THE RECENT TRENDS IN OPTIMIZATION OF THERMAL PERFORMANCE OF PARABOLIC TROUGH SOLAR COLLECTOR

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ABSTRACT
The concentrated solar collectors are attractive to the solar community to meet the most of the energy requirements when compared to other renewable sources of energy. Especially, parabolic trough and dish solar collectors are capable of supplying the heat and electricity for the domestic and industrial needs.Both the collectors are operating at different concentration ratios. The increased concentration ratio of parabolic dish collectors is producing higher temperatures. However, the plant level applications utilize the parabolic trough collectors. Various optimization techniques and methods are adopted to utilize the parabolic solar collectors effectively. The most efficient method is the integration of multiple applications to the solar systems. The recent trends in the optimization methods are discussed in this article.

Key words: Solar receiver, absorber tube, parabolic trough, parabolic dish, latent heat, sensible heat storage.


1. INTRODUCTION
A parabolic trough collector is a type of solar collector which is used to trap sunlight and supply heat to a specific application. It is usually straight in one dimension and parabolic in the other two sides. The plane of symmetry is along the straight side of the collector. The sun rays fall in the trough, parallel to the plane of symmetry. The parabolic surface is coated with a polished metal mirror which reflects the sunrays falling on it. The parabolic part of the collector acts as concave mirror and converges the rays falling on it to the focal point. The object that needs to be heated is kept at the focal point and all heat is transferred to it. Figure 1 shows the classification of concentrated solar collectors.
The major systems in the PTC are described in this section. The reflecting surface of the collector at which the sun rays fall and converges. An absorber is device that concentrates the sun rays and transmits to the object or working fluid. Support structure is a structure that supports the whole collector assembly. Tracking system regulates the movement of the collector according to the direction of the sun. Pumping system is used to pump the working fluid that has been heated to required places.

A PTC is made of infinite number of solar collector modules (SCM) assembled together as one solar collector assembly. An average SCM has a length up to 15m. More than 10 SCM assembled make a solar collector assembly, it can go up to 200m length. A SCM is usually made of number of small single parabolic mirrors or by a large single mirror. Smaller mirrors require smaller machines to manufacture and thereby the manufacturing cost is reduced.

![Classification of concentrating solar collectors](image)

**Figure 1** Classification of concentrating solar collectors

A study was carried out and instead of glass-based collectors, silver polymer sheets were used for collectors. They were 30% cheaper compared to the current ones. They also have the same efficiency as the currently used collectors. Some V-type collectors were also manufactured which had 2 mirrors placed inclined to each other. The trough or the collector must face the sun in order to trap heat. So the trough is equipped with motors. Usually the trough is aligned in the north-south axis and then it is allowed to track the sun along the day. It can also be aligned in the east-west axis, but that reduces the efficiency of the collector. The tracking motors are placed in the collectors to adapt to seasonal changes. Usually in the spring and autumn the efficiencies are higher compared to the other seasons.

The efficiency of a conventional PTC is about 30% of its theoretical value for the same acceptance angle. Acceptance angle is the maximum angle at which the sun rays hit the trough. To increase the efficiency more elaborate concentrators are used, usually they have better modified design and the efficiency is almost doubled in those enhanced collectors. A heat transfer fluid is used to absorb the heat of the sun rays and then it is used for conversion of water to steam. Steam runs the generator. The thermal efficiency is about 70% for this process. The merits of PTC are since solar energy is used there is no fuel cost for PTC, the manufacturing cost for solar cells can be lowered if the design is modified, since there is fuel used there is no pollution to the environment and they are more efficient than other types of solar collectors. The drawbacks are the cost of the solar cell is high, without any
enhancement, these types of collectors use a lot of water, which depletes the ground water and these collectors can only be used in specific places.

2. OPTIMIZATION OF PARABOLIC TROUGH COLLECTORS

The optimization techniques and methods are used to predict the thermal performance of the PTC. The experimental design for the optimum performance also investigated by several researchers in the recent years. Figure 2 describes the possible areas of thermal performance of PTC. Bellos and Tzivanidis [1] studied an multi-objective optimization of a solar driven trigeneration system. The main aim of their study is to optimize a solar driven tri-generation system under different optimization condition. They finally managed to obtain the following results. The efficiency was 11.26% and 87.39% for exergy and energy respectively.

Prakash and Rai [2] attempted an optimization of solar PTC using Taguchi method. Their experiment was carried out on solar parabolic trough collector while the using water as working fluid. The obtained results clearly showed a significant improvement on the performance characteristics of solar flat plate collector. Thalange et al. [3] suggested a deformation and optic based structural design and cost optimization of cylindrical reflector system. Since thermal plants are found to have a huge investment cost they quoted that somehow reducing the unit cost is the most efficient way to economically attractive technology. Some changes have been introduced and those were validated with experiments and it was considered a step toward achieving the economically attractive line concentrator technology.

Zhang et al. [4] carried out a research and found that it would be effective if the heat loss in annular space between the absorber and the glass envelope was decreased. Hence, they suggested a structure and gas optimization for annular space of parabolic trough solar linear receiver, and also provided with an encouraging result. Bellos and Tzivanidis [5] carried out an analysis and optimization of a solar driven trigeneration system based on ORC and absorption heat pump. And according to this parametric analysis results toluene was found to
be the working fluid with maximum exergetic output of 29.42% with n-octane and MDM to follow that with the following outputs 28.50% and 28.35% respectively.

Chang et al. [6] carried out a study in effect of dust accumulation on focal energy flux density distribution of trough solar concentrator and concentration optimization. They found that there was a certain influence on circumferential temperature distribution (CTD) due to the accumulated dust, and addition of a secondary reflector makes the energy flux distribution uniform and CTD of that tube reduce significantly thus reducing the dust accumulated effect. González-Portillo et al. [7] initiated an analytical optimization of thermal energy storage for electricity cost reduction in solar thermal electric plants. Nowadays TES technology has become an important asset for this type of renewable energy source but had an electricity cost rise. It is assessed that the lower the TES efficiency, the greater the relevance of reducing solar field costs is in order to obtain low electricity generation costs.

3. PARABOLIC DISH COLLECTORS
The phase change materials (PCM) are recently researched much to store the solar energy and to provide the stored heat during the non-solar times. A variety of PCM were researched in the past decades for the various thermal applications. The major drawback of the PCM is the poor thermal conductivity and the various methods used to melt the PCM fast are discussed from the construction of PCM container and thermal conductivity enhancers [8-10]. The various high temperature solar collectors and the different receiver designs are discussed to optimize the thermal performance of such solar thermal systems by Senthil and Cheralathan [11 -13]. Various effective applications are also described.

The optical analysis of the parabolic dish collectors was analysed with the parametric and experimental investigations [14 -16]. The optical efficiency is vital to determine the effective concentration ratio and the optimum temperature attainable at the solar receiver. The effect of PCM in the solar receiver for the parabolic dish collector was experimentally investigated with different PCM for the domestic hot water, steam cooking applications. The PCM receiver acts as the thermal battery for the several domestic and industrial applications [17 – 20]. The stability and container compatibility of PCM is important factor to be considered. The different receiver configurations like cascaded PCM and coaxial cylindrical PCM [21 - 23]. The suitable PCM enclosure size found to be effective for the outdoor applications.

4. APPLICATIONS OF PARABOLIC TROUGH COLLECTORS
Parabolic trough collectors are used in numerous domestic and industrial applications ranges from the hot water to steam generation. Bellas and Lidorikis [24] presented a design of high temperature solar selective coatings for application in solar collectors. Their objective was to get a design for efficient coating selection in higher temperatures exhibiting maximum absorption in the solar spectrum and minimum emissivity in the infrared spectrum. They evaluated for a wide range of temperature from 400 up to 1000°C and obtained a maximum efficiency at 850°C.

Cruz-Silva et al. [25] reformulated the formulation of DTIRCs to obtain a framework for feasible designs, that is easily implemented in computer numerical control (CNC). In additional they extend it to aspherical front surfaces. They discussed their relevant features in concentrated solar applications and analysed them in the solar flux distribution in a linear Fresnel reflector. Shirazi et al. [26] presented a systematic simulation based on multi objective optimization. They performed the proposed systems at their optimal designs is then compared to that of a reference conventional system. It resulted that the SHC double effect chiller has the best trade-off between the energetic, economic and environmental performance of the system, having a total cost of ~0.7–0.9 M$ per year. Ratismith et al. [27] reported that the
concentrator accepts diffuse solar radiation with an intercept factor of nearly 100%, so it is suitable particularly for tropical climates. The superior performance of the concentrating collector is suitable both for residential and industrial applications.

Stanciu and Bădescu [28] focused their study on Joule cycle reciprocating ericsson engine with a solar parabolic trough collector (PTC). They analyzed and made conclusions on two main contributions that are on design parameters to avoid improper JCREE operation and proper strategy to switch between different speeds to increase the work generated per day. The overall efficiency is from 8:46 to 15:15 which is almost constant along the effective operation time interval. Nunez et al. [29] proposed a new symmetric non-imaging parabolic trough collector for an evacuated circular receiver. By their design process, they neglect the transmission, absorption and reflection losses. Monte Carlo ray-tracing results show that only 15% of the rays undergo secondary reflection before arriving to the absorber.

Masood et al. [30] proposed a technique used for generating electricity by steam power cycle. They designed parabolic trough heating system and simulated using meteorological data of Ipoh, Malaysia. They resulted that the combination of solar with conventional fuel system can significantly contribute in reduction of fuel usage.

5. CONCLUSIONS

The increase in concentration ratio of parabolic dish or trough collectors is useful to produce the higher fluid temperatures. However, plant level applications utilize the parabolic trough collectors. Parabolic dish collectors are useful for the standalone applications. The most efficient method is the integration of multiple applications to the solar collector systems.

Further, the various optimization techniques are employed to investigate the solar thermal system effectively. Taguchi methods and optical structural design of the solar collectors are useful to design the effective parabolic solar collectors. Various optimization techniques and methods are adopted to utilize the parabolic solar collectors effectively.

The absorber design with internal fins, metal foams and PCM increases the efficient heat absorption of absorber tubes. The secondary reflectors are useful in capturing the escaping concentrated solar rays. The corrugated absorber with internal as well as external fins are useful to absorb maximum solar incidence. The application-specific absorber design is economically beneficial to the stake holders.

REFERENCES


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The Recent Trends in Optimization of Thermal Performance of Parabolic Trough Solar Collector


