Thermal Analysis of Solar Parabolic Collector Using Goal Programming

[1]N. Manikantachari, [2]S. Bhaskar
[1](Assistant Professor) Department of Mechanical Engineering,MJR College of Engineering & Technology ,Piler,A.P,India.
[2] (Assistant Professor) Department of Mechanical Engineering,Siddartha Educational Academy Group of Institutions, C.Gollapalle,Tirupathi,A.P,India.
Email: nagavetimani99@gmail.com , BHASKAR.197@gmail.com

Abstract:- Energy is the key input to drive and improve the life cycle. Primarily, it is the gift of the nature to the mankind in various forms. Solar thermal systems play an important role in providing non-polluting energy for domestic and industrial applications. Concentrating solar technologies, such as, parabolic trough collectors are used to supply industrial process heat, off-grid electricity and bulk electrical power. In a Solar ParabolicCollector, the reflective surface focuses sunlight on aa heat collecting element (absorber tube) through which fluid is flows. The fluid captures solar energy in the form of heat that can be used in a variety of applications.In this system the main parts are reflecting surfaces and absorber tube. These arevery important for optimum performance of collector.

In the present work the behavior of linear solar parabolic Collector for cooking system is studied and analyzed using a Mathematical model. This model has been simulated with MATLAB program. An experimental design is prepared based on the considered parabolic collector parameters: Absorptivity, Reflectivity and Period of Sun Incidence. The Absorber tube is considered at four levels and the reflective surface is considered at two levels, one is Glass mirror and other is polished aluminum. The experiments are conducted according to the Taguchi design on the solar parabolic collector. During experiments, outlet temperature of water and discharge are recorded for each experimental run. This data is analyzed using Goal Programming and optimal parameter combination has been identified.

*****

I. INTRODUCTION

Solar Thermal systems

Solar thermal systems play an important role in providing non-polluting energy for domestic and industrial applications. 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. Key components of a PTSC include the collector structure, the receiver or HCE, the drive system and the fluid circulation system, which delivers thermal energy to its point of use.

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 programme, it can be thought of as an extension or generalization of linear programming to handle multiple, normally conflicting objective measures.

Goal programming is used to perform three types of analysis:

i. Determine the required resources to achieve a desired set of objectives.
ii. Determine the degree of attainment of the goals with the available resources.
iii. Providing the best satisfying solution under a varying amount of resources and priorities of the goals.

Example: The GP formulation for the problem is:

Minimize: $Z = d_1^- + d_2^- + d_3^-$

Subjected to:

$$x_1 + x_2 + d_1^+ - d_1^- = n_1$$
$$x_1 + d_2^+ - d_2^- = n_2$$
$$x_2 + d_3^+ - d_3^- = n_3$$
$$x_1, x_2, d_1^+, d_1^-, d_2^+, d_2^-, d_3^+, d_3^- \geq 0$$

II.THERMAL ANALYSIS

Useful Thermal energy:

The useful thermal energy $Q_u(t)$ by a solar collector can be expressed mathematically as

Useful energy collected= Energy Absorbed-Convective losses-Radiation losses

$$Q_u(t) = A_c F_R[I_t(\tau\alpha) - (T_{fi}-T_a)]$$

Collector performance or Conversion efficiency is the ratio of useful energy collected $Q_u(t)$ to the available incident energy $(I_t A_C)$

$$\eta_c = \frac{Q_u(t)}{I_t A_C}$$

We know that,

$$Q_u(t) = m_s C_{ps}(T_{fo} - T_{fi})$$

Exit Temperature: Equating the heat gained by the fluid to the useful heat gain rate, we get

$$\boldsymbol{T_{fo} = \frac{Q_u(t)}{m_s C_{ps}} + T_{fi}}$$

Thermal (Conversion) efficiency: The thermal efficiency of a parabolic trough concentrator is expressed as

$$\eta_{th} = \eta_o - \frac{U_L(T_{abs} - T_a)}{I_b\, C}$$

Discharge: The discharge of solar absorber tube is expressed as

$$Q = CA\sqrt{2gH}$$

III.EXPERIMENTAL WORK

Description of the experimental setup

The experimental setup consists of the following components.

a) Parabolic Shaped Structure
b) Supporting legs
c) Reflective Surfaces
d) Heat collecting element(Absorber)
e) Auto Tracking System
f) Data acquisition and Instrumentation
g) Piping system and Storage tank

Working Principle

All the components are assembled on the top of the building as shown in the figure. The equipment is placed in N-S direction, such that the front view of the setup faces east. When ball valve in opened, Water enters into the absorber tube through the flexible hose. The absorber which is placed at the focal point of the parabolic trough is heated by direct radiation as well as reflected radiation from the reflective surface. 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. This is repeated for several cycles and after some time the water in the Storage tank. The hot water is collected at the top of the tank. An solar Auto tracking system operated by 12 V DC battery is used to utilize the maximum radiation

Data considered for Numerical simulation

Feature/Parameters	Value
Aperture area (A_C)	1-20 m^2
Receiver area (A_R)	0.424 m^2
Transmittance (τ)	0.95
Absorptance (α)	0.95
Absorber tube dia (D_o)	0.011-0.11 m
Absorber tube dia (D_i)	0.01-0.1m
Ambient Temperature (T_a)	305° K
Inlet temperature (T_i)	313-343° K
Thermal conductivity of copper (k)	390 W/m^2
Mass flow rate (m_w)	0.5 kg/s
Specific heat of water(C_{pw})	4184 J/Kg
Specific heat of steam (C_{ps})	2093 J/kg
Heat transfer coefficient (h_{cf})	1500 W/m^2
Overall heat transfer coefficient(U_L)	75 W/m^2
Solar Insolation (I_t)	800-1500 W/m^2

Aperture area and Conversion efficiency

Figure shows the variation of Conversion efficiency with respect to Aperture area for different inlet temperatures. As the aperture area increases, the conversion efficiency is increased.

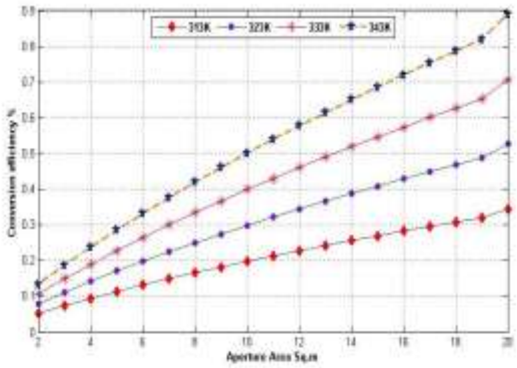


Fig.Effect of Aperture area on Conversion efficiency

Discharge and Optical efficiency

From the Figure it is inferred that the slope of curve is gradually increase with increase discharge and optical efficiency also increase. The optimal point getting by slope calculation.

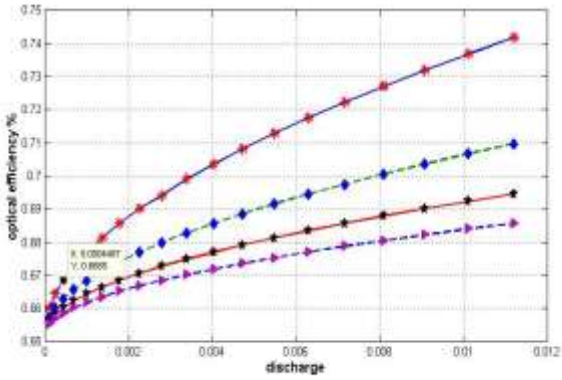


fig.Effect of discharge on optical efficiency

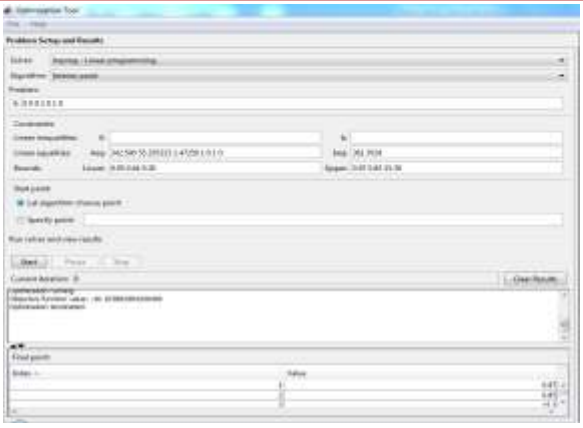
Numerical simulation results

Criteria	Results
Aperture area	4 m^2
Width of the parabolic trough	1.5m
Depth of the parabolic trough	0.5m
Length of the trough	2m
Absorber tube Diameter	0.02m
Concentration Ratio	20-25

Optimization of parameters

Before applying optimization toolbox the present problem has been converted into suitable mathematical form using the following steps.

i. Get an overall idea of the problem
ii. Identify the goal (maximizing or minimizing something)
iii. Identify (name) variables
iv. Identify constraints
v. Determine which variables you can control
vi. Specify all quantities in mathematical notation
vii. Check the model for completeness and correctness



Goal programming linear constraint optimization

IV.CONCLUSIONS AND SCOPE FOR FUTURE WORK

In the present work the experimental setup of solar parabolic trough has been fabricated based on the simulation result. The controllable parameters such as Reflective materials, Absorber materials, Period of sun incidence which influence the responses (Temperature and discharge) are considered and the experiment are conducted according to Taguchi experimental design.

Finally experimental response data is analyzed using goal programming and optimum parameter levels have been identified. It is observed that among the reflective materials glass mirror is the best reflector and copper tube is the best absorber.

Scope for Future Work

This work may be extended to achieve higher temperatures with the following updations in the setup.

- Use of Composite material in the place of copper tube (Absorber material)
- Increase the reflectivity range by using other materials
- Use of sensors for auto tracking

REFERENCES

[1] P. Sairam , P. Mohan Reddy and P. Venkataramaiah (2012):Opimization 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, pp816-824

[2] ShirishGarud (2006)- Making solar thermal power generation in india a reality- Overview of technologies, opportunities and challenges

[3] A. Kahrobaian and H. Malekmohammadi (2008): Energy optimization Applied to Linear Parabolic Solar collectors. Journal of faculty of engineering. Vol.42.No.1 2008 PP-131-144

[4] U.K Sinha and S.P Sharma (2008): Modeling The Parabolic Collector for Solar Thermal Electric power: ARISER Vpol.4 (2008) 205-211

[5] Socrates Kaplanis and George Barakos: (2002) Flat Plate and Concentrating collectors: A comparision of their performances: Transilvania University of Brasov

[6] S Faraht, F.Sarhaddi (2009): Exergetic Optimization of flat plate solar collectors: Renewable energy 34 (2009) 1169-1174

[7] DelfinSilioSalcines, Carlos RenedoEstebanez (2009): Simulation of solar domestic water heating system, with different collector efficiencies and different volume storage tanks.

[8] R. karthikeya (2001): Optimization of electrical discharge machining characteristics of SiCp/LM25 Al composites Using Goal programming, J.Mater.sci. Technol.,Vol.17 suppl.1.2011.

[9] Aneirson Francisco and dasilva(2013):Multi-choice mixed integer goal programming optimizationfor real problems in a sugar and ethanol milling company, Applied Mathematical Modelling 37(2013) 6146-6162.

[10] Kai XU et al.(2004): Multi response systems optimization using a goal attainment approach,IIE Transactions 36, 433-445.