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EXPERIMENTAL INVESTIGATION OF BOX TYPE SOLAR COOKER WITH FRESNEL LENS & MIRROR REFLECTOR

Kundan Jawale[1], Prof.Tushar Koli[2], Prof.V.H.Patil[3], Prof.Atul Patil[4]

Department of Mechanical Engginering, Godavari College of Engineering
Jalgaon, Maharashta, (India)
D.Y.Patil College of Engineering Pimpri, Pune (India)

ABSTRACT

Box type solar cooker used to cook the food by using solar energy which is available in free,but many researches shows that there are lot of improvement are required . In this paper we use Box type solar cooker having pyra shape which are recently developed .Thermal performance of this pyra shape Box type solar cooker used cooker are improved by using Fresnel lens and Mirror reflector.For this test are carried out as per BIS standard in two condition,In first condition Box type cooker without application of Fresnel lens and mirror reflector are used and in second condition box type cooker with application of Fresnel lens and mirror reflector.Stagnation and water heating tests are conducted for 1.1 kg of water to find out First figure limit,second figure limit and Cooking power.Pupose of this paper is to show how the results of Box type cooker are improved using Fresnel lens and mirror reflector.

Index Terms— Box type Solar Cooker, Fresnel lens, Mirror Reflecor, Stagnation test , Water heating test , First figure limit,Second figure limit, Cooking power .

I. INTRODUCTION

Solar cooker used to cook the food by using solar energy having many types like box type cooker, a panel type cooker, parabolic cooker etc. and many researches are done for imrovement of solar cooker. Box type cooker having simple Box shape insulated from inside & also have glass cover for reducing heat loss to the atmosphere.It has provided absorber plate at bootom side to place the cooking pots.All the inside suface should be black in colour to absorb more solar radiation by cooker. Some of the researches on box type solar are as follows,

C Z M Kimambo[1] tested four types of cooker in which glass type reflector cooker gives better performamce than oher type of cooker which is used alluminium foil as a reflector.Ademola K Aremu [2] tested different types of cooker with different types of insulating materials among them cocknut coir gives best result. Mullick [3] compares different values of F2 (second figure limit) for different load and for different number of pots,as per his investigation as the load or no.of pots increases value of F2 also increases.M.Abu-khader et al [4] shows that internal reflecting mirror in box type cooker on sun tracking system gives higher water and pot temperature. Pradeep Kumar [5] shows in his investigation that thermal performance of box type cooker is increased by using

rectangular fins. M.J.Brook[6] shows that augmented sunlight concentration improves the thermal performance of solar ovan.I.L.Mohammed [7] tested the performance of Mirror Reflector on Pyramid Solar Cooker and shows that it gives better result than cooker without Mirror Reflector. Thre is also lot of research is going on application of Fresnel lens in Solar technology.Some of them are as follows .Gaurav [8] reviews on various type of concentrator.On his review he shows that parabolic concentrator gives high concentration and Fresnel lens also concentrated solar energy than conventional one in furnace heating.Abdukkarim [9] shows in his investigation that fresnel Lens ouput in relation to its geometric size gives better permonce and utilized for high temperature generation. M. S. Mahmoud [10] investigating the performance of Fresnel lens in heating saline water for water desalination by humidification and dehumidification technique,his result water heating by Fresnel lens showed that the theoretical yield was not accomplished due to energy loss by radiations.R.Senthil [11] utilized Fresnel lens for heating of thermal mass through fin by thermal conduction to phase change material in domestic water heater. Awash Tekale [12] developed Pyra Box Solar Cooker and compared with regular shaped box type cooker ,he investigated that thermal efficiency increased by decreasing 25% total collector area.Our model is based on this cooker,we have to increase the thermal performace of pyra box solar cooker by utilizing Fresnel lens & Mirror reflector,

II. DISCRIPTION OF BOX TYPE COOKER

Box type Cooker having pyra shape are used for testing as per BIS standard. The Model of this cooker is as shiown in fig.Insulating material attaced inside of cooker having thickness 5mm from each side.after insulating material alluminium foil are attached from inside as a inner reflector. Absorber plate having thickenss 2 mm fixed at bottom side of cooker.Paint given to absorber plate is black .Glass cover are used in this cooker to reduce heat loss to the atmosphere.

Mirror which is fixed in wooden frame are attached to cooker by hinge.There is also provided a side plate having groove so that mirror with frame are fixed in suitable position so that all the solar radition are reflected towards inside of cooker.Linear Fresnel lens are fixed in frame used for concentrating are fixed to cooker by two side plate.It can be move as per solar radiation by loosening and tightening the bolts of side plate.Distance of fresnel lens from absorber plate is kept 600mm .

Fig. 1.Experimental Setup for Pyra box cooker

III. EXPERIMENTAL POCEDURE

Test conducted on box type cooker having pyra shape on the land of pune Univercity.All the test conduced as per BIS standard.Two main test as per BIS standard are stagnation test and water heating test are conducted in two different condition .In first condition Cooker without fesnel lens are used and in second condition cooker with Fresnel lens and mirror reflector are used

3.1 Stagnation Test

This experiment monitored the rise in temperature of the absorber plate.

a) Place the solar cooker without pot in open sun condition;

b) Cover the reflector of the solar cooker with a black cloth;

c) Monitor the cooker tray temperature at an interval of 5 min continuously. Also measure intensity of total solar radiation, ambient temperature and wind speed at the level of glazing's of solar cooker; and

d) When the cooker tray temperature has reached a quasi-steady state note down the final steady cooker tray temperature (Tpz) and the corresponding outside ambient air temperature (Taz) along with the solar radiation (Gs) at that time.

As per above given condition two stagnation test are conducted.From this test value of First figure limit F1 is calculated form following standard BIS formula

$$F_1 = \frac{T_{pz} - T_{az}}{G_s} \quad \text{.....(1)}$$

Where

T_{pz} is stangnation temperature for absorber plate in ^{o}c.

T_{az} is ambient temperature at the time of stagnation in ^{o}c

G_s are solar radiation at the time of stagnation. In W/m^2

3.2 Water Heating Test or Full Load Test

A) The empty cooking pots are weighted then filled water as a load 1 Kg of water at equally distributed in all cooking pots if they are of same size. If the sizes are different then water quantity in each cooking pot shall be in proportion to their bottom area. By reweighting the exact mass of water is calculated then pots are placed in the cooker after removing the reflector with black cloth

B) Temperature probe of thermocouple is placed in the largest at the cooking pot with the measuring tip submerged in the water the temperature lead should be seal where it leaves the cooking pots & the cooker

C) Ambient temperature ,intensity total solar radiation at the level of glazing of solar cooker are measured through the test

D) Test is started in the morning between 10 to 10.30 am of local solar time. following measurement are done

- Water temperature in pot with exact time
- Data is recorded until the water temperature exceeds 95 ^{0}C
- Initial & final water temperature is recorded with time .Range of temperature is 6o ^{0}C to 90 ^{0}C is taken
- The average ambient temperature and average solar radiation intercity between time t1 & t2 is calculated

- Experiment is conducted in clear whether & it is assumed that test is carried out at 600 W/m^2

As per above given condition two water heating test are conducted.From this test value of Second figure limit F2 is calculated form following standard BIS formula

$$F_2 = \frac{F_1 (MC)_w}{A(t_2 - t_1)} \ln \frac{\left[1 - \left(\frac{T_{w1} - T_a}{F_1 G}\right)\right]}{\left[1 - \left(\frac{T_{w2} - T_a}{F_1 G}\right)\right]} \quad \text{.....(2)}$$

*Where F*1 = First figure of merit from stagnation test,

(*MC*) w = Product of the mass of water and specific heat in J/°C,

A = Aperture area of the cooker of cover plate in m^2

(*t*2 – *t*1) = Time taken for heating from *T*w1=60^{0}C and *T*w2 = 90^{0}C seconds,

*T*a = Average air temperature over time period (*t*2 — *t*1) in °C,

G = Average solar radiation.

3.3 COOKING POWER (P)

Cooking power P is defined as rate of useful energy available during heating period. It may be determined by change in water temperature for each interval & mass & specific heat of water contained in the cooking pot .Dividing the product by time contained in a periodic interval yields cooking power in watt. Cooking power calculated by

$$P = (M_w C_w) \frac{(T_{wb} - T_{wa})}{\tau} \quad \text{.....(3)}$$

Where

M_w is mass of water in cooking pot.

C_w is specific Heat of water in J/Kg K

T_{wb} & T_{wa} temperature.of water at beginning & end of time duration T.

III. RESULTS AND DICUSSION

Stagnation Test 1 without Fresnel lens was conducted at Energy Department of Pune Univercity (latitude 18 ^{0} 32 $'$ 0" N , longitude 74 ^{0} 20$'$ 30" E).Test was started at 10 a.m. till maximum absorber plate temperature reached after 2 hours 35 minutes.Result table for Stanation test 1 is given in table 1.Variation of air and plate temperature with respect to time for stagnation test 1 is shown in Fig.2.It shows that as the time increases plate temperature also increased .Plate temperature increased up to 109^{0}C.This is Stangnation temperature achieved at solar intencity 725 W/m^{2}and 35.5^{0}C air temperature.From this test F1 is found 0.10 which is less than BIS Standard value 0.12 so it is called as B grade type cooker

TABLE 1

Stangnation Test 1 Without Fresnel Lens & Mirror Reflector

Local time (hh:mm)	Air Temperature (˚C)	Plate Temperature (˚c)	Solar Radiation (W/m^2)
10:00	26.0	52	517
10:05	27.5	55	585
10:10	28.0	58	600
10:15	29.0	61	610
10:20	30.0	64	620
10:25	30.0	67	625
10:30	30.0	70	635
10:35	31.0	72	637
10:40	32.0	74	641
10:45	32.0	77	642
10:50	32.0	80	646
10:55	32.0	84	650
11:00	32.0	86	651
11:05	32.5	88	656
11:10	32.5	90	657
11:15	33.0	91	660
11:20	33.5	92	665
11:25	33.5	94	666
11:30	33.5	96	670
11:35	34.0	98	671
11:40	34.0	100	674
11:45	34.5	101	675
11:50	34.5	103	678
11:55	34.5	104	680
12:00	35.0	106	700
12:05	35.0	107	710
12:10	35.0	108	712
12:15	35.0	108	715

12:20	35.0	109	720
12:25	35.0	109	722
12.30	35.5	109	724
12.35	35.5	109	725

On next day Water heating test 1 without Fresnel lens was conducted.Test started at 10.35 a.m.and Completed at 2.05 p.m.at that time water temperatue increased above 95 ^{0}C.Total time required to attain 96 ^{0}C.was 3 hours 30 minutes. Summary of results are given below in table 2.Variation of air and water temperature with respect time for Water heating test 1 is shown in Fig.4.It shows that as the time increases water temperature also increased .Water temperature increased from 60^{0}C to 90^0 C in 90 minutes.This water temperature achieved at average solar intencity 818 W/m^{2}and 32.5^{0}C average air temperature.From this test F2 is found 0.344.

TABLE 2

Water Heating Test 1 Without Fresnel Lens & Mirror Reflector

Local time (hh:mm)	Air Temperature (˚C)	Water Temperature (˚c)	Solar Radiation (W/m^2)
10.35	24.0	24	651
10.40	25.0	26	655
10.45	25.0	29	660
10.50	25.0	32	675
10.55	25.5	35	721
11.00	26.0	37	736
11.05	26.0	40	746
11.10	27.5	42	747
11.15	27.5	43	750
11.20	28.0	44	751
11.25	28.2	47	756
11.30	29.0	48	760
11.35	30.0	49	780
11.40	30.5	52	785
11.45	30.7	54	790
11.50	31.0	57	790
11.55	31.5	58	800
12.00	32.0	60	810

12.50	32.2	63	810
12.10	32.5	65	815
12.15	33.0	67	820
12.20	33.2	68	830
12.25	34.0	70	840
12.30	34.2	72	845
12.35	34.5	74	861
12.40	35.0	75	865
12.45	35.2	76	865
12.50	35.5	78	871
12.55	35.7	80	872
1.00	36.0	82	875
1.05	36.1	84	880
1.10	36.2	86	890
1.15	36.5	87	890
1.20	37.0	88	891
1.25	37.1	89	892
1.30	37.2	90	890
1.35	37.2	92	890
1.40	37.5	94	895
1.45	38.0	95	900
1.50	38.2	96	901
1.55	38.0	96	902
2.00	38.0	96	905
2.05	38.0	97	910

Again stagnation test 2 with Fresnel lens was conducted on next day, test started at 10.30 a.m. and maximum absorber plate temperature obtained after this test was 145 ^{0}C.Test results for Stagnation test 2 is given below in table 3. Variation of air and plate temperature with respect to time for stagnation test 2 is shown in Fig.4.It shows that as the time increases plate temperature also increased .Plate temperature increased up to 145^{0}C.This is Stangnation temperature achieved at solar intencity 850 W/m^{2}and 38 ^{0}C air temperature.From this test F1 is found 0.13 which is more than BIS Standard value 0.12 so it is called as A grade type cooker.

TABLE 3

Stangnation Test 2 Without Fresnel Lens & Mirror Reflector

Local time (hh:mm)	Air Temperature (˚C)	Plate Temperature (˚C)	Solar Radiation (W/m^2)
10:30	28.0	28	629
10:35	29.0	33	636
10:40	30.0	40	640
10:45	31.0	45	646
10:50	32.0	52	655
10:55	32.0	59	660
11:00	32.1	65	680
11:05	32.8	71	686
11:10	33.0	78	688
11:15	33.5	84	692
11:20	34.0	91	694
11:25	34.5	97	695
11:30	35.0	103	701
11:35	35.1	110	712
11:40	35.3	118	716
11:45	35.5	125	729
11:50	35.7	131	740
11:55	36.0	137	780
12:00	36.2	140	800
12:05	36.3	142	825
12:10	36.7	145	830
12:15	37.0	145	850
12:20	37.2	145	851
12:25	37.7	145	850

On next day water heating test 2 with Fresnel lens was conducted.Test started at 10.10 a.m.and Completed at 12.45 p.m.at that time water temperatue increased above 95 ^{0}C.Total time required to attain 96 ^{0}C.was 2 hours 35 minutes.Summary of results are given below in table 4. Variation of air and water temperature with respect to

time for water heating test 2 is shown in Fig.5.It shows that as the time increases water temperature also increased .Water temperature increased from 60^0C to 90^0C in just 71 minutes.It shows that time requird for boiling is minimized as compared to water heating test 1.This water temperature achieved at average solar intencity 791.4 W/$m^2$and 33.4^0C average air temperature.From this test F2 is found 0.385 which is equal to BIS Standard value and more than the value for water heating test 1.

TABLE 4

Water Heating Test 2 With Fresnel Lens & Mirror Reflector

Local time (hh:mm)	AirTemperature (˚C)	Water Temperature (˚c)	Solar Radiation (W/m^2)
10.10	29.0	29	650
10.15	29.5	32	656
10.20	29.5	35	661
10.25	30.0	38	674
10.30	30.1	42	720
10.35	30.5	45	735
10.40	30.5	48	745
10.45	31.0	51	746
10.50	31.5	54	750
10.55	31.5	56	751
11.00	32.0	58	756
11.05	32.5	60	770
11.10	32.5	64	780
11.15	33.0	68	785
11.20	33.0	70	790
11.25	33.5	73	790
11.30	33.7	75	800
11.35	34.0	78	810
11.40	34.2	80	810
11.45	34.5	82	815
11.5	34.8	83	820

11.55	34.5	85	830
12.00	35.0	87	840
12.05	35.1	89	850
12.10	35.5	89	855
12.16	35.5	90	857
12.20	36.0	92	865
12.25	36.5	93	870
12.30	36.5	95	875
12.35	37.0	95	880
12.40	37.5	96	890
12.45	38.0	96	900

Value of First Figure limit F1 obtained from Stagnation Test 1&2, and value of Second Figure limit F2 & Cooking power obtained from Full load test 1&2. These values are summarized in table 5

Table 5

Result Table For Both Cookers With Fresnel Lens & Without Fresnel Lens

	Cooker without Fresnel lens	Cooker with Fresnel lens & Mirror relector
First Figure Limit (F1)	0.10	0.13
Second Figure Limit (F2)	0.344	0.385
Initial water temperature (^{0}C)	24	29
Time of water boiling in pots (min)	210	155
Temperature of boil water (^{0}C)	96	96
Cooking power (W)	26.12	33.17

From table 5 shows Value of F1 and F2 improved in cooker with Fresnel lens and mirror reflector than Value of F1 and F2 of cooker without Fresnel lens and mirror reflector.

Percentage increase in cooking power = [(33.17 – 26.12)/26.12] x 100 = 27%

Time reduces for solar cooking = [(210 – 155)/210] x 100 = 26%

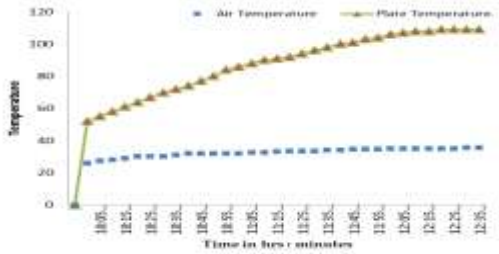

Fig.2. Graph showing variation of Air & plate temperature for Stagnation test 1

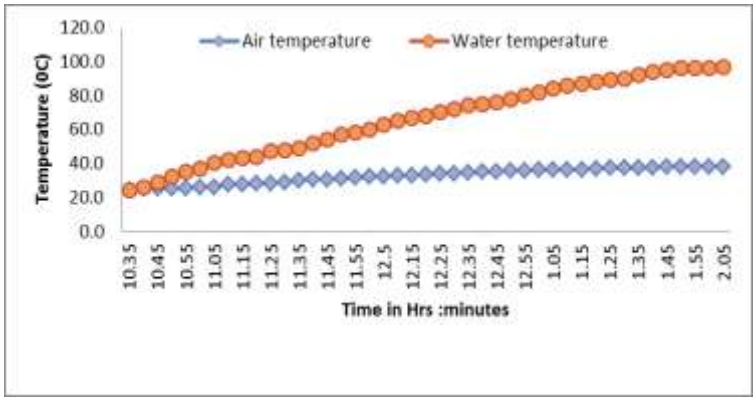

Fig.3. Graph showing variation of Air & water temperature for Water heating test 1

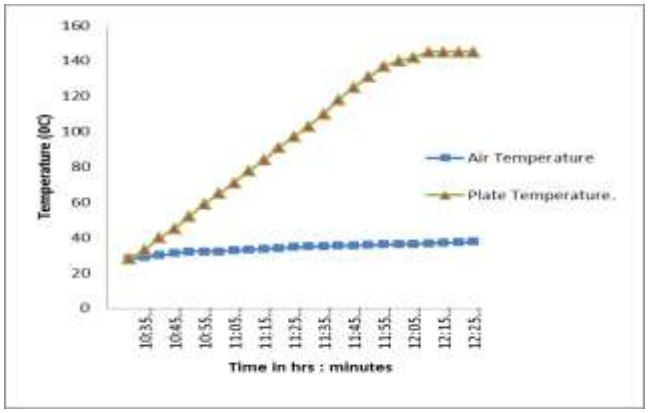

Fig.4. Graph showing variation of Air & plate temperature for Stagnation test 2

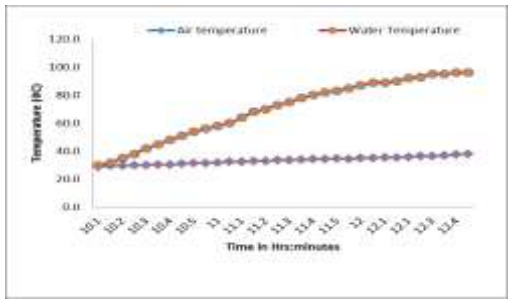

Fig.5 Graph showing variation of air & water temperature for Water heating test 2

IV. CONCLUSION

From above experiment as per results shows that cooker with Fresnel lens and mirror reflector improves the value of (F1=0.13, F2=0.385) than cooker without Fresnel lens and mirror reflector (F1=0.10, F2=0.344).This modified cooker with Fresnel lens mirror reflector also satisfies the Standard BIS value.Definitely by use of Fresnel lens in cooker minimizes time for solar cooking nearby 26% and improves the cooking power by 27%.

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REFERENCES

[1] C Z M Khimambo, “Development and performance testing of solar cookers,” vol. 18, no. 3, pp. 41-51, August. 2007. (Journal of Energy in Southern Africa)

[2] A.K.Aremu and R. Akinoso, “Potential Use of Box-Type Solar Cooker in Developing Countries,” vol. 41, no. 1, pp. 11-17, April/May 2013. (The Journal of the Association of Professional Engineers of Trinidad and Tobago)

[3] S.C.Mullick, T.C.Kandpal and S. Kumar, “Testing of Box type Solar cooker second figure merit F2 and its variations with load & no.of pots,’’ vol. 57, no. 5, pp. 409-413, July. 1996. (Solar Energy)

[4] M. Abu-Khadera, M. Abu Hilalb,S. Abdallahc,and O.Badrana, “ Evaluating Thermal Performance of Solar Cookers under Jordanian Climate, vol. 5, no. 1, pp. 107-112,ISSN 1995-6665 Feb. 2011. (Jordan Journal of Mechanical and Industrial Engineering.)

[5] P. Kumar and B.K.Chourasia, “Performance investigation of a two reflector box type solar cooker with finned absober plate,”vol. 4, no. 4, pp. 162-177, ISSN 2249-6149 ,June - July 2014. (International Journal of Emerging Trends in Engineering and Development)

[6] M.Brooks, “Thermal performance of a solar oven with augmented sunlight concentration,” vol. 18, no. 2, pp. 04-10, May 2007. (Journal of Energy in Southern Africa)

[7] I. L. Mohammed, M. M. Aliyu, I. Garba, “The Effect of Booster-Mirror Reflector on the Thermal Performance of a Truncated Pyramid Solar Thermal Cooker,” vol. 4, no. 5, pp. 126-135, ISSN: 2248-9622, May 2014. (Int. Journal of Engineering Research and Applications)

[8] G. Madugiri and S. Karale, “High solar energy concentration with a Fresnel lens: A Review,” vol. 2, no. 3, pp. 1381-1385, ISSN: 2249-6645, May-June 2012. (International Journal of Modern Engineering Research)

[9] Abdukkarim H. El-Ladan, C. Yen, Mohd H. Ruslan,K. Sopian, S.H. Zaidi, “The Prospects of a Promising Solar Thermal Concentrator (Fresnel Lens) for Cooking, Heating and Electricity Generation,” vol. 1, no. 3, pp. 175-180, ISBN: 978-1-61804-175-3, Apr. 1985. (Latest Trends in Renewable Energy and Environmental Informatics)

[10] M. S. Mahmoud, A. A. Mohamed, “Utilization Of Fresnel Lens Solar Collector In Water Heating For Desalination By Humidification-Dehumidification Process,” Proc.Fifteenth International Water Technology Conference, pp. 02-12, 2011. (IWTC-15)

[11] R.Senthil and Dr.M.Cheralathan, "Solar Integrated Collector Storage Using Fresnel lens for Domestic Hot Water," vol. 2, no. 2, pp. 53-77, August 2012. (International Journal of Engineering Research and Development)

[12] Awash Tekale, "Experiment Assessment on Thermal Performance and Efficiency of Pyra-Box Solar Cooker," vol. 4 no. 7, ISSN: 2224-3232, pp. 58-65, 2014. (Journal of Energy Technologies and Policy)

[13] Bureau of Indian Standards (BIS) IS 13429 (part 3):2000,"Test Method"pp. 01-03, May 2003.