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Development of Convex Lens Solar Concentrator with Parabolic Tracking

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ABSTRACT

Solar energy helps in achieving new levels to satisfy world's energy needs. The effective way of utilizing sunlight with solar energy concentration technology and recent developments of its applications using convex lens solar concentrator is reviewed in this paper. The present status of application, the ongoing research and development works suggest that with some amount of efforts regarding the manufacturing the convex lens solar concentrators will bring an outstanding market to solar energy concentration application technology in the coming era. The project was focused on the Solar Energy high temperatures using parabolic solar concentrator, Convex lens, transmitting materials and solar tracking. It identified their level of performance. This paper will provide a contemporary review of convex lens solar concentrators and their benefits to make solar technology cheap. It will also analyze on some of the existing solar concentrators used in the solar technology for the past four decades and performance of each concentrator will be explained and compared. This paper makes a review about the recent trends of the concentrated solar energy applications using solar concentrators. The current research and development involves imaging as well as non-imaging systems. In comparison with imaging systems, the other non-imaging systems have the advantages of greater accept angles, greater concentration ratios with minimum volume and short focal length, greater optical efficiency, etc. Based on imaging, concentrated photovoltaic is an important application and the highest solar-to-electric conversion efficiency.

Keywords*: Parabolic solar concentrator, Fresnel lens, transmitting acrylic materials, Solar tracking*

1. INTRODUCTION

In this paper, the development of the cheapest solar concentrator with the acrylic material and its use for the cooking application explained. To overcome the disadvantages we have in our solar heating system with parabolic tracking system and optimizing the cost of the solar devices to make it available at cheaper rates in the market. Solar tracking makes the system very agile and adaptable to the positions of the sun. The main objectives of the development of concentrator are: 1) To achieve sufficient temperature with the help of solar concentrator which can be utilized for the cooking applications 2) To design a solar tracking system to utilize maximum energy radiated by the sun and increase the efficiency of the system. 3) To develop a cheaper solar cooking application and making the renewable energy available at cheaper cost.

1.1 Literature Review

[1] Among the different energy end uses, energy for cooking is one of the basic and dominant end uses in developing countries. There are numerous solar energy based cooking equipments has been design, developed and tested for various applications across the world. The main aim of the research paper is to provide extensive view on standard testing approach of solar cooker, energy and exergy analysis approach and economic

evolution of different types of solar cooker. Also the size of the job is a considerable factor for deciding the type of forging process[1].

[2] The use of dish systems is among the most potential methods for solar power collection. However, the popularity of the application of traditional dish systems has been retarded because they are structurally complex, heavy, and costly. According to this, a novel ultralight dish system is brought into picture where it includes a cable mesh reflector, an ultralight thermoelectric converter, and a three-extensible-rod (TER) solar tracker[2].

[3] The product developed involves use of mirror polished aluminum reflectors, solar tilt and aluminum pressure cooker manual trackers. With the help of social awareness camps, 70 solar cookers were installed in an indigenous society in México; previously it was designed a diagnostic of timber resources use to each beneficiary family. For selecting thermal and ergonomic characteristics, firing tests were performed with different types of prototype plots. To encourage the use of renewable energy, the project expects to reduce the consumption of timber as a fuel for cooking by about 30%;, to mitigate respiratory diseases caused by the inhalation of combustion smoke and help the family’s economy[3].

1.2 Objectives and Scope

1] To achieve sufficient temperature with the help of solar concentrator which can be utilized for the cooking application.

2] To design a solar tracking system to utilize maximum energy radiated by the sun and increase maximum efficiency of sun.

3] To develop a cheaper solar cooking application and making the renewable energy available at cheaper cost.

2. Theoretical Design

I) **Convex Lens:** For the manufacturing of the convex lens we had two options like glass or acrylic. Due to easy availability and flexible Manufacturing we go for acrylic. The acrylic material we chose had the properties we needed. Some Properties and its range are listed as:

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1)Specific Gravity: 1.19 2)Refractive Index: 1.49 3)Light Transmission Capacity: 92%
4)Coefficient of thermal expansion (k): 1.3 BTU/hr 5)Specific heat (at 77o F): 0.35 BTU/hr.

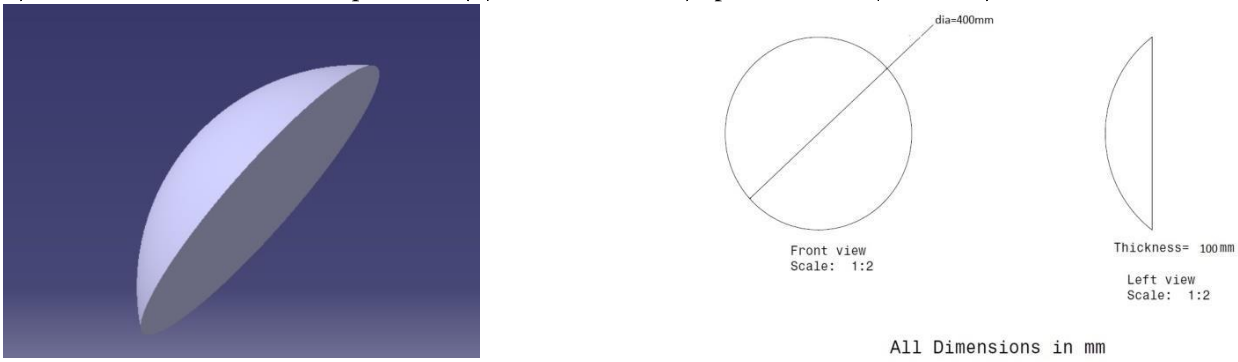

Fig-1: One half of Convex lens

II) MS Plate: MS are bolted to the lens which hold the lens which is slotted at the bottom which enables it to rotate along the pivot point.
Dimensions= 600mm X 30mm X 5mm

III) Driving mechanism:
Motor Specifications: Johnson Geared Motor (Made In India) 100 RPM Rated Voltage:12V
Rated Torque: 5.7 kg-cm Weight (gm):164gm
Gearbox Dimensions: 25×37 (LxW) mm Lead screw: M12 X 1.25 mm

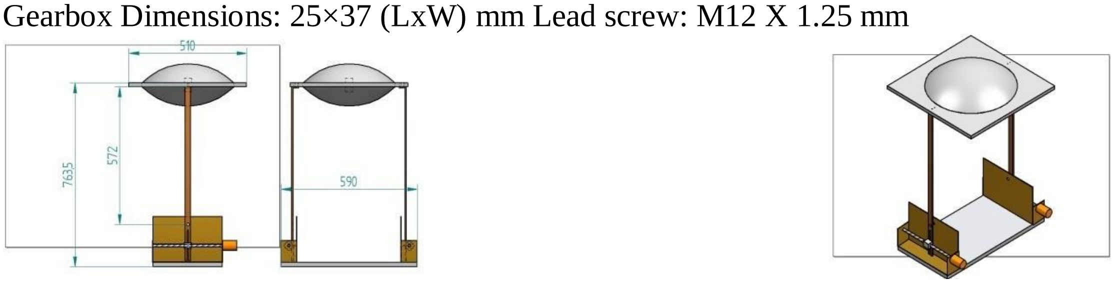

Fig. Overall Design for the Tracking

3. Calculations for
Lens:
Focal length( ) α −(= Depth of lens)

= (μ -μ)

2 1

Where, μ_1=Refractive index of acrylic sheet

μ_2= Refractive index of water where μ_1 =1.33 μ_2= 1.49
R= Radius of curvature

r= radius of lens=400 mm= 0.4m h= Depth of lens=100mm=0.1m
By varying lens depth( )

Area of lens=2πR r=√
Assuming the radius of le~~ns(r)=0.5~~m

R= = =0.9083m

Focal length( )= = = 5.6768 m

Initial assumptions were according to the data from the various research papers of solar cooker concentrator. But the lenses are much more efficient than the mirror concentrators. So it resulted that the solar lens concentrator can produce the same amount of heat with the half of the dimensions of the mirror concentrators. It helped us optimizing the size of the setup with no compromise in the heat generation.
New radius of lens (r)=0.2m

R= = =0.85m

Focal length( )= = = 1.5625 m

Energy loss per m^2 by sun =343 W/m^2

The Earth receives 174 petawatts (PW) of solar radiation coming to the earth at the upper atmosphere. About 30% is reflected back to space while the remaining is absorbed by clouds, sea and land areas. Most of the people in the world live in areas with insolation levels of 160–300 watts/m², or 3–7 kWh/m² per day.
By the equation,

Losses= reflected radiations (30%)+ absorbed radiations(21%) Available radiations =49%
=0.49(343)=168W/m^2

Available energy= 168 W/m^2 Radiation heat transfer(q)
$q=\sigma A[(T)^4-(Ts)^4)]$

174= 5.67 10^{-8} [T^4-303^4] T=327k =54°C
By Using
Water:- q=500W/m^2 $q=\sigma A[(T)^4-(Ts)^4)]$
500=5.67 10^{-8} 2 π(0.2)(0.1)[T^4-308^4] T=530^0K =257^0C

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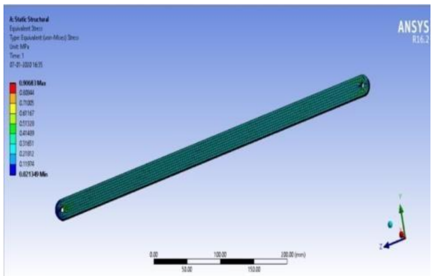
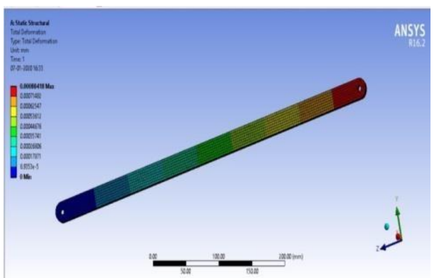
The calculations results the temperature as 257^0C

Analysis of supporting links:



Static Structural Analysis of lens for equivalent stress:

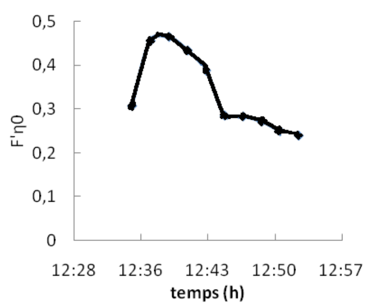
- Load applied= 100N
- Max stress= 1Mpa
- Location of max stress= At the holes made for bolts



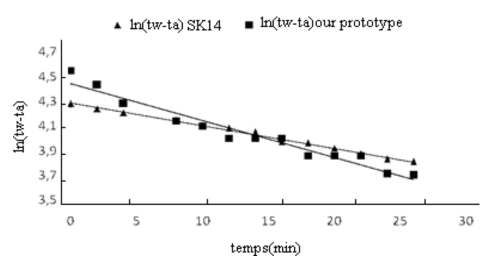
Static Structural Analysis of lens for total deformation:

- Load applied= 100N
- Max deformation= 0.0008mm
- Location of max deformation= Near the lens, at the top

Heating Test:



Cooling Test:



Heating test:

Heating test is conducted to determine optical efficiency factor (F'_o) of the parabolic concentrator solar cooker. For this test, the cooking utensil with a already defined amount of the water (as the cooking load) is mounted at the focus of the parabola.

Cooling test:

As soon as the water reaches 95°C temperature during this test, the concentrator shall be covered with the sufficiently large umbrella (with dark colour, preferably black) so that it will block all the solar radiation. Minimum interference in the heat loss process from the cooking pot must be

ensured with the shading arrangement.

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Time	9:30 am	10:30 am	11:30 am	12:30 pm	1:30 pm	2:30 pm	3:30 pm
Day	T_1-T_2	T_1-T_2	T_1-T_2	T_1-T_2	T_1-T_2	T_1-T_2	T_1-T_2
1	26 -37	30-43	29-41	30-44	29-63	27-61	25-59
2	27-39	29-35	30-53	31-77	30-67	26-53	28-61
3	28-41	29-55	30-67	31-79	29-73	29-67	27-61
4	28-37	29-72	30-78	31-82	31-85	28-77	27-66
5	29-34	30-74	30-84	30-90	31-97	31-95	30-83
6	27-44	30-74	35-97	34-104	38-99	31-96	28-87

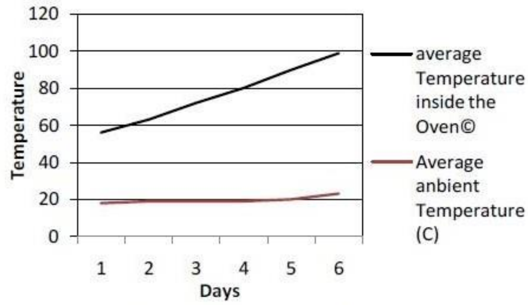

Figure 3: Average temperatures.

CONCLUSION:

The solar concentrator was designed from the ground up with the needs of research in mind. All components are to be designed to be as lightweight and high performance as possible. The knowledge of all the research papers are to be incorporated within the prototype. All initial tests have to be conducted and results to be estimated if the desired temperature is achieved by the lens or not. The working of Arduino is also monitored.

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