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APPLICATION OF TAGUCHI METHOD TO OPTIMIZE THE HYBRID PHOTO- VOLTAIC/THERMAL SYSTEM DEVELOPMENT

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ABSTRACT

In This study, designed and developed a photovoltaic/thermal (PV/T) system, which produce electricity and heat (hot water) simultaneously. All Experiments are conducted inside room to check the influence of the temperature of the PV cell on the PV conversion efficiency. If the open circuit voltage of photovoltaic cell is reduced then conversion efficiency of the cell can be reduced at higher working temperatures. effect of these on the photovoltaic cell as extended payback period of the photovoltaic cell and shorten the life of photovoltaic cell. In order to prevent from these problem we need to dispatched more heat form the photovoltaic cell with the help of effective cooling methods. In this paper we study and design experimental model to experiment and development of combined photovoltaic/thermal (PV/T) model that incorporates phase change material (PCM). For increasing the performance and efficiency of photovoltaic cell we need to decreases the temperature of the photovoltaic cell. Efficiency of the photovoltaic cell is related to the temperature of photovoltaic cell, there is linear change between Efficiency of the photovoltaic cell and temperature.

The research methodology is focused on the analysis of select optimum material to get highest efficiency of hybrid PVT panel. Experiment was designed using Taguchi method and 16 experiments were designed by this process and experiment conducted. The result is analyzed using analysis of variance (ANOVA) method.

The processing parameters of the PVT panel based on the orthogonal arrays. Processing parameters of a PVT panel are the key factors affecting its performance. These parameters include the endothermic plate material, collector tube material, collector tube diameter, number of collector tubes, thickness of the bottom heat insulating material, absorption film type, and PCM (phase change material). The quality characteristics include the efficiency coefficient.

Key words: solar energy, corrugated poly carbonate sheet, phase change material, Taguchi method, grey relational analysis

I. INTRODUCTION

RESEARCH OBJECTIVE

1.In this project an Experimental model is proposed for generic combined photovoltaic/thermal (PVT) system that used phase change material (PCM).
2. A corrugated polycarbonate (CPC) sheet is used as a solar heat collector with attaching encapsulated in EVA mono-crystalline silicon solar cells on the top of it to get Simultaneous electricity and heat from this hybrid PVT system.
3. panel is filled by water and phase change material (PCM) in alternate channel
4. Taguchi method is designed the processing parameters of the hybrid PVT system based on the orthogonal arrays. Processing parameters of a hybrid PVT system are the key factors affecting its performance.
5. These parameters include the collector tube material, thickness of the bottom heat insulating material endothermic plate material, , collector tube diameter, absorption film type, number of collector tubes and & PCM.

II. EXPERIMENTAL PROCEDURES

Firstly a CPC sheet is taken in which 8 intricate passes in it. Both end side passes with insulating material. After that alternate passes filled with suitable PCM and remain passes for water circulation. After filling PCM the opening tightly closed with EVA rubber and acrylic sheet pieces with a strong adhesive. Such as araldite or bondite. For footer and header a fiber door side casing (beading) were used. Side casing cut in desire size and make hole in it with desire dimension. then fixed by strong adhesive. One end of both casing which called here footer and header are packed with acrylic chip and EVA rubber with strong adhesive and other remain open for water circulating. Black mate painting done over the CPC sheet with spray or brush. Insulating material thermocol pasted on its one side and other side EVA encapsulated silicon solar cell pasted. According to this project there are seven factors and two levels of the so called seven factors. Taguchi orthogonal array applied here for factors and levels so there are possibilities of 16 models arrangement. This is made by above described method. We make 16 models with requirement of desired material. Here we discussed two type of hybrid photovoltaic thermal system.

1. Made by assembling of CPC sheet with EVA encapsulated solar cell with PCM filling
2. Commercial PV panel to be combined with PCM and pipe at back

III. METHODOLOGY/STATISTICAL TOOL

Taguchi method

Dr Genichi Taguchi **(**Japan) has developed this statistical methods for improving the quality of manufactured products, then this method is also used in other fields, such as engineering, biotechnology, marketing and advertising etc. now modern statisticians accept Taguchi's statistical approach in design development study with variation. By use of Taguchi method, Plane set of experiments. Orthogonal arrays are used to conduct these experiments. In which all the parameters are taken over a specified range, ought to given desired results with minimum experiments. Results of these experiment data can be analyze based on SN ratio. For flat plate collector the efficiency coefficient is taken as important design property. So that quality characteristics of the efficiency coefficient factor are respectively the-larger-the-better which are defined as follows.

$$SN = -10\log_{10}\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{y_i^2}\right)$$

(1)

Where y_i is a quality measurement;

After experimental planning, conducted experiment to obtain the test data generated by the combination of various orthogonal parameters and graph is plotted. Firstly, by the use of experimental data calculated the SN ratio, and the calculation method depends on the requested quality characteristics. The average response value $\bar{f}i$ of various levels of factor is calculated, and then the value of Δf (main effect) of various levels of factor is calculated. These data are plotted into a graph for the effect analysis of all factors. Higher the value of Δf (main effect) of a factor, greater the influence of the factor on the system, as compared to other factors. On the contrary, if the value of Δf (main effect) of a factor is less than that of other factors, its quality improvement effect is not significant. The calculations is expressed as below.

$$\bar{f\iota} = \frac{1}{m}\sum_{j=1}^{m}\eta_{ij}$$

(2)

$$\Delta f = max(\bar{f_1}, \bar{f_2}, \ldots.. \bar{f_d},) - min(\bar{f_1}, \bar{f_2}, \ldots\ldots.. \bar{f_d},)$$

(3)

where

$\bar{f_1}$ = the mean SN ratio for the i[th] level of factor f,

m = the number of the i[th] level of each factor

η_j = the j[th] SN ratio of the i[th] level

d = the number of the level of each factor.

ANOVA (Analysis of variance)

ANOVA is statistical technique which is used to analyze the difference between experimental data and test procedure. There is unable to design main structure of flat plate collector through SN ratio, which is obtain through the Taguchi experiments with various quality factors. The ANOVA estimate the experimental errors and test of significance to understand the effect of various factors. The ANOVA method and equation are as follows.

Orthogonal arrays

Orthogonal arrays is a mathematical, systematic software testing method. it is used when the number of input parameter are less as compare to required for testing. Orthogonal arrays is allows testing the result with small input for give exhaustive output.

In the analysis of the flat-plate collector, mathematical model is developed for study the relationship between required values to the obtain values, which are taken after experiments. Orthogonal arrays Primarily analyze the difference between the required values to the obtain values of flat plate collector then base of this Result Orthogonal arrays are set to mathematical equation to the study of the effect of various controlling factor to analyze

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the quality characteristic of flat plate collector.
If two levels and 7 factors, then orthogonal array is

L8(2**7)
L16(2**7)
L32(2**7)

So, choose any one of them for the good efficiency. So select the L16(2**7).

GRA (Grey relational analysis)

GRA (Grey relational analysis) method is used to measure the relationship of similarity rate between the chosen factors for experiments. Its show the relationship between various factors based on the similarity rate and difference rate of the various factors. GRA is a method, which is explain as the analysis based on small given data but gives multiple test result.
The following given steps are follows for GRA (Grey relational analysis).

IV. CALCULATION

Table 1.
Controlling factors of the flat plate collectors and their levels

Controlling factor	Level value	
	1	2
A. Collector tube material	(A_1) CPC Tube	(A_1) polymer tube
B. Endothermic plate material	(B_1) Corrugated Polycarbonate	(B_2) Hybrid acrilyc
C. Number of collector tubes(piece)	(C_1) 3	(C_2) 4
D. Collector tube cross-section	(D_1) 30cm^2	(D_2)1.27cm^2
E. Absorption film type	(E_1) Spray Painting	(E_1) Brush Painting
F. Thickness of the bottom heat Insulating material	(F_1) 10mm	(F_2) 12mm
G. Phase change material	(G_1) 46	(G_2) 35

Table 2.
Interference factor of the hybrid PVT system

Interference factor	Level value		
	1.	2.	3.
P Illumination intensity	(p) 500	700	900
Q Temperature (℃)	(q) 15	20	25

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Table 3.
Allocation table of experimental factors of the hybrid PVT system collector

P	1	1	1	2	2	2	3	3	3
Q	1	2	3	1	2	3	1	2	3
	1	2	3	4	5	6	7	8	9

s No.	A	B	C	D	E	F	G
1	1	1	1	1	1	1	1
2	1	1	1	2	1	2	2
3	1	1	2	1	2	1	2
4	1	1	2	2	2	2	1
5	1	2	1	1	2	2	1
6	1	2	1	2	2	1	2
7	1	2	2	1	1	2	2
8	1	2	2	2	1	1	1
9	2	1	1	1	2	2	2
10	2	1	1	2	2	1	1
11	2	1	2	1	1	2	1
12	2	1	2	2	1	1	2
13	2	2	1	1	1	1	2
14	2	2	1	2	1	2	1
15	2	2	2	1	2	1	1
16	2	2	2	2	2	2	2

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TEST RESULT OF THE EFFICIENCY COEFFICIENT

S.N.	1	2	3	4	5	6	7	8	9	Average	S/N Ratio
1	0.690262	0.70798	0.728551	0.717487	0.7289	0.726733	0.687016	0.705958	0.712929	0.711757	-2.95902
2	0.712493	0.729466	0.749805	0.716763	0.724312	0.740862	0.59862	0.662868	0.680541	0.701748	-3.13586
3	0.711687	0.728642	0.731369	0.612193	0.634608	0.653315	0.556528	0.571827	0.604704	0.644986	-3.92955
4	0.709478	0.726495	0.739958	0.663804	0.677185	0.698928	0.617479	0.627102	0.632179	0.676957	-3.44013
5	0.709256	0.723925	0.734592	0.650669	0.667879	0.695804	0.555665	0.596094	0.635731	0.663291	-3.66855
6	0.708876	0.72196	0.74512	0.61048	0.61868	0.626317	0.555455	0.581439	0.622255	0.643398	-3.94773
7	0.706274	0.729623	0.732999	0.6349	0.651781	0.666952	0.553486	0.58712	0.597423	0.651173	-3.84099
8	0.708122	0.732237	0.740811	0.608017	0.626776	0.636949	0.513292	0.54785	0.557912	0.630218	-4.21181
9	0.665039	0.697142	0.731172	0.583738	0.605398	0.638501	0.560537	0.618841	0.632333	0.636967	-3.99866
10	0.667732	0.70037	0.731643	0.585349	0.607045	0.638528	0.582151	0.601405	0.638501	0.639191	-3.96063
11	0.666806	0.703915	0.746488	0.666484	0.692895	0.714042	0.568644	0.624003	0.682182	0.67394	-3.50395
12	0.662596	0.693062	0.739142	0.584052	0.598422	0.625818	0.565211	0.604747	0.633453	0.634056	-4.0415
13	0.73879	0.837542	0.810475	0.527459	0.594811	0.800558	0.41036	0.462677	0.611123	0.643755	-4.61541
14	0.661361	0.683689	0.693441	0.690338	0.715276	0.715812	0.579321	0.618507	0.638658	0.666267	-3.58677
15	0.70055	0.722821	0.733995	0.683862	0.704069	0.745929	0.559073	0.568901	0.611123	0.670036	-3.623
16	0.737842	0.748698	0.769921	0.717653	0.742591	0.743126	0.558077	0.576018	0.617413	0.690149	-3.40701

TAGUCHI ANALYSIS

Taguchi Analysis: C8, C9, C10, C11, C12, C13, ... versus A, B, C, D, E, F, ...

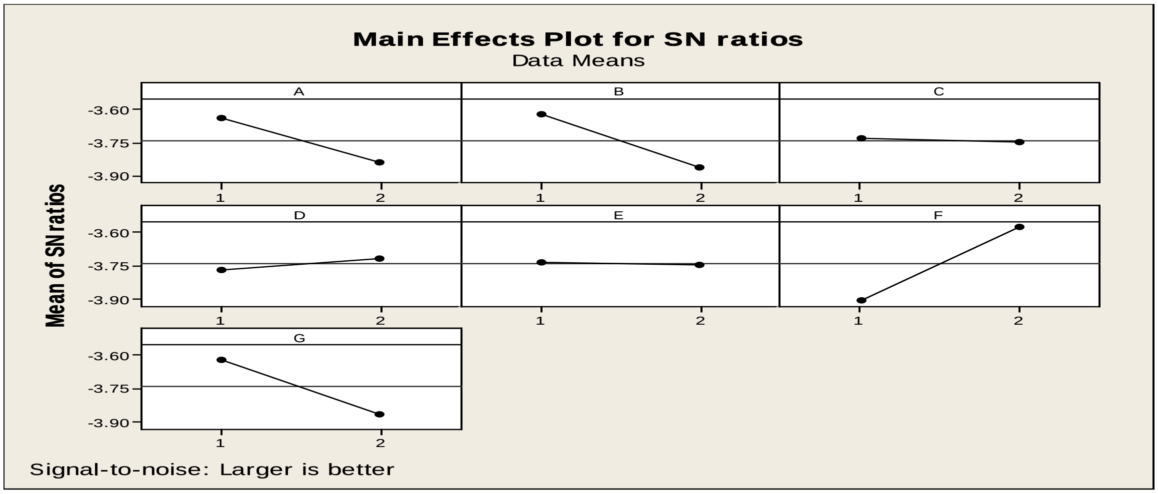

Figure5.1 Response graph of S/N ratio

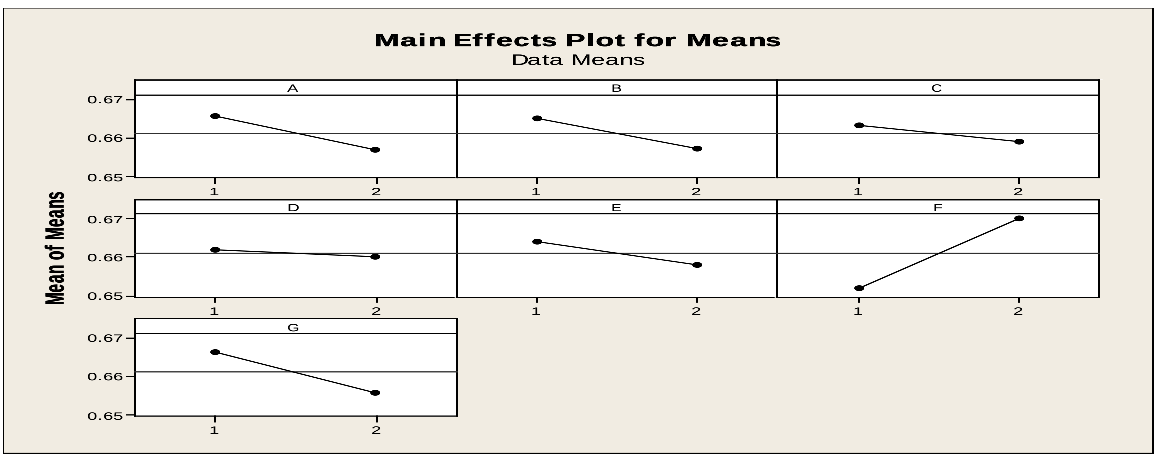

Figure5.2 Response graph of means

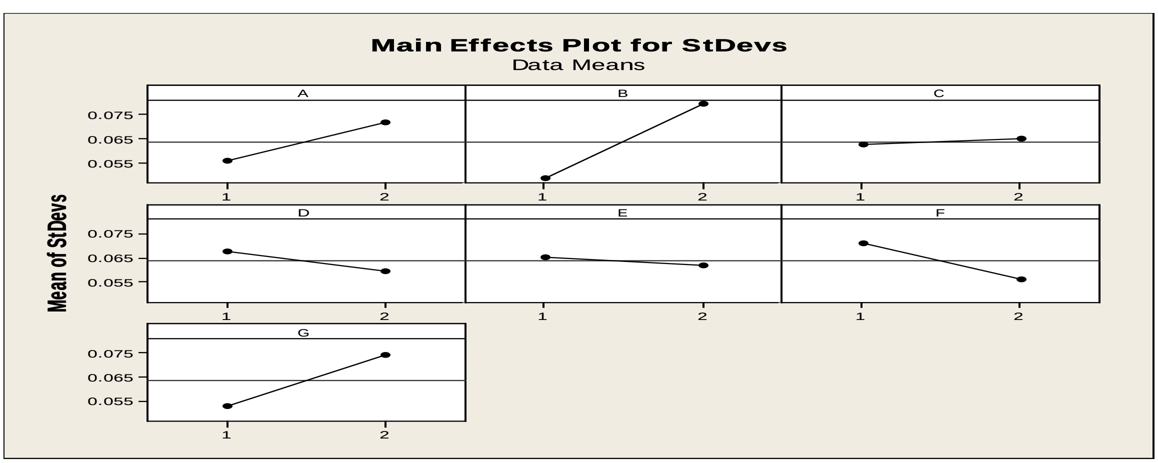

Figure5.3 Response graph of std deviation

V. RESULT

This paper discussed the relationship between the design processing parameters and quality characteristics of flat-plate collectors, in order to determine the optimized combination of processing parameters. First, based on the Taguchi method the composition of various controlling factors, level values and interference factors are designed, as shown in Tables 1 and 2. There are two quality characteristics of Flat-plate collectors are heat dissipation factor and efficiency coefficient. As a flat-plate collector requires a lower heat dissipation factor and a higher efficiency coefficient, this thesis selected the heat dissipation factor as the-smaller-the-better the and efficiency coefficient as the-larger-the-better. Based on the required quality characteristics, the level values of controlling factors and interference factors are respectively applied to orthogonal array L16(2**7) as the planning form of the experiment, as shown in Table 3. The performance of the flat-plate collector is calculated based on the MINITAB software, Followed by 16 groups of experiments, the data of each quality characteristic are collected, and the data of a total 144 experiments are obtained. The SN ratio for each group in the experiments is calculated based on the experimental data.

VI. CONCLUSION

The experimental data of the efficiency coefficient of the hybrid PVT system are shown in Table 4. Based on the SN ratios obtained through the experiments, the main effects of each control factor can be calculated, and its response graph can be plotted, as shown in Fig. 1. The calculation of the main effects of each controlling factor aims at analyzing the influence of each factor at different levels on the SN ratios of quality characteristics; hence, the total influencing effect of each level of each controlling factor on the efficiency coefficient needs to be calculated. The factor response graph shows that the optimal factor levels are selected as A1, B1, C1, D2, E1, F2, andG1. The collector tube is made of CPC material, the endothermic plate is made of polycarbonate, the number of collector tubes is 3, the collector tube diameter is 1.27cm^{2,} the absorption film type is Mat black spray painting, the thickness of the bottom heat insulating material is 12 mm and PCM is 46. As shown in the response graph, the controlling factor F has the maximum influence on the efficiency coefficient, followed by B, G, A, D, C and E in sequence.

Future scope

- Evaluate overall efficiency with measuring electrical efficiency.
- This PVT system can be used in dome, parking shed & hybrid roofing.
- Heat dissipation & confirmatory test will be measure.
- Level & factor of the test will be increased.
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REFERENCES

[1]Y. Tripanagnostopoulos, M. Souliotis, R. Battisti, A. Corrado "APPLICATION ASPECTS OF HYBRID PV/T SOLAR SYSTEMS taguchi

[2] Farahat S, Sarhaddi F, Ajam H. Exergetic optimization of flat plate solar collectors. Renew Energy 2009;34:1169e74.

[3] Chen CB, Lin CT, Chang CW, Ho CP. Grey relation for solving multi-quality characteristics problems of Taguchi methods. J Technol 2000;15:25e33.

[4] Kuo CFJ, Su TL. Optimization of multiple quality characteristics for polyether ether ketone injection molding process. Fiber Polym 2006;7:404e13.

[5] Kuo CFJ, Su TL. Gray relational analysis for recognizing fabric defects. Text Res J 2003;73:461e5.

[6] ISO 9806-1. Test methods for solar collectors e part 1: thermal performance of glazed liquid heating collectors including pressure drop. ISO; 1994. Fig. 7. Schematic diagram of performance test equipment for the flat-plate collector pcm.

[7] Sharma, Atul; Tyagi, V.V.; Chen, C.R.; Buddhi, D. (2009). "Review on thermal energy storage with phase change materials and applications". Renewable and Sustainable Energy Reviews 13 (2): 318–345. DOI:10.1016/j.rser.2007.10.005.

[8]. Mettawee, E.-B.S. and G.M.R. Assassa, Experimental study of a compact PCM solar collector. Energy, 2006. **31**(14): p. 2958-2968).