

Design And Fabrication of Parabolic Trough Collector

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Abstract- The present study focuses on the design and performance evaluation of a parabolic trough solar collector (PTSC) with the aim of enhancing thermal efficiency. The analysis considers key geometric parameters such as aperture dimensions, concentration ratio, and absorber tube characteristics. A detailed analytical approach is adopted to estimate heat gain, thermal losses, and system efficiency under given operating conditions. The collector utilizes a copper absorber and aluminum reflector, making it suitable for medium-temperature applications in regions with high solar irradiance.

I. INTRODUCTION

Parabolic trough solar collectors are widely used in solar thermal systems due to their ability to concentrate direct solar radiation onto a linear receiver. These systems operate by reflecting incident radiation using a parabolic surface toward an absorber tube positioned at the focal line. The collected energy is transferred to a working fluid flowing through the absorber, which can then be utilized for heating or power generation purposes. Due to their relatively simple construction and effective performance, PTSCs are considered suitable for both industrial and domestic thermal applications.

II. PROBLEM DEFINITION

Despite the abundance of solar energy, its effective utilization remains limited due to inefficient collection methods. Conventional flat plate collectors often fail to achieve higher temperatures required for industrial processes. Therefore, there is a need to design a system capable of concentrating solar radiation to improve thermal output. The parabolic trough collector offers a feasible solution by focusing solar energy onto a smaller surface area, thereby increasing temperature and efficiency.

III. OBJECTIVES

- To design a functional parabolic trough solar collector using practical engineering parameters.
- To evaluate the influence of geometric parameters such as aperture width and concentration ratio.
- To analyze thermal performance based on heat gain and losses.
- To determine system efficiency under given environmental conditions.

IV. MATERIALS AND METHODS

Material selection plays a critical role in determining the performance of the collector. The absorber tube is made of copper due to its high thermal conductivity, which enhances heat transfer efficiency. The reflector surface is constructed using polished aluminum to ensure high reflectivity. Mild steel is used for the supporting frame due to its structural strength and availability. A glass cover is provided around the absorber to reduce convective heat losses and improve thermal retention.

V. DESIGN ANALYSIS

For analytical evaluation, the collector dimensions are selected as follows:

- Aperture width = 1.2 m
- Trough length = 2.4 m

The focal length is determined based on the rim angle, which defines the geometry of the parabolic reflector. The concentration ratio is calculated to assess the ability of the collector to focus solar radiation onto the absorber tube. These parameters play a crucial role in determining the thermal performance of the system.

VI. WORKING PRINCIPLE

The working principle of the parabolic trough collector is based on the reflection and concentration of solar radiation. Incident sunlight falling on the parabolic reflector is directed toward the absorber tube located at the focal line. As the working fluid flows through the absorber, it absorbs the concentrated heat energy, resulting in an increase in temperature. Proper alignment with the sun is maintained through manual or automatic tracking to ensure maximum energy absorption throughout the day.

VII. THERMAL CALCULATION

7.1 Aperture Area

$$A = a \times L = 1.2 \times 2.4 = 2.88 \text{ m}^2$$

7.2 Available Solar Energy

$$Q_{\text{available}} = A \times I_b = 2.88 \times 800 = 2304 \text{ W}$$

7.3 Useful Heat Gain

$$Q_u = \eta \times Q_{\text{available}} = 0.65 \times 2304 = 1497.6 \text{ W}$$

7.4 Temperature Rise

$$Q_u = m \times C_p \times (T_{\text{out}} - T_{\text{in}})$$

Substituting the values:

$$1497.6 = 0.01 \times 4184 \times (T_{\text{out}} - T_{\text{in}})$$

Therefore,

$$(T_{\text{out}} - T_{\text{in}}) = 35.8^\circ\text{C}$$

7.5 Efficiency

$$\eta = \frac{Q_u}{Q_a} = 65\%$$

7.6 Reynolds Number

$$Re = 34808 \text{ (Turbulent)}$$

7.7 Pressure Drop

$$(L/d) \cdot \left(\frac{\rho v^2}{2} \right) = 705 \text{ Pa}$$

VIII. RESULTS

The analysis indicates that the designed collector is capable of delivering efficient thermal performance under assumed operating conditions. The calculated values of heat gain and efficiency demonstrate the effectiveness of the system in concentrating solar energy.



Fig 1. Experimental Hardware Prototype developed at Nagpur.

IX. ADVANTAGES

- Economical due to use of locally available materials.
- Simple construction and maintenance.
- Environment-friendly and reduces fossil fuel usage.

X. CONCLUSION

The designed parabolic trough solar collector demonstrates effective utilization of solar energy through concentration techniques. The performance depends on geometric design and operating parameters. The system can be successfully implemented for medium-temperature applications in solar-rich regions.

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