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Optimizing the size for Solar Parabolic Trough Concentrator numerically

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Abstract

A numerical study of the performance of a concentrated solar parabolic trough is presented in this article. On two parabolic trough models measuring 12.5 and 20 cm respectively, in length of focal point, the study is being carried out. In order to test the parabolic mirror, an aluminum structure was used. This paper presents a regular calculation for optimizing the shape of the parabolic trough numerically. Researchers found that rays are most effectively reflected in the parabolic surface's middle and top, according to results of focal and slope errors. Length of parabolic had been reduced by 27 percent, allowing for a better suitable shape and size of a concentrator with parabolic type.

***Keywords**: CPC, Parabolic, trough, angle of reflection, slope error.*

Introduction

Electricity demand is increasing significantly, especially in developed nations. In addition to enhancing the efficiency of power, power utilities, government agencies, and academic institutions are working hard to explore and develop renewable energy sources. There are many sources of solar energy, including the sun. Approximately 1000W/m2 of solar irradiance falls on Earth each day [1]. About 15TW could be generated based on estimates of the current global energy supply [2]. It is therefore possible to meet current energy demands with solar energy alone. With the help of photovoltaic (PV) modules, the sun's light is converted into electricity. Eco-friendly, non-polluting, and sustainable energy are just some of its many benefits. When compared to a conventional flat plate solar module, photovoltaics (PV) have a higher cost per unit energy output. When using multi-junction solar cells, the efficiency of commercial flat-plane solar modules can easily be increased to 40 percent. The cost of PV material, on the other hand, is relatively high and requires a high initial investment, requiring a long payback period [3-4]. To save money on PV modules, solar concentrators - also known as sun concentrators - are a better option. An array of solar panels is used to collect the sun's energy from focus and large area the energy on one of the receiver's small areas to generate electricity [5-8]. It is possible to reduce the cost of PV systems using optical concentration with replacing large solar semiconductor cell areas with smaller concentrator areas.

There are many types and designs of sun concentrator systems available today, including concentrating optics, tracking systems, and solar cells, among others. This is a Fresnel lens module [9-10] that usages cells with silicon working at a 20-suns attentiveness, developed by ENTECH cutting-edge United States. To focus on the sun's rays, you can also use a mirror. Australia's Solar Systems has developed a PV system with a dish concentrator [11-13]. Thin glass sheets are used to create parabolic mirrors that have been silvered on the backside and are protected by concave aluminum pans that have a rounded shape. Euclide's parabolic mirror reflector array tracks the sun around its axis [14].

The focus of this research is on optimizing a parabolic trough solar concentrator by using numerical approach, which can be considered as the objective for the present article.

Problem description

Fig.1 shows the present idea for this article which investigated numerically. Laser pointer, parabolic trough, and a mirror as a target reflected plane include the device that indicated with (A), (B) and (C) respectively. The optical axis of the parabolic trough was parallel to that line of laser which founded at 90° directly above the aperture for a parabolic collector with type of trough. In the focus plane, a mirror (C) was placed on the target. Ten points positioned with symbols marked as P, on the trough parabolic surface had been used to simulate to analyze the present problem.

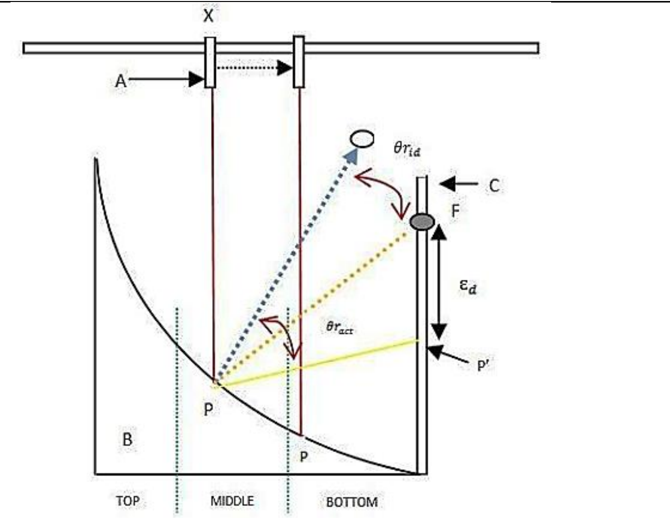

Fig. 1. Schematic diagram for the present problem

$P(a-j)$: Position for the striking rays that reach the surface of trough surface.
P'(a'-j') : point of incident ray on the surface
ε_d : error for the focal point
θr_{id} : reflected angle for the ideal case
θr_{act} : reflected angle actually

When the laser beam enters the parabolic trough, it will strike at a particular point. Optical perfection of the parabolic trough was expected if and only once the reflector ray citations through its point of focus, that corresponds to beam had been reflected with an ideal case. In addition, the remoteness between the received ray point of (a-j) and the falling point to the point of focus, f was logged. Equation 1 was used to calculate the ideal reflection angle for that specific point.

Mathematical model

The mathematical model for the present analysis can be shown in the following.

Angle of Reflection

$$\theta r = \tan^{-1}\frac{(p(x)-\varepsilon_d)}{x} \qquad 1$$

The error present,

$$\%\text{Error} = \left|\frac{\theta r_{\text{act}} - \theta r_{id}}{\theta r_{\text{act}}}\right| \times 100\% \qquad 2$$

$$\%\ \text{Error} = \left|\frac{\theta r_m - \theta r_{id}}{\theta r_m}\right| \times 100\% \qquad 3$$

$$\%\ \text{Error} = \left|\frac{\theta r_m - \theta r_{\text{act}}}{\theta r_m}\right| \times 100\% \qquad 4$$

Slope of the error

$$\epsilon_\alpha = \frac{\theta r_{act} - \theta r_{id}}{2} \qquad 5$$

$$\epsilon_\alpha = \frac{\theta r_m - \theta r_{id}}{2} \qquad 6$$

The profile for the trough parabolic surface can be shown as,

$$p(x) = \frac{x^2}{4f} \qquad 7$$

where $p(x)$ is function of parabolic, d is the distance between the points of focus and the incidence, θr_{act} is actual angle of reflection and θr_{id} is ideal angle for reflection. The length of the focal point for this parabolic design had been varied with 12.5 cm and 20 cm.

Results and discussion

When all reflected light passes through the focal point, it's assumed to be 0. As a result, this case does not take into account the high disparity estimation error and ideal reflection angle, point a, point b, and point c. Calculated using Equations 1 to 6, Table 1 and Table 2 summarize the results of the studied cases, for Case 1 (*f = 12.5 cm)* and Case 2 (*f = 20 cm*).When analyzing the parabolic mirror, it is assumed that the sun had been similar to its affiliation. It is a distance between the point of focus and the incident point that's measured in centimeters. Using the calculated errors, the mirror's absorber tube's diameter is determined to safeguard that the complete energy for solar permits through an absorber. The definition of focal error is shown in Fig.3. It is also possible to develop other metrics, such as the percentage of energy that falls on a target (absorber tube).

On Fig. 4, guests could see a plot of the laser's focal error at different positions on a slider. When the reflected ray passes above the focus point, the focal error is positive; when it passes below, the focal error is negative. From point *(a)* to point *d*, the focal errors have the opposite sign. A positive focal error is obtained in Case 1 with *f = 12.5 cm*, while negative values are obtained with *f = 20 cm* in Case 2. These results indicate that the reflector hits above or below the focus line. You could say that the bottom part *(a-d)* gives relatively large focal error (d) because the reflection interrupts remote absent from the focal point (*f*) of the parabolic trough. As the laser beam moves towards the middle, the focal errors, as shown in Fig. 3, decrease. In this case, the reflected rays get closer to the focal point, *f*, which is 0. At point E, the focal error in Case 1 is close to zero. In contrast, in Case 2, there are two points, namely *f* and *g* that are exactly on the focal point. Thereafter, the reflected light for both cases stops. In this case, the reflected rays get closer to the focal point, F, which is 0. Focusing error is near zero in Case 1, while in Case 2, the focus point is exactly at points *f* and *g* This is the point at which the laser is moving towards the top position, i.e. point *i-j* of the parabolic trough, where the reflection of both cases continues to move away from the focus line. There is an overall similarity between the two parabolic troughs reflecting surfaces. Most effective and ideal reflective surface for a parabolic reflector can be evaluated to be a region of small focal errors located between the middle point and the top side (see Fig. 3).Case 1, *f = 12.5* cm, ideal case and caseal data are shown in Fig. 5. As can be seen, the reflection angle discrepancy for the bottom part of the parabola is quite large. Parabolic's middle tends to have fewer discrepancies, which tend to become closer together. Figure 4 shows that point *e*, located in the middle of the parabolic trough at *4.9 cm* to its most effective reflective surface, is expected to be the most effective reflective surface. These angles are very close to each other, as well as to the ideal parabola's angle of 21.3°. Ideal focus is achieved by reflecting the normal rays that enter the optical axis from the parabola's focus point.

Fig.6 shows the results of Case 2 with f = 20 cm under three similar conditions. The measurements of the reflection angle show good agreement between these three cases. The parabola's best reflective surface is found at points "g" and "h", where the reflection angle is over 90% of the ideal reflection angle. On the other hand, the worst reflective surface is located at point „b, which is about 30% of the ideal value. According to Fig. 5, the middle and top regions of a parabolic surface are the most effective at reflecting the incoming ray. As a result, it is possible to predict the optimal length of the solar trough, this could help solar manufacturers significantly reduce production costs by reducing the size and dimensions of the solar panels while maintaining the output power at the maximum efficiency possible. When the inefficient reflective surface from point „a to „c due to large differences between the actual and the ideal reflection, the curve length of the parabolic design can be reduced by 3.8 cm from 15.4 cm to 11.6 cm, representing about 24.7 percent of surface reduction.

To calculate the slope error, we measure it at each point along a parabolic trough's top surface. For both measurement and caseal purposes, the smallest slope error is again found at point "f" and "e" in the middle of the parabola. Slope error for Case 1 is greatest near "a" in parabola's lower region. Comparison of slope errors between the actual and the measurement can be used to evaluate the effectiveness of the caseal approach Around the points "e" and "f" in the middle, there is a difference of almost zero percent, while the bottom region around the point "a" has a difference of about 43 percent.

According to Figure 8, the slope errors for Case 2 show a similar trend to Case 1, where the smallest errors appear to be in the region between the middle and top of a parabolic curve (Fig. 7). Case 2's slope error can also be evaluated using the caseal method, which shows that there is a small difference between the actual and the measured slope error, with a difference of 76 percent at point "c" and only 0.3 percent at points "g" and "h."

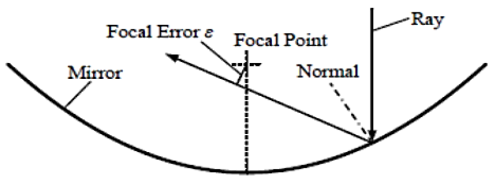

Fig. 3. Error definition for focal point, ε_d.

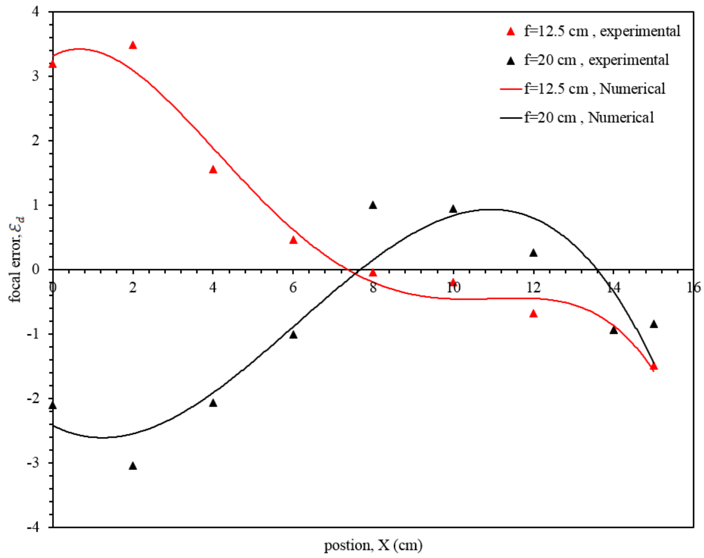

Fig. 4. Comparison between the experimental and numerical results for the focal error,

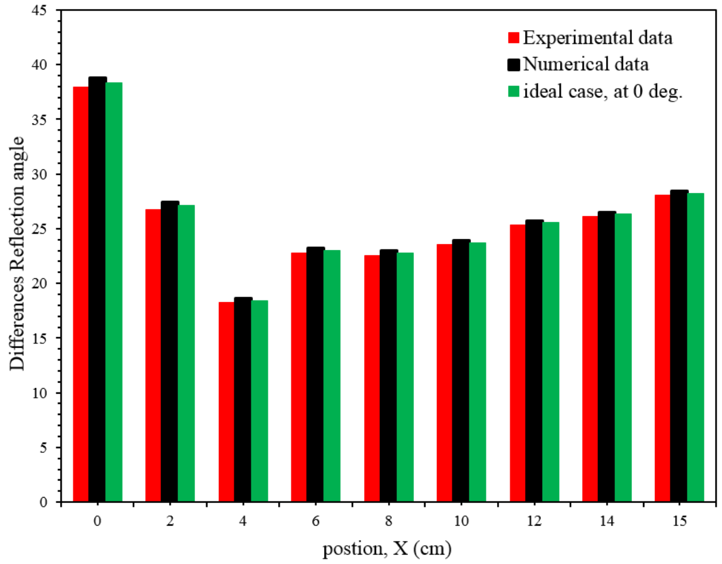

Fig. 5. Different angle of reflection for of rays, case 1with f= 12.5 cm

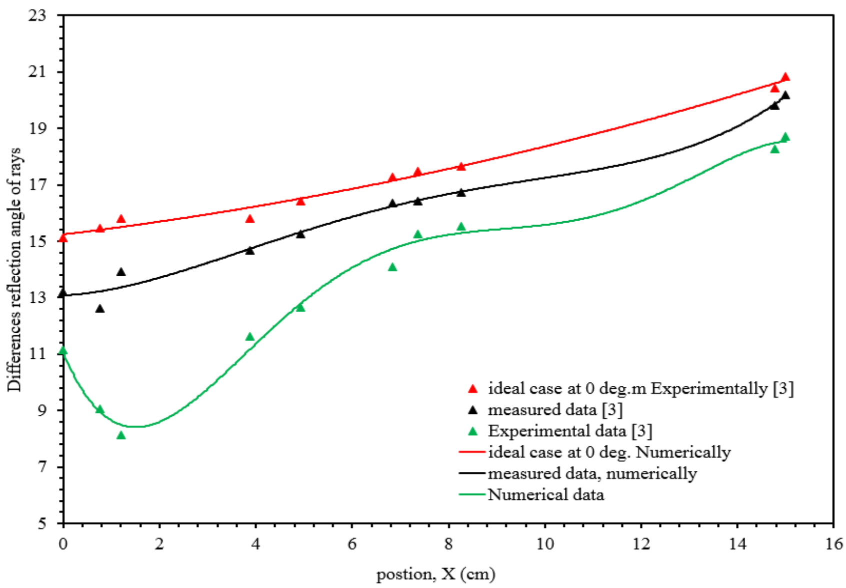

Fig. 6. Different angle of reflection for of rays, case 2, with f= 20 cm

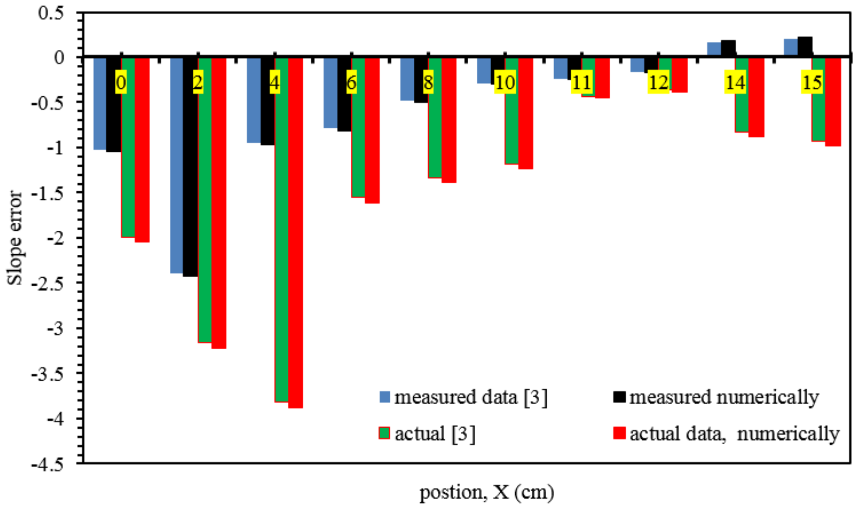

Fig. 7. Slope error for case 1, with f= 12.5 cm

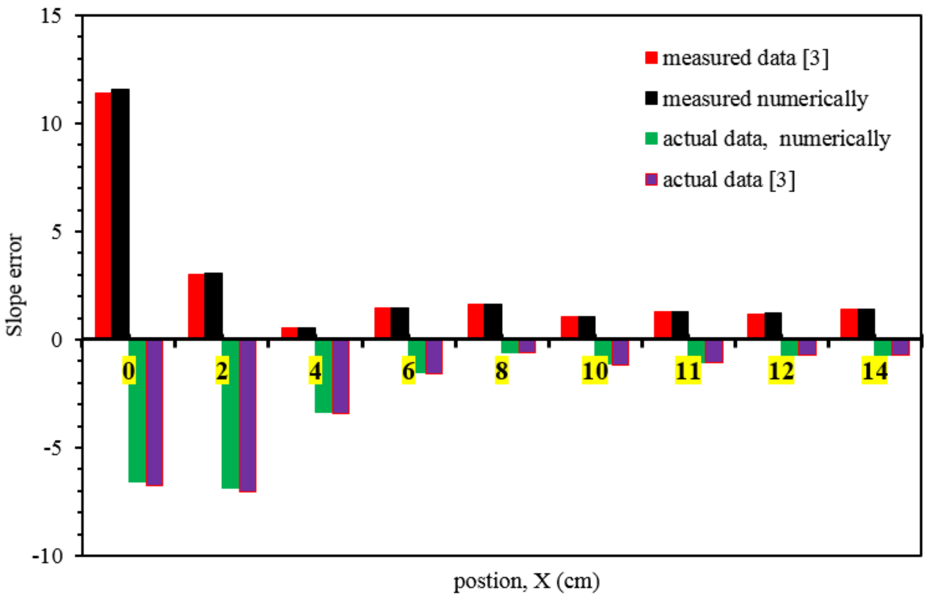

Fig. 7. Slope error for case 2, with f= 20 cm

Conclusions

An inexpensive parabolic mirror solar concentrator is described in detail. A mathematical calculation is used to evaluate the parabolic design. In addition to the reflection angle of the rays, there is also a reflection angle percentage error, as well as focal and slope errors. For effective ray reflection, the parabolic surface's middle and top appear to be the best regions based on results from focal and slope errors. On average, the parabolic length can be reduced by nearly 25 percent, allowing for a better shape and size of the parabolic trough concentrators' surface area.

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