Effect of Angle of Inclination on Thermal Performance of Solar Cooker

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Abstract— Energy is an important source for all sectors of any country's economy. It is a major input for socioeconomic development and poverty eradication. The standard of living of any country is mostly dependent on per capita energy consumption. Due to rapid deterioration in the supply of fossil fuels, the solar energy can be the most appropriate option compared to other alternative energy resources. In rural areas almost 75% of the energy is used for cooking purpose. The solar cookers have a relevant place in the present fuel consumption pattern. But the position of the sun varies continuously throughout the daytime which affects the absorption rate. An advance design is to be proposed for the maximum utilization of solar radiation concentrated over solar cooker. In the proposed trapezoidal solar cooker the shape will be such that the solar radiation incident upon the surface gets concentrated towards the Centre of the cooker. From above description the objective of present work is to study the effect of angle of inclination on the thermal performance of trapezoidal of solar cooker.

Key words: Solar Cooker, Effect of Angle of Inclination

I. INTRODUCTION

The energy availability plays a vital role in economic activity because production and manufacturing can be fulfilled by energy consumption only. Nowadays low cost energy is necessary for economical development of any country but because still the major energy extraction is possible using fossil fuels and those countries which have not sufficient amount of such fossil fuel facing lot many issues related unemployment; but the solution of this energy crisis is available from alternative energy sources like solar energy, wind energy and bio mass and bio fuel etc.

II. SOLAR COOKER

The evolution for the need of renewable energy resources is rising these days. Also the availability of conventional resources is drying up. The idea of utilizing renewable energy in our day to day life is popular now. In a tropical country like India there is sunshine for nearly 9 months in a year. This kindled the idea, that if a cost efficient solar cooker is used in a house for most of the domestic purposes, replacing gas-stoves, it not only benefits the household but also reduces the cooking fuel demand. Solar cooker is a device that cooks food using only sun energy in the form of solar radiation. The solar cooking saves a significant amount of conventional fuels. The solar cooking is the simplest, safest, clean, environment friendly, and most convenient way to cook food without consuming fuels or heating up the kitchen. A major concern of today is the rapidly depleting natural resources. So it is the urgent need of time to reduce the dependency on non-renewable sources, judiciously using the remaining sources and at the same time switching to new and better alternatives and renewable source of energy. In most parts of India, solar energy is available almost throughout the year and can be used as alternate input to meet out energy needs. Today there are about 60 major designs and more than 100 of however the solar cooking has not caught the imagination of peoples, except in places where shortage of conventional fuel like fire wood and the Solar cookers have attracted the attention of many researchers so far. Different types of solar cookers have been developed and tested all over the world.

A. Types of Solar Cooker

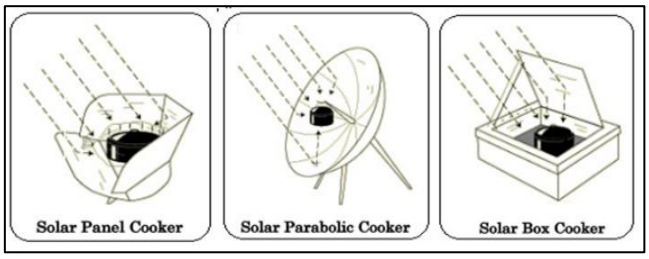


Fig. 1: Types of Solar Cookers

1) Feasible Applications of Solar Box Cooker

The cooker is used to prepare simple cakes, roast cashew nuts, dry grapes, etc. It is an ideal device for domestic cooking during most of the year except the monsoon season and cloudy days. The cooking takes place at relatively low temperature, thus cooking is very similar to that of microwave cooking. The cooked items are very tastier, healthier and with all natural minerals, vitamins and proteins. It however cannot be used for frying or Chapatti making.

III. LITERATURE REVIEW

In the present chapter the contribution of different researchers are included which will be helped to decide dimensions and instrument of experimental set up.

C Z M Kimambo (2007) has studied a comprehensive study involving theoretical review, development work, experimental testing and evaluation of solar cookers was conducted for several years on six different types of solar cookers. The cookers are the 'Sun Stove' box cooker, wooden box cooker, panel cooker, reflector cooker with unpolished aluminum reflectors, reflector cooker with polished aluminum reflectors and reflector cooker with glass mirror reflectors. Results obtained indicate that many of the cookers could be used to cook food for households in areas with medium and high insolation, with appropriate selection of the type and specification of the cookers. The specification should be based on the measured insolation data of the location indication of the direct and diffuse components.

Test standard	*Advantages*	*Disadvantages*
American Society of Agricultural Engineers Standard (Funk, 2000)	Simple Applicable in less developed areas	Analysis of performance of a cooker, rather than simply comparison is very difficult Does not address qualitative factors e.g. ease of use, safety, or financial issues
Bureau of Indian Standards Testing Method (Mullick et al, 1987)	Presented in a more technical framework than ASAE S580 Independent of weather conditions (such as wind speed, insolation, etc.)	Does not address qualitative factors e.g. ease of use, safety, or financial issues
European Committee on Solar Cooking Research (ECSCR) Testing Standard	Includes an exhaustive thermal testing regime Cheaper and easier to run – tracking pyranometer not required Explores qualitative factors e.g. safety, ease of cooking, pot access, durability etc. Useful for comparison of any cookers	Relies on measurements of time taken for certain conditions to occur Not well suited to multiple testing – procedure is quite comprehensive Requires long time – time taken for the basic test alone is 3 clear days

Type of cooker	*Glazing*	*Reflector*	*No. of pots*	*Nominal vol. (l)*	*Aperture area (m^2)*	*Collector area (m^2)*
'Sunstove' box cooker	Single PVC	Aluminium	1	2	0.34	0.34
Wooden box cooker	Double glass	None	1	2	0.24	0.24
Panel cooker	Single glass	Glass mirror	1	2	0.56	0.14
Reflector cooker – unpolished aluminium	–	Unpolished aluminium	1	4	1.61	1.61
Reflector cooker – polished aluminium	–	Polished aluminium1	1	4	1.61	1.6
Reflector cooker – glass mirror	–	Glass mirror	1	4	2.15	2.15

Table 1: Specifications of Cookers Tested

Rajendra C. Patil Mahesh M. Rathore Manojkumar Chopra (2012) discussed about the solar cooker with its principal, types and advantages and disadvantages.

URBAN SECTOR	RURAL SECTOR
• LPG (47.96%)	• Firewood (64.10%)
• Firewood (22.74%)	• Other sources of biomass –crop residue (13.10%)
• Kerosene (19.16%)	• Cow-dung (12.80%)
• Other fuels(10.14)	• LPG (5.67%) is now Increasing in importance.

Table 2: Cooking Energy Scenario in India

Ibrahim Ladan Mohammed (2013) studied a parabolic dish solar thermal cooker, PDSTC, was designed and constructed. The cooker was required to cook food equivalent of 12 kg of dry (uncooked) rice per day for relatively medium size family, with a designed efficiency of about 50%.

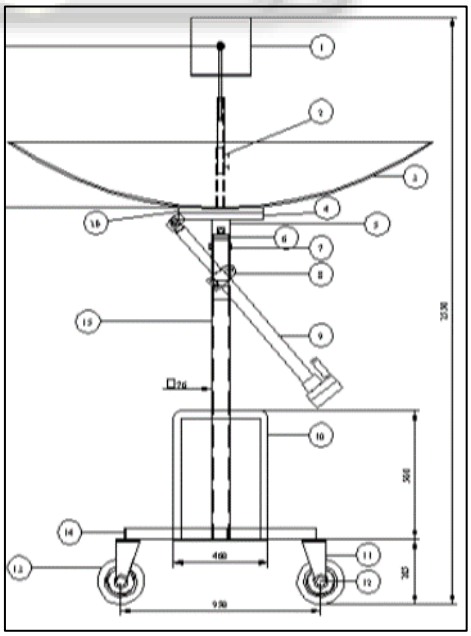


Fig. 2: Assembled Drawing of the PDSTC

Fig. 3: Photograph of the PDSTC

The design and development of a parabolic dish solar thermal cooker for domestic cooking applications has been presented, together with the predicted and actual performance of the system. Although no detailed thermal performance analysis is presented, the cooking test results show that the cooker is always capable of cooking food equivalent of 3 kg of dry rice at a time, within the expected length of time and solar radiation levels. The total cooked food capacity of the cooker per cycle of cooking operation is about 9.7 kg, and the total per day is about 38.8 kg. The main research points of this paper are food-water volume and mass ratios.

IV. EXPERIMENTAL SET UP

In the present project work the Trapezium solar cooker will be made as first part of experiment. The both set up will be placed together and then in sunshine and observation will be noted using K type thermocouples to measure temperature.

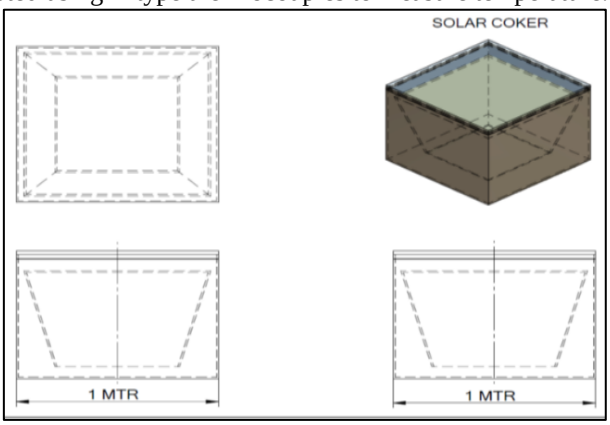


Fig. 4: Proposed Experimental Set

V. CONSTRUCTIONAL DETAIL

R (Geometric concentration ratio), ratio between aperture area (collector) and absorber area (receiver)

$$R = \frac{\text{Top Area}}{\text{Absorber area}}$$

1) Case 1: Rectangular Design with square top

$$R_1 = \frac{45.7^2}{45.7^2} = 1 = 100\%$$

2) Case 2: Trapezoidal Design with square top (Internal reflecting mirrors)

$$R_2 = \frac{45.7^2}{25.4^2} = 3.23 = 323\%$$

Difference: R2 - R_1 = 323 - 100 = 223%

F (Effective volume factor) ($\frac{cm^2}{cm^3}$): F = $\frac{\text{Top Area}}{\text{Volume of cooking Chamber}}$

Volume of cooking Chamber= length × breadth × height

1) Case 1: Rectangular Design with square top

$$F_1 = \frac{45.7^2}{45.7^2 \times 30.48} = 0.032 \ \frac{cm^2}{cm^3}$$

2) Case 2: Trapezoidal Design with square top

$$F_2 = \frac{45.7^2}{30.48 \times (45.7^2 + 25.4^2)/2} = 0.050 \frac{cm^2}{cm^3}$$

Difference: F2 – F_1 = 0.050 - 0.032 = 0.018 = 1.8%

VI. CONSTRUCTION

In the present work first of all 1 feet X 1 feet X 1.25 feet wooden box is prepared and then the mirror of trapezium shape with 1 feet height and 8 inch boom length and 12 inch upper length is pated in the box with silicon glue,

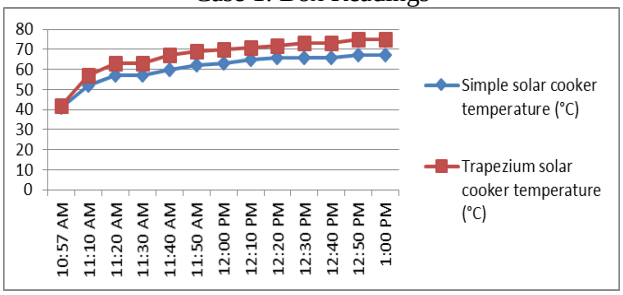
Fig. 5: Rectangular Model

VII. RESULT AND DISCUSSION

Sr. no	Time	Simple solar cooker temperature	Trapezium solar cooker temperature (°C)	Difference (°C)
1	10:45 AM	49	49	0
2	11:02 AM	60	66	6
3	11:12 AM	66	73	7
4	11:22 AM	70	79	9
5	11:32 AM	73	85	12
6	11:42 AM	74	89	15
7	11:52 AM	77	93	16
8	12:02 PM	78	96	18
9	12:12 PM	78	99	21
10	12:22 PM	79	104	25
11	12:32 PM	79	106	27
12	12:42 PM	80	107	27

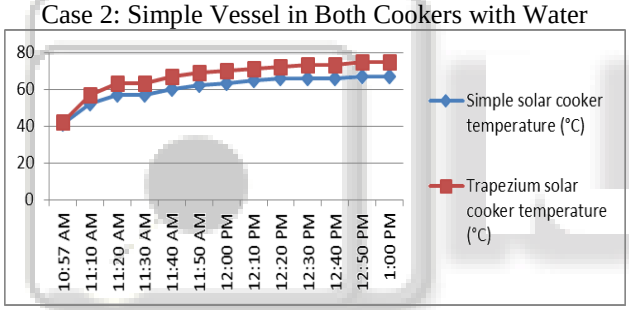
13	12:52 PM	78	104	26
14	01:02 PM	81	105	24

Case 1: Box Readings



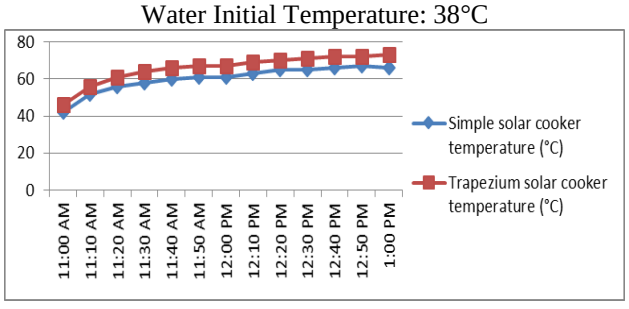
Sr. no	Time	Simple solar cooker temperature	Trapezium solar cooker temperature (°C)	Difference (°C)
1	10:57 AM	41	42	1
2	11:10 AM	52	57	5
3	11:20 AM	57	63	6
4	11:30 AM	57	63	6
5	11:40 AM	60	67	7
6	11:50 AM	62	69	7
7	12:00 PM	63	70	7
8	12:10 PM	65	71	6
9	12:20 PM	66	72	6
10	12:30 PM	66	73	7
11	12:40 PM	66	73	7
12	12:50 PM	67	75	8
13	01:00 PM	67	75	8

Case 2: Simple Vessel in Both Cookers with Water



Sr. no	Time	Simple solar cooker temperature	Trapezium solar cooker temperature (°C)	Difference (°C)
1	11:00 AM	42	46	4
2	11:10 AM	52	56	4
3	11:20 AM	56	61	5
4	11:30 AM	58	64	6
5	11:40 AM	60	66	6
6	11:50 AM	61	67	6
7	12:00 PM	61	67	6
8	12:10 PM	63	69	6
9	12:20 PM	65	70	5
10	12:30 PM	65	71	6
11	12:40 PM	66	72	6
12	12:50 PM	67	72	5
13	01:00 PM	66	73	7

Case 3: Fin Type Vessel in Both Solar Cookers
Water Initial Temperature: 38°C



From the above results it is quite clear that in case of trapezium solar cooker the results are better compare to conventional due to more black body radiation effect can be achieved in case of trapezium solar cooker also due to fin type vessel as surface area will increase which will increases the rate of heat transfer.

VIII. Conclusion

The major conclusion from the present work is with the proposed trapezium solar cooker with mirror as a reflecting medium better results can be obtained in terms of thermal performance of solar cooker.

IX. Future Scope

By reducing weight of solar cooker using aluminum as reflecting material better results can be obtained.

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