PERFORMANCE OPTIMIZATION OF CONCENTRATED SOLAR THERMAL COLLECTOR

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**INTRODUCTION**

CSP technologies all work beneath a standard principle that is aggregation sunrays over an oversized space and concentrate them at a smaller space that corresponds to a circular surface for purpose focus CSP or over the outer surface of a cylinder for line focus CSP. the world accustomed welcome sunrays is named the solar furnace and corresponds to a reflective surface. The concentration point/line is named the concentrate or focal line and it's wherever the receiver is found. The receiver options associate absorbent material that is that the medium accustomed carry the warmth. For parabolic dish systems, the receiver comprehends, in addition to the absorbent material, an influence conversion unit. regarding the subsequent work, it'll analyze deeply a particular parabolic dish system that is that the Dish Stirling system.

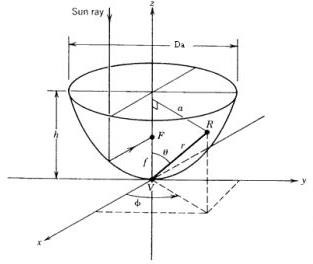
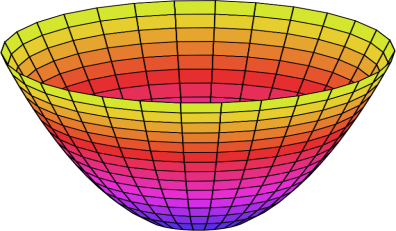
## OBJECTIVES OF WORK

The Aim of this work is to maximize the power output of the solar disc collector. For optimization mathematical model por formulation will be establish in order to calculate the various performance parameter of the system like efficiency and power output. Performance of parabolic concentrating type solar disc collector. Performance optimization will be done by the variation in parameters like emissivity of absorber cavity and a appropriate design or material will be suggested to enhance the performance of the system.

**Formulation of problem**

## GEOMETRY OF THE DISH COLLECTOR

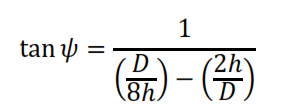
The parabolic solar collector we are interested in, has a first important parameter which is the focal length. The focal length 𝑓 defines the distance at which the focal point will be located wrt the vertex 𝑉 of the parabola. This vertex shows the deepest point of the parabolic. In spatial geometry, the paraboloid of revolution is parameterized as : **𝑥2 + 𝑦2 = 4𝑓𝑧**

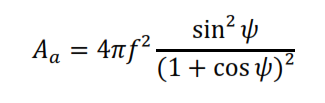


***illustration and a Graph of a Parabolic of Revolution***

The depth ℎ refers to the distance from the center of its aperture to the vertex 𝑉. On the other hand, the diameter 𝐷 is the diameter of the paraboloid’s aperture which is the circular surface of its upper base. These parameters are critical to defining the shape of the solar collector and thus to determining the position of its focal point 𝐹. If we take the two-dimensional plane 𝑦𝑧, the equation of the parabola will simply be **𝑦2= 4𝑓𝑧**

As 𝐷 is directed along the 𝑦 axis and the plane of interest is the 𝑦𝑧 plane, the 𝑦 parameter is simply the radius of the aperture 𝑅. Therefore, as ℎ is directed along the 𝑧 axis, the equation becomes as follows, 𝑅2 = 4𝑓ℎ which is equivalent to 𝐷² = 4𝑓ℎ. Then, 𝑓 can be expressed as a function of parameters ℎ and 𝐷 as shown in equation [**f = D2/16h]**

When designing a parabolic solar collector, the rim angle 𝜓 is the most important parameters as it gathers all the dimensions of the collector and thus defines its focal length. The rim angle refers to the angle made by the line, drawn from the edge of the rim to the focal point 𝐹, and the 𝑧 axis. 𝜓 is defined by equation

The rim angle is the metric that defines how curved or flat is the parabolic dish collector. Consequently, a collector with a relatively great rim angle is relatively curved and one with a relatively small one is relatively flat. Since, the upper base of the paraboloid is a circular surface, the area or the aperture’s defined by the area of a circle.

**SIZING OF THE COLLECTOR/RECEIVER**

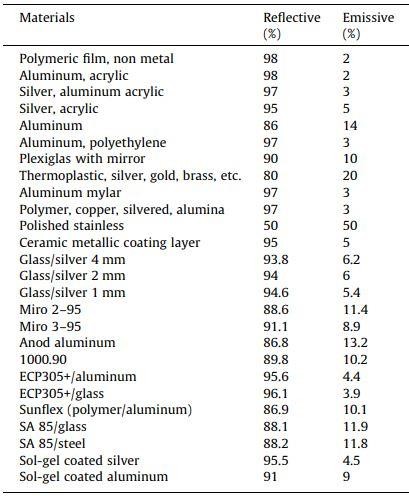
The most common utilized types of receivers are cavity receivers and they are placed at the focal point; thus the concentration of sunrays will occur at its basis. The optical performance of the system strongly related to the size of the receiver.. For Dish Stirling systems, the concentration ratio can reach high values since the application of such systems require a large collector’s area. The geometric concentration ratio 𝐶𝑔is given by the equation. **Cg=Adish/Arec**

It is important to introduce the optical concentration ratio which is the exact measurement of the concentration ratio and it corresponds to the ratio of the radiant flux density at the receiver 𝐼𝑟 (intensity at the receiver) to the direct normal irradiance 𝐷𝑁𝐼. The optical concentration ratio is given by the following formula. The dimensions are given in Watts per meter square (𝑊. 𝑚−2) while 𝐶 is dimensionless. **C=Ir/DNI**

**REFLECTOR MATERIAL SELECTION**

The selection of the material to be used to reflect the incoming solar .It produce a major effect on the amount of solar radiation transmitted to the receiver. The surface of the collector must be highly reflective in order to minimize the energy absorbed by the reflector material and reflect most of the incident solar radiation to the focal plane. The usually used mirror materials have a great reflectivity. The range of reflectivity of reflective materials range from 0.85 to 0.98. Besides mirror materials, the surface may be in the form of a

polished metal such as aluminum or stainless steel. The most used material is silver coated glass. Some of the reflector materials.

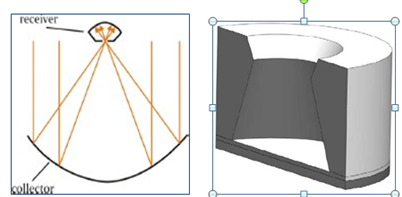


***Table of Potential Reflector Materials [2]***

For this application, the preferred reflector material is the glass silver coated material Glass/Silver 2mm with a reflectivity of 0.94 (94%) as shown in the table. The anti-soiling coating for the reflector is titanium dioxide for its attracting properties.

**RECEIVER MODEL**

The selection of the receiver comprehends different criteria which are most importantly good absorption rates of energy but also high heat transfer properties. In the design of solar dish systems, two main types of receivers’ geometry are considered and they are external receivers and cavity receivers. The advantage of cavities is that it reduces thermal losses and thus maximize the heat transferred to the working fluid. Also, convective heat losses are minimum in case of cavity receiver compared to an external receiver which would be exposed to the outer environment. the aperture of the receiver is located on the focal plane of the parabolic collector while the absorber is located behind it. as seen in the figure below.

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***Illustration of a Cavity Receiver (left) and a Modeled Geometry of the Cavity (right)***

## Efficiency of the Collector/Receiver system

**Optical Efficiency of the Concentrator**

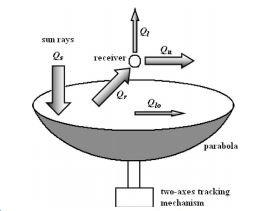
The optical efficiency of the concentrator is denoted as ɳ𝑂, it evaluates how much radiation the collector is able to reflect towards the receiver.The system is subject to shading loss which occurs due to the receiver and the Stirling Engine which block the sun from radiating on a little area over the concentrator. It is computed as the percentage of the receiver’s aperture over the dish’s aperture. The efficiency due to shading loss **Ɣ=**The efficiency due to shading loss is therefore calculated as **Ɣ = (1-Aa/Ar)**

Reflectivity loss is another loss experienced by the concentrator, it refers to the radiation lost due to the emissivity of the concentrator. It depends on the reflectivity of the reflector material. The efficiency in this case is simply the reflectivity of our material which is 𝜌 = 0.94.

The loss is evaluated to be between 2-4% . In this study, we are not considering a transparent interface at the receiver’s opening so the receiver can be considered as a black body with null transmittance. The efficiency of the system with regard to the transmission/absorption loss is Ɛ = 1 – (2 – 4%), we will take the average loss value 3% and set Ɛ = 0.97 (97%).

The spillage loss shall be considered as well and it corresponds to the reflected radiation that miss the receiver’s entrance. It is estimated to be 1-3% [4], therefore we take the efficiency considering this loss to be 2% and we set Ə = 0.98 (98%). Finally, the optical efficiency ɳ𝑂 is the product of all the previously stated efficiencies and it is given by **ɳ𝑂 = Ɣ𝜌ƏƐ**

## Thermal Modeling of the Receiver



Thermal losses

A major part of the total system thermal losses occurs in the receiver. So therefore, calculation

These losses are an important aspect. These losses include

* Conduction through the receiver walls.
* Radiation through the opening of the aperture to the environment.
* Convection from the cavity.

**The Conduction Losses:** The conduction losses from the receiver-cavity is calculated by

**Qcond = (Tcav –Tamb)/ln[(dcav/2+δin )/(2KinsLcav)**

**Tcav** =temperature of cavity

**Stefan boltz mann constant** = σ = 5.67\*10-8w/m2k4

**The Convection Losses** The natural convective heat transfer coefficient, which refers to transfer through the receiver cavity, depends on the aperture and receiver diameters, and the cavity location on a specific day. To estimate this coefficient, the Nusselt number can be calculated as below

**NU =0.88Gr1/3 (Tcav/Ta)0.18 .cos(ɵ)2.4.(dap/dcav)-0.982(dap/dcav)+1.12**

**Gr = {g. βair.( Tcav- Tamb). Lcav3 . ρair} / µ2**} **Βair=1/Tcav**

The forced convective heat transfer coefﬁcient of the receiver cavity can be expressed as a function of the wind speed, as follows

**hforced = 0.1967 . v 1.849, h𝑛𝑎𝑡𝑢𝑟𝑎𝑙 = 𝑁𝑢. 𝜆/𝑑**

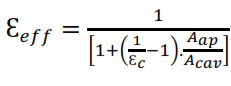
The total convective heat transfer coefﬁcient and total convection losses through the receiver cavity are calculated using the following equations.

**H total= hnatural+ hforced**

**Qconvection= Htotal. Acav(Tcav -Tamb )**

**The Radiation Losses** A major portion of the heat loss experienced by the receiver is due to radiation losses. Radiation heat transfers can be distinguished as two mechanisms, emission and reflection. The radiation loss is computed according to the relation below

**𝑄𝑟𝑎𝑑𝑖𝑎𝑡𝑖𝑜𝑛= Ɛ𝑒𝑓𝑓. 𝐴𝑐𝑎𝑣. 𝜎. (𝑇𝑐𝑎𝑣4- 𝑇𝑎4)** Ɛ𝑒𝑓𝑓 is the effective absorptance of the cavity receiver and can be calculated by the following

****

### 

**Total heat loss of system** **QL=Qcond+Qconv+Qrad**

**efficiency of the system** The efficiency of the reciver dicribed its ability to transfer heat from the cavity to absorber of strilling engine is

**Ƞthermal=**

**Ƞo= Ɣ𝜌ƏƐ**

**Ɣ=**The efficiency due to shading loss is therefore calculated as Ɣ = (1-Aa/Ar)

**Ƞgen=50%**

**Ƞengine=70%**

The total efficiency of the system is the multiple of all the efficiencies.

**ȠTotal=Ƞo\*Ƞthermal\*Ƞgen\*Ƞengine**

**POWER OUTPUT OF THE SYSTEM** The overall efficiency of the system is the multiple of all the efficiencies multiplied by the efficiency of the power generator. So that the total efficiency will give us the amount of Power generated in function of the direct normal solar radiation. It would simply be the product of the total efficiency, the total area of the collector 𝐴a and the 𝐷𝑁𝐼. **P= ȠTotal\* 𝐴a\* 𝐷𝑁𝐼**

By using all equations an aproch is made to calculate the efficicncy and power output of taken system and by making parametric variations optimization of the system is performed in order to find the best possible design of the system to gain maximum power output of the system.

**METHODOLOGY (SAMPLE-CALCULATION)**

Solar energy data is taken from NASA **website (**[**https://power.larc.nasa.gov/data-access- iewer/**](https://power.larc.nasa.gov/data-access-%20iewer/)**)** Sample data for jan-2023 similarly all month data has been taken

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| DY | T2M\_MAX | T2M\_MIN |  | WS10M | Ir | DNI |
| 1 | 19.42 | 10.93 | 292.42 | 2.63 | 8.44 | 8440 |
| 2 | 20.48 | 11.98 | 293.48 | 3.28 | 8.86 | 8860 |
| 3 | 21.35 | 11.35 | 294.35 | 2.78 | 8.61 | 8610 |
| 4 | 20.86 | 10.52 | 293.86 | 2.37 | 7.8 | 7800 |
| 5 | 20.65 | 6.98 | 293.65 | 2.89 | 7.31 | 7310 |
| 6 | 22.17 | 6.4 | 295.17 | 2.45 | 7.14 | 7140 |
| 7 | 24.01 | 7.24 | 297.01 | 2.44 | 7.76 | 7760 |
| 8 | 20.88 | 11.73 | 293.88 | 3.76 | 8.64 | 8640 |
| 9 | 19.7 | 6.55 | 292.7 | 3.52 | 7.1 | 7100 |
| 10 | 17.81 | 3.5 | 290.81 | 2.54 | 6.15 | 6150 |

**ESTIMATION OF OPTICAL EFFICIENCY**

ɳ𝑂 = Ɣ𝜌ƏƐ=0.891

Ɣ=1-Ar/Aa=0.997, =0.94, Ə=0.97, Ɛ=0.98

**ESTIMATION OF HEAT ENERGY RECEIVE IN RECEIVER**

Qr= ɳ𝑂\*DNI\*Aa Qr =0.891\*1089.171\*19.63= 19049.95159 watt

**ESTIMATION OF THERMAL LOSSES**

|  |  |
| --- | --- |
| Concentrator Parameters | |
| Diameter (m) | 5 |
| Depth (m) | 0.2 |
| Reflectivity (-) | 0.94 |
| Focal Length (m) | 7.81 |
| Rim Angle (rad) | 0.32 |
| Aperture's Area (m²) | 19.63 |

**Dimentional parameters**

Table dimensional parameters of csp system (4)

**Conduction heat loss**

Qcond = (Tcav –Tamb)/loge[(dcav/2+δin )/(2KinsLcav) [2]

Tcav= 1670.29 K

Tamb= 295.8674

Ɛr=0.86 ,0.88,0.91,0.93,0.18,0.12

At=0.05 m2 σ = 5.67\*10-8w/m2k4

Temperature of cavity is depend on the emmicivity of reciver as well so with the variation the different temperature of reciver cavity is calculated with the help of ms excel

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Ɛ | 0.86 | 0.88 | 0.91 | 0.93 | 0.12 | 0.18 |
| Qcond | 189.62 | 188.4 | 186.64 | 185.51 | 324.7 | 291.21 |

**Qcond =**

The conduction losses from body to environment reduced with reduction in emmicivity of receiver

### 4.3.2 The Convection Loss

Qconvection= Htotal. Acav(Tcav -Tamb ) [2]

H total= hnatural+ hforced

hforced = 0.1967 . v 1.849,

h𝑛𝑎𝑡𝑢𝑟𝑎𝑙 = 𝑁𝑢. 𝜆/𝑑𝑐

Nusselt number (NU) =0.88Gr1/3 (Tcav/Ta)0.18 .cos(ɵ)2.4.(dap/dcav) -0.982(dap/dcav)+1.12

Gr= grasoff number

ɵ=0.89 rad

Dap= dia of arpeture 0.25m

Dcav =0.15

**Gr = {g.** βair.( Tcav- Tamb). Lcav3 . ρair} / µ2}

βair = 1/Tcav ,

Tcav= 1670.29 K

Tamb= 295.8674

βair= 0.000358

Lcav=length of cavity 0.1

ρair=1.125kg/m3

µ= viscosity of air =1.8110^(-5) kg/m-s

**Gr= 41454542**

**Nusselt number**

**(NU)** =0.88Gr1/3 (Tcav/Ta)0.18 .cos(ɵ)2.4.(dap/dcav) -0.982(dap/dcav)+1.12

**NU=** 10.11976746

hforced = 0.1967 . v 1.849, V=wind velocity = 3.67m/s, hforced= 2.5638,

h𝑛𝑎𝑡𝑢𝑟𝑎𝑙 = 𝑁𝑢. 𝜆/𝑑 , 𝜆=thermal conductivity of air=0.024

h𝑛𝑎𝑡𝑢𝑟𝑎𝑙= 0.971498, H total= hnatural+ hforced , Htotal = 3.535297

Qconvection.= Htotal. Acav(Tcav -Tamb)

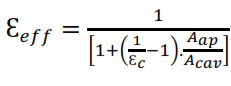
**Acav=0.24**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Ɛ | 0.86 | 0.88 | 0.91 | 0.93 | 0.12 | 0.18 |
| Qconv | 191.1331 | 189.9075 | 188.1331 | 186.9903 | 327.1761 | 293.4475 |

The reduction in losses is convection occurred with reduction in emissivity.

**4.3.3 The Radiation Losses**

𝑄𝑟𝑎𝑑𝑖𝑎𝑡𝑖𝑜𝑛= Ɛ𝑒𝑓𝑓. 𝐴𝑐𝑎𝑣. 𝜎. (𝑇𝑐𝑎𝑣4- 𝑇𝑎4) [4]



[4]

Ɛc= 0.86,0.88,.91,0.93,0.18,0.12,

Ɛ𝑒𝑓𝑓=0.786585, 𝐴𝑐𝑎𝑣=0.24, 𝐴a=19.63

σ = 5.67\*10-8w/m2k4  , Tcav= 1670.29 K, Tamb= 295.8674

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Ɛ | 0.86 | 0.88 | 0.91 | 0.93 | 0.12 | 0.18 |
| Qrad | 6280.01 | 7228.79 | 9347.02 | 11616.30 | 1072.46 | 1149.76 |

**Qrad=**

The reduction in losses is convection occurred with reduction in emissivity

**TOTAL HEAT LOSS OF SYSTEM**

QL=Qcond+Qconv+Qrad

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Ɛ | 0.86 | 0.88 | 0.91 | 0.93 | 0.12 | 0.18 |
| Total heat losses (watt) | 6660.76 | 7607.10 | 9721.80 | 11988.80 | 1724.34 | 1734.41 |

Heat losses has been calculated similarly formulating in ms –excel and the reduction in losses is found with reduction in emmesivity of the absorber cavity.

## 4.4 Estimation of the efficiency of the system

The efficiency of the reciver dicribed its ability to transfer heat from the cavity to absorber of starling engine is

Ƞthermal= = 0.55

Ƞo= Ɣ𝜌ƏƐ= 0.891

Ɣ=The efficiency due to shading loss is therefore calculated as Ɣ = (1-Aa/Ar)

Ƞgen=50% .........................[1].genrator efficiency from research paper

Ƞengine=70%.....................[1] consider the efficiency of sterling engine from the system describe in research paper 1

The total efficiency of the system is the multiple of all the efficiencies.

**ȠTotal=Ƞo\*Ƞthermal\*Ƞgen\*Ƞengine [1]**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Ɛ | 0.86 | 0.88 | 0.91 | 0.93 | 0.12 | 0.18 |
| **Ƞthermal** | 95.87% | 95.28% | 93.97% | 92.56% | 98.93% | 98.92% |
| **ȠTotal** | 29.90% | 29.71% | 29.30% | 28.86% | 30.85% | 30.85% |

The overall system effcincy is matched with base papers reading at 0.86 emmsisivity to validate the calculations and further calculation is establish in Ms –excel to elobrate the calculations in order to find the best possible results in term of power output.

# 4.5 Estimation Power output of the system

The overall efficiency of the system is the multiple of all the efficiencies multiplied by the efficiency of the power generator. So that the total efficiency will give us the amount of Power generated in function of the direct normal solar radiation. It would simply be the product of the total efficiency, the total area of the collector 𝐴a and the 𝐷𝑁𝐼.

P= **ȠTotal\*** 𝐴a\* 𝐷𝑁𝐼\*

𝐴a=19.63, 𝐷𝑁𝐼= 1089.171w/m2

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Ɛ | 0.86 | 0.88 | 0.91 | 0.93 | 0.12 | 0.18 |
| power output | 54049.48 | 53718.26 | 52978.12 | 52184.67 | 55777.23 | 55773.70 |

the over all efficiency and power output of the system is calculated with the emmisivity of 0.86 as taken from litelature review and the effect of the emmisivity is determined by taking various emmisivity of the material in to the accounts.

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Ɛ | Qr | Qcond | Qconv | Qrad | QL | effrR | eff overall | power output |
| 0.86 | 161087.85 | 189.62 | 191.131 | 6280.01 | 6660.76 | 95.87% | 29.90% | 54049.48 |
| 0.88 | 161087.85 | 188.40 | 189.975 | 7228.79 | 7607.10 | 95.28% | 29.71% | 53718.26 |
| 0.91 | 161087.85 | 186.64 | 188.131 | 9347.02 | 9721.80 | 93.97% | 29.30% | 52978.12 |
| 0.93 | 161087.85 | 185.51 | 186.903 | 11616.30 | 11988.80 | 92.56% | 28.86% | 52184.67 |
| 0.18 | 161087.85 | 291.21 | 293.447 | 1149.76 | 1734.41 | 98.92% | 30.85% | 55773.70 |
| 0.12 | 161087.85 | 324.70 | 327.176 | 1072.46 | 1724.34 | 98.93% | 30.85% | 55777.23 |

The higher emissivity cause the reduction in overall performance of the system so material with lower emissivity can be a solution to maximize the power output of the system the improvement in efficiency is gain with reduction in

**RESULTS AND DISCUSSION**

**Location and Monthly Weather Data of the Site on a Specific**

The simulation shall be conducted under ALL conditions to test the reliability of the model. The site used for the Excel calculations is JABALPUR (M.P)with a latitude of 23°11’9.18”. The day simulated is a ALL day, JAN – DEC of 2023. The direct normal irradiance, ambient temperatures as well as wind speeds have been extracted from historical weather data. The data has been analyzed on an hourly basis to evaluate the variation of the thermal efficiency of the receiver and the total electrical output of the system at different times of the day AND MONTHS. Our model tests the Dish Stirling system performance from JAN to DEC . The collected weather data as summarized in the table below.

**Monthly average Weather of year 2023**

|  |  |  |  |
| --- | --- | --- | --- |
| MONTH | DNI (W/m²) | Ambient Temperature-Ta | Wind Speed (m/s)-V |
| JAN | 7624.193548 | 295.8674194 | 3.887419355 |
| FEB | 7530.344828 | 300.5593103 | 4.102068966 |
| MAR | 8666.774194 | 305.8554839 | 4.076129032 |
| APR | 9341.666667 | 312.4516667 | 4.707333333 |
| MAY | 10074.51613 | 315.2848387 | 5.409354839 |
| JUN | 10905.33333 | 307.3463333 | 5.710333333 |
| JUL | 10808.3871 | 304.6806452 | 4.731612903 |
| AUG | 10825.48387 | 302.7006452 | 5.336774194 |
| SEP | 10361.33333 | 303.3146667 | 3.520333333 |
| OCT | 9188.709677 | 302.2793548 | 3.291612903 |
| NOV | 7663.333333 | 300.2863333 | 3.096000111 |
| DEC | 7469.032258 | 299.2341935 | 3.047741935 |

Table 5.1 Solar Data Jabalpur

**Calculation of Solar Position and Monthly Incident Angles** The input angles for trigonometric built-in functions on Microsoft Excel take angles in radians; that is why, the latitude of the site and the solar incident angles must be converted to radians. The incident angles are exactly the altitude angles (𝑡) of the monthly fixed system since we assume that the Dish Sterling is constantly oriented towards the sun. On the 21st December, the sun will rise 80° east of due south and set 80° west of due south. On the 21st March/21st September, the sun will rise 91° east of due south and set 91° west of due south. On the 21st June, the sun will rise 102° east of due south and set 102° west of due south. Figures shown in degrees from vertical



|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** |
| **51°(0.89rad)** | **59°(1.02rad)** | **67°91.16rad)** | **75°(1.30rad)** | **83°(1.44rad)** | **89°(1.55rad)** |
| **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** |
| **83°(1.44rad)** | **75°(1.30rad)** | **67°(1.16rad)** | **59°(1.02rad)** | **51°(0.89rad)** | **44°9(0.76rad)** |

Jabalpur Optimum Tilt of Solar collector by Month

Table solar inclination monthly

**Sizing of the Parabolic Dish and Receiver** The simulation conducted is done on a 5-m diameter parabolic dish Stirling system with a concentration ratio of 400. Therefore its receiver’s diameter is approximately 25 cm.

𝐶 =𝐴𝑎/ 𝐴𝑟 =𝐷𝑎2/ 𝐷𝑟2= 400, so 𝐷𝑟 = √𝐷𝑎² 𝐶 Since the cavity is similar to a conical shape, let us estimate the diameter of the lower base of the cavity to 𝑑𝑐𝑎𝑣 = 3 5 𝐷𝑟. The diameter of the cavity is then equal to 15 cm.

**Calculation of Geometric Metrics of the Collector** Relying on the equations stated in section, we calculate the geometric metrics of the receiver and the parabolic concentrator.

|  |  |
| --- | --- |
| Concentrator Parameters | |
| Diameter (m) | 5 |
| Depth (m) | 0.2 |
| Reflectivity (-) | 0.94 |
| Focal Length (m) | 7.81 |
| Rim Angle (rad) | 0.32 |
| Aperture's Area (m²) | 19.63 |

**Characteristics and Sizing of the Receiver** The results showing the characteristics of the receiver upon which the simulation is conducted are as in the following table. In fact, to minimize heat losses through radiation, the cavity walls are insulated with an insulator of conductivity k.

|  |  |
| --- | --- |
| Receiver Parameters | |
| Receiver's Diameter (m) | 0.25 |
| Receiver's Radius (m) | 0.13 |
| Receiver Aperture's Area (m²) | 0.05 |
| Thermal Conductivity of Insulation k (W/m.K) | 0.04 |
| Thickness Insulation (m) | 0.05 |
| Emissivity of Cavity | 0.86 |
| Cavity Length (m) | 0.1 |
| Cavity Diameter (m) | 0.15 |
| Cavity Radius (m) | 0.075 |
| Effective Absorptance | 0.24 |
| Cavity Area (m²) | 0.024 |

**Table 5.4. Sizing and Characteristics of the Receiver**

**COMPUTATION OF EFFICIENCIES**

**Calculations of efficiencies and output of system**

Variation in thermal efficiency of the receiver and power output of system.

Monthly average of all the data calculated is considered for displaying of results . Results are summarized in the form of tables and respective graphs are produced to elaborate the results of performance of solar disc in Jabalpur (M.P.)

This work is focused on 1: calculation of thermal performance of solar parabolic disc . 2 : evaluation of effect of receiver emissivity on solar parabolic disc.

Emissivity is an important parameter for the evolution of performance of solar parabolic disc collector. Radiation losses are the major loss in the system. So higher emissivity cause the increment in radiations losses and reduce the thermal efficiency and power-output of the system. So lower emissive material is a better solution to improve the performance of the system in present work various emissivity materials are tested analytically the emissivity of material considered are.-

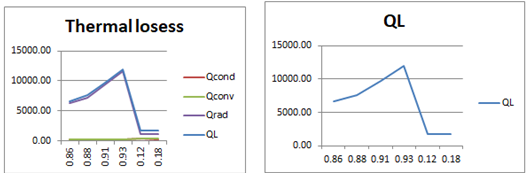
|  |  |  |
| --- | --- | --- |
| s.n. | Ɛ | MATERIAL |
| 1 | 0.12 | black NICKEL GLAVNIZED IRON |
| 2 | 0.18 | hastelloy X |
| 3 | 0.86 | Stainless steel |
| 4 | 0.88 | Asphalt |
| 5 | 0.91 | Concrete |
| 6 | 0.93 | Quartz glass |

Table 5.11 Absorber Materials

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| s.n. | Ɛ | Qr | Qcond | Qconv | Qrad | QL | Ƞthermal | Ƞsystem | power output |
| 1 | 0.86 | 161087.85 | 189.62 | 191.1331 | 6280.01 | 6660.76 | 95.87% | 29.90% | 54049.48 |
| 2 | 0.88 | 161087.85 | 188.40 | 189.9075 | 7228.79 | 7607.10 | 95.28% | 29.71% | 53718.26 |
| 3 | 0.91 | 161087.85 | 186.64 | 188.1331 | 9347.02 | 9721.80 | 93.97% | 29.30% | 52978.12 |
| 4 | 0.93 | 161087.85 | 185.51 | 186.9903 | 11616.30 | 11988.80 | 92.56% | 28.86% | 52184.67 |
| 5 | 0.12 | 161087.85 | 324.70 | 327.1761 | 1072.46 | 1724.34 | 98.93% | 30.85% | 55777.23 |
| 6 | 0.18 | 161087.85 | 291.21 | 293.4475 | 1149.76 | 1734.41 | 98.92% | 30.85% | 55773.70 |

And further calculations were made to optimize the performance.The results are elaborated in table and graphs.

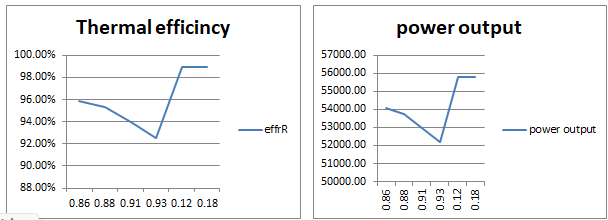
emissivity v/s performance parameter



**Thermal Losses Overall Heat Loss**

Conductive and convective losses reduces with increase emissivity but radiative losses increases.

Overall heat loss is a additive of the all losses : Qcond+Qconv+Qrad=QL Total heat loss from the system increase with increment in emissivity so that material with lesser emissivity should to be consider in design.



Thermal efficiency power output

Thermal efficiency and power output increases during reduction in emissive value of receiver material.

**Conclusion**

In his research, a method was proposed to increase the performance by calculating various parameters to increase the output power. Power loss is the main loss in the system. Therefore, a higher emission leads to more electricity and reduces the thermal efficiency and energy output of the system. Therefore, low energy products are a better solution to increase performance. Conduction and convection losses decrease with increasing emission, but electrical loss increases.

Total heat loss from the system increase with increment in emissivity so that material with lesser emissivity(black NICKEL GLAVNIZED IRON) should to be consider in design & also the material which can sustain under higher temperature occurred for the receiver cavity. So considering that material having emissivity of 0.18 (hastelloy X) is better solution because it can sustain under high temperature about 2800 K.”

**REFRENCES**

* Parabolic trough solar collectors: A sustainable and efficient energy source Asim Ahmad a , Om Prakash b , Rukaiya Kausher c , Gaurav Kumar a, Shatrudhan Pandey d, S.M. Mozammil Hasnain……………2024
* CONCENTRATED SOLAR POWER Design of a CSP Tower Plant in NEOM (Saudi Arabia) Mohammed Arfa Umar Farooq Praveen Partibhan …………et al 2023
* Designing and Performance Analysis of a Concentrated Solar Power System in Cold Arid High DNI Area.Vennila, . Muralikrishnan,…………........................et al 2023
* Design and optimization of CSP power plants for Pakistan: a comparative study Kashif Liaqat\*, and Juan C. Ordonez………………….et al 2022
* A validated energy model of a solar dish-Stirling system considering the cleanliness of mirrors Alessandro Buscemi1, Valerio Lo Brano, ………….…et al 2020
* Polynomial Expressions for the Thermal Efficiency of the Parabolic Trough Solar Collector Evangelos Bellos and Christos Tzivanidis……………………..et at 2020
* Design and comparative analysis of photovoltaic and parabolic trough based CSP plants Ahmed Bilal Awan , Muhammad Zubair , R.P. Praveen , ……....et al 2019
* Solar Thermal Dish Collector Capstone Design 22nd, 2019 Hamza Werzgan Supervised by Dr. Hassane Darhmaoui………………...………………………et al 2019
* Optical design and experimental characterization of a solar concentrating dish system for fuel production via thermochemical redox cycles Fabian Dählera, Michael Wilda, Remo Schäppia, Philipp Hauetera, Thomas Coopera, ……….………et al 2018
* Experimental Study of Two Different Types of Solar Dish Characteristics and its Efficiency Based on Tikrit, Yaseen H. Mahmood…………………………..….et al 2018
* Advanced Thermodynamic Analysis Applied to an Integrated Solar Combined Cycle System Shucheng Wang ID , Zhongguang Fu, Gaoqiang Zhang ……….et al 2018
* Design And Fabrication Of Parabolic Solar Collector And To Study The Heat Transfer Characteristics Of Zno Nanofluid ……………………………….……….2017
* Solar Irradiance Forecasting Using Deep Neural Networks. BY AhmadAlzahrani ,PouryaShamsi ,CihanDagli ,MehdiFerdowsi -……….et al 2017
* Predicting the Power Output of a Grid-Connected Solar Panel Using Multi-Input Support Vector Regression Ruby Nageema, Jayabarathi Rb ………………..et al 2017
* Prediction of solar radiation for solar systems by using ANN models with different back propagation algorithms. By Premalatha Neelamegam [,](#_bookmark0) ………...et al 2016
* Effect Of The Pcm In A Solar Receiver On Thermal Performance Of Parabolic Dish Collector Ramalingam Senthil ……………………….……………………et al 2016
* Analysis of Parabolic Solar Dish Collector for Various Reflecting Materials Mr. S. D. Kulal 1, Prof. S. R. Patil …………………………………………………..……….
* Solar parabolic dish Stirling engine system design, simulation, and thermal analysis A.Z. Hafeza,⇑, Ahmed Solimana,b, K.A. El-Metwallyc, I.M. Ismaila, et al 2016
* Data on photovoltaic power forecasting models for Mediterranean climate.by M. Malvoni, M.G. De Giorgi, P.M. Congedo ……………et al 2016
* On recent advances in PV output power forecast. By Muhammad Qamar Raza, Mithulananthan Nadarajah, Chandima Ekanayake ………..et al 2016
* Photovoltaic and Solar Power Forecasting for Smart Grid Energy Management Can Wan, , Jian Zhao, Student, Yonghua, and Zechun Hu,…………..……et al 2015
* Design And Fabrication Of Parabolic Solar Collector And To Study The Heat Transfer Characteristics Of Zno Nanofluid ……………………………….……….2017
* A Comparative Evaluation of Photovoltaic Electricity Production Assessment Software (PVGIS, PVWatts and RETScreen). By Constantinos S. Psomopoulos1 & George Ch. Ioannidis1 …………………et al 2015
* Effect of receiver temperature on performance evaluation of silver coated selective surface