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Theoretical Performance Analysis of Linear Fresnel Reflector Concentrating Solar System with Horizontal Absorber

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ABSTRACT

In this paper, the effect of reflector width on the performance of Linear Fresnel Reflector (LFR) concepts with horizontal absorber for boilers is examined. A theoretical model encompassing all the governing parameters is developed by taking into account the intricate phenomenal interdependencies and influences of parameters on the designs output. The designed and subsequently realized test LFR concentrating solar system with horizontal absorber is evaluated major from the insight of concentration ratio. Two systems fitted with horizontal absorbers with reflectors of varying and constant width arrangements have been investigated. Further, effect of different design parameters on the concentration ratio for both the systems is thoroughly investigated. Coating Materials for the absorber are considered for the experiments and their performance is evaluated based on the Thermal efficiency. The coating material with maximum Thermal efficiency is selected for the design analysis. The concentrated power is calculated for various reflector materials based on the reflectivity. The design procedures and the characterization methods have been summarized. The final observations are recorded and their outcome emphasizes that the horizontal absorber with varying width outperforms the system with constant reflector width.

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INTRODUCTION

Linear Fresnel Reflector (LFR) is a line-focusing system. A typical LFR uses modular, flat mirrors that track the sun to focus the sun's heat onto long, elevated tubular receiver (absorber) through which water flows. The concentrated sunlight boils the water in the tubes, generating hot water, saturated or superheated steam for use in power generation in steam Rankine cycle for instance or for process heat in industrial applications.

The prominent asset of the LFR system is its cost effectiveness as compared with the concentrated solar power systems attributed to the use of water as the heat transfer fluid which eliminates the expensive and hazardous thermal oil as heat transfer fluid and eliminates the extra cost of oil/water heat exchanger. A supplementary profitable facet of the technology is that the moving parts are accessible which allows for easier maintenance of the system. Also, the absorber/heat transfer loop is isolated from the reflector field and does not move, thus avoiding the high cost of flexible high pressure lines or rotating joints. The design of LFR in the present is undertaken mainly in power generation. However, this study has been undertaken with the main objective of determining the feasibility of LFR for pre-heating water to be used in boilers.

There are several literatures discussing LFR's and the corresponding electro-mechanical-metallurgical conceptual governance. The most important literatures directly contributing to this research study have been discussed briefly in this section. Aveek Chatterjee (2012) reported on the thermal power and system level efficiency of Concentrated Solar Thermal (CST). An emphasis was laid on the dependence of thermal power and efficiency on global radiation, direct normal irradiation (DNI), and ΔT/ Insolation. The possibility to obtain thermal power of greater than 1.6 kW for DNI of 850 W/m2 was demonstrated. It was further observed that the efficiency of the system fluctuates significantly and is dependent on global radiation. Michael(2012) Presented an overview of the recently added LFR model. Besides it reports a Levelized Cost of Energy LCOE-optimized plant

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comparison between various Concentrating Solar Power technologies. The analysis reveals that while LFR is cost-competitive with other Concentrated Solar Power (CSP) technologies -especially Parabolic Troughs. The point of stress was the numerous advantages offered by LFR, including low-cost collectors and simplified receiver piping that facilitate relatively high-temperature operation. Reynolds *et al*., (2004) presented "oven-box" concept that employs a set of small parallel absorber tubes nested within a trapezoidal insulated cavity. Gabriel *et al*., (2004) developed the compound parabolic secondary concentrator tubular receiver and analysis its performance and techno-economical factors. A comparative study was undertaken for evaluating the thermal performance of the four identical trapezoidal cavity absorbers for linear Fresnel reflecting solar device by (Panna Lal Singh *et al*., 2010) and (Baum *et al*.,1976) studied two-axis solar tracking systems. However, the pivotal attempt to employ it for large linear system for solar collection was done. Francia (1968) developed both linear and two- axis tracking Fresnel reflector systems. Riaz(1976) developed the associated theory for two-axis systems. Mathur *et al*., (1990) performed a detailed evaluation of two designs linear fresnel reflector solar concentrator (LFRSC) with flat horizontal absorber has been undertaken. Martin Haagen1(2012) presented the estimation of the prospective of generating solar heat for industrial processes with linear Fresnel collectors. A single variable sensitivity analysis examines the factors which influence the internal rate of return and thermal energy costs of solar process heat systems. Negi *et al*.,(1989) Worked on various optical designs and estimated the performance characteristics of a linear Fresnel reflector solar concentrator (LFRSC) with a flat vertical absorber. Different approaches were employed for designing a LFRSC. One of the approaches allows a variation in the width of the constituent mirror elements, while the second approach uses mirror elements of equal width. A detailed performance analysis including the effect of variation in the height of the absorber from the concentrator plane, aperture diameter of the concentrator, width of the absorber and the width of the mirror elements on the concentration on the surface of the absorber has been made for each design, in the present work. An LFRSC can be designed using two different approaches. In one approach, using the pre-specified size absorber, the size of mirror elements and hence the size of concentrator are determined Singh *et al*., (1980) and Sawhney & Aro (1983). In LFRSC systems, long narrow plane-mirror element are suitably mounted on flat base (Singh *et al*., 1980, Kandpal *et al*., 1981, Singhal *et al*., 1986). This approach allows a variation in the width of the constituent mirror elements. In the second approach, using an equal width of constituent mirror elements, the size of the absorber determined (Mathur *et al*., 1990). Manikumar & A. Valan Arasu (2014) performed experimental and theoretical analysis on LFR solar system with V-shaped cavity receiver.The assumptions are made to facilitate the designing of LFRSC (i)the reflector elements are specularly reflective and (ii) the solar radiation incident normally on the reflector elements (Lin *et al*., 2013). Designs have been developed to utilize line focus solar concentrators for reducing the cost of the present systems as per the reviews of renewable energy resources (Mathur *et al*., 1984)

There are few other literatures discussing concepts related to these studies from the insight of various other disciplines. However, the literatures pertaining to horizontal absorbers in LFR's with constant reflector width configuration and variable reflector width configuration have either scanty or unavailable. Hence, in this research study, an attempt is made to compare LFR's with horizontal absorbers for constant and variable width reflector configurations.

An LFRSC for a flat horizontal absorber configuration was designed in which the solar radiation reflected from each constituent mirror element illuminates one side of the absorber (i.e. the side of the absorber facing towards the concentrator).Two different approaches can be used for designing an LFRSC. When the concentrator is designed for a pre-specified width of the flat horizontal absorber, a variation in the width of the constituent mirror elements is allowed so that the solar radiation incident normally on each constituent mirror element, after reflection, illuminates the complete width of the absorber. In the second approach, using mirror elements of equal width, an appropriate size of the absorber is determined. In each case an appropriate shift is introduced between two consecutive mirror elements so as to avoid the blocking of reflected solar radiation from any mirror element by its adjacent mirror element. The following simplifying assumptions have been made in the design of the linear Fresnel reflector solar concentrators:(i) The concentrator is perfectly tracked so as to follow the diurnal movement of the sun, (ii) The mirror elements are specularly reflecting,(iii) The solar radiation is axially incident (Mathur *et al*., 1990). A complete study was made on vertical absorber with varying and constant width reflector LFRCS system (Babu & Valan Arasu 2015)

In this research study, an attempt is made to compare LFR's with horizontal absorber for varying and constant width reflector configurations. The local concentration ratio (LCR) on the absorber surface has been determined for the each design using the analytical technique. The formulae for the various parameters have been derived from the geometrical figures plotted from the system design. The basic objective and scheme of work are presented in figure

The work is also included with a study of

material selection for increasing the performance of the system Coating material study is done for the absorber and the reflector material study is done for the reflector both are undertaken to find the best materials to increase the efficiency of the LFRCS system.

Materials and methodology:

Design of LFRCS system:

The concentrated Linear Fresnel reflector (LFR) for flat Horizontal absorber is designed such that the solar radiation is incident normally on the concentrator aperture, after reflection from the constituent reflecting elements and it illuminates both the surfaces of the absorber. This means, the reflecting elements on the left half of the concentrator illuminate the left surface of the absorber and reflecting elements placed on the right half illuminate the right surface of the absorber.

In the first design, reflecting elements are designed to have uniform/constant width and in the second design, reflecting elements have varying widths. In both these design, a suitable shift between two consecutive mirror elements is introduced, so as to avoid blocking of solar radiation reflected from any reflecting element by its neighboring reflecting element. In both the design, the reflecting element is characterized by four parameters: shift (S), location (Q) on the concentrator plane, tilt (θ) with respect to the concentrator plane and width (W).

The ray radiating from the centre of the solar disc and striking the midpoint of the mirror element, reflects and reaches the focal point F and the extreme ray of lower edge of the mirror element reflects and touches the upper edge of the first mirror element and strikes to the absorber width thus the radiation from the second mirror is not blocked by the first mirror this is done by introducing space between consecutive mirror element it is done by necessary shift(s). These parameters are accounted for by a geometric function called a "view factor". The main assumption of this model is that, any absorption, emission or scattering of radiation can be ignored. The energy flux leaving in a given surface is composed of directly emitted and reflected energy. The reflected energy flux is dependent on the incident energy flux from the surroundings, which can be expressed in terms of the energy flux leaving all other surfaces (Manikumar & Valan Arasu 2013).

Design of LFRCS system with horizontal absorber:

The LFRCS system with horizontal absorber is mainly classified into two categories depending on the width of the reflector which may either be varying or constant. This study accounts for investigations addressing both the scenarios and finally summarizes the pros and cons of the system with different arrangement and configurations.

Design of LFRCS system with horizontal absorber with varying width reflector:

Figure 2 shows the geometry of a LFR with reflecting elements of varying width reflector, which is designed using conventional geometrical optics. In the present case, the aperture diameter, D, of the concentrator is fixed and the required number of reflecting elements is determined by optical considerations. The first reflecting element should be place at an appropriate location (Q_1), so it can contribute to the concentration on the absorber surface. An iterative approach along with simple geometrical optics is incorporated to determine the design parameters of the reflecting elements. The initial values for location, tilt, and shift are set as $Q_0 = d/2, \theta_0 = 0$ and $S_1 = 0$ and $W_0 = 0$ respectively, where d is the absorber width. The initial tilt θ_n, for all the n reflecting element is set as 0 (Mathur *et al*., 1990)

Derivation of horizontal absorber with varying width reflector LFR system, Condition:

- The reflected ray from the bottom of the reflector plate should reach the focal plane at –d/2 and the reflected ray from the top of the plate should reach at +d/2.
- The reflected ray from the bottom of n^{th} reflector should graze the top of $(n-1)^{th}$ reflector plate.

From figure 3 (a)The two triangles CAB and BPQ are similar triangles and are used to derive the relation for shift between subsequent plates.

Equating the base and height ratios of the two triangles,

$$S_n \left(W_{n-1}.\sin\theta_{n-1}\right) = \left(Q_{n-1} + W_{n-1}.\cos\theta_{n-1} + d/2\right) / \left(f - W_{n-1}.\sin\theta_{n-1}\right) \quad (1)$$

In triangle CSQ, figure 3 (a)

$$S_n = \tan\left(2\theta_n + \xi_0\right) = \left(Q_n + d/2\right) / f \quad (2)$$

For formulating the width of the reflector plate we equalize the image width to the width of the absorber,

Image width = absorber width, from figure 3 (b)

$$d = \left(U_n + J_n + I_n\right) \quad (3)$$

$$U_n = \frac{\left(f - W.\sin\theta_n\right)\sec 2\theta_n.\sin\xi_0}{\left[\cos\left(2\theta_n - \xi_0\right)\right]} \quad (4)$$

$$J_n = \left[W\cos\theta_n.\sec 2\theta_n\right] \quad (5)$$

$$I_n = \frac{\left[f.\sec 2\theta.\sin\xi\right]}{\left[\cos\left(2\theta_0 + \xi_0\right)\right]} \quad (6)$$

$$d = \frac{\left[\left(f - W.\sin\theta_n\right)\sec 2\theta_n.\sin\xi_0\right]\left[\cos\left(2\theta_n - \xi_0\right)\right] + \left[W.\cos\theta_n.\sec 2\theta_n\right] + \left[f.\sec 2\theta.\sin\xi\right]}{\left[\cos\left(2\theta_0 + \xi_0\right)\right]} \quad (7)$$

Rearranging Equation (7) the width of the first mirror element be calculated from

$$W_1 = \frac{d\sin(2\theta_1+\xi_0)\cos(2\theta_1-\xi_0)-(Q_1+d/2)\sin(2\xi_0)}{\sin(2\theta_1+\xi_0)\cos(\theta_1-\xi_0)} \quad (8)$$

The location of the second mirror element and its tilt with the concentrator plane are chosen such that the solar radiation reflected form it is not blocked by the first mirror element and finally produces an image on the surface of the absorber. Thus, a certain space is introduced between the first and second mirror element. The necessary shift for the second mirror element is given by

$$S_2 = \frac{(Q_1 + W_1\cos\theta_1 + d/2)W_1\sin\theta_1}{f - W_1\sin\theta_1} \quad (9)$$

The location of the second reflecting element and its tilt with concentrator plane is given by

$$Q_2 = \frac{Q_1(f - W_1\sin\theta_1) - 0.5dW_1\sin\theta_1}{f} - W_1\cos\theta_1 \quad (10)$$

and

$$\theta_2 = \frac{1}{2}\left[\tan^{-1}\left(\frac{Q_2 + d/2}{f}\right) - \xi_0\right] \quad (11)$$

The following are the generalized expressions for the shift (S_n), location (Q_n), tilt (θ_n), and the width (W_n) are the parameters for the n th mirror element is obtained by rearranging the above equations derived by

$$S_n = \frac{(Q_{n-1} + W_{n-1}\cos\theta_{n-1} + d/2)W_{n-1}\sin\theta_{n-1}}{f - W_{n-1}\sin\theta_{n-1}} \quad (12)$$

$$Q_n = \frac{Q_{n+1}(f - W_n\sin\theta_n) - 0.5dW_n\sin\theta_n}{f} - W_n\cos\theta_n$$

(13)

$$\theta_n = \frac{1}{2}\left[\tan^{-1}\left(\frac{Q_n + d/2}{f}\right) - \xi_0\right]$$

(14)

$$W_n = \frac{d\sin(2\theta_n+\xi_0)\cos(2\theta_n-\xi_0)-(Q_n+d/2)\sin 2\xi_0}{(\sin(2\theta_n+\xi_0)+\cos(\theta_n-\xi_0))} \quad (15)$$

Design of LFR system with horizontal absorber with constant width:

The LFR system with horizontal absorber with constant width reflectors is shown in the Figure 4. This study accounts for investigations addressing both the scenarios and finally summarizes the system with different arrangement and configurations.

Figure 4 shows the geometry of a LFR with reflecting elements of equal width, which is designed using conventional geometrical optics. In the present case, the aperture diameter, D, of the concentrator is fixed and the required number of reflecting elements is determined by optical considerations. The first reflecting element should be place at an appropriate location (Q_1), so it can contribute to the concentration on the absorber surface. An iterative approach along with simple geometrical optics is incorporated to determine the design parameters of the reflecting elements. The initial values for location, tilt, and shift are set as $Q_0 = d/2, \theta_0 = 0$ and $S_1 = 0$ respectively, where d is the absorber width. The initial tilt θ_n, for all the n reflecting element is set as 0. The necessary shift for the second reflecting element required to prevent the first reflecting element from blocking the radiation reflected element is given by (Mathur *et al.*, 1990).

Derivation of horizontal absorber with constant width reflector LFR system condition:

- The reflected ray from the centre of the reflector plate should reach the focus.
- The reflected ray from the bottom of nth reflector should graze the top of (n-1)th reflector plate.

In triangle ABF, from figure 5 (a)

$$\tan 2\theta_n = (Q_n + W/2\cos\theta_n) \;/\; (f - W/2\sin\theta_n) \quad 16)$$

$$\theta_n = \tfrac{1}{2}\tan^{-1}\left[\{Q_n + (W/2).\cos\theta_n\} \;/\; \{f - (W/2).\sin\theta_n\}\right] \quad (17)$$

From triangle ABC, from figure 5 (b)

$$\tan(2\theta_n + \xi_0) = S_n \;/\; W\sin\theta_{n-1} \quad (18)$$

$$S_n = W\sin\theta_{n-1}\tan(2\theta_n + \xi_0) \quad (19)$$

$$Q_n = Q_{n-1} + W\cos\theta_{n-1} + S_n \quad (20)$$

The shift of the second mirror element is given by

$$S_2 = W\sin\theta_1\tan(2\theta_2 + \xi_0) \quad (21)$$

The location of the second reflecting element is given by

$$Q_2 = Q_1 + W\cos\theta_1 + S_2 \quad (22)$$

Then, the following condition is verified,

$$if \quad \left(\tan(2\theta_2) - \frac{Q_2 + W/2\cos\theta_2}{f - W/2\sin\theta_2}\right) < 0 \qquad then \quad \theta_2 = \theta_2 + \Delta\theta$$

$$else \;\; \theta_2 \;\; is \; unchanged \quad (23)$$

where, ξ_0 is the half of the angular sub-tense of the sun at any point on the earth(=16'), W is the width of the constituent reflecting elements and f is the distance between the center of the absorber and the concentrator plane. As discussed earlier, initially θ_2 is assumed as 0 and $\Delta\theta$ is a small angular increment and it is assumed as 1^o. θ_2 is incremented by $\Delta\theta$ for every iteration and its corresponding S_2 and Q_2 are computed using equation (9) and (10) until the final value of θ_2 is determined.

Next step is to determine whether aperture diameter D, is sufficient enough to include the next reflecting element. It is known that the aperture diameter D, of the concentrator can be expressed as

$$D = 2\left[Q_1 + \sum_{n=1}^{k}(W\cos\theta_n + S_n)\right] \quad (24)$$

Equation (24) can be modified and the following condition can be derived to determine if there is sufficient space to place the next reflecting element.

if $2\left[Q_1+\sum_{n=1}^{k}(W\cos\theta_n+S_n)\right]<D$ *then add one reflecting element*
else no space for additional reflecting element

On the basis of similar geometrical optical considerations, the following generalized expressions for shift (S_n), location (Q_n) and tilt (θ_n) associated with the n^{th} reflecting element is determined as follows

$$S_n = W\sin\theta_{n-1}\tan\left(2\theta_n+\xi_0\right) \quad (25)$$

$$Q_n = Q_{n-1}+W\cos\theta_{n-1}+S_n \quad (26)$$

and

if $\left(\tan(2\theta_n)-\frac{Q_n+W/2\cos\theta_n}{f-W/2\sin\theta_n}\right)<0$ *then* $\theta_n=\theta_n+\Delta\theta$
else θ_n *is unchanged*

(27)

$$\theta_n=\frac{1}{2}\left[\tan^{-1}\left(\frac{Q_n+w/2\times\cos\theta_n}{f-w/2\times\sin\theta_n}\right)\right] \quad (28)$$

Here, n varies from $1,2,...,k$, and k is total number of mirror elements on each half of the concentrator.

Distribution of LCR on absorber surface:

Babu & Valan Arasu (2015) have assumed that the solar radiation reflected from each reflecting element is distributed uniformly over the width of the image the reflecting element produces on the absorber surface. The concentration at any point on the absorber is determined by summing up the contributions of all the reflecting elements. For a CLFR employing reflecting elements of uniform width, the contribution of any constituent reflecting element (say, n^{th}) to local concentration ratio (LCR) at any point within the image produced on the absorber by the reflecting element of varying width by (Mathur *et al*., 1990) and is given by

$$CI_n=\frac{W_n\cos(\theta_n)}{d} \quad (29)$$

The contribution of any constituent reflecting element (say, n^{th}) to local concentration ratio (LCR) at any point within the image produced on the absorber by the reflecting element of constant width is given by

$$CI_n=\frac{W\cos(\theta_n)}{r_n} \quad (30)$$

where r_n is the width of the image produced on the absorber by the radiation reflected from the n^{th} reflecting element and is defined as

$$r_n=W\cos\theta_n\sec2\theta_n+\left(\frac{Q_n+W\cos\theta_n(1-0.5\sec2\theta_n)}{\sin2\theta_n}\right)\frac{\sin\xi_0}{\cos(2\theta_n-\xi_0)}+\left(\frac{Q_n+0.5W\cos\theta_n\sec2\theta_n}{\sin2\theta_n}\right)\frac{\sin\xi_0}{\cos(2\theta_n+\xi_0)} \quad (31)$$

Since each constituent reflecting element on one half of the concentrator illuminates the complete one surface of the flat horizontal absorber, total concentration at any point on the surface of the absorber is given by

$$C=2\sum_{n=1}^{k}CI_n \quad (32)$$

In frensel concentrator tubular collector system, the reflector elements, reflect energy to different portions of the absorber and the concentrated flux from all the reflectors distributes large on the tubular absorber. So, it is more meaningful to determine the total concentrated power reaching the absorber and then the obtained value is used to find the boundary temperature applied to the absorber surface in the cavity absorber. Solar power (P_n) that reached the absorber, which is contributed from the nth reflector, is given by

$$P_n=\rho I_b W\cos\theta_n L \quad (33)$$

Where, ρ is the reflectivity of the reflector and is given in Table and I_b represents the intensity of beam radiation which is assumed as 800 W/m^2. Thus, the total concentrated power on the absorber due to the contribution from all the reflector elements is given by,

$$CP=\left(2\sum_{n=1}^{N}P_n\right) \quad (34)$$

The schematic flow diagram showing the various calculations done for the horizontal absorber with varying width reflector in LFR solar system and the horizontal absorber with constant width reflector in LFR solar system based on the design procedure are given in the figure 6 (a) and figure 3 (b) respectively.

Optical and Thermal efficiency:

The optical efficiency and thermal efficiency are calculated using MATLAB program for the different absorbtivity of the coating materials and the concentrated power for various reflector materials based on the reflectivity . The optical efficiency (η_o) is the fraction of solar radiation incident on the aperture of the reflectors which is absorbed at the surface of the absorber (Sukhatme and Nayak 2009). The area of the aperture is (A_a) 2 m^2 ,aperture width (A_w) 1m , the absorbance value coating materials (α), the outer diameter of the absorber (d_{oa}) transmittance of glass (τ) taken as 100%, Mass flow rate of fluid is (m) 0.029 kg/s , specific heat (c), the inlet and out let temperatures are taken based on the simulated value from computational fluid dynamics for the design of horizontal absorber varying width reflector for a concentrated value of 31.4 with the concentrated power of 3.14, Heat gained (H_{Gain}) (Duffie and Beckman 1980), the efficiency's are calculated by the given formulae,

$$\eta_o=\frac{S(A_w-d_{oa})}{I_bA_w} \quad (35)$$

$$S_f = \rho I_b \gamma \tau \alpha \quad (36)$$

$$\eta_{th} = \frac{H_{Gain}}{I_b A_a} \quad (37)$$

$$H_{Gain} = mc(T_o - T_i) \quad (38)$$

RESULT AND DISCUSSION

The area occupied by the system is fixed initially and other system parameters like width of reflector plates, number of reflector plates, their tilt and relative positioning are determined using the available formulas reported in the literatures. The formulae being iterative in nature are solved computationally using programs written in MATLAB. The formulae are unable to yield a single solution; instead they give a set of solutions when each of the system parameters like width of reflector plates, number of reflector plates, land area constraints are varied. Optimal design parameters are selected from the solutions which in terms minimizes the material and land requirements. This procedure is repeated for the two different configurations and thermal analysis is performed in terms of concentration power to determine the optimum configuration according to the required application. The aperture diameter "D" of the concentrator for the design is taken to be 2.0m, for rays incident on the absorber at angle $>60^o$ the transmittance of the glass cover decreases considerably. For practical values of f, an appropriate value of D is taken to be around 2.0 m in this design.1.0 m taken by (mathur *et al*., 1990).

Modeling for LFRCS horizontal absorber varying width reflector design:

Figure 7 shows the performance analysis in term of concentration ratio for varying width reflectors, focal height "f" is set from 0.1 to 1.0 m and the best focal height from the graph is found to be f=0.9 m. values of the absorber diameter "d" is set from 0.01 to 0.1m and from the graph it is found that d=0.5m is the best absorber diameter where the concentration ratio is maximum.

The Aperture Diameter is fixed as, D=2m; the focal height is optimized based upon the Concentration ratio obtained by solving computationally, f = 0.9m; Absorber width is solved computationally by iterating the value of d from 0.01 to 0.1, then optimized, d =0.05m; No of Reflectors is optimized by solving computationally for the fixed value of D which first done in this paper, N = 29; The said parameters are optimized based on the concentration ratio, when the system is modeled with the obtained parameter, we get the maximum concentration for the taken D = 2 m; the concentration ratio, CR = 31.4.

Modeling for LFRCS horizontal absorber constant width reflector design:

Figure 8 shows the performance analysis in term of concentration ratio for constant width reflectors, focal height "f" is set from 0.2 to 1.0 m and the best focal height from the graph is found to be f=0.6 m. values of width of the reflector "w" and the absorber diameter "d" is set from 0.01 to 0.1m and from the graph it is found that w= 0.06m & d=0.06 is the best width and absorber diameter where the concentration ratio is maximum.

The Aperture Diameter is fixed as, D=2m; the focal height is optimized based upon the concentration ratio obtained by solving computationally by iterating focal height f from 0.1m to 1.0m,the optimized focal height is f = 0.6m; Absorber width is solved computationally by iterating the value of d from 0.01 to 0.1 then optimized, d =0.06m as that the width of reflector is optimized, w=0.06m; No of Reflectors is optimized by solving computationally for the fixed value of aperture diameter D, N = 12; The said parameters are optimized based on the concentration ratio, when the system is modeled with the computed parameter, we get the maximum concentration ratio for the taken D value, the concentration ratio, CR = 2.103.

The concentrator aperture area is 2 m^2 with horizontal absorber varying width system of concentration ratio of 31.4 with glass as reflector

Table 1 give the details of the coating materials which have been taken for study , the absorber coating is done to increase the performance of the system thus increases the efficiency of the LFRSC system. The selective coating materials like black copper, black chrome, black nickel and nickel alloy were studied their coating method was also studied it is found that Black chrome-Ni-Cu/Cu/Steel is the best coating material for the absorber which gives the maximum thermal efficiency, this is a cost effective coating and method is electro deposition which is comparatively simplest method for coating for experimental use this can be adopted.

Table 2 give the details of the reflecting materials which have been taken for study, the study is done to find the performance of the system thus increases the efficiency of the LFRSC system. The selective reflecting materials like glass, highly polished aluminium sheet, acrylic sheet and chromium coated sheet were studied using their reflectivity the concentrated power is calculated based on the horizontal absorber varying width reflector system design. The best reflector material is glass due to its reflectivity which in produces maximum concentrated power. Coating material and reflective material is adopted for the system for experimental use.

Conclusion:

This paper analyzes the theoretical performance of LFR concentrating solar system with horizontal

absorber with varying and constant width reflectors. From the results, it is evident that the LFR system with the horizontal absorber with varying width reflectors offers a better performance in terms of concentration on the surfaces of the absorber. The performance of the LFR concentrating solar system with horizontal absorber with constant width reflectors does not compare constructively with that of the varying width design. The best coating material for the absorber is selected based on the absorbtivity and thermal efficiency, black chrome is been selected as a coating material for absorber which gives the maximum efficiency of the system. The concentrated power is calculated for different reflector materials based on the reflectivity and for the horizontal absorber varying width reflector system the concentrated power is 3.04 fro a concentration ratio of 31.4. In summary, the horizontal absorber with varying width LFR concentrating solar system succumb better performance in terms of concentration ratio, concentrated power and Thermal efficiency.

Table 1: optical and thermal efficiency of the LFRCS system based on coating materials for absorber.

Sl:No	Material	Method of Coating	Absorbtivity	Optical Efficiency %	Thermal Efficiency %
1	Black Copper-Cu	Electro deposition	0.96-0.97	0.629	30.82
2	Black Chrome- Ni-Cu/Cu/Steel	Electro deposition	0.97-0.98	0.633	35.79
3	Black Nickel- Steel/Ni coated steel	Electro deposition	0.88-0.96	0.604	27.46
4	Black Nickel Alloy Ni-Nox- Al	Reactive sputtering	0.96	0.616	29.35

Table 2: Reflecting Materials for reflectors and the concentrated power for horizontal absorber varying width reflectors.

Sl. No.	Reflector Material	Reflectivity (ρ)	Concentrated Power, CP (kW)
1	Glass	0.98	3.14
2	Highly polished anodized aluminium Sheet	0.86	1.91
3	Acrylic Sheet	0.78	1.82
4	Chromium Coated Sheet	0.6	1.63

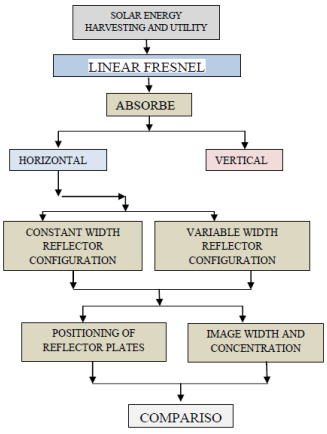

Fig. 1: Schematic block diagram of the work flow.

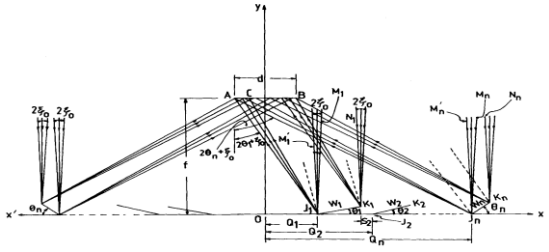

Fig. 2: A linear Fresnel Reflector concentrating System(LFRCS) with horizontal absorber and varying reflector width.

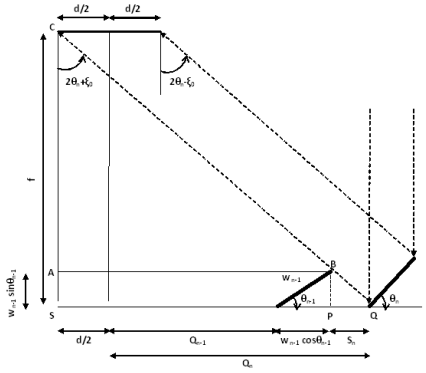

Fig. 3: (a) Geometrical view of (LFRCS) with horizontal absorber and varying reflector width.

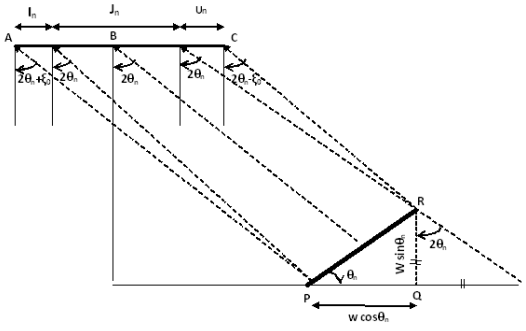

Fig. 3: (b) Geometrical view of (LFRCS) with horizontal absorber and varying reflector width.

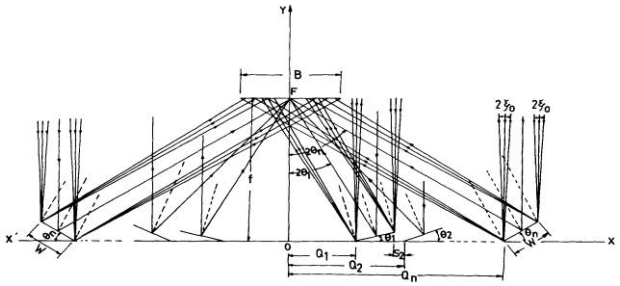

Fig. 4: A linear Fresnel Reflector concentrating System(LFRCS) with horizontal absorber and Constant Reflector Width.

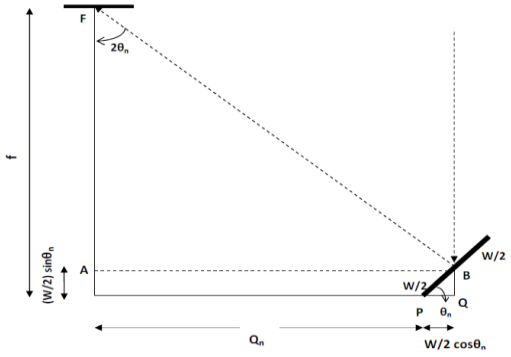

Fig. 5: (a) Geometrical view of (LFRCS) with horizontal absorber and constant reflector width.

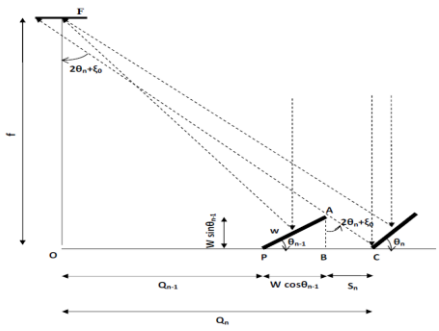

Fig. 5: (b) Geometrical view of (LFRCS) with horizontal absorber and constant reflector width.

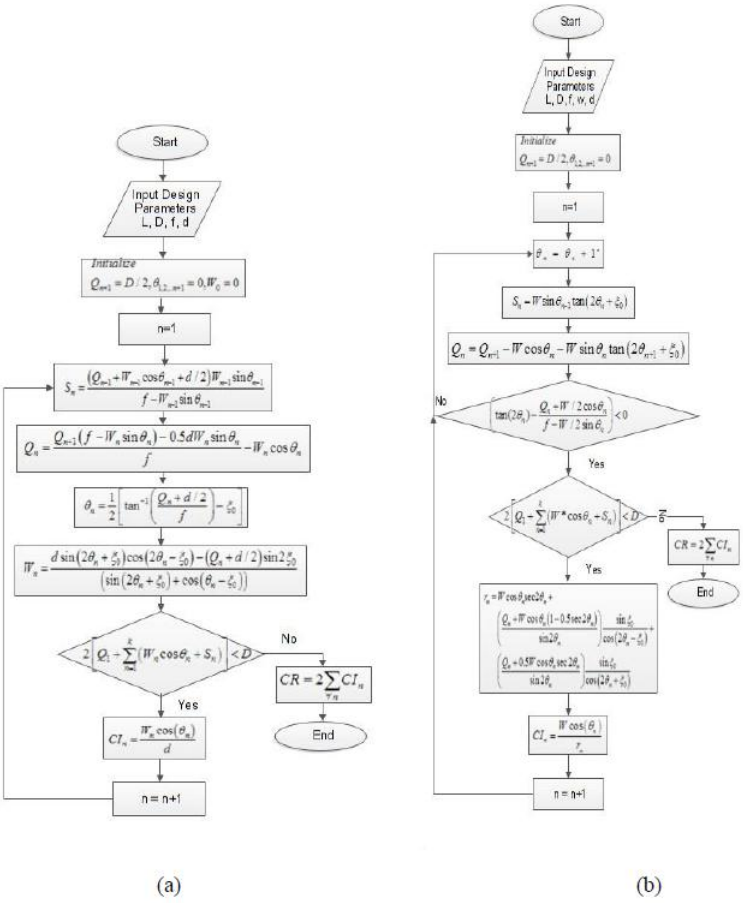

Fig. 6: Flow Chart for (a) Varying Width Reflector (b) Constant Width Reflector.

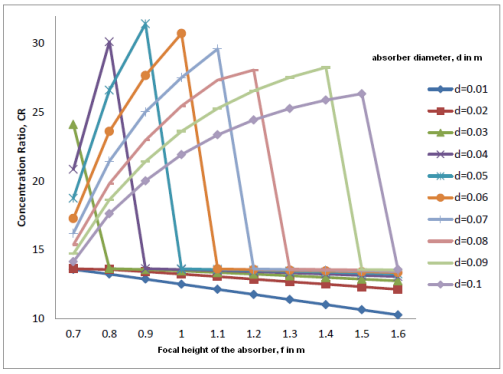

Fig. 7: Performance Analysis in term of Concentration Ratio, for varying width reflecting system.

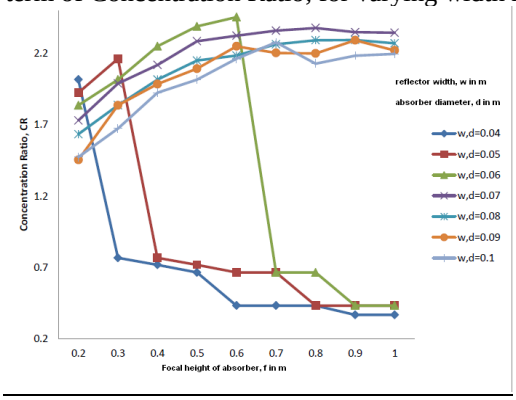

Fig. 8: Performance Analysis in term of Concentration Ratio, for constant width reflecting elements.

Nomenclature:

Symbol	Description
Q_n	Location of the n^{th} reflector from the centre (m)
P_n	Power reflected from n^{th} plate in (kW)
n,k	Number of reflector
W_n	Width of the n^{th} reflector (m)
d	Diameter of the absorber (m)
S_n	Shift between the n^{th} reflector (m)
L	Length of the absorber (m)
f	Height of the absorber center from the base (m)
D	Aperture diameter (m)
N	Number of reflectors
CP	Total Concentrated Power (kW)
CR	Concentration Ratio
CI_n	Concentrated Power from n^{th} reflector (kW)
H_{Gain}	Total heat gain (kW)
A_a	Concentrator aperture area (m^2)
d_{oa}	Outer diameter of absorber (m)
S_f	Absorbed flux (W/m^2)
τ	Transmittance of glass
α	Absorbance of the tubular absorber
γ	Intercept factor
η_o	Optical efficiency (%)
η_{th}	Thermal efficiency (%)
θ_n	Tilt angle of n^{th} reflector (degrees)
ξ_0	Half of the angular sub-tense of the sun at any point on the earth(=16')
ρ	Reflectivity of the reflector
I_b	Beam radiation (W/m^2)

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