“STUDY OF PARABOLIC TROUGH COLLECTOR FOR TAPPING SOLAR ENERGY”

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Introduction:
The solar energy has been the most favorite renewable energy source in the present times. It is noted for its high reliability than other systems and allows more energy generation than other renewable resources. But the overall capacity of solar systems is limited due to its space requirements and low efficiency particularly in flat plate tube and evacuated tube units. The lower heating capacity of fluid in flat plate and evacuated tube solar units limits the rise in temperature and reduces the thermal efficiency. This reduces its utilization in commercial areas reducing its reach as emerging potential market for tapping solar energy.

Z.D. Cheng et al. (2010) presented a paper an “Three-dimensional numerical study of heat transfer characteristics in the receiver tube of parabolic trough solar collector” In this paper, three-dimensional numerical simulation of coupled heat transfer characteristics in the receiver tube is performed by combining the MCRT Method and the FLUENT CFD software. Numerical results show that the predicted results agree well with the experimental data, the average relative error is within 2%. Najla El Gharbi et al.(2010) numerically compared two optical technologies which showed promising results, the first one is the Linear Fresnel mirror
and the second one is the parabolic trough. A methodological analysis to design and evaluate the technical feasibility for the use of Fresnel mirror or parabolic trough in a Concentrating Solar Power (CSP) system has been carried out. *Ricardo Vasquez Padilla et al. (2011)* performed a one-dimensional numerical heat transfer analysis of a PTC. The receiver and envelope were divided into several segments and mass and energy balance were applied in each segment. *P. Rhushi Prasad et al. (2012)* compared the performance of fixed flat plate water heater with that of heater with tracking by conducting experiments. A flat plate water heater, which is commercially available with a capacity of 100 litres/day is instrumented and developed into a test-rig to conduct the experimental work. Data is collected for both fixed and tracked conditions of the flat plate collector. The results show that there is an increase of about 21% in the percentage of efficiency.

A prototype of a module of parabolic trough collector is made based on ease of transportation, manufacturing and maintenance and usage. The performance of the parabolic trough collector is studied under various conditions and the data is analysed under various different absorber tube designs and flow rate of the fluid. The fluid used is water and a suitable computer model is used compare the design against the model and results are plotted.

**Objectives:**

To

- Study the thermal performance of the Parabolic Trough Collector under various absorber tube varieties (Acrylic tube covered, coating, annular tube, acrylic tube with graphite coating).
- Comparison of the actual Parabolic Trough Collector performance against CFD model.
- Comparison of the Parabolic Trough Collector under various flow rates (1.1 LPM, 0.7 LPM, 0.3 LPM)
- Improvements of the Parabolic Trough Collector performance with variants against bare standard Stainless Steel absorber tube.

**Methodology:**

Stages in the Project:

1. **Design and Construction:**
   - Material selection: Based on cost, precision needed, machining capability and ease of procurement, major construction was based on MS and Aluminum was used for
reflective surface for its cost and availability. Teflon was used for bearings. Also it was made sure that the prototype is comparable to industrial scale products and suits the requirements.

- Design constraints: Ease of machining, transportation, construction and manufacturing. Standard available sizes of material and average size of household rooftops and ease in tracking was also considered.

2. Installation and instrumentation:

- Installation was performed at Mechanical Department roof top of Dayananda Sagar College of Engineering. The site was selected based on the low wind speeds achieved due to other buildings available around it also these buildings did not hinder any sun light availability.
- The other auxiliary instruments used were:
  - K-Type Thermocouples with Digital Temperature Indicator for measuring surface temperature wood based mounts for the thermocouples.
  - Thermal Probe for water temperature measurement
  - 0.5 Hp centrifugal pump for water flow condition
  - Graphite powder, resin and hardener and acrylic hollow tube and.
  - Screw jack was used for tracking the solar tracking.
  - Piping and flow control setup
  - Annular tube with CPVC pipe

3. Operation:

This stage involved operation of the Parabolic Trough collector with both stagnant and flow condition of flow rate (1.1 LPM, 0.7 LPM and 0.3 LPM) with accurate tracking. Readings of water inlet and outlet and surfaces were taken for every 5-minute from 11:30 am to 2:30 pm. The conditions which were used for the study are:

- a. Uncoated
- b. Uncoated with acrylic covered
- c. Graphite coated
- d. Graphite coated with annular tube
- e. Graphite coated with acrylic covered

4. Analysis, result comparison and report preparation:
• Analysis was done with the obtained data and analyzing it. Also the CFD model was developed for the operated condition and the result was compared against the experimental results.

• The variations were compared under three conditions
  i. Surface temperatures of absorber tube
  ii. Rise in water temperature from inlet to outlet
  iii. Efficiency of absorber tube
  iv. CFD analysis comparison with uncoated conditions only

Fig.1 Auto CAD drawings for the prototype.

Fig.2 Schematic of the Parabolic Trough Collector Test-rig
Results and conclusions:

Fig. 3 Experimental setup

Fig. 4 CFD Results for Temperature (Q = 1.1 LPM)
Fig. 5 CFD Results for Temperature (Q = 0.7 LPM)

Fig. 6 CFD Results for Temperature (Q = 0.3 LPM)

Fig. 7 Comparison of Outlet Water Temperature between Experiments and CFD for Acrylic covered Absorber Tube
Fig. 8 VARIATION OF SURFACE TEMPERATURE WITH VARIOUS VARIANTS OF ABSORBER TUBE

Fig. 9 RISE IN TEMPERATURE GRAPH WITH FLOW RATE UNDER VARIANTS IN ABSORBER TUBE
Conclusions:

The project aimed to design parabolic trough collector (PTC) to develop high temperature in water. The design of PTC is done with help of existing literature thumb rules available at commercial websites and local techniques to overcome hardships.

The advanced technique like laser cutting for frame, TIG welds for frames, wood fixtures for thermocouple mount and Teflon bushing have been provided based on the present requirement. In the first phase bare absorber tube has been used and the maximum temperature increase for three flow rate at same time interval by use of K-type thermocouples.

The variation of temperature along the absorber tube for different time is tabulated. The numerical computation using ANSYS-Fluent and is found to be in agreement. In the second stage of experiments are conducted by aim to increase the efficiency of the collector. This is achieved by covering it with an acrylic tube. Also other variants like coating are provided to improve the absorber’s efficiency.

The maximum temperature raise is reported under stagnation condition as 35°C which coincides with numeric computation. In each case numeric calculation are done to estimate the efficiency of each case and are calculated. The experiments, theoretical and analytical
calculations have clearly shown the performance of PTC is satisfactory and technology used for commercial use in the industry.

**Scope for Future Work:**

Since the area is still under development in India more research and development is needed on various components of the Parabolic Trough Collector to make it more efficient, effective and to make it useful to its full potential. The major areas of future work where development is required are:

1. Efficient and low power tracking mechanism and it must have the ability to be automated and must be highly precise in nature
2. The study of coated and filmed reflective material that can operate in more rugged conditions and maintain high reflective finish is emphasized
3. Use of advanced composites and other light weight but strong material is emphasized. Such a study would help to improve the structural stability and strength of overall construction and also reduce the weight of the construction.
4. Absorber tube material can be changed and tested under various conditions.
5. Better parabolic structural design are needed such that these devices can withstand higher wind and larger structural loads without damaging the shape of the parabola
6. Different coating materials and thickness of coating can be used to coat the absorber tube surface to improve its absorptive and reduce the losses
7. Storage of heat using insulated tank can be further studied by integrating it with the parabolic trough collector allowing the heat to be stored and used even during night or during off weather conditions
8. Closed circuit system can be used in the parabolic trough collector allowing to store higher heat and at higher pressure conditions increasing its potential
9. Different fluids can be used in the absorber tube as the heat absorbing medium as compared to only water being used in this study
10. Absorber tube can be improved by adding covering material and using specially designed evacuated tubes
11. Different technology like porous plug and annular tube can be studied more extensively by varying the dimensions and sizes to know their actual effect in the performance