

Determining of Influential Parameters and Comparison of Various Absorber Tubes in Solar Parabolic Collector trough in Winter

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ABSTRACT: In the present work the behaviour of linear solar parabolic Collector is studied. An experimental design is prepared based on the considered parabolic collector parameters such as Absorptive (α), Reflectivity (ρ) and Period of Sun Incidence (POI). Here the experiment was conducted on various absorber tubes pure materials like aluminium, copper, stainless steel, iron and coated materials. And three coated copper tubes are used in experimental setup as absorber. These three coating materials are black enamel paint, mixing of black enamel paint with charcoal powder and black enamel paint with copper oxide powder. Comparison has taken to pure materials and coated materials and the reflective surfaces are considered at two levels, one is Glass mirror and other is polished aluminium. Present work only focuses on improvement of temperature of working fluid (water) and discharge of fluid, which influenced by parameters such as absorber tube materials, reflective sheet materials, time duration. The experiments are conducted according to the Taguchi design on the solar parabolic collector. This data is analysed using Goal Programming and optimal parameter combination has been identified.

KEYWORDS: Coating materials, goal programming, orthogonal arrays, pure materials reflectors, solar parabolic collectors.

I. INTRODUCTION OF SOLAR THERMAL SYSTEMS

Concentrating solar technologies, such as the parabolic dish, compound parabolic collector and parabolic trough can operate at high temperatures and are used to supply industrial process heat, off-grid electricity and bulk electrical power. In a parabolic trough solar collector, or PTSC, the reflective profile focuses sunlight on a linear heat collecting element (HCE) through which a heat transfer fluid is pumped. The fluid captures solar energy in the form of heat that can then be used in a variety of applications

A. Description experimental setup: From the previous literature review, a solar parabolic trough has been fabricated as show in below figure.



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(a) The experimental setup consists of the following components:

- 1) Parabolic Shaped Structure, 2) Supporting legs,
- 3) Reflective Surfaces, 4) Heat collecting element (Absorber),
- 5) Auto Tracking System, 6) Piping system and Storage tank.

Table: 1

Feature/Parameters	Value
Length of the trough (L)	2m
Width of the trough (W)	1.5m
Depth of the trough	0.5m
Aperture area	4m ²
Absorber diameter, D	20mm
Focal length, f	0.28125m from vertex
Structure	Ms Flat bent structure
Concentration ratio, C	25.146
Auto tracking	Hydraulic Actuator
Battery	12 V DC

The whole experimental setup is placed on the top of the buildings. All the components are assembled to form the entire setup. The entire set is placed in the N_S direction to face the axis of the parabolic trough towards east.

II. REVIEWS ON MATERIALS

The materials used for solar concentrators need to have spectral reflectance properties to achieve good results and to ensure long life of the system. A brief description of the commonly used materials is given below.

Materials for reflecting surfaces:

- a) For reflecting systems, mirrors of high quality and good secular reflectance properties are required.
- b) Due considerations must be given to effect of accumulation of dust and contamination, stability of reflective coatings, environmental effects, cleaning problems and cost.

A variety of mirrors in use include:

- 1) The glass reflectors
- 2) Metalized plastic films (in general aluminized)
- 3) Polished aluminum surfaces
- 4) Other metallic surfaces such as stainless steel, etc.

Materials for the absorber:

The factors on which the choice of absorber materials depends are:

- a) Physical properties, such as the modulus of elasticity, the melting point, thermal inertia and the yield strength. Corrosion resistance of the outer and inner surfaces to surroundings and heat transfer fluid respectively.
- b) Energy effectiveness in use of material, for example, energy consumed to produce steel has been estimated to be 16500 KJ/kg, for Aluminum 141000 KJ/kg and for copper 93000 KJ/kg

Review of coating materials:

In this present work I have considered three coating materials depends on optimal cost they are,

- a) Black enamel paint: Conventional black paint reflects about 2.5% of incident light. The absorbance value (α) of black enamel paint is 0.97
 - b) Char coal powder mixing with black enamel paint: It is good absorbance of water and heat. The absorbance value (α) of this coating material is 0.96
 - c) Cupper oxide (cuo) mixing with black paint: Can be applied to the catalyst, super conducting materials, thermo electric materials sensing materials etc. The absorbance value (α) of this coating material is 0.93.
- These coating materials are coated on cupper tube.

(b) **Plan of investigation:** It is planned that the experiments are conducted according to the L₁₈, L₃₂ array with respect

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of factors and levels of problem for coated materials (experiment1) and pure materials (experiment2).

Table 2: Input parameters and levels of experiment 1

Symbol	System parameter	Level 1	Level 2	Level 3
A	R	Polished aluminum ($\rho=0.97$)	Glass mirror ($\rho=0.95$)	–
B	A	Copper tube coating of black enamel paint ($\alpha=0.97$)	Copper tube coating of black enamel paint and charcoal powder ($\alpha=0.96$)	Copper tube coating of black paint and copper oxide powder ($\alpha=0.93$)
C	POI	10.00 -12.00AM	12.00 - 2.00PM	2.00 - 4.00PM

Table 3: Input parameters and levels of experiment 2

Symbol	System parameter	Level 1	Level 2	Level 3	Level4
A	R	Polished aluminum	Glass mirror	–	–
B	A	Stainless steel	copper	aluminum	Galvanized iron
C	POI	8.00-10.00AM	10.00-12.00PM	12.00-2.00PM	2.00-4.00PM

III. EXPERIMENTAL RESULTS

Experiments were conducted for several days for various tubes on the solar parabolic trough by changing the reflective and absorber materials. After absorbing sufficient radiation, the water in the absorber tube gets heated and its density decreases. Due to the differential, and the end of the absorber tube is closed the natural convection in counter flow direction has occurred .at each experiment the temperature is noted at the surface of the surface of the absorber and bottom of the water tank ,the water in storage tank is heated by the natural convection.

Table 4: Experimental results for 1

S.no	Combination			Temperature (° C)	Discharge (lit/hr)
	Reflector	Absorptive	Period of incidence		
1	0.97	0.97	10	42.3	19
2	0.97	0.97	12	66.7	16
3	0.97	0.97	14	76.7	17
4	0.97	0.96	10	41.2	18
5	0.97	0.96	12	61.2	16
6	0.97	0.96	14	74.2	14

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S.no	Combination			Temperature (° C)	Discharge (lit/hr)
	Reflector	Absorptive	Period of incidence		
7	0.97	0.93	10	39.6	17
8	0.97	0.93	12	58.2	18
9	0.97	0.93	14	66.3	20
10	0.95	0.97	10	38.5	18
11	0.95	0.97	12	63.7	15
12	0.95	0.97	14	68.2	17
13	0.95	0.96	10	41.2	20
14	0.95	0.96	12	59.5	17
15	0.95	0.96	14	66	15
16	0.95	0.93	10	37.2	18
17	0.95	0.93	12	59.1	20
18	0.95	0.93	14	67.2	17

Table 5: Experimental results for 2

S.no	Combination			Temperature (° C)	Discharge (lit/hr)
	Reflectivity	Absorptive	Period of incidence		
1	0.97	0.78	10	38.2	19
2	0.97	0.78	12	41.2	16
3	0.97	0.78	14	47.6	15
4	0.97	0.78	16	41.2	17
5	0.97	0.85	10	43.2	18
6	0.97	0.85	12	51.7	16
7	0.97	0.85	14	69.6	14
8	0.97	0.85	16	43.3	17
9	0.97	0.80	10	39.6	18
10	0.97	0.80	12	47.6	20
11	0.97	0.80	14	61.2	16
12	0.97	0.80	16	51.2	18
13	0.97	0.64	10	35.3	20
14	0.97	0.64	12	39.3	18
15	0.97	0.64	14	43.5	15
16	0.97	0.64	16	35	17
17	0.95	0.78	10	37.2	20
18	0.95	0.78	12	45.6	17
19	0.95	0.78	14	46.7	15
20	0.95	0.78	16	39.6	18
21	0.95	0.85	10	42.3	20
22	0.95	0.85	12	49.6	17
23	0.95	0.85	14	56.5	15
24	0.95	0.85	16	39.7	21

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S.no	Combination			Temperature (° C)	Discharge (lit/hr)
	Reflectivity	Absorptive	Period of incidence		
25	0.95	0.80	10	38.2	19
26	0.95	0.80	12	45.6	17
27	0.95	0.80	14	46.6	16
28	0.95	0.80	16	38.6	18
29	0.95	0.64	10	35.6	20
30	0.95	0.64	12	40.6	18
31	0.95	0.64	14	42.6	15
32	0.95	0.64	16	36.7	17

IV. REGRESSION SOLUTION

Experimental data obtained using Taguchi design is utilized to establish the linear regression models. Regression models are developed using MINITAB8.1. The responses Temp and Discharge are related to the variables Reflectivity(X_1), Absorbance(X_2), and Period of Time (X_3) through the equations in the un-coded form as:

(a) Linear Regression for experiment 1:

Temperature: $87.2X_1 + 81.5X_2 + 7.48X_3 = 195$

Discharge: $11.1X_1 + 38.5X_2 + 0.417X_3 = 69.7$

(b) Linear Regression for experiment 2:

Temperature: $148X_1 + 49X_2 + 0.619X_3 = 143$

Discharge: $28.1X_1 + 0.71X_2 + 0.319X_3 = 69.7$

V. GOAL PROGRAMMING

Goal programming is a branch of multi objective optimization, which in turn is a branch of Multi-Criteria Decision Analysis (MCDA), also known as Multi-Criteria Decision Making (MCDM). This is an optimization program, it can be thought of as an extension or generalization of linear programming to handle multiple, normally conflicting objective measures. Each of these measures is given a goal or target value to be achieved. Unwanted deviations from this set of target values are then minimized in an achievement function.

(a) Determinations of optimum process parameters using Goal Programming: The experimental data is analyzed using Goal Programming and to determine optimum process parameters as in the following.

(b) Problem formulation:

The objective considered for the present problem as follows:

- 1) Maximize the temperature,
- 2) Maximize the discharge

The goals for above objective were listed as follow:

The regression equations convert into goal constraints of temperature and discharge.

The GP formulation for the problem is:

Goal objective function:

Minimize: $Z = d_1^- + d_2^-$;

Minimize:

$Z = 98.3X_1 + 120X_2 + 7.897X_3 + X_4 + X_6$

In the above equation x_1, x_2 and x_3 are input parameters, x_4, x_5, x_6, x_7 are the under achievement and over achievement.

For maximization objectives under achievement x_5, x_7 should be minimized.

Subjected to

Temp: $87.2X_1 + 38.5X_2 + 7.48X_3 = 195$; Discharge: $11.1X_1 + 38.5X_2 + 0.417X_3 = 69.7$

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$$0.95 \leq X_1 \leq 0.97; 0.93 \leq X_2 \leq 0.97; 10 \leq X_3 \leq 14$$

Solution to the problem

The problem was solved using Linear Programming the solution obtained as

Optimum values are $Z = -28.804$ $X_1 = 0.97$; $X_2 = 0.97$; $X_3 = 14.00$;

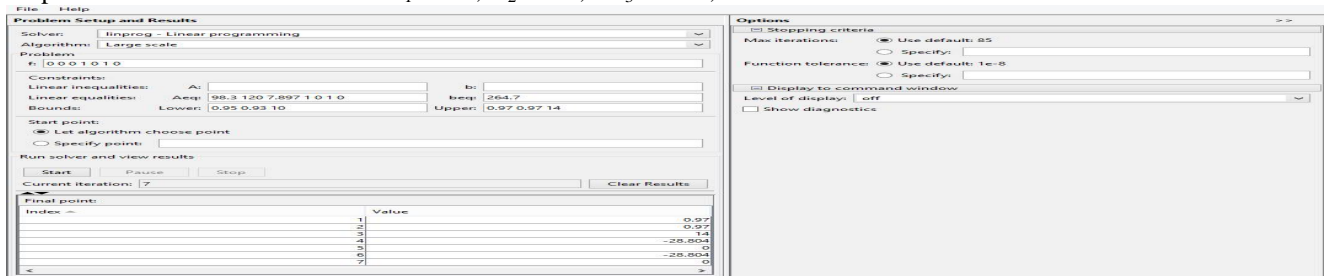


Figure (1): Goal programming linear constraint optimization for experiment 1.

(c) Problem formulation:

The GP formulation for the problem is:

Goal objective function:

Minimize: $Z = d_1 + d_2$;

Minimize:

$$Z = 176.1X_1 + 49.71X_2 + 0.938X_3 + X_4 + X_6$$

In the above equation x_1, x_2 and x_3 are input parameters, x_4, x_5, x_6, x_7 are the under achievement and over achievement.

For maximization objectives under achievement x_5, x_7 should be minimized.

Subjected to

$$\text{Temp: } 148X_1 + 49X_2 + 0.619X_3 = 143; \text{ Discharge: } 28.1X_1 + 0.71X_2 + 0.319X_3 = 69.7$$

$$0.95 \leq X_1 \leq 0.97; 0.64 \leq X_2 \leq 0.85; 10 \leq X_3 \leq 16$$

Solution to the problem

The problem was solved using Linear Programming the solution obtained as

Optimum values are $Z = -17.989$ $X_1 = 0.97$; $X_2 = 0.85$; $X_3 = 16.00$;

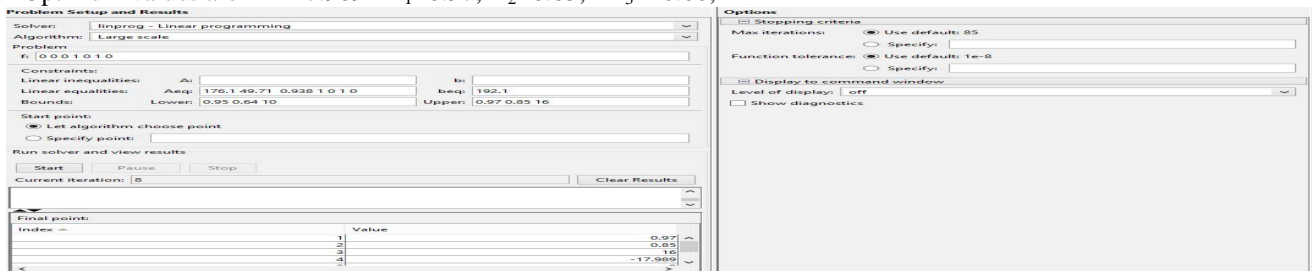


Figure (2): Goal programming linear constraint optimization

VI. RESULTS AND DISCUSSION

From the results it is evident that among the reflective materials, glass mirrors is the best option and among absorber tubes the black enamel paint coated copper tube materials plays a vital role. Finally, it is found that the goal programming can analyze the data for determination of optimal parameters in the optimization process. With the present setup the maximum temperature of water achieved 76.7°C and discharge is 17 lit/hr.

VII. CONCLUSION

In the present work the behavior of linear solar parabolic Collector system is studied and analyzed using Mathematical models. The controllable parameters such as Reflective materials, Absorber materials, Period of sun incidence which influence the responses (Temperature and discharge) are identified and the experiment are conducted

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according to Taguchi experimental design. Equations for responses (temp, discharge) are formulated using general regression in Minitab. Finally experimental response data is analyzed using goal programming and optimum parameters levels have been identified. It is observed that among the reflective materials glass mirror is the best reflector and black enamel paint coated copper tube is the best absorber both are play vital role.

To achieve higher temperatures it can be extended with the following steps in the present setup. (a) By using different combination of coatings on the absorber tube, (b) Use of higher reflectivity materials, (c) Coating on absorber tube by electro deposition.

REFERENCES

- [1] P. Sairam, P. Mohan Reddy and P. Venkataramaiah (2012): Optimization of a solar parabolic in winter using Grey-Taguchi approach: International Journal of Engineering Research and Applications (IJERA). ISSN: 2248-9622, Vol.2, Issue 1, Jan-Feb 2012, PP. 816-824
- [2] Delfin Silio Salcines, Carlos Renedo Estebanez (2009): Simulation of solar domestic water heating system, with different collector efficiencies and different volume storage tanks.
- [3] Fernandez-Garcia, E.Zarza (2010) "Parabolic solar through collectors and their applications" Elsevier journal of Renewable energy, Vol.14, pp.1695-1721
- [4] G. Rajyalakshmi and P. Venkataramaiah (2013) "Optimization of Process Parameters of Wire Electrical Discharge Machining Using Fuzzy logic Integrated with Taguchi Method "International Journal of Scientific Engineering and Technology Volume No.2, Issue No.6, pp. 600-606
- [5] H.P Garg and J Prakash: Solar Energy Fundamentals and Applications
- [6] John. A. Duffie: Solar Engineering of Thermal Processes
- [7] Kai XU et al.(2004): Multi response systems optimization using a goal attainment approach,IIE Transactions 36, 433-445.