Performance Evaluation of a Parabolic Dish Solar Thermal Cooker

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ABSTRACT — Cooking is the prime requirement of people all over the world. Solar Energy is contributing major energy requirements of the world population. Parabolic Concentrator is used to utilize the solar energy for heating purposes. The Experimental investigations were carried out to determine performance of solar parabolic cooker during summer season. A parabolic collector having aperture diameter, depth, focal length was selected for fabrication. First the parabolic solar cooker was tested under no load condition, and then cooker filled with different volume of water viz. half, one and two liters along with the suitable quantity of rice. The solar radiation and temperatures of reflector, pot, ambient were recorded. Performance parameters of parabolic concentrator cooker are obtained. The cooking power, thermal efficiency & rate of useful energy are also calculated. Pressure cooker of 2 liters is used for the experiment. The solar cooker was found to be useful in cooking a variety of foods.

KEYWORDS — Solar energy, Solar Cooker, Cooking power, Thermal efficiency**.**

I. INTRODUCTION

Solar energy is one of the most promising renewable energy resources which is available in most of the developing countries including India. Cooking in a rural area mainly depends upon conventional energy sources such as cow dung, straw, wood, coal and hence, solar cooking can play an important role in rural areas in cooking. Solar cookers are the most promising devices since firewood used for coking causes deforestation while commercial fuels such as LPG and electricity are not available besides cooking accounts for a major share of energy consumption in developing countries. Solar cooking saves not only fossil fuels but also keeps the environment free from pollution without hampering the nutritional value of the food. PSC are low cost options for meeting the cooking energy needs as well as environmental protection.

The Parabolic Solar Cooker is an emerging device which has a great potential in India. However, PSC technology will have to compete with prevalent cooking devices in the country. The parabolic solar cooker rests on the principle of the concentration of the rays. Cooking is one of the very important and necessary household chores in every society of the world. Energy consumption for cooking in developing countries is a major component of the total energy consumption, including commercial and non-commercial energy sources. In the rural areas of most developing countries cooking is usually done in open fires fuelled by firewood. In the cities, stoves are more common, fuelled by wood, charcoal, kerosene of sometimes fuel gas. In many regions, especially East Africa and West Africa (including Nigeria), oil-derived fuels are expensive, and wood-based fuels are becoming increasingly scarce, as rising demand presses hard on dwindling number of trees. In developing countries like Nigeria, cooking is the main source of demand for firewood, and is an important cause of deforestation.

This type of cookers usually employs mirrors / reflectors to concentrate the total solar energy incident on the collector surface, so the collector surface is usually very wide and the temperature achieved is very high. Parabolic dish cooker has the highest efficiency in terms of the utilization of the reflector area because in fully steerable dish system there are no losses due to aperture projection effects. Also radiation losses are small because of the small area of the absorber at the focus. Additional advantages include higher cooking temperatures, as virtually any type of food can be cooked, and short heat-up times. In the present work a parabolic dish solar thermal cooker, PDSTC, was designed and constructed. The parabolic solar cooker rests on the principle of the concentration of the rays. It is well known that the parallel beam of ray of the sun is reflected on the parabolic mirror and the rays converge in the same point, the hearth of the parabola. While running up against a dark container placed in this point, the rays are released their energy in the form of heat. It is obvious that when the parabola is larger, the cooker will be powerful.

II. SELECTION OF MATERIALS FOR THE CONSTRUCTION OF THE PDSTC

1. Material for the Body of the Dish

Steel was selected over aluminium because of its strength, durability, and energy effectiveness in use of material. Energy consumed to produce steel is estimated to be16500 kJ/kg compared to that of aluminium of 141,000 kJ/kg, commercially-available dish was adopted so as to reduce errors in the process of manufacture, its smooth contour shape minimizes the sloping error of the reflective, glass material.

2. Material for the Reflecting Surface

A light glass mirror of high surface quality and good specular reflectance was selected. A glass mirror of 2 mm thickness was selected over 3mm- and 4mm-thick glasses to reduce the overall weight of the PDSTC. Glass mirror was selected over polished aluminium surface because its reflectivity of 95% is better than that of aluminium (85%).

3. Material for the Absorber

Aluminium was selected over copper and steel because of its lower cost, light weight, and ease of fabrication. Its light weight reduces the overall weight of the solar cooker and also reduces the amount of work to be done by the solar tracking system in turning the dish on its axis.

4. Material for the Absorber Surface Coating

Black paint was selected for the absorber coating. It was selected over other coatings because of its higher absorptivity at angles other than normal incidence, adherence and durability when exposed to weathering, sunlight and high stagnation temperatures, cost effectiveness, and protection to the absorber material.

5. Food Material and Heat Transfer Fluid

Rice was selected as a representative food to be cooked because it is a staple food for about two-third population of the world. It is also a non-perishable food item and can be cooked simply without adding any additive. Water was selected as the heat transfer fluid because of its stability at high temperatures, low material maintenance and transport costs, safe to use, and is the most commonly used fluid for domestic heating applications.

6. Material for the Vertical Support of the Dish

A rectangular, hollow, steel bar was selected for the support of the dish. This is because of its strength, rigidity, resistance to deflection by commonly encountered winds, and its ability to withstand transverse and cross-sectional loads of the entire heating portion of the PDSTC.

7. Material for the Base of the PDSTC

A combination of angle and channel-section steel bars were selected for the base which support the whole solar cooker structure. Channel-section and angle bars were chosen to provide solid and rigid support for the rectangular, vertical-axis steel bar which supports the parabolic dish.[1]

III. EXPERIMENTAL SETUP

1.Gravimetric and Volumetric Rice - Water Ratios

The heat demand load of the cooker is such that it will cook about 4-5 kg of rice in a day. In order to reduce space requirement, the cooker is designed. Thus at an average uniform rate of solar radiation intensity, the cooker will make 4 cycles of almost equal length in time to cook the quantity of food required.

The volume of rice, v_{r1}, to be cooked is given as -

$v_{r1} = m_{rl} / \rho_{r1}$ (1)

The density of rice, ρ_{r1}, varies between 777 – 847 kg/m^3, due to the different varieties of rice, Average value of 812 kg/m^3 is adopted for the design.

Applying Eq. (1) Consider, m_{r1} = 100 gms

$v_{r1} = m_{rl} / \rho_{r1} = [(100 / 1000) / 812] = 0.000123\ m^3$

For the cooking process, the optimum rice-to-water ratio by volume is 1:2. The volume of water, v_{w1}, required to cook v_{r1} volume of rice is

$v_{w1} = 2 v_{r1} = 2(m_{rl} / \rho_{r1})$ (2)

$v_{w1} = 2 \times 0.000123 = 0.000246\ m^3$

Total volume of food to be cooked, v_{f1} is

$v_{f1} = v_{r1} + v_{w1} = 0.000123 + 0.000246$ (3)

$v_{f1} = 0.000369\ m^3$

The mass of water, m_{w1} required for the cooking is

$m_{w1} = \rho_{w1} \times v_{w1} = \rho_{w1} \times [2 (m_{r1} / \rho_{r1})]$ (4)

Where ρ_{w1} is the density of water evaluated at 25 ^oC and has the value of 997.01 kg/m^3 .

$m_{w1} = 997.01 \times 0.000246 = 0.245$ kg = 245 gms

Total mass of food to be cooked, m_{f1} is -

$m_{f1} = m_{r1} + m_{w1}$ (5)

$m_{f1} = 100 + 245 = 345$ gms

After the cooking process, the volume of cooked rice (including water) expands to about 3.2 – 3.5 times the volume of dry (uncooked) rice. An average factor of 3.35 is taken for this design.

Hence -

$v_{f2} = 3.35\ v_{r1}$ (6)

$v_{f2} = 3.35 \times 0.000123 = 0.000412\ m^3$

The ratio, by volume, of cooked food to uncooked food is

$v_{f2} / v_{f1} = 3.35 v_{r1} / 100 v_{r1}$

$v_{f2} = 0.0335\ v_{f1}$ (7)

Cooking of rice using conventional methods requires five volume of water to one volume of rice, while cooking using solar cooker requires two volume of water to one volume of rice. In conventional methods, about 25% of the water required for cooking is lost to the surrounding by evaporation. If the amount of water lost is taken as directly proportional to the amount of water required, then the amount of water lost during cooking using solar cookers is 10%.

Hence, the mass of water, m_{w2}, remaining in the cooked food is -

$m_{w2} = 0.9\ m_{w1}$ (8)

$m_{w2} = 0.9 \times 245 = 220.5$ gms

Mass of water lost, $m_{wl} = m_{w1} - m_{w2} = 245 – 220.5$ (9)

$m_{wl} = 24.5$ gms

Mass of cooked food,

$m_{f2} = m_{r1} + m_{w2}$ (10)

$m_{f2} = 100 + 220.5 = 320.5$ gms

The ratio, by mass, of cooked food to uncooked food is

$m_{f2} / m_{f1} = 320.5 / 345$

$m_{f2} = 0.9289\ m_{f1}$ (11)

After the cooking process, the mass of the initial uncooked food decreases by about 8. 11%.

For four cycles of cooking in a day the total mass of cooked food is -

$(4 \times m_{f2}) = 4 \times 320.5 = 1282$ gms.

2. Working Principle of a Parabolic Dish Solar Thermal Cooker

Solar tracking system is main component of this parabolic dish solar thermal cooker assembly. First assembled all component as specified above then start the electronic control unit & battery, The supply of battery is given to 12 v dc motor. On this motor shaft small pulley is mounted from this pulley to centre MDF pulley belt arrangement is given for rotation of assembly. When we supply of battery is given to small motor pulley it will be rotates & also rotates the big MDF pulley by using a belt arrangement. This MDF pulley is attached to vertical support & tracking system then this whole system can rotates, but at same time electronic control unit work properly.

Two LDR are used above the horizontal MS pipe to east – west direction, due to this when solar radiation incident on this two LDR they can be track this assembly in that direction where maximum solar radiation gain. Also for north to south manual arrangement are used to give proper position of parabolic dish. The electronic control unit work as – The PIC microcontroller consist 8 channels inbuilt of ADC. Therefore we choose the PIC microcontroller for this project. This microcontroller is easily available in the market and cheap in cost. Also the programming part is easy. These microcontrollers also have UART for serial communication. It works on 5V supply. We used voltage regulator 7805 for supply. The transformer 09V, 750 mA is used to step down 230V to 9V. For converting DC voltage, bridge rectifier is used. For filtration 1000 mf 25Vcapacitor is used.

Crystal is used for to keep the microcontroller in running mode. Resistance is attached with LDR in series where resistance is connected to ground and LDR to Vcc. We take the output from between the LDR and resistance. This output is connected to the ADC of microcontroller. Two LDR are used simultaneously. The voltage shifter is used for convert 0 – 5V into ±12V because PC common port works on ±12V whereas microcontroller operates on 5V. When the PC send the data to controller, it converts into 0-5V. When microcontroller send the data to PC then voltage shifter converts ±8V. Motor driver is used for driving motor. This motor driver consists of 4 power transistor and 2 darlington pairs. When the motor is in forward direction, 2 power transistor and 1 darlington pair is used. When it is in reverse direction, another 2 power transistor and darlington pair drives the motor. When the PC send the data for ADC reading, microcontroller sends the data to PC. The ADC value i.e LDR voltage shows the Visual Basic form. Two readings will be displayed in two text boxes. If the difference in two readings is +10 the motor rotates in forward direction whereas if the difference is –10, the motor rotates in reverse direction. The working model of Parabolic Dish Solar Thermal Cooker is shown in figure 1.

When this Parabolic Dish Solar Thermal Cooker work properly then tested this for No load test, Water heating & Cooling test then after this two test Cooking test performed on it & set of readings are taken for all three tests.

Table 1. Design specification of Parabolic Dish Solar Thermal Cooker

Description	**Specification**
Parabolic Dish Solar Thermal Cooker	
Total Height of PDSTC, H (m)	1.828 m
Concentrated type	Parabolic, 2- Dish
Aperture area, A_a (m^2)	1.370 m^2
Aperture diameter, D_a (m)	1.321 m
Focal length, (m)	0.39 m
Absorber diameter, D_{abs} (m)	0.14 m
Absorber area, A_{abs} (m^2)	0.0716 m^2
Concentration ratio, C_{area}	19.14
Reflector Material	Glass
Cooking Vessel	
Material	Aluminium
Shape	Cylindrical
Capacity (Liters)	2 Liters
Inner diameter, (m)	0.136 m
Outer diameter, (m)	0.14 m
Thickness, (m)	0.002 m
Depth, (m)	0.128 m
Solar Tracking System	
Microcontroller	PIC16F877A
Voltage Regulator	IC 7805
Resistor	Linear , Non Linear
Capacitor	Ceramic, Electrolytic
LDR	Cadmium sulfide (CdS)
Motor	Permanent Magnet DC 12 V
Crystal	Quartz crystals
Caster Wheel	2″ , 4 – Wheels

Figure 1 : Working Model of PDSTC

IV. PARAMETERS FOR THE THERMAL PERFORMANCE OF PDSTC

The basic function of a parabolic dish solar cooker is to collect solar radiation over a large area and concentrate it onto a smaller area, the focal point, where the absorber containing the food is located. The temperature of the absorber and the food rises, and after some time the food is cooked.

Concentrators can be defined by the following two methods: geometric concentration and flux concentration. Geometric concentration is defined as the ratio of aperture area to absorber area -

$$C_{area} = A_a / A_{abs} \quad (12)$$

The flux concentration is defined as the ratio of intensity at the aperture to intensity at the absorber -

$$C_{flux} = I_b / I_{abs} \quad (13)$$

This involves an absorption effect in addition to geometry. In solar concentrator cookers geometric flux is the most widely used method.

The optical efficiency, η_o is defined as the ratio of the energy absorbed by the absorber to the energy incident on the concentrator aperture. It includes the effect of mirror/lens surface, shape and reflection/transmission losses, tracking accuracy, shading, absorber cover transmittance, absorptance of the of the absorber, and solar beam incidence effects. The optical efficiency is given as-

$$\eta_o = P_{abs} / A_a I_b \quad (14)$$

The optical efficiency of most solar concentrators lies between 0.6 and 0.7. In a solar thermal cooker, a combination of a working fluid and food substance is used to extract energy from the absorber.

The thermal efficiency is defined as the ratio of the useful energy delivered, to the energy incident at the concentrator aperture. For solar thermal cookers, the thermal efficiency (including evaporation of water to steam) is given as-

$$\eta_{th} = [\, m_f \; C_{pw} \; (T_{f2} - T_{f1}) + m_{wl} \, L_w \,] \; / \; A_a I_b$$

Also,

$$t_c = [\, m_f \times C_{pw} \; (T_{f2} - T_{f1}) \,] \; / \; \eta_{th} \; A_a \, I_b \quad (15)$$

The incident solar radiation consists of beam and diffuse radiation. Consider average solar radiation is 700 W/ m^2. However, the majority of concentrating collectors can utilize only beam radiation.[5]

V. COOKING TEST

1.Water Heating and Cooling Test :-

The water heating test was conducted by placing a vessel with half liter of water at room temperature on the cooker. The temperature at the middle of the water mass was monitored. The water temperature, ambient temperature are measured in 60 minutes of interval. The pot with a full load of water is heated by exposing the concentrator to solar radiation until boiling occurs and then cooled by shading the concentrator. Also at different places temperatures will be recorded. Readings of heating and cooling test are recorded & tabulated in Table 2. & Table 3.

2. Cooking Test :-

This was done to evaluate the time taken to cook a certain quantity of food items like rice, green gram, red gram, bean nut and khichadi. An equal quantity of these items was cooked individually on solar cooker. An equal quantity of water was added with each item. During the test the ambient temperature, Cooking temperature and time taken to cook the food are recorded. Reading are recorded in Table 4. & Table 5.

Table 2. Readings for 500 ml. of Water

Time AM/PM	Ambient Temp T_a (^0C)	Water Temp T_w (^0C)	$\ln(T_w - T_a)$	Atmospheric condition during Test
Date :- 15/03/2016				
09:30	35.4	63.9	3.35	Clear Sky Condition
10:30	35.9	66.8	3.43	
11:30	36.2	67.1	3.43	
12:30	36.2	67.9	3.45	Fairly Cloud Sky Condition
01:30	36.3	67.9	3.46	
02:30	37.2	68.2	3.43	
03:30	36.1	68.4	3.48	Clear Sky Condition
04:30	36	68	3.47	
Date :- 22/03/2016				
09:30	35.5	64.3	3.37	Clear Sky Condition
10:30	36.9	67.2	3.41	
11:30	37.9	67.3	3.38	
12:30	38.1	71.3	3.50	
01:30	38.9	72.4	3.52	
02:30	38.8	72.1	3.50	
03:30	38.2	71.6	3.50	
04:30	36.8	66.8	3.40	
Date :- 29/03/2016				
09:30	37.2	67.2	3.40	Clear Sky Condition
10:30	38.4	73.1	3.55	
11:30	39.5	75.3	3.58	
12:30	40.2	78.6	3.64	
01:30	41.1	81.9	3.70	
02:30	42.2	90.1	3.87	
03:30	41	89.3	3.88	
04:30	40.1	81.9	3.73	

Table 3. Variation of Temperatures at Different Places

Time AM/PM	Ambient Temp T_a (^0C)	Water Temp T_w (^0C)	Pot Surface Temp T_{pot} (^0C)	Reflector Temp T_{Ref} (^0C)
Date :- 15/03/2016				
09:30	35.4	35.4	35.4	35.4
10:30	35.9	66.8	99	39.9
11:30	36.2	67.1	101	40.3
12:30	36.2	67.9	100.3	41.1
01:30	36.3	67.9	100.2	41
02:30	37.2	68.2	101.3	40

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03:30	36.1	68.4	105.2	42.7
04:30	36	68	103	41
Date :- 22/03/2016				
09:30	35.5	35.5	35.5	35.5
10:30	36.9	67.2	101.2	41.8
11:30	37.9	67.3	101.4	42.1
12:30	38.1	71.3	110.6	44.5
01:30	38.9	72.4	116.7	48.9
02:30	38.8	72.1	117.6	49.7
03:30	38.2	71.6	113.7	47.3
04:30	36.8	66.8	103.2	46.9
Date :- 29/03/2016				
09:30	37.2	37.2	37.2	37.2
10:30	38.4	73.1	122.1	43.6
11:30	39.5	75.3	123.4	45.7
12:30	40.2	78.6	126.1	48.3
01:30	41.1	81.9	160.2	49.9
02:30	42.2	90.1	181.2	50.1
03:30	41	89.3	196.2	49.8
04:30	40.1	81.9	123.6	48

Table 4. Readings for 100 gm. Rice + 200 ml. Water

Time AM/PM	Cooking Time t_c (Min)	Ambient Temp T_a (^{0}C)	Cooking Temp T_c (^{0}C)
Date :- 16/03/2016			
09:30 - 10:30	45	35.9	83.2
11:30 – 12:30	43	37.2	85.4
01:30 – 02:30	40	39.2	86
03:30 – 04:30	42	36.1	83.8
Date :- 23/03/2016			
09:30 - 10:30	42	36.9	84.3
11:30 – 12:30	40	37.2	85.4
01:30 – 02:30	40	39.3	86.6
03:30 – 04:30	41	38.2	85.3
Date :- 30/03/2016			
09:30 - 10:30	40	39.5	86.5
11:30 – 12:30	38	42.4	90.2
01:30 – 02:30	33	43	94.5
03:30 – 04:30	35	42.6	94.3

Table 5. Reading of PDSTC for cooking various Food Items

Food Items	Quantity	Cooking Time t_c (Min)	Ambient Temp T_a (^{0}C)	Cooking Temp T_c (^{0}C)
Date :- 31/03/2016				
Khichadi	Rice 100 gms Red gram 20gms Water 250 ml.	9:30 - 10:15 (45 min)	39.6	86.5
Green gram	Green gram 100 gms, Water 200 ml.	11:00 - 11:45 (45 min)	40.6	89.4
Bean nut	Bean nut 100 gms, Water 200 ml.	12:30 - 01:18 (48 min)	42.7	92.1
Red gram	Red gram 100 gms, Water 200 ml.	01:3 – 02:15 (45 min)	42.9	93.4

VI. THERMAL PERFORMANCE OF THE PDSTC

Considering First reading recorded on 16/03/2016 at 9:30 - 10:30 AM For this time, The Thermal Performance of Parabolic Dish Solar Thermal Cooker are calculated by using following Equations.[5] –

<u>Sample Calculation</u>:-

Let,

The estimated rate of useful energy absorbed by the food for one cycle of the designed PDSTC is given by -

$Q_u = \eta_{th}\ I_b\ A_a$ (16)

The efficiency range of most solar concentrators is 40% - 60%.

Let, Standard Average Direct Solar Radiation is given as [5]

$I_b = 700\ W / m^2$

Aperture area (m^2) is given as -

$A_a = (\pi D^2_a) / 4 = [\pi (1.321)^2] / 4 = 1.370\ m^2$

Standard Value of , $C_{pw} = 4186$ KJ / Kg K

The rate of energy absorbed by the absorber, P_{abs} i.e Cooking Power is obtained as-

$P_{abs} = [\ m_w \times C_{pw} \times (T_{f2} - T_{f1})\ ] / [\ t_c\ ]$ (17)

$P_{abs} = [\ (200/ 1000) \times 4186 \times (83.2 - 35.9)\ ] / [\ 45\ ]$

$P_{abs} = 879.99\ W$

Optical efficiency is given as -

$\eta_o = P_{abs} / A_a\ I_b$

The optical efficiency of most solar concentrators lies between 0.6 and 0.7.[5]

Also,

Thermal efficiency is given as -

$t_c = [\ m_f \times C_{pw} (T_{f2} - T_{f1})\ ] / \eta_{th}\ A_a\ I_b$

$45 = [\ 0.1 \times 4186 (83.2 - 35.9\ ) / \eta_{th} \times 1.370 \times 700$

$\eta_{th} = 0.45 = 45\ \%$

Then, In this design, The useful energy, Q_u for one cycle of cooking is calculated as -

$Q_u = \eta_{th}\ I_b\ A_a$

$Q_u = 0.45 \times 700 \times 1.370$

$Q_u = 431.55\ W$

Also, follow the above same procedure to calculate the thermal performance values for different times & Date's, these values are tabulated in following Table 6. & Table 7.

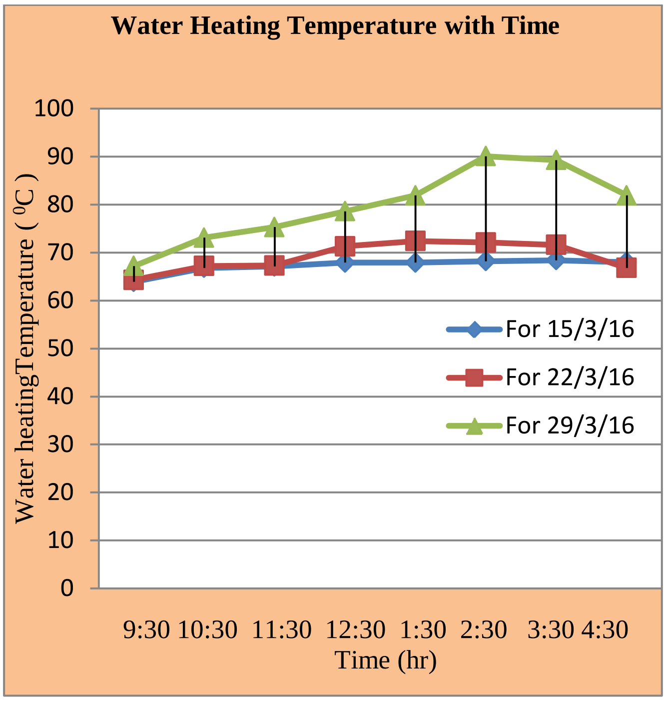
Table 6. Thermal Performance of Parabolic Dish Solar Thermal Cooker for Rice

Time AM/PM	Cooking Power P_{abs} (W)	Thermal Efficiency η_{th} (%)	Rate of Useful Energy Q_u (W)
Date :- 16/03/2016			
09:30 - 10:30	879.99	0.45	431.55
11:30 – 12:30	938.44	0.48	460.32
01:30 – 02:30	979.52	0.51	489.09
03:30 – 04:30	950.82	0.49	469.91
Date :- 23/03/2016			
09:30 - 10:30	944.84	0.49	469.91
11:30 – 12:30	1008.82	0.52	498.68
01:30 – 02:30	989.99	0.51	489.09
03:30 – 04:30	961.76	0.50	479.50
Date :- 30/03/2016			
09:30 - 10:30	983.71	0.51	489.09
11:30 – 12:30	1053.10	0.53	508.27
01:30 – 02:30	1306.53	0.68	652.12
03:30 – 04:30	1236.66	0.64	613.76

Table 7. Thermal Performance of Parabolic Dish Solar Thermal Cooker for cooking various Food Items

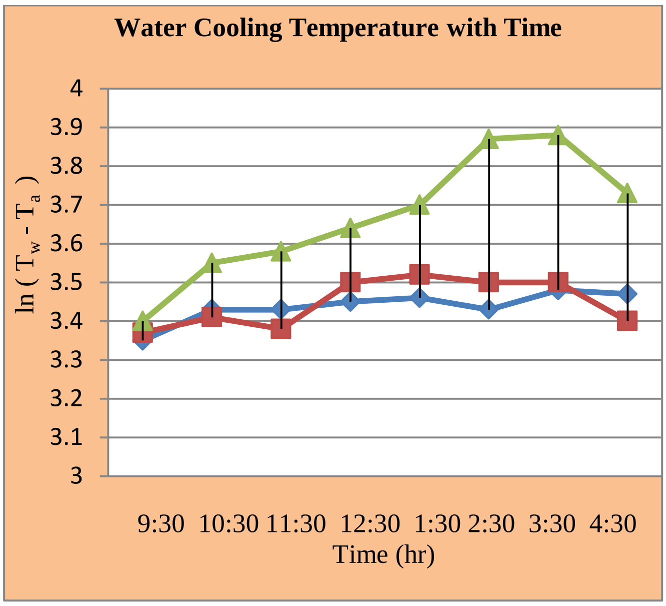
Food Items	Cooking Power P_{abs} (W)	Thermal Efficiency η_{th} (%)	Rate of Useful Energy Q_u (W)
Date :- 31/03/2016			
Khichadi	1090.21	0.54	517.86
Green gram	907.89	0.47	450.73
Bean nut	861.61	0.44	421.96
Red gram	939.52	0.48	460.32

VII. RESULTS & DISCUSSIONS



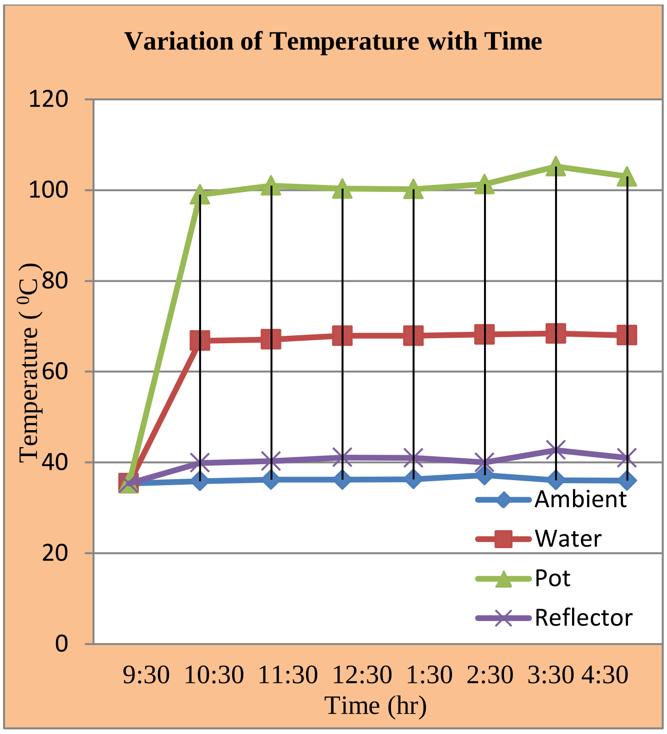
Graph 1 : Water Heating Temperature Vs Time

In above graph, shows the variation in water heating temperature, for the water having different masses. For half liter water test, maximum water temperatures achieved are 90.1^{0}C. The maximum ambient temperature recorded will be 42.2^{0}C. Graph shows that water heating temperature increases with time initially & then decreases after some time.



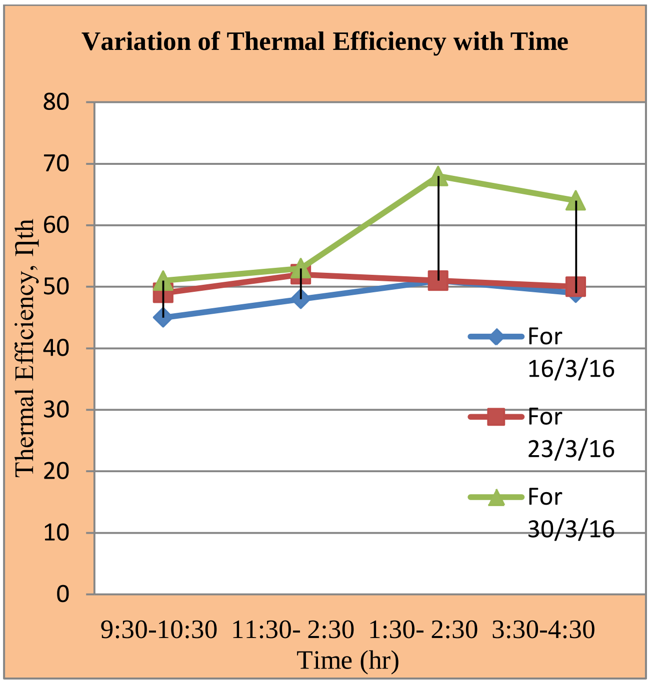
Graph 2 : Water Cooling Temperature Vs Time

Above graph refers to Water Cooling Temperature with Time. The graph shows that Water is cooled from Water heating temperature T_w to ambient temperature T_a. The cooling rate is ln(T_w - T_a). That is cooling rate is increases initially & decreases with time. The pot with half liter of water are heated by exposing the concentrator to solar radiation until the temperature reached to its maximum position and then cooled by shading the concentrator and the complete setup. A set reading of heating and cooling test was recorded. Results of cooling tests are shown in above graph.



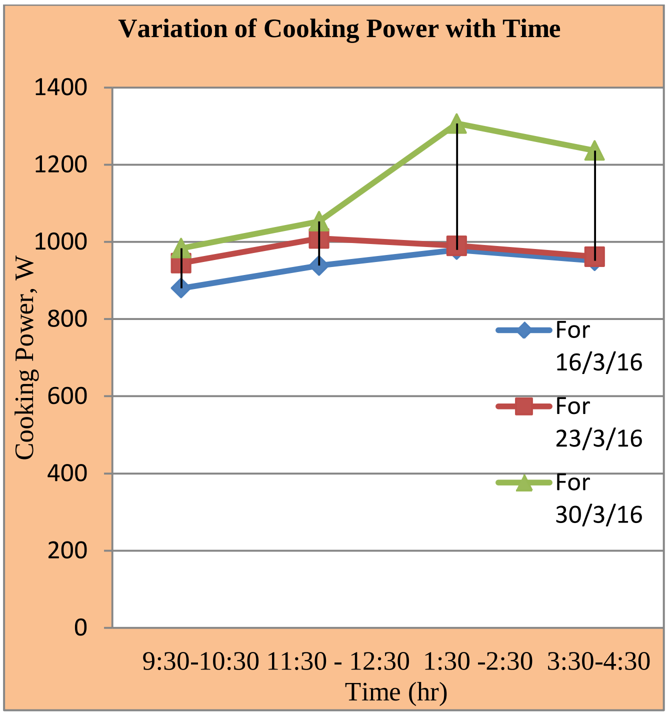
Graph 3 : Temperature Vs Time

In this graph I have analyzed variation of temperature at different places. The maximum pot temperature during the tests on the day are found to be 105.2 ^{0}C for pot surface and 37.2 ^{0}C ambient temperature, water temperature reached 68.4 ^{0}C & maximum reflector temperature 42.7 ^{0}C as shown in above graph. The temperature increases as solar radiation increases. This high temperature can be utilized for cooking, heating, and steaming. This graph for reading taken on 15/03/2016.



Graph 4 : Thermal Efficiency Vs Time

Above graph shows, The maximum thermal efficiencies are found to be 68 percent for average solar radiations. The determination of the thermal efficiency is another criterion for comparing the performance of the parabolic concentrator as a solar cooker under different climatic conditions. Thermal efficiency is better than other types of solar cooking devices.



Graph 5 : Cooking Power Vs Time

From above graph, shows that the cooking power was initially increases and then decreases gradually along time. The maximum cooking power 1306.53 W for average solar radiation as shown in graph 5.

CONCLUSION

In this work a Parabolic Dish Solar Thermal Cooker unit was fabricated and tested for the No load test, Water heating & cooling test, Cooking test purpose. The design and development of a Parabolic dish solar thermal cooker for domestic cooking applications are presented, together with the predicted actual performance of the system. Although detailed thermal performance analysis is presented, the cooking test results shows that the cooker is always capable of cooking food within the expected length of time and solar radiation levels. Also items like Rice, green gram, red gram, bean nut and khichadi are to be cooked & give satisfied results. The main research points of this are food-water volume and mass ratios, cooker component design and development, material and labour economy, and energy cost savings. Analysis of various Parameters is plotted on graphs as time on X-axis and Water heating temperature, Cooling temperature, Thermal efficiency, Cooking power on Y-axis. The analysis of various graphs indicates that -

i) The heating rate of water is higher than cooling rate.
ii) Solar Radiation is increases along the time.
iii) Cooking power is high initially & then decreases gradually along time.
iv) Thermal efficiency is better than other types of solar cookers.

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NOMENCLATURE

A_a = aperture area (m^2)
A_{abs} = absorber area (m^2)
A = distance from the Z – axis (m)
C_{area} = geometric concentration ratio
C_{flux} = flux concentration ratio
C_{pw} = specific heat capacity at constant pressure of water (kJ/kgK)
D_a = aperture diameter (m)
D_{abs} = external diameter of absorber (m)
d_{abs} = internal diameter of absorber (m)
F = focal point
f = focal length of dish (m)
h = height of parabolic dish (m)
L_{abs} = external height of absorber (m)
L_w = latent heat of evaporation of water (J/kg)
l_{abs} = internal height of absorber (m)
m_{f1} = mass of food before cooking (kg)
m_{f2} = mass of food after cooking (kg)
m_{r1} = mass of dry rice before cooking (kg)
m_{r2} = mass of rice after cooking (kg)
m_{wl} = mass of water lost, due to evaporation (kg)
m_{w1} = initial mass of water added to uncooked rice (kg)
m_{w2} = final mass of water remaining in cooked food (kg)
P_{abs} = rate of energy absorbed by the absorber (W)
Q_u = rate of useful energy for one cycle of cooking (W)
I_b = Average solar radiation (W/m^2)
t_x = Thickness of Cylindrical cooker (m)
R = arbitrary point on a paraboloid
r = distance from polar origin (m)
T_{f1} = initial temperature of uncooked food (°C)
T_{f2} = final temperature of cooked food (°C)
t_c = cooking time (min)
V = vertex of a parabola
v_{f1} = volume of food before cooking (m^3)
v_{f2} = volume of food after cooking (m^3)
v_{w1} = volume of water added to uncooked rice (m^3)
v_{w2} = volume of water remaining in cooked food (m^3)
v_{r1} = volume of dry rice before cooking (m^3)
v_{r2} = volume of rice after cooking (m^3)
η_o = optical efficiency of the solar cooker
η_{th} = thermal efficiency of the solar cooker
ø = polar coordinate angle (degrees)
ψ_{rim} = rim angle (degrees)
θ = angle about vertex (degrees)
T_a = Ambient temperature (°C)
T_c = Cooking temperature (°C)
T_w = Water temperature (°C)
T_{pot} = Pot temperature (°C)
T_{Ref} = Reflector temperature (°C)

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