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Numerical Analysis of Parabolic Disc Solar Collector for Jabalpur Region

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A B S T R A C T

In present work an approach is made for performance optimization of parabolic concentrating type solar disc collector. performance optimization is done by by the variation in emissivity of absorber cavity and a appropriate material is suggested to enhance the performance of the system. In this work a solar-Stilling engine is applied to utilize the heat energy gain from solar radiation. The calculation of all parameters were done by using ms-excel and elaborative graphs showing the results are produce for explanations.

Keywords: Solar Collector, optimization, absorber plate

1. Introduction

CSP technologies all work under a common principle which is collecting sunrays over a large area and concentrate them at a smaller area which corresponds to a circular surface for point focus CSP or over the outer surface of a cylinder for line focus CSP. The area used to welcome sunrays is called the solar collector and corresponds to a reflecting surface. The concentration point/line is called the focal point or focal line and it is where the receiver is located. The receiver features an absorber which is the medium used to carry the heat. For parabolic dish systems, the receiver comprehends, additionally to the absorber, a power conversion unit . Concerning the following work, it will analyze deeply a specific parabolic dish system which is the Dish Stirling engine.

2. Literature Review

SR. NO	AUTHOR	AREA OF RESEARCH	RESULT AND APPLICATIONS OFRESEARCH
1.	Hamza Werzgan(2019)	Solar Thermal Dish Collector Capstone Design	A CSP sterling dish featuring a solar tracking system to maximize the solar irradiance throughout the day. Thermal analysis will be conducted using fundamental equations.
2	Fabian Dählera, Michael Wilda, Remo Schäppia, Philipp Hauetera, Thomas Coopera, Philipp Gooda	Solar Dish Concentrating Systemfor Performing The Twostep Thermochemical Redox Splitting Of H2o And Co2	A detailed optical analysis elucidates measures to increase the optical efficiency and concentration ratio.
3	Yaseen.h. Mahmood1, rafa y. J. Al-salih2	Solar dish characteristics and its efficiency based on tikrit, iraq weather conditions	The Materials Used In This Research Are Economic, With High Quality To Obtain Solar Concentrator, But The Dish Which Is Covered With Pieces Of Mirrors Is Better, And It Can Be Used For Water Heatin
4	System Shucheng Wang 1,2,* Id , Zhongguang Fu 1,2, Gaoqiang Zhang 2 And Tianqing Zhang June 2018	Integrated solar combined cycle system	In addition, with the increase of solar energy input to the iscc system, the exergy destruction of brayton cycle components decreases; however, the exergy destruction of rankine cycle components increases. Furthermore, the exergy destruction of solar field has a large extended from 14.55 mw to 58.03 mw. Moreover, the heat recovery Steam Generator (Hrsg) And The Steam turbines have the largest exergy destruction rate of 11.26% and 13.63% at 15:00 p.m.

3. Methodology (Sample-Calculation)

Solar energy data is taken from NASA website (https://power.larc.nasa.gov/data-access-viewer/)Sample data for jan-2020 similarly all month data has been taken

Table 1 Solar energy data (similarly for all month and year)

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

ESTIMATION OF OPTICAL EFFICIENCY

$\eta_{\rho} = Ɣ \rho Ə Ɛ = 0.891$

Ɣ=1-Ar/Aa=0.997

ρ=0.94

Ə=0.97

Ɛ=0.98

ESTIMATION OF HEAT ENERGY RECEIVE IN RECEIVER

Qr= η_{ρ}*DNI*Aa

Qr =0.891*1089.171*19.63= 19049.95159watt

ESTIMATION OF THERMAL LOSSES

Dimensional parameters

Table 2 Dimensional Parameters

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

Conduction heat loss

$Q_{cond} = (T_{cav} - T_{amb}) / \ln[(d_{cav}/2 + \delta_{in}) / (2 \pi K_{ins} L_{cav})$

Tcav= 1670.29 K

Tamb= 295.8674

Ɛr=0.86

At=0.05 m^2

$\sigma = 5.67 \times 10^{-8} w/m^2k^4$

$$T_{cav} = \sqrt[4]{\frac{Q_R}{A_t . \varepsilon_r . \sigma}}$$

Q_{cond} =

The Convection Loss

$Q_{convection} = H_{total} . A_{cav}(T_{cav} - T_{amb})$

$H_{total} = h_{natural} + h_{forced}$

$h_{forced} = 0.1967 . v^{1.849}$,

$h_{natural} = Nu. \lambda / d_c$

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 $G_r = \frac{g.\beta_{air}.(T_{cav}-T_{amb}).L_{cav}^3.\rho_{air}}{\mu^2}$

ɵ=0.89 rad

Dap= dia of arpeture 0.25m

Dcav =0.15

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

$h_{forced} = 0.1967 . v^{1.849}$,

V=wind velocity = 3.67m/s

h_{forced}= 2.5638

$h_{natural} = Nu. \lambda / d_c$

λ=thermal conductivity of air=0.024

$h_{natural}$= 0.971498

$H_{total} = h_{natural} + h_{forced}$,

H_{total} = 3.535297

$Q_{convection} = H_{total}. A_{cav}(T_{cav} - T_{amb})$

Acav=0.24

$Q_{convection}$= **117.27**

The Radiation Losses

$Q_{radiation} = \mathcal{E}_{eff}. A_{cav}. \sigma. (T_{cav}^4 - T_a^4)$

$$\mathcal{E}_{eff} = \frac{1}{\left[1+\left(\frac{1}{\mathcal{E}_c}-1\right)\frac{A_{ap}}{A_{cav}}\right]}$$

$\mathcal{E}_c$**=0.86**

Q_{rad}=8355.1

$\mathcal{E}_{eff}$=0.786585

A_{cav}**=0.24,** A**a=19.63**

$$\sigma = 5.67.10^{-8}\, W.m^{-2}.K^{-4}$$

Tcav= 1670.29 K

Tamb= 295.8674

Q_L= 8575.07

Total heat loss of system

$Q_L = Q_{cond} + Q_{conv} + Q_{rad}$

Estimation of the efficiency of the system

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

ηthermal=$\frac{Qr-QL}{Qr}$ = 0.55

ηo= $\gamma \rho \partial \mathcal{E}$= 0.891

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

ηgen=50%

ηengine=70%

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

$\eta_{Total} = \eta_o * \eta_{thermal} * \eta_{gen} * \eta_{engine}$

η_{Total} = 0.17

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= η_{Total}* Aa* DNI*

Aa=19.63, DNI= 1089.171w/m^2

$$P_{out} = 3666.21 \text{ watt}$$

4. Result and Discussion

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.-

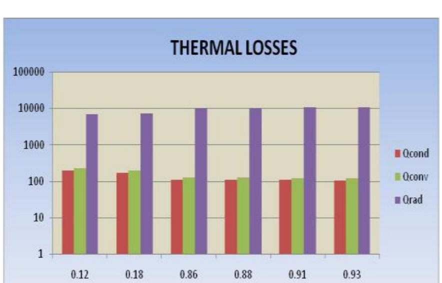
Table 3 Absorber Materials

S.No	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

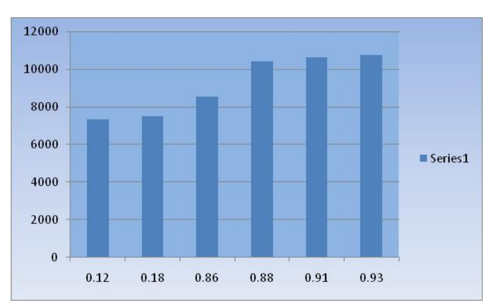
And further calculations were made to optimize the performance.The results are elaborated in table and graphs.

Table 4 emissivity v/s performance parameter

s.n.	Ɛ	Qr	Qcond	Qconv	Qrad	QL	Ƞthermal	Ƞsystem	power output
1	0.12	22993.72115	107.7999	123.9037	10085.63	10317.33	0.55124	0.171904	4436.737
2	0.18	22993.72115	107.052	123.0228	10209.92	10440	0.545906	0.170241	4393.803
3	0.86	22993.72115	105.969	121.7478	10402.23	10629.95	0.537647	0.167665	4327.32
4	0.88	22993.72115	105.2716	120.9267	10534.52	10760.72	0.53196	0.165892	4281.55
5	0.91	22993.72115	170.241	197.9566	7134.624	7502.822	0.673576	0.210055	5421.815
6	0.93	22993.72115	190.8251	222.5571	6955.201	7368.583	0.679392	0.211869	5468.798



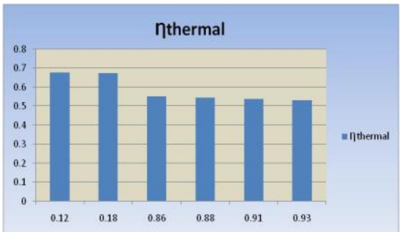
Thermal losses

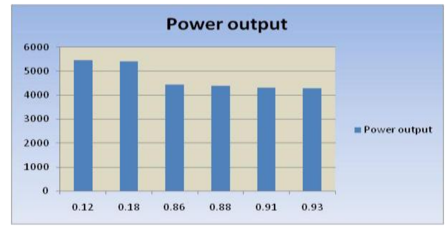


Overall heat loss

Condutive 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.

5. Conclusion

"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."

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References

[1] Solar Thermal Dish Collector Capstone Design 22nd, 2019 Hamza Werzgan Supervised by Dr. Hassane Darhmaoui.

[2] 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, Philipp Gooda, Carlos Larreaa, Max Schmitza, Philipp Furlera b,, Aldo Steinfelda, 2018.

[3] Experimental Study of Two Different Types of Solar Dish Characteristics and its Efficiency Based on Tikrit, Iraq Weather Conditions Yaseen .H. Mahmood1, Rafa Y. J. Al-Salih2.

[4] Advanced Thermodynamic Analysis Applied to an Integrated Solar Combined Cycle System Shucheng Wang 1,2,* ID , Zhongguang Fu 1,2, Gaoqiang Zhang 2 and Tianqing Zhang June 2018.

[5] A validated energy model of a solar dish-Stirling system considering the cleanliness of mirrors Alessandro Buscemi1*, Valerio Lo Brano2, Christian Chiaruzzi3, Giuseppina Ciulla2, Christina Kalogeri 2020 in https://www.sciencedirect.com/science/article/pii/S0306261919320653.

[6] Effect Of The Pcm In A Solar Receiver On Thermal Performance Of Parabolic Dish Collector Ramalingam SENTHIL* and Marimuthu Cheralathan Department of Mechanical Engineering, SRM University, Chennai-603203, India.

[7] Field Survey Of Parabolic Trough Receiver Thermal Performance Henry Price, Russell Forristall, Timothy Wendelin, Allan Lewandowski National Renewable Energy Laboratory Golden, Colorado Timothy Moss Sandia National Laboratories Albuquerque, New Mexico Carin Gummo Apple Valley, California.

[8] .International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395 -0056 Volume: 03 Issue: 11 | Nov -2016 p-ISSN: 2395-0072 © 2016, IRJET | Impact Factor value: 4.45 | ISO 9001:2008 Certified Journal | Performance Analysis of Parabolic Solar Dish Collector for Various Reflecting Materials Mr. S. D. Kulal 1, Prof. S. R. Patil 2.

[9] Design And Fabrication Of Parabolic Solar Collector And To Study The Heat Transfer Characteristics Of Zno Nanofluid May 2017..

[10] Polynomial Expressions for the Thermal Efficiency of the Parabolic Trough Solar Collector Evangelos Bellos * and Christos Tzivanidis.