water (W)
T_a ambient temperature (K)
T_{av} average ambient temperature (K)
T_{as} ambient temperature at stagnation (K)
Tf final water temperature (K)
Ti initial water temperature WK^{-1} m^{-2})
δ Declination angle

Equations

$$Q_1 = Q_t + Q_b + Q_w + Q_c + Q_e + Q_s$$

$$U_1 = U_t + U_b\frac{A_p}{A_c} + U_w\frac{A_w}{A_c} + K_i\frac{S_e}{A_c} + K_i\frac{S_c}{A_c} + K_1$$

5. Comparative Analysis

Graph plotted for No load test from 10:30 a.m. to 3:50 p.m. as on 22nd May 2012 at SV NIT surat. It is seen that Isolation increases from morning to noon and maximum value is seen between 12:30 to 1:00p.m. Maximum mean temperature of plate is 139 °C. maximum temperature of air inside the solar cooker is 128.5 °C. Maximum temperature of inner glass upper side temperature is 81.5 °C. Maximum temperature of top glass inside temperature is 68.5 °C.

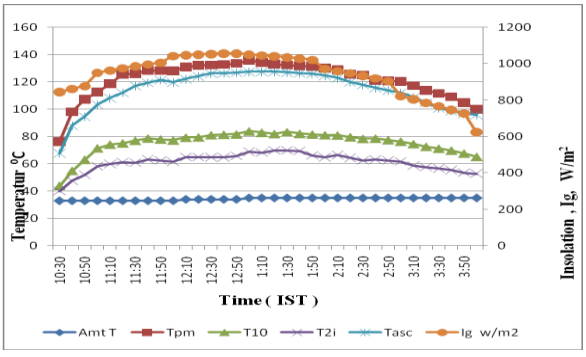

Fig: 4. No Load Test, 22 may 2012

(B) Graph plotted for Load test10:10 a.m. to 4:50 p.m. as on 27th May 2012 at SV NIT surat. It is seen that Isolation increases from morning to noon and maximum value is seen between 12:30 to 1:00p.m. Maximum mean temperature of plate is 139.2 °C. maximum temperature of water inside the solar cooker is 98.45 °C. Maximum temperature of inner glass upper side temperature is 87.38 °C. Maximum temperature of top glass inside temperature is 73.68°C.

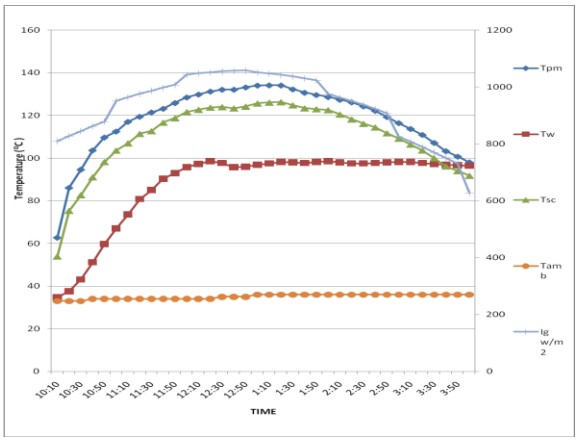

Fig: 5. Load Test, 27 may 2012

(A) Solar Cooker Thermal Performance (FIGURE OF MERIT F 1)

Stagnation test is to measure the optical efficiency of solar cooker. The optical efficiency is known as figure of merit F1.

$$F1 = \frac{T_{pm} - T_{at}}{I_g}$$

Figure of merit **F1 = 0.123**

(d) Figure of merit F2

$$F_2 = \frac{F_1(MC)_w}{A(t_2 - t_1)} \times ln\left\{\frac{1 - (\frac{1}{F_1})[(T_{w2} - T_a)/I_G]}{1 - (\frac{1}{F_1})[(T_{w1} - T_a)/I_G]}\right\}$$

After calculating,

F2 = 0.39

Thus the present cooker is classified as a "good cooker ''as per BIS standard.

6. Conclusion

A new model of box type solar cooker has been designed optimised , and fabricated for the cooking need of four person.

The reflector effect is managed by absorber tray with black nickel coating of low emissivity value, which provides more energy for cooking during cooking operation, due to the reduced top loss. It is obtained that the combination of material selected for this cooker as MS plate with black nickel coating as absorber. The figure of merit F1= 0.123 has been obtained during stagnation test and F2= 0.39 during operation for this new cooker. This means that the new model of solar cooker meets the requirement of BIS for solar cooker.

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