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Performance Evaluation of a Box-Type Solar Cooker with Flat Top and Inclined Top without Reflector Under Natural Sunlight Conditions

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Abstract: The present study investigates the thermal and cooking performance of a box-type solar cooker without reflector under natural sunlight conditions. The primary objective is to experimentally evaluate stagnation temperature, cooking power, thermal efficiency, and figures of merit (F_1 and F_2) in accordance with the Bureau of Indian Standards (IS 13429:2000). The solar cooker was fabricated using locally available materials and consisted of a blackened aluminum absorber plate, double-glazed glass cover, and insulated wooden casing. Experimental tests were carried out under clear-sky conditions using water as the cooking load. No-load tests were conducted to determine stagnation temperature and first figure of merit, while load tests evaluated cooking power, thermal efficiency, and second figure of merit. Results indicated a maximum stagnation temperature of 86 °C for the flat-top cooker and 89.5 °C for the inclined-top cooker. The thermal efficiency under load conditions was found to be 7.5% and 13.8% for flat and inclined tops, respectively. The first figure of merit values were below BIS recommendations due to the absence of a reflector, whereas the second figure of merit values demonstrated efficient heat transfer. The study confirms that a non-reflector box-type solar cooker is a cost-effective, environmentally friendly solution suitable for slow cooking applications in regions with high solar insolation.

Keywords: *Solar Cooker, Box-Type, Thermal Efficiency, Stagnation Temperature, Cooking Power, Figure of Merit, Renewable Energy, Sustainable Cooking.*

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I. INTRODUCTION

➢ *Background*

Energy plays a crucial role in economic and social development. The increasing global demand for energy has led to excessive reliance on fossil fuels such as coal, petroleum, and natural gas. These conventional energy sources are finite and contribute significantly to environmental degradation through greenhouse gas emissions and air pollution. Consequently, there is an urgent need to transition toward clean, renewable, and sustainable energy systems.

Solar energy is the most abundant and inexhaustible renewable energy source available. Under clear-sky conditions, the Earth receives an average solar radiation intensity of approximately 1000 W/m². Solar energy can be harnessed through photovoltaic systems for electricity generation and solar thermal systems for heating applications. Among solar thermal devices, solar cookers represent one of the simplest and most economical technologies.

Cooking accounts for a major share of household energy consumption, particularly in rural India where it reaches nearly 64%. Traditional cooking fuels such as firewood, crop residues, and cow dung not only contribute to deforestation but also pose serious health risks due to indoor air pollution. Solar cookers provide a clean, fuel-free alternative, reducing dependence on biomass and fossil fuels.

➢ *Box-Type Solar Cooker*

A box-type solar cooker consists of an insulated enclosure with a transparent glass cover and a blackened absorber plate at the bottom. Cooking vessels are placed on the absorber plate. The cooker operates on the greenhouse effect, where solar radiation enters through the glass cover,

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is absorbed by the black surface, and converted into heat. Temperatures in the range of 110–150 °C can typically be achieved depending on design and climatic conditions.

➢ *Need for the Study*

Although many studies focus on improving solar cooker performance using reflectors and advanced materials, the baseline performance of simple, non-reflector box-type solar cookers is less documented. Such cookers are the most affordable and suitable for rural households. Evaluating their performance under real operating conditions is essential to establish reference data and guide future design improvements.

➢ *Objectives*

The objectives of this study are:

- To fabricate a box-type solar cooker without reflector using locally available materials
- To determine stagnation temperature, cooking power, and thermal efficiency
- To evaluate figures of merit (F_1 and F_2) as per IS 13429:2000
- To compare flat-top and inclined-top configurations

II. LITERATURE REVIEW

Extensive research has been carried out on box-type solar cookers focusing on design, materials, and performance enhancement. Sharma et al. (2012) reported stagnation temperatures up to 125 °C using double glazing. El-Sebaii and Ibrahim (2013) showed that selective coatings significantly improve absorptivity. Kumar and Sharma (2015) demonstrated that reflectors can increase efficiency by up to 40%. However, studies specifically addressing non-reflector cookers remain limited.

According to BIS standards, performance evaluation includes stagnation temperature, cooking power, and figures of merit. Typical ranges for non-reflector cookers are 110–140 °C for stagnation temperature and 20–35% for thermal efficiency. This study addresses the identified research gap by experimentally analyzing a simple box-type solar cooker without reflector.

➢ *Design and Fabrication*

The solar cooker cavity was rectangular with dimensions 59.6 × 59.6 × 16.5 cm³. The absorber plate was made of aluminum and coated with black matte paint. Double-glazed glass was used as the transparent cover. Plywood and sawdust were used as insulation materials. Two configurations were tested: flat-top and inclined-top.

III. EXPERIMENTAL METHODOLOGY

➢ *Instrumentation*

Solar radiation was measured using a pyranometer, while K-type thermocouples were used to record absorber plate and water temperatures. Temperature readings were taken at regular intervals during testing.

➢ *Performance Parameters*

Key performance parameters include:

- Stagnation Temperature (T_s)
- Cooking Power (P)

$$P = \frac{mC_p\,(T_2 - T_1)}{t_2 - t_1}]$$

- Thermal Efficiency (η)

$$\eta = \frac{mC_p\,(T_f - T_i)}{I * A * t}$$

- First Figure of Merit (F_1)

$$F_1 = \frac{T_{ps} - T_a}{I}$$

- Second Figure of Merit (F_2)

$$F_2 = \frac{T_{w2} - T_{w1}}{T_{ps} - T_a}$$

IV. RESULTS AND DISCUSSION

➢ *Stagnation Temperature*

Figure 1 shows the variation of absorber plate temperature with time. The inclined-top cooker achieved a slightly higher maximum stagnation temperature (89.5 °C) compared to the flat-top cooker (86 °C), indicating improved solar interception.

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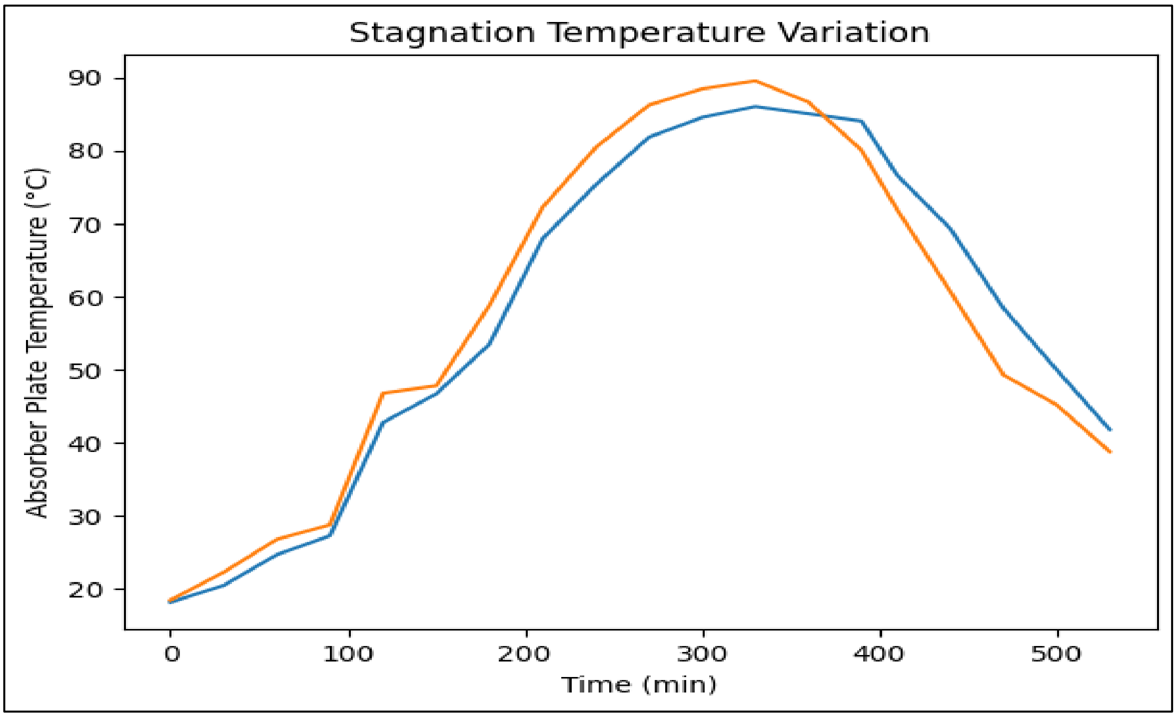

Fig 1 Stagnation Temperature Variation

➢ *Load Test and Cooking Power*

Figure 2 illustrates the water heating curves. The inclined-top cooker exhibited faster heating, resulting in higher cooking power.

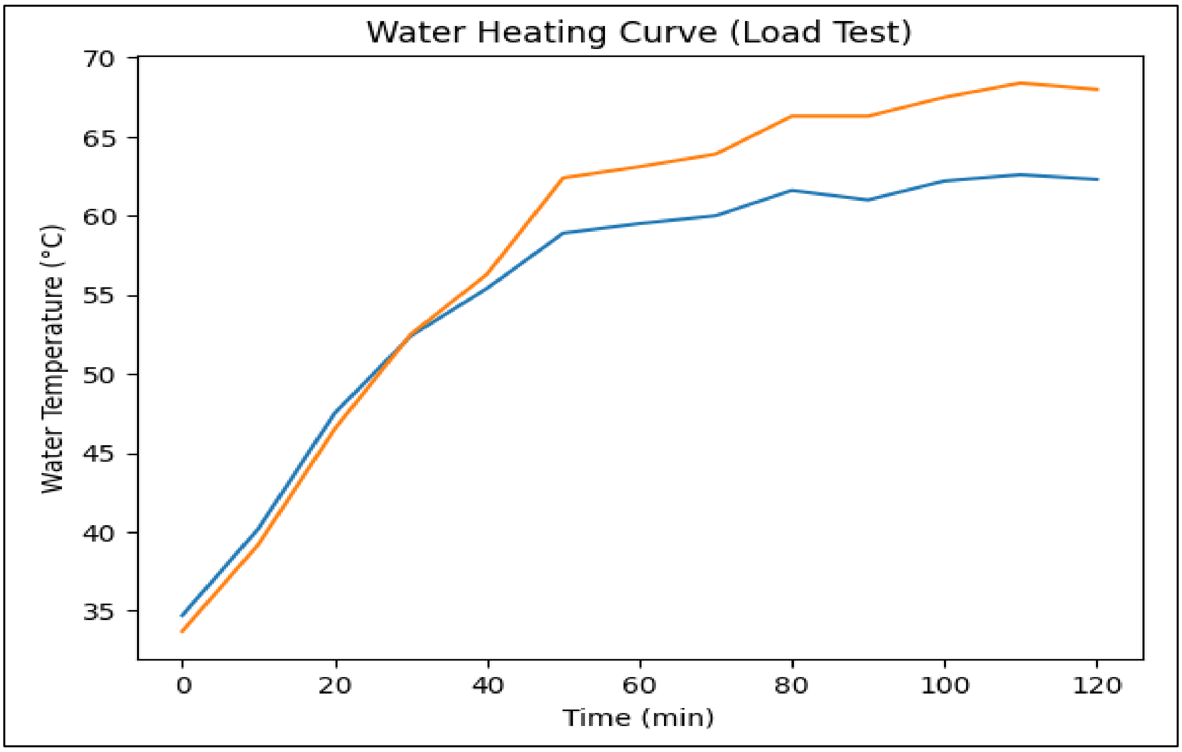

Fig 2 Water Heating Curve (Load Test)

The calculated cooking power was 24.06 W for the flat top and 39.94 W for the inclined top.

➢ *Thermal Efficiency*

Figure 3 compares the thermal efficiencies of both configurations. The inclined-top cooker achieved a higher efficiency (13.8%) due to improved solar incidence angle.

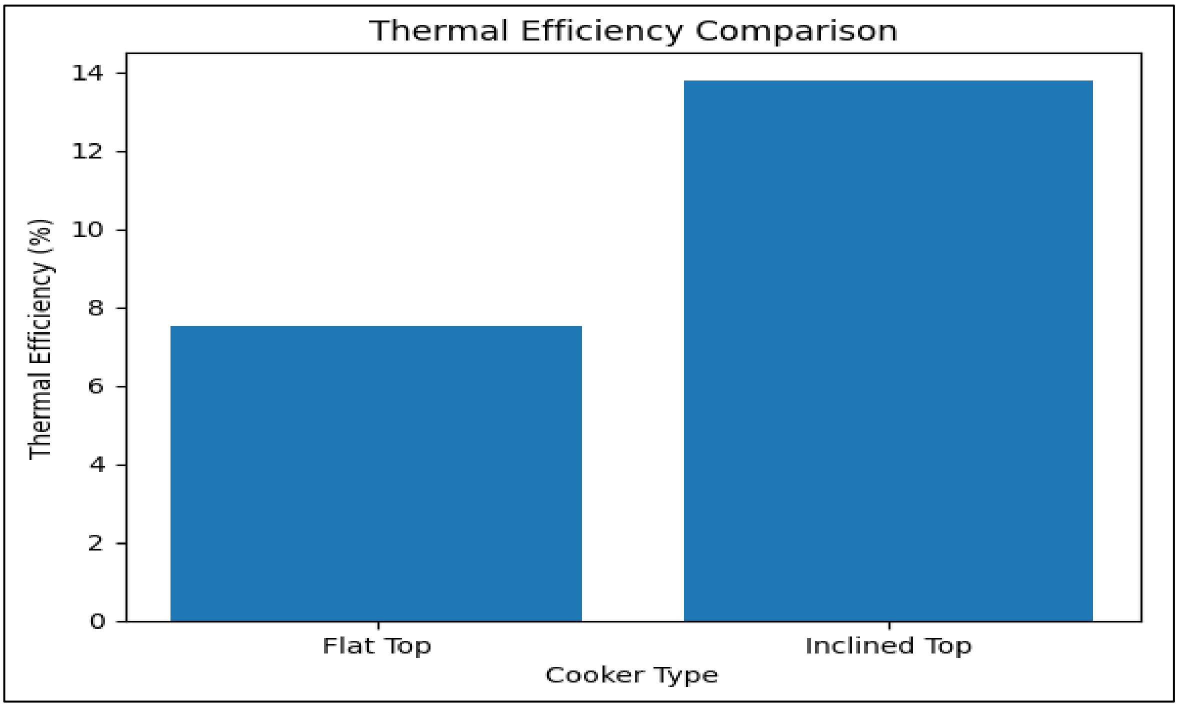

Fig 3 Thermal Efficiency Comparison

➢ *Figures of Merit*

The first figure of merit values were below BIS recommendations, primarily due to the absence of a reflector. However, the second figure of merit values were within or above the acceptable range, indicating efficient heat transfer.

V. CONCLUSION

The experimental evaluation of a box-type solar cooker without reflector demonstrates that such a system can achieve satisfactory thermal performance under clear-sky conditions. Although the efficiency and F_1 values are lower than BIS standards, the cooker is suitable for slow cooking applications. The inclined-top configuration performed better than the flat-top design. With minor design improvements such as reflectors or enhanced insulation, performance can be significantly improved.

FUTURE SCOPE

Future work may include the addition of reflectors, selective coatings, phase change materials for heat storage, and CFD-based thermal analysis to further enhance performance.

REFERENCES

[1]. Sharma, S., & Sengar, S. H. (2012). *Experimental analysis of box-type solar cooker with double glazing and improved insulation.* Renewable Energy, 45, 113–120.
[2]. El-Sebaii, A. A., & Ibrahim, A. (2013). *Experimental investigation of solar box cookers with different absorber plate coatings.* Solar Energy, 92, 70–76.
[3]. Sengar, S. H., Tiwari, G. N., & Yadav, A. (2014). *Performance evaluation of solar cooker for different load conditions.* International Journal of Energy Research, 38(5), 661–670.
[4]. Kumar, R., & Sharma, A. (2015). *Comparative study of solar cookers with and without plane reflectors.* Energy Conversion and Management, 105, 1015–1021.
[5]. Tiwari, G. N., & Dubey, S. (2016). *Analytical modeling and performance study of box-type solar cooker*. Journal of Solar Energy Engineering, 138(4), 041001–041010.
[6]. Saxena, A., & Agarwal, N. (2017). *Development of a low-cost solar cooker using locally available materials.* International Journal of Renewable Energy Research, 7(3), 1450–1457.
[7]. Singh, R. K., & Yadav, V. K. (2018). *Thermal performance comparison of single and double-glazed solar cookers.* Energy Procedia, 153, 244–250.
[8]. Malik, M. A., Kumar, R., & Kothari, R. (2015). *Effect of plane reflector on temperature distribution in a solar box cooker.* International Journal of Sustainable Energy, 34(3), 195–202.
[9]. Abdulrahim, H. A., & Hassan, M. S. (2016). *Enhancement of absorber plate performance using selective coatings for solar cookers.* Applied Thermal Engineering, 103, 250–257.
[10]. Nandwani, S. S. (2019). *Importance of insulation materials for improving solar cooker efficiency*. Solar Energy, 189, 567–573.
[11]. Kumar, A., & Buddhi, D. (2021). *Use of phase change materials for heat storage in box-type solar cookers.* Renewable and Sustainable Energy Reviews, 143, 110931.
[12]. Goyal, S., & Mehta, R. (2022). *Optimization of box geometry and glazing tilt angle for improved solar*

ISSN No:-2456-2165 https://doi.org/10.38124/ijisrt/26may1150

cooker performance. Journal of Cleaner Production, 350, 131574.
[13]. Otte, P. P., & Mbow, M. (2020). *Performance testing of box-type solar cookers under East African climatic conditions.* Renewable Energy, 157, 897–905.
[14]. Bureau of Indian Standards. (2000). *IS 13429: 2000 — Solar Cooker Box Type — Specification.* New Delhi: BIS Publications.
[15]. Tiwari, G. N., & Sodha, M. S. (2010). *Solar Cooking and Greenhouse Solar Devices: Design, Performance and Applications.* Alpha Science International, Oxford.
[16]. Sukhatme, S. P., & Nayak, J. K. (2018). *Solar Energy: Principles of Thermal Collection and Storage* (4th ed.). McGraw-Hill Education, New Delhi.
[17]. Modi, A., & Deshmukh, D. (2021). *Review on performance evaluation of box-type solar cookers with and without reflectors.* Journal of Renewable Energy and Environment, 8(2), 56–64.
[18]. Husein, M., & Mohsen, M. (2019). *Experimental study of solar box cookers for household applications.* Energy Reports, 5, 306–314.
[19]. Jain, R., & Gupta, S. (2017). *Impact of glazing and insulation on thermal efficiency of solar cookers.* International Journal of Sustainable Energy, 36(9), 834–842.
[20]. Meena, R. S., & Tiwari, G. N. (2020). *Thermal performance and cost analysis of solar cookers for rural applications in India.* Energy for Sustainable Development, 57, 36–44.