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Design of 20m^2 Parabolic Trough Solar Thermal Collector (PTSC) and using Linaer Actuator for Single Axis Tracking

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Abstract: ***Design of 22m^2 Parabolic Trough Solar Thermal Collector is reported in his paper. Among solar thermal collectors family parabolic trough solar thermal collector (PTSTC) has significant due to its high thermal performance and operating temperature. PTC can be used to generate hot water, low and medium pressure steam. It is difficult to form the parabola curvature mechanically required manual work to form from arc to parabola curvature.Only mathematical design for parabolic trough solar collector and electrical type linear actuator for single axis tracking are discussed.***
Keywords: PTC,Focal length, Aperture are

I. INTRODUCTION

Every small to large scale industries uses Steam (low and medium temperature, i.e., 80-250^{0}C) extensively for various process like power generation, drying, cleaning, evaporating, steaming, and conditioning (heating and cooling). At low pressure also used in the household process (cooking, washing, dyeing, etc,). When compare other solar collectors, PTC is very simple to construct. Nevertheless we should take utmost care to form curvature of PTC, because deformation in curvature makes scattering the focussed radiation on receiver pipe of PTC and in turn affects the efficiency.

In a detailed work published in 1992, Thomas and Guven [1] outlined the main structural design requirements for a PTC. A PTC should: a) provide and maintain the correct optical shape of the reflective surfaces; b) maintain its shape within the specified tolerances during operations; c) protect the reflective surfaces under extreme weather conditions; d) withstand long-term environmental exposure. In other words, the stresses and deflections experienced by the receiver and the reflector must remain below specified levels under gravitational, wind, and thermal loads. On the other hand, the choice of materials depends on environmental stability, durability, mechanical and physical properties, suitability of the construction method, fitness for high production rates, low total weight, and cost. The authors also state that a sandwich structure is a good design, but high precision moulds are required in order to successfully fabricate high quality PTCs.

II. MATHEMATICAL DESIGN OF PTSC

We designed 2m^2 PTC and a rim angle of 90^0 (φ_r= 90^0). Based on these two parameters, it is possible to determine other parameters.

Parabola aperture (W_a) = 4 f tan (φ_r/2)
= 4m

Focal length (f) = W_a /4 tan (φ_r/2)
= 1m

Total aperture area (A_a) = L x W_a
= 5 m X 4m
= 20m^2

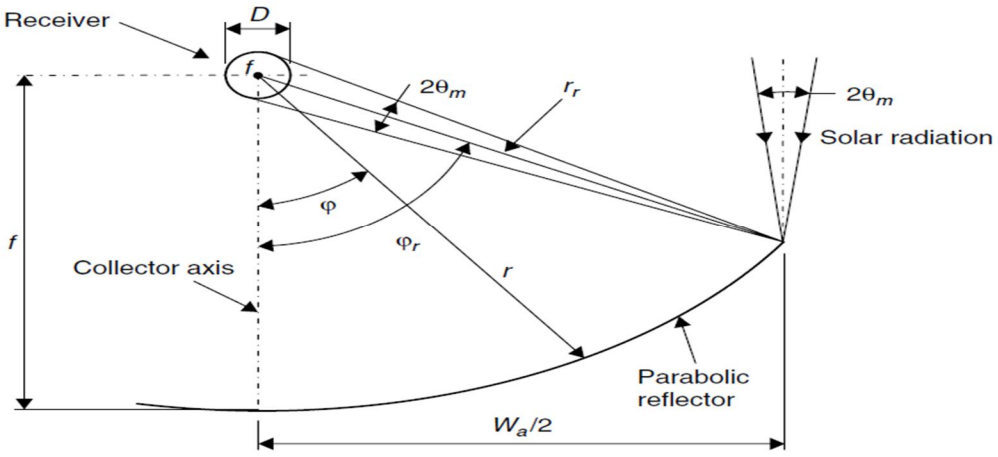

Fig 1. PTC Design

Parabola aperture (W_a) = 4 f tan (φ_r/2)
= 4m

Focal length (f) = W_a /4 tan (φ_r/2)
= 1m

Total aperture area (A_a) = L x W_a
= 5m X 4m
= 20m^2

Parabola arc length (S) = 2f [(sec (φ_r/2) tan (φ_r/2) + (ln (sec (φ_r/2) + tan (φ_r/2))]
= 4.590 m

Radius (r) = 2f/1+cosφ

Where φ angel between collector axis and a reflected beam at beam, shown in **fig1.** Another important parameter in the PTCs is the collector concentration ratio C, defined as the ratio of the area of aperture Aa to the area of the receiver Ar. This parameter for a tubular receiver is given by Kalogirou [solar energy engineering],

Concentration ratio (C) = W_a / πD_0
= 38.14

Rim radius (r_r) = 2f / (1 + cos φ_r)
= 2m

Receiver pipe diameter = W_a sin 0.267 / sin φ_r
= 18.6 mm

Where D_0 is the outer diameter of the receiver pipe and W_a is the width of the parabola. Solar image width on focal point increases with increasing rim angle. So the size receiver pipe should be capable to intercept all reflected radiation. Nevertheless, reflected radiations get dispersed because the shake in PTC structure due to sudden change in wind velocity and slight deformation in PTC curvature due to fabrication fault. In order to overcome such problem we should increase the receiver pipe diameter and got good solar image.So selected 1 inch sch40 pipe (OD=33.4 mm, ID=26.64mm and wall thickness=3.38mm) and a length of 6m. MOC (Material of construction) of receiver pipe is stainless steel.The stainless steel pipe is coated with heat resistance matt finish black paint which is good characterized and low cost and this type of paint used to coat the exposed surface of the receiver pipe. The receiver tube is insulated by borosilicate glass tube having transmittance of 99% and the size (OD=40mm, ID=36 mm and L= 1345 x 4no's) is suitable to cover the receiver pipe. Teflon insulator is used to connect glass tube and make non-contact with receiver pipe. The assembly of receiver pipe is fixed by c-clamp on receiver pipe support pipe of PTC.

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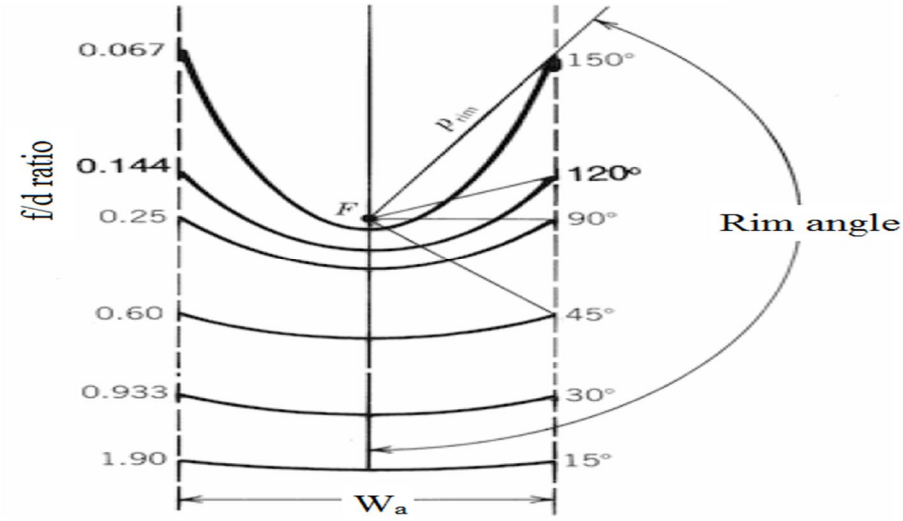

Fig 2. PTC f/d ratio

It is observed from the fig2 for the same aperture, various rim angles are possible. It can be also shown that, for different rim angles, the focus-to- aperture ratio, which delineates the curvature of the parabola changes. It can be demonstrated that, with a 90^0 rim angle, the mean focus-to-reflector distance and hence the reflected beam spread is minimized, so that the slope and tracking errors are less pronounced[4] (solar energy engg). From the references of various journals for PTC design. It is observed (commercial Point) that When decreases the collector's surface area, the rim angle is decreased. As result sacrifice in optical efficiency is small, but the saving in reflective material cost is great.

III. GEOMETRY FACTOR (A_F)

Geometry factor A_f is a measure of area loss of aperture area due to irregular incident effects surface deformation, shadows and blockages. Due to the sun movement from south to north, reflected radiation incident beyond the receiver tube. This called End effect (A_e) and area lost due to opaque plate (A_b) which is shown in fig3 and given by

$A_e = f W_a \tan\theta (1+ (W_a^2/48f^2)$
$\theta = 12.96$
$= 1.227\ m^2$
$A_b = 2/3\ W_a h_p \tan\theta$
$= 0.6136\ m^2$

Where θ is angle of incidence and h_p height of parabola

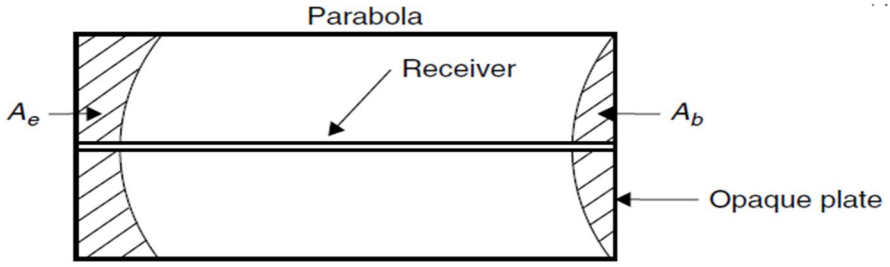

Fig.3 End effect

Total area lost of aperture area A_l will be find by adding A_e and A_b without including tanθ due to jeter

Area lost (A_l) $= A_e + A_b$
$= 2/3\ W_a h_p + f W_a (1+ (W_a^2/48f^2))$
$= (1.227 + 0.6136)\ m^2$
$= 1.8\ m^2$

Geometry factor is the ratio of shaded area (A_l) to aperture area (A_a).

$$A_f = A_l / A_a$$

$$= 0.081$$

Fig 4 PTC assembly with Linear actuator

IV. RESULT AND DISCUSSION

Facing much more problem to form parabola curvature. Suitable automatic machine is not available for parabola , so it should be reformed to parabola from arc bend by manual work. In manual work surface of the parabola deformed, so we will face the focus problem in receiver pipe. Trying to use electrical actuator but collector can not be moved linearly towards the sun.Because Surface area is very large in this 22m^2 PTC, so tracking from morning 8. But it is working from mornig 11 to evening.

V. CONCLUSION

Electrical Actuator is only suitable for small size PTC rotation. Worm wheel, helicalgear or planetary gear will be suitable for very large size. Rotation towards sun is important for higher efficiency. Good tracking system and gear for PTC will give linear steam output.

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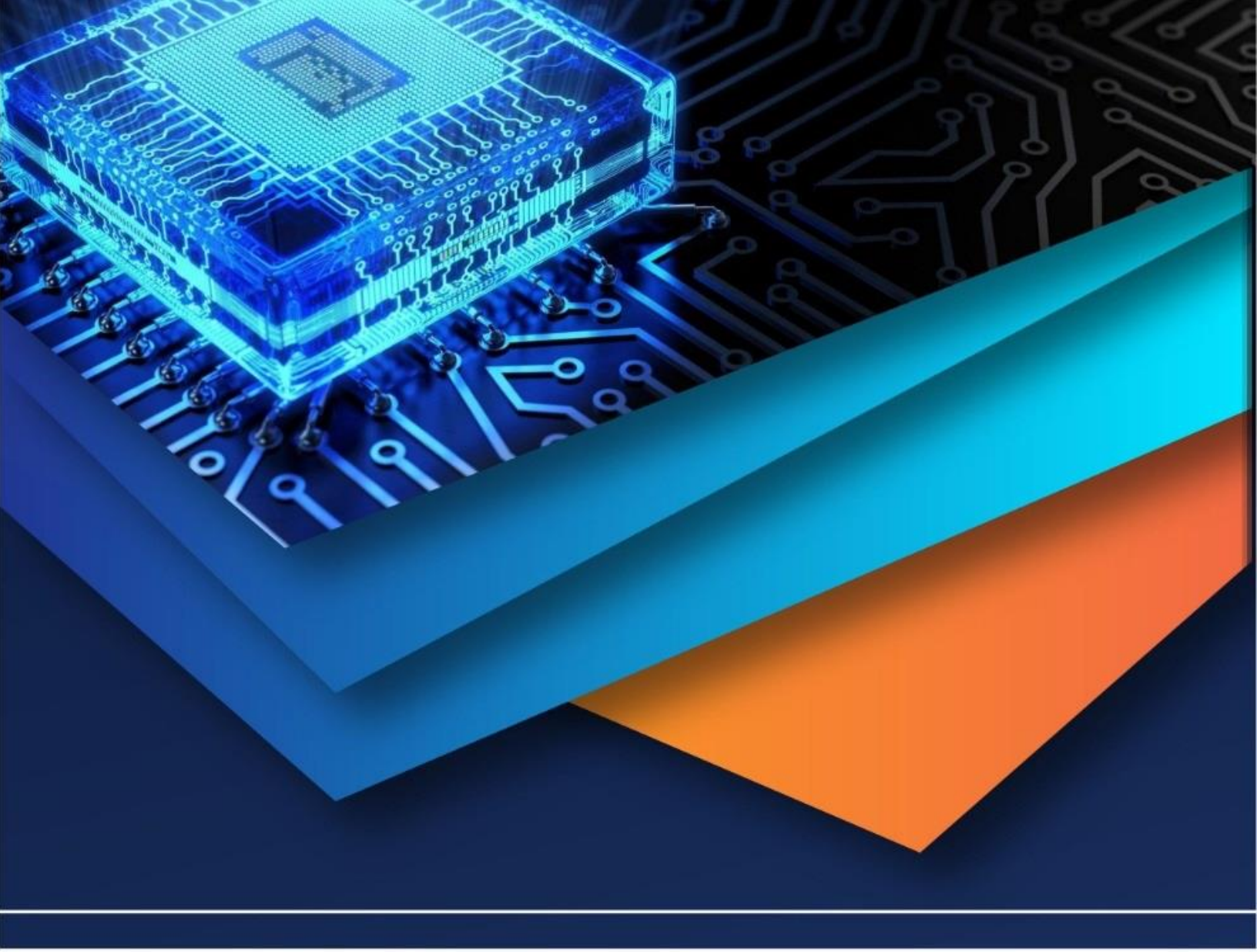

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