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# ESTIMATION OF DESIGN ERRORS ON ITS EFFECT ON PERFORMANCE OF SMALL SIZE SS-304 PARABOLA

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## ABSTRACT

Energy is one of the issues that is causing the most controversy as fossil fuels are the greatest pollutants and the greatest contributors to the greenhouse effect .The increasing importance of environmental concern, fuel savings and unavailability of power has led to the renewal of interest in renewable energies. It therefore stands to reason that developing countries whose energy consumption rate is increasing at a very fast rate should be investigating new energy systems based on renewable energies that do not pollute and which are inexhaustible such as the Solar system. This research based on small size ss-304 parabola for the domestic application. Its design errors like slope error, focal error & tracking error have been determine and analysis of the design performance have been made.A formula is derived for the optimal geometric concentration ratio, maximizing net power output as a function of all relevant variables (all-day average insolation, optical errors, effective transmittance-absorptance, heat loss, and concentrator configuration). Graphical solution of this equation consists of finding the intersection between a univer- sal curve and a straight line representing a critical intensity ratio

**Key word: SS-304 parabola, solar collector, Greenhouse effect, Renewable energy, Optical errors**

## INTRODUCTION

The solar energy comes in to the earth and we used for different work. We have also used the solar energy for steam generation. Generated steam would be used for run the steam engine and domestic work, for steam generation we used the solar parabola through concentrator. In this setup includes steel pipe, iron pipe, aluminium pipe, copper pipe and steel sheet (concentrator). Our objective is to find out the outlet temperature and temperature variation with the help of ANSYS 14.5 workbench. The solar pipe made by ANSYS workbench and analysed and find out the outlet temperature. First we would modelled the solar pipe and then applied the boundary condition and last run the software and get the result. In this software give some input values in the geometry i.e. inlet velocity, inlet temperature, atmospheric pressure and heat flux. We have also use no slip boundary condition. In this analysis the flow of water is Laminar flow, no slip wall condition and the geometry model is k-e model. The CFD analysis of model is 3D analysis and single phase based analysis.

The solar energy has been the most favourite renewable energy source in the present times. It is noted for its high reliability than other systems and allows more energy generation than other renewable resources. But the overall capacity of solar systems is limited due to its space requirements and low efficiency particularly in flat plate tube and evacuated tube units. The lower heating capacity of fluid in flat plate and evacuated tube solar units limits the rise in temperature and reduces the thermal efficiency. This reduces its utilization in commercial areas reducing its reach as emerging potential market for taping solar energy. Energy generated from solar, wind, ocean, tidal, hydropower, biomass, geothermal resources, bio fuels and hydrogen is renewable resources. Non-renewable energy is energy sources that cannot resupply in the near future such as coal, oil, petroleum and natural gas. Renewable and non-renewable energy sources can be used to produce secondary energy sources as electricity.

Energy is one of the crucial inputs for socio-economic development. The rate at which energy is being consumed by a nation often reflects the level of prosperity that it could achieve and total energy consumption has increased along with economic and population growth and, at the same time, various environmental problems associated with human activities have become increasingly serious. The water is applied as the heat transfer fluid in a solar parabolic trough collector system. Firstly, the system dynamic model was established and validated by the real operating data in typical summer and spring days in references. Secondly, the alteration characteristics of different solar radiation, inlet water temperature and flow rate are analyzed and compared with the normal working condition. The model can be used for studying, system designing, and better understanding of the performance of parabolic trough systems.

## SOLAR PARABOLIC TROUGH CONCENTRATOR TECHNOLOGY

Parabolic trough concentrator (PTC) systems are currently the most mature and cost-effective technology to generate electricity through concentrating solar power (CSP). Unlike photovoltaic cells that convert solar radiation directly into electricity, CSP system concentrates the incident solar radiation to generate heat. The thermal energy is then converted to electricity in a heat engine, distributed as process heat, or used in chemical applications. In a PTC, an array of parabolic-shaped mirrors concentrates the incident solar radiation onto the focal line where a tubular receiver is placed. The receiver generally consists of an absorber tube and a protective glass envelope surrounding the absorber. The absorbed solar radiation is transferred to a heat transfer fluid (HTF) that flows through the absorber tube and provides the thermal energy for the power cycle. The HTF is also used to provide heat to the thermal storage system, either directly using the fluid, or indirectly by transferring heat to a storage medium. The storage of the thermal energy produced by the solar field to overcome intermittence of the solar radiation (e.g. at night or during overcast weather) is an important aspect in lowering the cost of electricity production in PTC systems. In Figure 1.1, a PTC is shown, including the primary concentrator mirror, the tubular receiver, and the supporting structure.

The primary concentrator mirror usually consists of parabolic-shaped glass facets that are coated with a highly reflective metallic material. As a result, these mirrors display excellent optical behaviour even after many years of operation. On the other hand, the glass is heavy, expensive, requires a rigid supporting structure, and is prone to breakage. Several alternatives have been proposed, including the use of thinner glass or metallic panels that are coated with a polymer reflector. The absorber tube, which absorbs the concentrated solar radiation and transfers the energy to the HTF, is generally made of stainless steel and coated with a selective coating. The coating has a high optical absorptance in the visible light part and a very low thermal emittance in the infrared (IR) part of the spectrum. As a result, high fraction of the incident solar radiation is absorbed, while significantly reducing losses through emitted thermal radiation. To protect the selective coating from degradation and to reduce heat losses, a glass envelope is placed concentrically.

## METHODOLOGY

## PRINCIPLE OF OPERATION

Parabolic trough work on the same principle as the magnifying glass held in the sun ,the lens concentrates the rays to produce temperatures high enough to ignite paper , but here parabolic trough concentrate the sun's rays with enormous curved stainless steel trough. The 3-metre-long and 1-metre-wide parabolic trough focus the sunlight onto an absorber tube, the 'receiver'. Inside this vacuum-insulated tube flows a heat transfer fluid, usually oil or water that the sun can heat to temperatures of up to 300 degrees Celsius.

The solar field continuously tracks the sun (using manually-driven Tracking system) and transfer the collected energy to the HTF which is the water that flows through the receivers of the solar collectors. The water is circulated in the system by means of flow controlled burette.

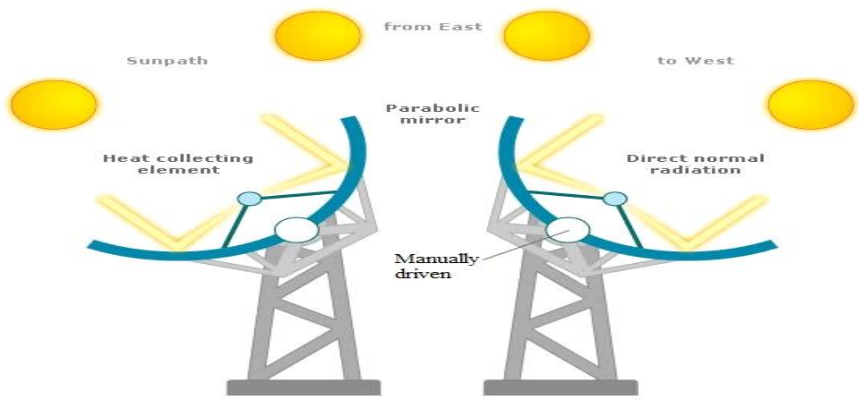



**Figure : Tracking of sun**

## PARAMETERS

**Table : The Parabolic Trough Dimension**

| Parameter | Dimensions |
|---|---|
| Length | 300 cm |
| Focal length | 30 cm |
| Width | 100 cm |
| Diameter of tube(OD) | 25 cm |
| Aperture area | 30000 $cm^2$ |

**Table : Details of Absorber Tube**

| Material | Stainless steel |
|---|---|
| Coating | Black chrome |
| External Dia. | 25mm |
| Wall thickness | 1mm |

# COST ESTIMATION

**Table : Cost of Apparatus**

| **Material** | **Cost (Rs)** |
|---|---|
| Plywood | 2000 |
| Stainless steel sheet | 1900 |
| Stainless steel tube | 350 |
| Mild steel tube | 500 |
| Bearing | 500 |
| Mild steel material | 900 |
| Machining | 2300 |
| **Total** | **8450** |

## ANALYSIS OF COLLECTOR

In analyzing the solar parabolic collector, it is important to identify each and every part of the collector and the terms used on the solar collector. Figure 5.1 briefly describes the solar parabolic collector. In the concept and design of the parabolic collector, the first definition is strictly geometric as ratio of aperture area to receiver area. The ratio of these two areas defines the concentration ratio of the parabolic trough as:

$$\mathbf{C} = \frac{A_a}{A_r}$$

$$A_a = W_a \times L$$

$$A_r = \pi \mathbf{DL}$$

***where*:**

**$C$ = concentration ratio** **$W_a$ = aperture width (m)**

**$A_a$ = aperture area** $(m^2)$ **L = aperture length (m)**

**$A_r$ = receiver area** $(m^2)$

**Performance of parabolic trough**

The purpose of this chapter is to develop an empirical mathematical model that characterizes the performance of the solar field under different operating Conditions for the system under study. The parameters that will be used to estimate the performance are the solar field efficiency and the useful heat output from the solar field.

- **The efficiency of Trough**
  $\eta_c$ = Q & u / ($A_c$ G)

- **The global irradiance G**

$G = G_n \cos \theta_z + G_d$

The amount of the beam irradiance received by the collector aperture Gb is less than the normal beam irradiance due to the cosine loss caused by the angle of incidence θ between the aperture normal and $G_n$.

- **The relation between the two irradiances is**

$G_d = G_n \cos\theta$

Concentrating solar collectors operate on the principle of concentrating the beam irradiance in clear sky conditions (low diffuse radiation). Therefore, the contribution of diffuse radiation in the useful power output and the collector efficiency will be neglected in the model development.

So, for parabolic trough collectors, the global irradiance in the dominator of equation is replaced with the beam irradiance received by the aperture $G_b$.

- **The useful output $Q_u$ can be expressed as**

$Q_u = m*c\,(T_o - T_i) = A_c \cdot G_b \cdot \eta_{op}(\theta) - A_{abs} \cdot U_L\,(T_{abs} - T_a)$

Where m: mass flow rate of the HTF (water in over system); $[Kg/s]$

C: Average specific heat of the HTF between inlet and outlet; $[J/Kg.K]$

$T_o$ : HTF outlet temperature; [K]

$T_i$ : HTF inlet temperature; [K]

$T_a$ : Ambient temperature; [K]

$T_{abs}$: The average absorber surface temperature; [K]

$A_{abs}$: Absorber outer surface area; $[m^2]$

$U_L$: Overall heat loss coefficient from absorber surface; $[W/m^2.K]$

It is easier to express $Q_u$ as a function of the fluid inlet temperature $T_i$ due to the difficulty of measuring the absorber surface temperature $T_{abs}$.

$Q_u = A_c . F_R\,[G_b . \eta_{op}(\theta) - (A_{abs}/A_c). U_L\,(T_o - T_i)]$

Where $F_R$ is "the collector heat-removal factor" defined as the ratio of the actual power output of the collector to the imaginary output if the whole absorber surface was isothermal at the fluid-inlet temperature.

- **The optical efficiency**

  The optical efficiency $\eta_{op}(\theta)$ is defined as the amount of radiation absorbed by the absorber tube divided by the amount of direct normal radiation incident on the aperture area.

$$\eta_{op,n} = \rho_m . (\tau a_c)_e \gamma_n$$

Where $\rho_m$: Average specular reflectance of the mirror at normal incidence.

τ: Transmittance of the glass envelope.

$a_c$: Absorptance of the absorber surface coating.

$(\tau a_c)_e$: The effective product of τ and $a_c$.

$\gamma_n$: Intercept factor at normal incidence.

- The optical efficiency varies with the variation of the angle of incidence θ.

- This variation is quantified by the incidence angle modifier K(θ).
- There are additional losses associated with the cleanliness of the reflector.

Accordingly, the optical efficiency equation that accounts for optical losses at any angle of incidence is given by

$\eta_{op}(\theta) = F_{RS}\ K(\theta)\ \rho_m.\ (\tau a_c)\ {}_e\gamma_n$

**PERFORMANCE MODEL DEVELOPMENT**

Performance model is a method for the characterization of the efficiency and the useful output of the solar collector. When testing for collector performance, heat output is calculated from measurements of mass flow rate of HTF and temperature difference between inlet and outlet of the collector.

Reference introduces the following performance model for parabolic trough using the mean HTF temperature ($T_m$) across the collector.

$T_m = (T_o + T_a)/2$

$$\eta_c = Q_u\ /\ (A_c\ G) = K(\theta)\ \eta_{op,n} - [c_1\ (T_m - T_a)/G_b\ ] - [c_2\ (T_m - T_a)^2/G_b\ ]$$

Where the coefficients $c_1$ and $c_2$ are determined by a curve fit to test data. The nonlinearity of equation caused by the addition of the term $(T_m - T_a)^2$ is a simplified approach to account for the temperature dependence of *UL* which is quite complex because *UL* represents the conductive, convective, and radiative losses combined together.

**OPTICAL ERRORS**

In reality, the solar rays are incident from a range of directions covering the solar disc. In addition, surface imperfections and receiver displacement are common results from manufacturing and assembly as well as the operation of concentrating collectors.

- The sun shape and the collector components imperfections are the sources of optical errors that are expected to take place during operation. Therefore, the intercept factor is a function of the geometry and the inaccuracies of the collector components.
- The various sources of optical errors are shown in figure. The optical errors can be characterized by a statistical distribution function. The error distributions are usually well approximated by Gaussian or normal distribution with zero mean.

**TYPES OF OPTICAL ERRORS ARE**

- **Slope errors:** the deviation of the slope of mirror surface from the ideal
- **Parabolic shape:**
- **Specular errors:** the non-secularity of the mirror surface.
- **Tracking errors:** associated with the accuracy of the tracking drive system.
- **Receiver displacement error:** the misalignment of the receiver with respect to the focal line of the collector.

**SAMPLE CALCULATION OF PERFORMANCE MODEL TERMS**

A sample calculation is presented here to illustrate the application of the equations used to identify the different terns of the performance model. The performance data used in this illustration are those shown in the first row of, i.e. the measurements taken on 14$^{th}$ May 2014 at 12:30:01pm. The measured data are:

A parabolic trough solar field installed on the ground space of SGSITS Indore (longitude = 75.868°E, latitude = 22.717°N) using water as heat transfer fluid. The field consists of one collectors distributed with an aperture area of 3 square meter for collector (width=1m, length=3m). The solar field is oriented at 71° counterclockwise from north as shown in the stated figure. The following performance data were measured on 14th May 2014 at 12:30:00 pm.

**Figure : Experimental setup of solar parabolic trough**

Inlet temperature of fluid $T_{in}$= 315 K, 5

Outlet temperature of fluid $T_{out}$ = 373 K,

Ambient temperature $T_a$= 313 K,

Mass flow rate of fluid m =0.6 ml/sec,

Solar radiation G = 984 W/m$^2$,

Velocity of air u =8 m/s,

**SOLUTION**

**A.** On 16th May 2015

**a. Angle Of Incidence θ**

- Day number N (May 16) = 136,
- Local Clock Time LCT (12:30:01pm) = 12+30/60+1/3600 = 12.5 hours
- Equation Of Time EOT = 0.258cos $x$– 7.416sin $x$– 3.648 cos 2$x$ – 9.228 sin 2$x$
- x =360 (N-1)/365.242 = 360 (193-1)/365.242 = 133.06°

EOT = 3.859minutes

- Longitude correction LC = (30 – 75.868)/15 = −3.04 hours
- Solar time ts = LCT + (EOT/60) – LC – DLS = 12.5 – 3.859/60 + 3.04 – 1 =14.6 hours
- Hour angle $\omega$ = 15 ($t_s$ – 12) =15 (14.6 – 12) = 39°
- Latitude angle ϕ = 22.717° (known)
- Declination angle δ = $\sin^{-1}[0.39795\cos(0.98563(N-173))]$

= 18.664°

- Solar altitude angle α = $sin^{-1}$ (sin δ sin ϕ + cos δ cos ϕ cos ω)

= 53.393°

- Solar zenith angle $\theta_z$ = 90 – α = 90 – 53.393 = 36.607°
- Solar azimuth angle ß

ß' = $cos^{-1}$[(sin δ cos ϕ - cos δ sin ϕ cos ω)/ cos α)] = 88.956°

$\sin\omega > 0$; ß = 360−ß' = 271.044°

- Aperture azimuth angle Ω = 71° (from figure)
- Tracking angle ρ = 15°
- Angle of incidence θ = $cos^{-1}$ ([1- cos2 (α) cos2 (ß - Ω)]1/2) = 52.376

**b. Useful Output**

- $Q_u$ = m∗c($T_{out} - T_{in}$)+ L
- Mass flow rate m= 0.0006kg/sec or 0.6 ml/sec
- Specific heat= 4.189 kJ/ kg k
- L = 2250 kJ/ kg (Latent Heat of evaporation of water)
- $Q_u$ = 0.6x (( 4.187) (100 - 42) + 2250 = 2395.7W
- Average radiation coming from the son (G)=984w/$m^2$,
- Total heat input =G∗A∗ =984∗3 = 2952W
- Efficiency of parabolic trough=heat output/heat input
  2395.7/2952 = 81%

B. On 11th Jun 2015

**b. Angle of Incidence θ**

- Day number N (Jun 11) = 162,
- Local Clock Time LCT (12:30:01pm) = 12+30/60+1/3600 = 12.5 hours
- Equation Of Time EOT = 0.258cos $x$– 7.416sin $x$– 3.648 cos 2$x$ – 9.228 sin 2$x$
- x =360 (N-1)/365.242 = 360 (162−1)/365.242 = 158.68°
  EOT = 0.63 minutes
- Longitude correction LC = (30 – 75.586)/15 = −3.04 hours
- Solar time ts = LCT + (EOT/60) – LC – DLS = 12.5 – 0.63/60 +3.04 – 1 =14.53 hours
- Hour angle $\omega = 15\,(t_s - 12)$ =15 (14.53 – 12) = 37. 95°
- Latitude angle ϕ = 22.717° (known)
- Declination angle $\delta = \sin^{-1}[0.39795\cos(0.98563(N-173))]$

= 23°

- Solar altitude angle α = $sin^{-1}$ (sin δ sin ϕ + $cos$ δ $cos$ ϕ $cos$ ω)

= 55.12°

- Solar zenith angle $\theta_z$ = 90 – α = 90 – 55.12 = 34.88°
- Solar azimuth angle ß
- ß' = $cos^{-1}$[(sin δ $cos$ ϕ - $cos$ δ sin ϕ $cos$ ω)/ $cos$ α)] = 81.94° sin $\omega$ >0; ß =360− ß' = −278.06°
- Aperture azimuth angle Ω = 71° (from figure)
- Tracking angle ρ = 15°
- Angle of incidence θ = $cos^{-1}$ ([1- cos2 (α) cos2 (ß - Ω)]1/2) = 53.03

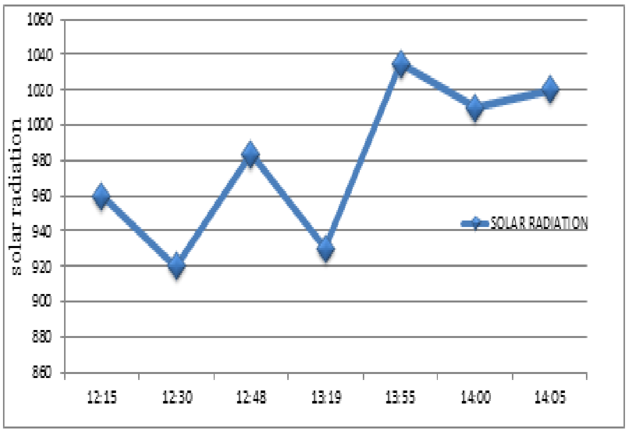
**c. Useful Output**

- $Q_u$ = m∗c ($T_{out} - T_{in}$)+ L
- Mass flow rate m= 0.012kg/sec or 1.2 ml/sec
- Specific heat= 4.189 kJ/ kg k
- L = 2250 kJ/ kg (Latent Heat of evaporation of water)
- $Q_u$ = 1.2 ( 4.187) (100 - 41) + 2250 = 2546.5W
- Average radiation coming from the son (G)=968w/$m^2$,
- Total heat input =G∗A =961∗3 = 2904W
- Efficiency of parabolic trough=heat output/heat input
  2546.5/2904 = 87%

**Solar radiation** – on 16th May 2015

**Table** **Figure : Solar radiation Vs time Note:** Location-Indore

| Time | Solar Radiation □/□ |
|---|---|
| 12:15 | 960 |
| 12:19 | 920 |
| 12:48 | 984 |
| 01:19 | 930 |
| 01:55 | 1080 |
| 01:58 | 1010 |
| 02:04 | 1020 |




## RESULT AND DISCUSSION

In this experiment, the thermal performance of parabolic trough solar collector is investigated using the measured data of the inlet and outlet temperature of the working fluid, ambient temperature, wind speed and global radiation around the experimental setup. Generally, in the test setup, water is circulated through the absorber tube and it heated, at inlet end enter water and at outlet got steam. Further we can used heat exchanger, reservoir and pump in this system. the circulation of water throughout the day starting from sunrise up to sunset. The absorber tube is tested in this project, stainless steel pipe. Without glass covers tube and with glass covers tube. The test results are listed below based on the test type. The tests are conducted on May 14, 2014 in S.G.S.I.T.S. Indore.

## STAINLESS STEEL PIPE WITHOUT GLASS COVER TUBE TEST RESULT

The data selected to demonstrate the result of stainless steel pipe is taken on May 14, 2014 at 12:30 pm. and ambient temperature, wind velocity, inlet temperature, outlet temperature of fluid and flow rate of fluid are measured.

Ambient temperature of surrounding $T_a$= 313 K

Inlet temperature of fluid $T_{in}$= 315 K

Outlet temperature of fluid $T_{out}$= 373 K

Velocity of air u =8 m/s,

Mass flow rate of fluid m = 0.6 ml/sec,

Beam solar radiation $G_b$ = 984 W/m$^2$,

Efficiency of parabolic trough = 81%

## STAINLESS STEEL PIPE WITH GLASS COVER TUBE TEST RESULT

The data selected to demonstrate the result of stainless steel pipe is taken on Jun 9, 2014 at 12:30 to 01 pm. and ambient temperature, wind velocity, inlet temperature, outlet temperature of fluid and flow rate of fluid are measured.

Ambient temperature of surrounding $T_a$= 312 K

Inlet temperature of fluid $T_{in}$= 314 K

Outlet temperature of fluid $T_{out}$= 373 K

Velocity of air u = 8 m/s,

Mass flow rate of fluid m = 1.2 ml/sec,

Beam solar radiation $G_b$ = 968 W/$m^2$,

Efficiency of parabolic trough = 87%

Glass tube surface temperature $T_{ts}$ = 391 k

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