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# An Experimental Study of Design and Fabrication Details of Parabolic Solar Dish Collector for Water Heating

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**Abstract**

The Design and fabrication of a parabolic solar dish collector for water heating and domestic household application is described. The parabolic solar dish collector provide 120 liter of hot water per day. For effective performance of the design requires that parabolic solar dish collector track the sun continuously, and an automatic time based circuit was designed and developed for this purpose. The experimental set up inclined adjusted to 26° and south faced, which is seemly for the geographical position of Jaipur (26.9260°N, 75.8235°E). The experiment set up was working in the sunshiny days of June 2015. The experimental test operates carried out showed that overall performance of the parabolic solar dish collector was satisfactory. Overall performance of 47.29% was obtained which is higher than designed value 40% to 60%. The use of a wiper motor and gear – pinion mechanism with time based electronic circuit to track the sun eliminates the need for constant monitoring by a human operator and, thus, reduces the cost of labour.

**Keywords:** Parabolic solar dish collector, Copper cylinder, Tracking circuit, and thermocouple.

**Introduction**

The World of today has been drudging hard to solve the dual problem related to the ever growing energy demand and growing environmental degradation. Solar energy possesses huge potential to solve this problem due to its characteristics of highly abundant in nature and clean energy. In this paper, an alternative technique (using solar energy) to cater a portion of hot water and steam required by mankind has been suggested. Parabolic solar dish collector is taking its capable position in the modern green technology market because of its low cost and high efficiency. Parabolic solar dish collector has got a wide application in hospitals, industries, cooking (which is also known as solar cookers), domestic applications. Parabolic solar dish collector employs parabolic reflector to concentrate the total solar energy incident on the absorber surface. The parabolic solar dish has the highest efficiency in terms of the utilization of the reflector area because in a 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. Ibrahim Ladan Mohammed (2002) design and development of solar parabolic dish water heater for 40 liters water heating per day for four members of family. Steven dubowsky et al. (2008) presented a new concept for designing and fabrication of large parabolic dish mirror. He approached a new design for parabolic solar dish collector which is based on optimized flexible petals. Chemisana (2013), To evaluate and test the optical quality of solar concentrators, he focused on devising the methodology of concentrating when it works at varied inclination angle for tracking the different positions of the Sun. This was based on application of absorber reflection method (ARM). Pelemo(2003) designed and constructed a parabolic solar concentrator which was then used and tested for water distillation.

In this experiment work, a parabolic solar dish collector was designed and fabricated. It was required to heat 120 liters of water in a day.

**Nomenclature**

$A_a$ - Aperuture Area

$A_{abs}$ - Absorber Area

CR - Concentration Ratio

$C_p$ - Specific heat capacity at constant pressure of water

$D_a$ - Diameter of aperature

$D_{abs}$ - Outside diameter of absorber

$d_{abs}$ - Internal diameter of absorber

*f* - Focal length

$I_b$ - Beam radiation

l - height of absorber

$\dot{m}$ - rate of heating water

$Q_u$ -useful energy per day

$T_1$ - temperature of heating water entering the cylinder

$T_2$ - temperature of heating water leaving the cylinder

$t_x$ - thickness of cylinder wall

$V_w$ - volume of water

$\eta_o$ - overall efficiency

$\Psi_{rim}$ - rim angle

**Aperture area ( $A_a$)** is the area of the collectors that intercepts solar radiation. It is also known as area of solar collectors.

Diameter of dish=70.24inch=178.40cm = 1.78m

Radius of dish=89.2cm=.89m

**Area of collectors =** $\pi r^2$

$= 3.14 \times (.89)^2$ .......eq. 1

$=2.5m^2$

**Area of absorber($A_{abs}$)** is defined as the total area of the absorber surface that receives the concentrated solar radiation.

Copper cylinder worked as absorber. Where,

**$D_{abs}$**= Outside diameter of absorber,

**$d_{abs}$**= internal diameter of absorber,

***l*** = height of absorber, and

**$t_x$** = 4mm, thickness of absorber

**$V_w$** = 4 liter ,Volume of water heated in cylinder

The internal volume of the cylinder is the same as the volume of water to be heated. So:

$\frac{\pi d^2 abs}{4} \times l = Vw$ ......eq. 2

For simple solution of the equation and optimum design of the absorber height ***l*** is made to be same as the diameter **$d_{abs.}$**

$\frac{\pi d^3 abs}{4} = Vw$

Since, 1000 liter = $1m^3$

Therefore

4 liter = $0.004m^3$.

$V_w = 0.004m^3$.

$d^3 abs = \frac{0.004 \times 4}{\pi}$

**$d_{abs}$**$= \sqrt[3]{0.0050}$

=0.1709m =17.09cm

$l = d_{abs}$ =17.09cm

Then,

$D_{abs}$= Outside diameter of cylinder

$D_{abs} = d_{abs} + 2t$

=17.09 + 2(0.4)

$D_{abs}$ = 17.89 cm =0.1789m

Now, we calculate the area of absorber

**$A_{abs}$ =** $\frac{\pi D^2 abs}{4} + \pi D abs l$ **.......**eq. 3

$= \frac{\pi \times (0.1789)^2}{4} + \pi \times .1789 \times .1709$

**$A_{abs}$= 0.1211$m^2$ =12.11$cm^2$**

**Concentration ratio (CR)** is defined as the ratio of the aperture area to the absorber area i.e

Where,

$A_a = 2.5m^2$ and $A_{abs} = 0.1211m^2$ from equation 1 and 4.

**CR = $A_a/A_{abs}$ ……**eq. 4

$= \frac{2.5}{.1211} = 20.64$

**Acceptance angle ($\emptyset$)** is defined as the angle through which a source of light can be moved and converge at the receiver.

**$\emptyset = \sin^{-1}\sqrt{1/C_r}$ ……**eq. 5

$= \sin^{-1}\sqrt{\frac{1}{20.64}}$

$= \sin^{-1} 0.22$

$\emptyset = 12.70°$

**The optimum rim angle $\Psi_{rim}$**

$\Psi_{rim} = 90° - \emptyset$ …….eq. 6

$= 90° - 12.70° = 77.30°$

**Focal length of the dish ($f$)** is defined as distance between centre of collector and its focus.

Where, $D_a$ = 1.78m

$\frac{f}{Da} = \frac{1+\cos\Psi rim}{4\sin\Psi rim}$ …….eq. 7

$f = \frac{1.78(1+\cos 77.30°)}{4\sin 77.30°}$

$= \frac{1.78(1+0.22)}{4\times 0.98}$

= 0.3176m=31.76cm

$f$ = 31.76cm

**Height of the dish (h)**

Obtained $D_a$=1.78m and $f$=31.76cm=0.3176m

$h = \frac{D^2a}{16f}$ ………………eq. 8

$= \frac{1.78^2}{16\times 0.3176} = 0.6235m = 62.35cm$

**Useful energy ($Q_u$) for daily**

**$Q_u = \dot{m}.C_p.\Delta t$ ……**eq. 9

**where,**

**$Q_u$** = useful energy

**$\dot{m}$=** 120 kg( volume of storage tank is 120Liter)

**Cp= 4.186kj/kg℃,** specific heat of water

**$\Delta t$ = temperature difference**

**$Q_u = \dot{m}.C_p.\Delta t$**

$= 120 \times 4.186 \times (78.9 - 41.1)$

$= 120 \times 4.186 \times (37.8)$

=18987.696 KJ per day

**Efficiency ($\eta_o$)**

**$\eta_o = Q_u / A_a \times I$ …….**eq. 10

where,

**$\eta_o$**= Overall efficiency of system

**$Q_u$**= 18987.696KJ, useful energy for daily

**$A_a$** = 2.5m$^2$ area of collector, and

**I** = Solar radiation (743.46w/m$^2$ ,average solar radiation found while investigate the experiment)

t = time in sec, ( $6\times 3600sec$)

Therefore,

$\eta_o = \frac{Qu}{Aa\times I\times t} \times 100$

$= \frac{18987.696\times 1000}{743.46\times 2.5\times 6\times 3600} \times 100$

**= 47.29%**

**Fabrication**

Parabolic dish collector is fabricated with the help of many components like satellite antenna, reflector sheet, copper cylinder, storage tank, centrifugal pump, time based tracking system, wiper motor, and etc.

a.) Frame of parabola: A 2.5m$^2$ size of satellite used as frame of parabolic dish because of it has low weight due to made of aluminum sheet and it has accurate focal length.
b.) Reflector sheet: A highly reflective fabric glass sheet placed over frame of parabolic dish. Reflector sheet thickness is 2 mm. It keeps clean and scratch free for better reflectivity.
c.) Copper cylinder: A 4 liter volume of copper cylinder used as receiver which is hanging at focal

point of parabolic dish. It used in this experiment because of high thermal conductivity (386w/m℃). It coated with black colors for attain maximum heat absorptivity.

d.) Wiper motor: In this experiment, wiper motor plays a vital role in tracking the sun continuously. It operates through the time based tracking circuit and rotated to gear, and gear attached to the shaft. The parabolic solar dish mounted on the shaft on both end of gear.

e.) Centrifugal pump: It is used for pumping the water fed to cylinder from the storage tank. It also used in cooler.

f.) Storage tank: In this experiment 120 liter volume of storage tank is used.

**Experimental Setup**

After the fabrication of parabolic solar dish, the experimentally set-up was done on roof of ISBM, Suresh Gyan Vihar University, Jaipur. Its latitude angle was 26.9260°N, longitude 75.8235°E, altitude 431m above the sea level), Rajasthan, India. The experiment investigated in June 2015 while the maximum sunshiny presented. An experimental set up has been prepared with a concentrating collector coupled to a Cu cylinder where steam is generated and was chosen for investigation. The technical specifications of the experimental setup are given in table 1,

Table 1: specification of experimental set-up

| | |
|---|---|
| Frame of parabola shape | Circumference= 178.40cm<br>Focal point = 31.76cm |
| Copper cylinder | Water volume = 4liter<br>Surface Area = 12.11cm$^2$ |
| Reflector sheet | Thickness = 2mm<br>No. of sheet = 12 (in leaf shape) |
| Wiper motor | 12v dc |
| Centrifugal pump | 165v to 265v |
| Gear | Used of 'TATA' truck |
| Pinion | Used of 'OMNI' car |

Parabolic solar dish collector reflects all solar energy coming from the sun towards the receiver Cu cylinder in same path and parallel to symmetric axis of dish. Therefore, it generates high temperature on receiver (Cu cylinder), then water heating occurs inside the cylinder because of high temperature on cylinder. The parabolic solar dish collector continuously track the sun with the help of time based tracking circuit. It tracks the sun one movement of parabolic dish after interval of 3minutes.Infrared thermometer measured surface temperature of cylinder surface. Thermocouple measured entering temperature and leaving temperature of water. It ranges up to 200℃. Alcohol thermometer used measurement for environment temperature. Digital solar power meter (TENMARS TM-207) used to measure the solar radiation in w/m$^2$ for daily solar incident. Solar power meter range is 2000w/m$^2$. Anemometer used to measure for air velocity near to parabolic solar dish collector. The experimental set up given below,

Figure 1: Experimental set up

## Observation

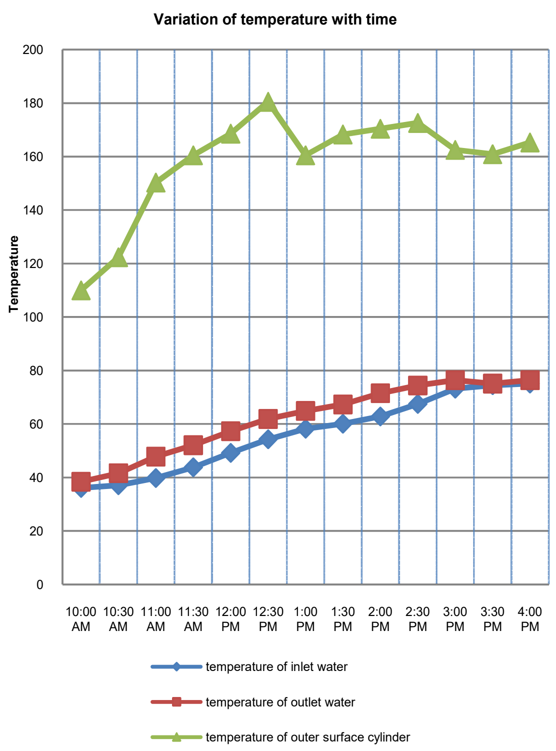


Table 2: Graph plotted between temperature Vs time

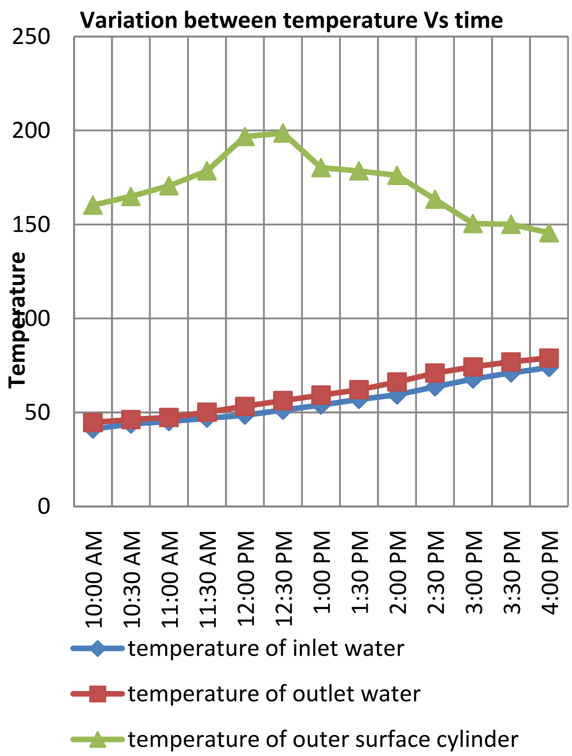


Table 3: Graph plotted between temperature Vs time

In table 3 represents the 30 minutes interval temperature deviations in the testing. The Secondary axis represents the outlet temperature of cylinder. The maximum temperature of outlet water obtained 78.9℃. The tertiary axis represents the surface temperature of cylinder. The maximum temperature obtained in a day was up to 198.6℃ while assumed it was increase in morning to greatest value up to 198.6℃ at noon and decrease beginning afternoon. The overall efficiency was determined 47.29%. The average useful energy was determined 18987.696 KJ per day for 120 liter water heating.

## Conclusion

The design and fabrication of parabolic solar dish collector for 120 liter water heating is presented in this paper together with actual overall efficiency (47.29%) and (18987.696KJ) useful energy per day of the system. The performance of parabolic solar dish collector in terms of efficiency is higher than expected. The detail of overall performance analysis is presented here, it has always been possible for water temperature to reach 100℃ . The main research fields for this work parabolic solar dish collector component design and fabrication, material economy, energy cost saving and reduction of carbon dioxide into the atmosphere. All components were made from locally available materials. The use of tracking mechanism, time based tracking circuit with wiper motor and gear pinion mechanism is continuously tracking the sun and increase the efficiency of parabolic solar dish collector.

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