A Simple Technique of Fabrication of Paraboloidal Concentrators

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Introduction

Paraboloidal concentrators have the ability to raise various absorbers and wor to high temperatures. The maximum concentration factor and temperature att practice depends on the aperture size (area intercepting solar radiation), r and accuracy of the surface contour, and the degree to which the co approximate a true paraboloidal geometry. Paraboloidal concentrators have for various applications, from cooking[1] and driving hot-air operated pumps water[2], to providing power for space-craft[3] through a mercury-vapor driv generator. In recent times the merits of various types of non-imaging concentrators[4] which collect not only the direct beams of radiation but also scattered component, has been described in literature.

It is generally believed that paraboloidal dish-shaped reflectors require sophisticated fabrication techniques of metal spinning, plastic moldin pressing'[5]. A practical and elegant technique of fabricating simple and paraboloidal concentrator, starting from a plane sheet of material is described

Aluminized Mylar which is known to be a very good reflecting material is now available. Pasted on a suitable backing such as cardboard, paper-mache, galvanized iron, or thin aluminum sheets, it can be fabricated into inexpe practical solar concentrators.

Principle of Fabrication

Figures 1 and 2 illustrate the principle of construction of a paraboloid starting plane sheet of material. Figure 1 is a plot of the parabola $Y=X^2/4f$ representin vertical section through a paraboloid having a focal length of f cm. If the para slit symmetrically along eight radial directions and flattened out, then it would like an eight petalled flower as in Fig. 2. the non-shaded portion in Fig. 2 repre

reflector part, and the shaded portion that part of the plane sheet which has to
out and removed. A circle of circumference ***2∏R*** on the plane sheet would occ
lesser circumference equal to ***2∏X*** in the paraboloid after fabrication. Thus the
consideration in the construction is to calculate the arc length of material that
cut out, namely (***2∏R -2∏X***) as a function of ***R***. Note that the radial distance ***I***
the origin and any point ***P*** on the plane sheet becomes the arc length alon the
the parabola between the origin and the same point P on the surface of the par

To derive an expression for ***R*** in terms of ***X***, the following procedure is used:

Let ***dR*** be an element alon the parabolic arc, and ***dX*** and ***dY*** the correponding
along the ***X*** and ***Y*** axes respectively (see Fig. 1).

$$(dR) = (dX)^2 + (dY)^2$$

Since:

$$Y = \frac{X^2}{4f}$$

Substituting,

$$dY = \frac{2XdX}{4f} = \frac{XdX}{2f}$$

Substituting,

$$dR^2 = dX^2\left[1+\frac{X^2}{4f^2}\right] \qquad dR = dX\left[1+\frac{X^2}{4f^2}\right]^{1/2}$$

Integrating,

$$R = \int_0^x \left[1+\frac{X^2}{4f^2}\right]^{1/2} dX$$

Since $X^2/4f^2 = (Y/f)<1$ for shallow paraboloids, the higher order terms can be neglected in the binomial expansion for $[1+(X^2/4f^2)]^{1/2}$ and we have

$$R = X\left[1+\frac{X^2}{24f^2}\right] = X\left[1+\frac{Y}{6f}\right]$$

The relation is valid for shallow paraboloids only. For deep paraboloids the higher order terms cannot be neglected. Using the standard integral result, namely:

$$\int\left[x^2 \pm a^2\right]^{1/2} dx = \frac{1}{2}\left[x(x^2 \pm a^2)^{1/2} \pm a^2 \log\left(x \pm \left[x^2 \pm a^2\right]^{1/2}\right)\right] + C$$

The general equation for R can be shown to be given by

$$R = \frac{1}{4f}\left[X(X^2+4f^2)^{1/2} + 4f^2 \log\left(\frac{X+\left[X^2+4f^2\right]^{1/2}}{2f}\right)\right]$$

The total length of material that has to be cut out at each value of R, i.e. the circumferential shrinkage is given by W = (2∏R-2∏X) = 2∏(R-X). For Shallow paraboiloids, since:

$$R = \left[X + \frac{X^3}{24f^2}\right] \qquad \text{we obtain} \qquad W = \frac{2\Pi X^3}{24f^2} = \frac{\Pi X^3}{12f^2}$$

In practice this shrinkage is distributed into 2N equal linear segments, N being the number of petals. The length of the segment which is to be cut out, measured perpendicular to the radial vectors on either side at distance R from the origin, is given by (for shallow paraboloids)

$$\Delta W = \frac{W}{2N} = \frac{\Pi}{N}\left(\frac{X^3}{24f^2}\right)$$

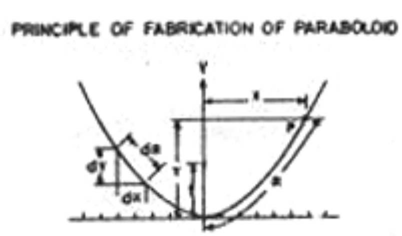

Fig. 1. Section through paraboloid.

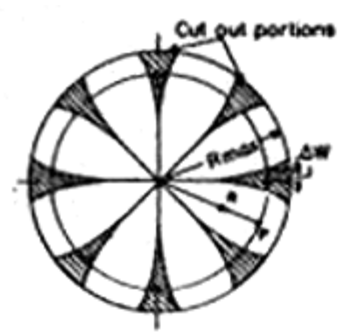

Fig. 2. Flattened paraboloid.

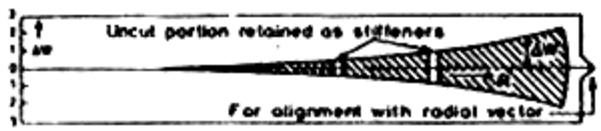

Fig. 3. Template for marking.

The shaded area which represents the portion to be cut out on either side of a
vector is shown in figure 3.

The procedure adopted for deep parabolaoids is identical except that the R has
evaluated for each value of X using the exact relations. Then the D W is calcula

$$\Delta W = \frac{\Pi}{N}\left(R - X\right)$$

Details of the Prototype Paraboloidal Concentrator Fabricated at Tro

Using the technique described above, a 1 m diameter prototype paraboloidal
concentrator was fabricated out of 1 mm thick commercial Aluminium sheet. A
mylar was first pasted neatly on the plane sheet (cut circular to ~ 12o mm dia
using Favicol adhesive, ensuring that no wrinkles or air pockets are present. Tl
equation for the parabola aimed for was Y = X2/115cm, having a focal length o
cm.

A card board template similar to Fig. 3 corrosponding to the above parabola wa
prepared. The portion to be cut out (shown shaded in Fig. 3) was marked off c
Aluminium sheet by means of brush and paint on either side of 16 symmetrical
radial vectors.After cutting out the unwanted painted portion, the 16 petals we
and fixed in position with their edges touching each other by means of suitable
arrangement such a wire clips, rivets, or screws and nut. A circular 30 cm dia c
region was left uncut as the circumferential shrinkage there was less than 0.15

This uncut portion in the center played an important role by providing mechan
rigidity to the fabricated paraboloid. The resultant paraboloid was found to be
supporting and structurally quite rigid. Fig 4 shows a photograph of prototype
paraboloid fabricated at Trombay. With care and gently pressure it was possibl
the upper portion of the paraboloid more circular and less polygonal in shape.
maximum width of each petal was 20 cm. Mechanical measurements made.

Laser beam Tests

The size of the focal region of the paraboloid was measured by means of a port
Ne Laser Unit. The Laser used had a power of 10 mW with a beam diameter of
at a waave length of 630 nm (red region). The paraboloid was mounted on a
horizontally on a framework such that it could be rotated around a central axis
of graph paper on a card board backing was mounted along the central verticle
the focal region of the paraboloid. The laser beam was made to shine vertically
downward on the reflector by means of mirror arrangement. The paraboloid wa
and the extreme points on the graph illuminated by the reflected laser spot we
off.

Fig. 4. Prototype paraboloid fabricated at Trombay.

There was a abrupt horizontal shift in the reflected spot by 10 cm when the inc
laser beam crossed over from one petal to next. The shape of wach petal was a
individually examined , and the scatter or drift of the reflected laser spot was o
It was thus determined that the focal region was ~ 10 cm in diameter and the f
length was 22+ 5 cm from the bottom. This was less than the expected value o
as the bottom uncut portion was flat.

Water heating experiment

The performance of the concentrator was assessed through water heating/boili
measurements. 0.8 l of water contained in a glass flask blakenned in the bottor
means of black enamel paint was placed in the focal region. An A-frame woode
structure was used to adjust the concentrator.

0.8 lit of water boiled in 15 min. This corresponds to ~ 300 W of absorbed Sola
Giving an efficiency of ~ 35% (on the basis of 1kW/m2 of intercepted radiation
efficiency was found to be dependent on nature of absorbing vessel, its shape,
degree of blackening. In some cases presence of outer clear glass enclosure ar

absorber vessel increased efficiency significantly.

Summary and conclusions

Measurments of the performance of paraboloid concentrator constructed out o aluminized mylar pasted on sheet meta backing, using fabrication method desc this paper, confirmed adequacy for various applications. The technique can be extended to compound parabolic concentrators (CPC) and other non imaging tv collectors also. If analytical expression between R and X is found to be cumber analogue technique of directly measuring R by means of a string or by other m may be adopted after drawing desired parabola or compound curve to full scal floor or wooden board.

References

1. M L Ghai, TD Bansal & BN Kaul Design of reflector type of Solar cooker, J.Sci.Ind.Res., 12A, 1953)

2. E A Farber, Solar Power generation Proc.ISES meeting Paris, 1973.

3. C H Castel & E S Kovaalcik, Development status of aluminium solar concentrator . Space po engineering, p 821, Academic Press, New York 1966.

4. R Winston, solar concentrator of novel design , Solar Energy 16,89, (1974)

5. VITA Report no 10, Evaluation of Solar Cookers (prepared under contract with US Departm Commerce office of Technical service) 1975.

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** Note that it need not be circular. One could also make a Paraboloid usir rectangular sheet, using the principle described in this paper.