Optimize the Solar Water Flat Plate Collector by the application of Taguchi Method and Grey Relational Analysis

[1]NARESH KUMAR SAFI, [2]DR. MANISH GANGIL

M.Tech.Scholar[1], *Professor*[2]

Department of Mechanical Engineering, RKDF, University Bhopal, (M.P.) India.

[1]naresh.kr5556@gmail.com, [2]rkdfbhojpal@gmail.com,

Abstract

Solar Energy is form of renewable energy. It is widely available all over the world. India is tropical country located between tropics, it has huge amount of direct solar energy. In this study we used this solar energy to useful application in solar photo-voltaic water heating with some modification in solar water heater by the used of phase change material. Now a day's solar energy is widely used for water heating application. In our study we trying to design and modify the present water heating system and make it more effective, efficient and reliable economic application in particularly all whether condition.

This study present the modify design of flat plate solar collector with optimum processing parameters based on orthogonal array. Selecting those process parameters which are affecting the performance of flat plate collector key optimum process parameters are like – copper plate material, collector tube material (polymer), bottom insulating material thickness, Number of collector tubes, diameter of collector tubes and iron tubes with phase changer material (PCM). The quality characteristics as chosen like efficiency coefficient on the basis of data obtained from main effect analysis, orthogonal arrays and ANOVA analysis. Then this obtain data is optimized by grey relation analysis and determining the optimum combination of processing parameter levels.

Key wards:- Solar Water Flat Plate Collector, Taguchi Method; Grey Relational Analysis; ANOVA..

Introduction

Solar energy development is main concern of present research. Solar energy industries mainly focus on development of efficient, effective and economic "passive" solar system. Many researcher are trying to develop and modify various solar system which is presently used for this purpose are like flat plate solar collector, solar heating system etc.

Solar energy is used for heating and cooking is older technology. That time solar is directly used for making food ad heating water as for as technology is developing day by day, the usability of solar energy is improve and developing new technology for cultivation of this renewable energy.

Today solar energy is one of the most important sources of energy after thermal energy, many country which is present in tropical belt are now mainly used this energy.

India has very waste source of solar energy because India has some geographical advantages India's location is made it highly reach source country of solar energy. India's total energy consumption is fulfil by two major source are is thermal and second is solar energy. So that it is very important for India to developed new and advance technology which helps to cultivate more and more solar energy for this purpose over study is one of the important research for development and modify the flat plate solar collector with used of PCM.

1.2 Design Procedure

Design of flat plate collector and manufacturing this collector with selected optimum process parameters like polymer tubes, iron tubes, iron box, copper sheet collector, insulating material, sealing glass cover and PCM.

Firstly we making water tank and collector tank is made by iron sheet metal shop and collector is also make with iron sheet in some sheet metal shape of workshop tank and collector is now arrange as the water is flow smoothly from tank to collector and collector to outlet device.

Secondly we prepare flat plate collector as our requirement so that making collector with PCM with water tank. PCM is filled in collector tubes and then it make insulted by the use of suitable insulating material for preventing the heat losses.

1.4 Fabrication of Flat Plate Collector

Firstly we collect all essential required material from market like iron sheet, polymer sheet, adhesive material, silver foil, point and toils then in sheet metal shope we can fabricate from box as per our required size and shape then make sufficient layer of coated primer and make sure the proper priming over box for giving highly surface finish of the box.

Fig.1 Fabrication of Iron box

Secondly we insulate the box by the used of insulating adhesive and make layer of thermacoll sheet over it for preventing the heat loss from the box for make perfect reflection of solar radiation from the box we used silver foil and pasted it over the all side of box above thermacoll sheet this silver foil make our box perfect for solar absorption and fabrication of iron box is done we check this box as it does not have any hole and it make defect free.

Fig: 2 Fabrication of Iron box with insulation

2. ANOVA (Analysis of Variance)

ANOVA is a statistical method of collecting data of statistic models. ANOVA is also collecting data of all procedures of method. In ANOVA, variable is collected and divided these variables in different-different variance of statistical models. In ANOVA analysis, it provided the statistical model of each variance in different level of variables. It does not provide the overall variable value of variance. ANOVA is method to analysis of each variance in more than two levels of variables. For evaluating the quality characteristic of flat plate solar collector, we can generate S-N ratio on the basis of Taguchi analysis. But the impact of each variable on the chosen quality characteristic of flat plate solar

collector is not given the optimum solution. S-N ratio is also not given the value of main structure of collector which affects the performance of characteristic of flat plate solar collector. So that we need another statistical model which give the main structural value of characteristic of flat plate solar collector. For this evaluation ANOVA method is used. ANOVA method is also evaluating the signification effects of various process parameter of flat plate solar collector and also evaluates the error in experiments. The following procedure is used in ANOVA method as follows:

2.1 N (Degree of freedom)

Number of possible movability of system is called degree of freedom. It can be calculated by subtracting 1 from total constraint value.

For each factor

n = DOF of each factor level – 1

For Total factor

n = DOF of total experiment – 1

Error in DOF

ne = Total DOF – sum of DOF of each factor

2.2 CF (Correction factor)

$$CF = \frac{\left(\sum_{j=1}^{n} \eta_j\right)^2}{n} \qquad (1)$$

Where:

η = the experimental observations of S-N ratio.

n = the number of the experiments.

2.3 SS (sum of square)

$$SS = \frac{\sum_{i=1}^{n/m}\left(\sum_{j}^{m} \eta_{ij}\right)}{m} - CF \qquad (2)$$

Where:

m = the number of each level of the factor

2.4 TSS (total sum of square)

$$TSS = \sum_{j=1}^{n}(\eta_j)^2 - CF \qquad (3)$$

2.5 SSe (error sum of square)

$$SSe = TSS - \sum_{k=1}^{p} SS_p \qquad (4)$$

SSe = zero

When there is no error term and there is no DOF for error. Where: p = the number of the factor.

2.6 V (variance)

Variance is define as the ratio of error sum of square to the DOF

$$V = \frac{SS}{v} \qquad (5)$$

2.7 Ve (error mean sum of square)

$$Ve = \frac{SSe}{ve} \qquad (6)$$

2.8 F (F-ratio)

$$F = \frac{V}{Ve} \qquad (7)$$

S.no.	M	c_{pf}	T_{outlet}	T_{inlet}	Q_u	$A_c \times I(t)$	n_{ff1}
1	0.287	4.2	66.781	30	44.336	61.856	0.716
2	0.287	4.2	75.515	32	52.453	61.856	0.846
3	0.287	4.2	82.529	40	51.264	61.856	0.823
4	0.287	4.2	71.873	30	49.269	62.875	0.785
5	0.287	4.2	83.386	32	51.462	62.875	0.813
6	0.287	4.2	90.053	48	53.481	62.875	0.801
7	0.287	4.2	75.933	30	51.231	68.130	0.812
8	0.287	4.2	82.289	32	52.264	68.130	0.812
9	0.287	4.2	95.099	48	52.501	68.130	0.821

Table: 1 Calculation of Experimental data

3. Calculation

Amount of energy for collector is calculated as

$$Qu = mC_{pf}(T_{fo} - T_{fI}) \qquad (7)$$

Where:

m = flow rate of the water through the collector

C_{pf} = specific heat of the water (4.2 kJ/kg specific heat of water)

T_{fo} = the outlet water temperature

T_{fI} = inlet water temperature

Collector instantaneous efficiency coefficient as follows:

$$neff = \frac{Qu}{A_c I(t)} \qquad (8)$$

Where:

A_c = collector area

$I(t)$ = Illumination intensity of the collector (W/m^2)

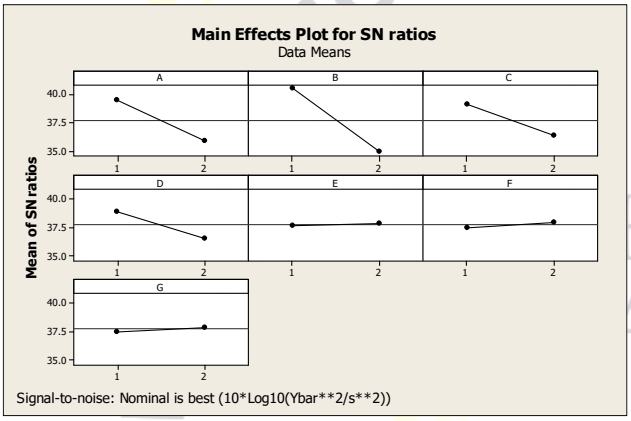

Fig. 1 Response graph for efficiency coefficient

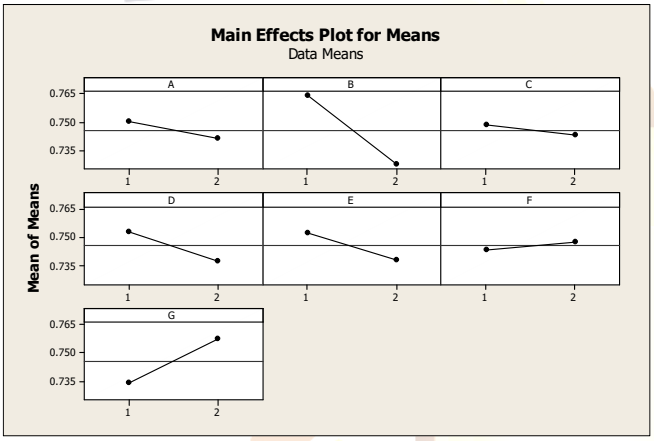

Fig. 2 Response graph for main effects of means

4. Results & Discussions

This study is mainly concern with analysis of process parameters, which affects the performance of flat plate solar collector most. According to the selected parameters effect we can modify and redesign the collector with some our recommended modification like using PCM material with iron tubes this help to improving the quality characteristic and efficiency of flat plate collector while reducing the heat losses. In our study we are mainly focus on determine the relation between quality characteristic and chosen design processing parameters of flat plate collector and find their effect over performance of solar collector. To optimization of the performance of flat plate collector and develop optimum combination of quality characteristic and process parameters we can conduct practical experiments on installed setup with different interference factors, controlling factors and level values of collector based on Taguchi method. In this study we can chosen quality characteristic i.e. efficiency coefficient is larger-the batter because efficiency coefficients factor of flat plate collector is always required higher.

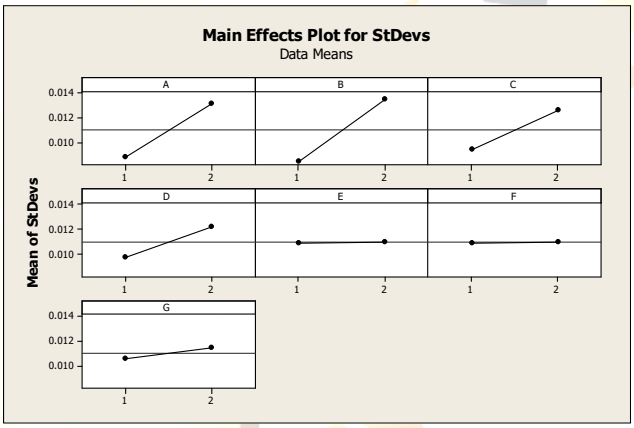

Fig. 3 Response graph for main effects of StDevs

Conclusion

This study is analyzing the process parameters of flat plate solar collector and gives optimum solution of design development and improves the performance of flat plate collector. For improving performance and increasing efficiency of collector

we can fabricated the practical experimental setup and conducted all experiments over it. By the used of Taguchi analysis we can plane the experiment and their procedure. Taguchi is also help to minimizing the number of experiments and cost of experiment. so that by the used of Taguchi we can save our time and cost also but there is some disadvantages of using Taguchi method in experiment that is it does not applicable where the multiple data or process parameters is used for experiments. This problem is solved by the used of grey rotation analysis. By the used of grey rotation we can optimize the perfect set of combination of process parameters based the main effect analysis. This selected combination of process parameters is based on calculation of multiple quality parameter and factor level parameters of flat plate solar collector.

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