A review: Solar Compound Parabolic Collector

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Abstract

Compound Parabolic Collector (CPC) has been used in industrial application where steam of inter medium pressure at around 150ºC is required. FPCis not much efficient to deliver water with temperature more than 100ºC. Hence Concentrating Collectors are to be used. Collector is one of the parts of the solar system where the solar energy is incident and energy is collected and then reflected to the receiver of the entire solar system. A concentrating collector concentrates the solar energy on the receiver resulting in higher solar performance and generating more temperatures. Compound Parabolic Collector (CPC) is a solar collector made-up in the shape of two meeting parabolas. It fit in to the non-imaging family, but is consider among the collector having the highest concentrating ratio. The manual tracking can also be provided. CPC has application in the field of power generation, steam generation, solar air conditioning in addition to water heating etc. In this existing review paper various material choice for receiver of CPC, Conceptual design, tracking ways of CPC, thermal efficiency and large variety of applications of Compound Parabolic Collector are described.

Keywords: Solar applications, Thermal performance, Compound parabolic collector, tracking

Introduction

Compound Parabolic Collector (CPC) has been used in industrialized application where steam medium pressure required at around 150ºC is required. FPC's are not competent enough to supply water at temperature more than 100ºC. Hence Concentrating Collectors are comes in the market. The name CPC may indicate that this collector fit in to the family of focusing collector, but in fact this is more alike to FPC, due to its typically fixed orientation and medium temperature water transfer. Collector is that part of the solar energy system where the solar energy is incident and energy is collected and then same has to be reflected to the receiver of the system. A concentrating collector further radiates the solar energy on the receiver ensuing in higher thermal performance and producing greater temperatures. The word *collector* is functional to the entire system comprising the receiver and the concentrator. The receiver is that part of the system where the radiation is collected and transformed to other energy form; it includes the insulation, the absorber and its cover. The concentrator is another part of the collector that leads radiation to the receiver. [1]

The manual and automatic tracking if needed can also be delivered. CPC has various applications in the field of power generation, steam generation, solar air conditioning in addition to existing water heating. As the CPC are dissimilar to the traditional concentrating collectors. Compound Parabolic Collector (CPC) is a superior type of solar collector manufactured in the shape of two gathering parabolas. It fit in to the non-imaging family, but is deliberate among the collector having the maximum concentrating ratio. Also because of its huge aperture area, solitary intermittent tracking is essential. A more stylish parabolic collector can be designed, that minimizes the need to track the sun altogether, by adding two parabolas together, to form the "Compound Parabolic Collector." When this has to be done, the co-focal point then converts into a co-focal line. Total concentrated solar energy delivered and transferred to the energy absorber tube, if a coolant occupied pipe solar energy absorber pipe, or a tubular evacuated tube solar energy absorber tube is co-located at the co-focal line. Such solar collectors do not require tracking, and only occasional season angle alterations (several times a year) be required to keep the aperture perpendicular to the noonday sun, to obtained more power output. Desired uses of the CPC are in the following mode:

1. In solar cooking
2. In power generation – in photovoltaic cells
3. In solar still (water pasteurization) – to eliminate impurity or microbes from the water
4. Insolar water heating – for water heating purpose in buildings.

Literature Survey

Winston had been the concept of Concentrating Collector in 1974, which is a non-imaging concentrator. As seen from Fig. 1,

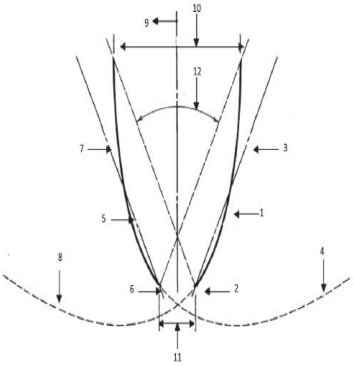

Figure 1- The geometry of compound parabolic collector (CPC). (1) Parabola A, (2) focus of parabola A

(FA), (3) axis of parabola A, (4) truncated part of parabola A, (5) Parabola B (6) focus of parabola B (FB) (7) axis of parabola B, (8) truncated part of parabola B,(9) axis of CPC, (10) aperture of CPC (d1), (11) receiver opening (d2), (12) acceptance angle (2θ)

CPC made of segments of two parabolas 'A' and 'B', with its focal points at 'FA' and 'FB' separately, such that the former depends on curve 'B'; and another relates with the curve 'A'. The dotted parts of the two curves have been truncated; and the segments displayed by solid lines create the CPC. Angle from the given two lines drawn equivalent to the axes of parabolas 'A' and 'B' through 'FB' and 'FA' correspondingly is its angle of acceptance '2h'. Rays incoming CPC through 2h' reach the gap between 'FA' and 'FB', after a single or numerous reflections, making a non-imaging type of concentration. The geometrical concentration of the CPC is (d1/d2) where d1 is aperture and d2 is receiver opening. In procedure, CPC is positioned with its linear receiver associated East–West, and aperture naturallyslanted toward south (for northern he misphe relocations). The tilt in such way that the solar rays directs on to collector inside its acceptance angle; and it is accustomed occasionally when the incident rays just fall out beyond that specified angle. Also, CPC is often shortened at the top in actual operation to limits its geometrical height; but at the price of drop in its concentration ratio. The application of CPC in the electric generation appliances has been linked with several losses. Many of the losses associated with PTC including thermal, optical and solar geometry losses. These entire losses lead to reduction in thermal efficiency of the CPC. The parabolic trough linear receiver, which can also be called as the Heat Collection Element, is a main component in a parabolic trough collector system.[1]Dongqiang Lei, Zhifeng Wang, Jian Li, "The analysis of residual stress in glass-to-metal seals for solar receiver tube", this paper comprises the solar receiver tube which is a main constituent in the parabolic trough solar thermal. The receiver tube contains of a metal pipe at central location including a cermet solar-selective absorber surface, bounded by an evacuated glass envelope. It combines glass–metal transitional elements and metal bellows to succeed with the essential vacuum-tight inclusion and to provide accommodations for thermal expansion which is modification between the glass envelope and the metal pipe. Glass-to-metal sealing breakage is main reason for damages of receivers in current power plants. The residual stresses that are produced during the conserving process of the seal can reduce the seal strength and encourage the breakage of the glass-to-metal sealing. Finite element software ANSYS™ were used to simulate residual stresses and also measured experimentally by photo-elastic techniques. The results of this research work have an important inference on the optimization of seal geometrical configuration in the solar receiver tubes. [2]

Ricardo Vasquez Padilla, Gokmen Demirkaya, D. Yogi Goswami, Elias Stefanakos, Muhammad M. Rahman, "Heat transfer analysis of parabolic trough solar receiver", this paper embraces use of Solar Parabolic Trough Collectors (PTCs) for the construction of electricity and applications with relatively more temperatures. A heat transfer fluid mixes through a metal tube (receiver) with an outer selective surface that absorbs solar radiation reflected from the mirror surfaces of the PTC.A parabolic trough solar collector (PTC) receipts the radiant energy from the sun and transforms it to beneficial thermal energy in the heat transfer fluid (HTF) that flows through the solar field. Once the solar geometry and thermal parameters of the system are defined, the thermal performance and energy added by the HTF can be planned under meteorological conditions and dissimilar configurations. In order to minimize the heat losses, the receiver is shielded by an envelope and the enclosure is usually reserved under vacuum pressure. The heat transfer and optical analysis of the PTC is important to enhance and appreciate its performance under several operating conditions. In this paper a thorough one dimensional numerical heat transfer analysis of a PTC has been achieved. [3] A.G. Bhave, "Industrial Process Heat Applications of Solar Energy", this study displays the concentrating solar collectors of low concentration ratio may supply process heat or hot water at middle temperatures, i.e. 80 to 180^{0}C, where flat plate collectors are not working in the effective way, and for which there are a number of rural, domestic and industrial applications. This paper described the possible applications of this technology and presents case studies to demonstrate its practicability. The expansion of solar thermal systems for industrial heat and for other applications like solar cooling is a plunge area of the Ministry of New and Renewable Energy, Government of India. Worldwide energy depletion for cooling and air-conditioning is growing rapidly and the market potential for solar thermal cooling is very bulky. [4] Ajitkumar S. Gudekar, Atul S. Jadhav, Sudhir V. Panse, Jyeshtharaj B. Joshi, Aniruddha B. Pandit, "Cost effective design of compound parabolic collector for steam generation", this paper explained that electricity is the richest quality of energy and should be given importance, energy consumption in the form of direct heat also forms a major mode of energy consumption. It has been used in various applications, from high use like space heating to domestic like cooking and to an extremely extensive range of industrial applications. Steam has been extensively used over the years as a mode of heat transfer mainly due to the benefit of its maximum latent heat content. Compound parabolic collector system has been considered for the application of process steam generation mainly. It is so much easy for conceptual design, stylish fabrication, and informal operation and has a lower cost compared to other existing concentrating solar collector systems with further opportunity of lowering the cost. An experimental demonstration solar system having an aperture area of approximately 30 m^{2}was manufactured and experienced for steam generation.

The thermal performance analysis of the system displays potential use of improving thermal efficiency. [5] Atul S. Jadhav, Ajitkumar S. Gudekar, Ramchandra G. Patil, Dhanaji M. Kale, Sudhir V. Panse, Jyeshtharaj B. Joshi, "Performance analysis of a novel and cost effective CPC system", International journal of Energy Conversion and Management Vol. No.66 , Page No.56–65

Compound Parabolic Collectors (CPCs) permit greater acceptance angle which concentrating the incident radiation and essential only infrequent tilt adjustments in its place of nonstop solar tracking. They have been initiating suitable in many low concentration applications, where low cost and comfort of operation, are important standards. One major restraint of CPC is its height which rises rapidly with an growth in the aperture, interpreting the supporting structure massive and costly. Truncation decreases height, however also decreases the concentration. And evelopment in the CPC design has been recommended in this paper, which brings down its height, without much cooperation on the concentration ratio. Outcomes show that the modified CPC design can captures the solar energy to deliver low cost Industrial Process Heat. [6]

Zhiyong Wu, Dongqiang Lei, Guofeng Yuan, Jiajia Shao, Yunting Zhang, ZhifengWang,"Structural reliability analysis of parabolic trough receivers"

This learning includes power coming from CSP (Concentrated Solar Power) is better than that from the PV (Photovoltaic) technology because this entire system contains a large heat storage capacity. The structure of a parabolic trough receiver is predominantly a stainless steel inside tube enclosed by a glass tube externally. Since geometrical details of the stainless steel tube has 4 m long and is relaxed to become in the bent shape, the glass outer tube is fairly fragile and consequently disposed to break. Practices in field operations show the stainless steel tube bending is the root cause of parabolic trough receiver's structural failure. This reading mainly investigates how and why the stainless steel tubes change to bent. Numerical simulations are carried out to examine the detailed temperature circulation and its equivalent structural distortion of the stainless steel tube of parabolic trough receivers. This paper also explained that unsuitable operational practices and installation of parabolic trough receivers are the root causes for the structural failure among parabolic trough's receiver. This study has been considering by excessive importance to guide the operation and installation of parabolic trough receivers.[7] XiaoguangGu, Robert A. Taylor, Graham Morrison, Gary Rosengarten, "Theoretical analysis of a novel, portable, CPC-based solar thermal collector for methanol reforming", the author proposed a new solar thermal collector which is quite appropriate for supplying heat for endothermic chemical reactions. The certain reaction that is measured is hydrogen production by menthol reforming. The detailed design is constructed on CPC technology, which can function without complex (and costly) tracking systems. It consists of a minor, double-sided selective surface receiver in a vacuum envelope contained of a glass aperture coverand CPC reflectors . Heat absorbed by the receiver is moved to the working fluid inside micro tubes where the chemical reaction is happening. This study founds both the thermal and optical models wanted to forecast the performance of collector. The outcomes displays that the collector stagnates at higher temperatures and can deliver solar heat in the form of a collector for a diversity of portable applications– e.g. methanol reforming that needs temperatures of around 250^0C.[8]GianlucaCoccia, Giovanni Di Nicola, Marco Sotte,"Design, manufacture, and test of a prototype for a parabolic trough collector for industrial process heat", the research covers a receiver is made up of an aluminum pipe of circular cross-section, enclosed within a low-iron glass envelope. The tracking system is depending on a solar-position computer program. The key features of this prototype are its high mechanical resistance, low weight, cost-effectiveness, and ease of manufacture. In the case of a parabolic chord between 4 and 6 m (common in PTC plants for electric power production), this method has severalrewards: e.g., the movement of small parts slightly than big sections and the opportunity of changing each reflective surface position with respect to the frame, which is essential toget the desired accuracy on a huge parabolic arch. But this method is time uncontrollable and expensive. [9]Yanjuan Wang, QibinLiu,Jing Lei, Hongguang Jin, "Performance analysis of a parabolic trough solar collector with non-uniform solar flux conditions", The development of the thermal performances of the parabolic trough solar collector system (PTC) shows a key role in the consumptions of solar energy. Solar ray trace method based numerical simulation method is planned to answer the complex problem fixed with fluid flow, heat transfer and thermal stress in a CPC solar system. The scattering pattern of the stress intensity and the thermal distortions of the receiver are mathematically studied. Numerical simulation outcomes indicate that the circumferential temperature difference (CTD) of the absorber reductions with the increases of in lettemperature and velocity of the heat transfer fluid (HTF) and rises with the addition of the direct normal irradiance (DNI). [10]

Conclusions

Solar energy is one of principal source of renewable energy that has conservational advantages compared with conventional energy sources. Its core advantage it is organically clean and does not harvest any waste products, process or polluting air which is needed in human activity for sustainable development. Translation of solar energy systems has been classified into two major systems mainly electrical energy system and thermal energy system. Compound Parabolic Collector solar systems are one of the most talented of a extensive range of the obtainable solar technologies. Continuous innovations are being achieved through CPC. Mainly

due to the significant amount of solar CPC plants that are being under action in many countries. Within this nonstop improvement effort, Direct Steam Generation (DSG) has been under progress. DSG will lead to low-cost systems, not only for electricity generation but for industrial heat process requirements. Employed with superheated steam as thermal fluid, implies heavier pipe walls. Vacuum annulus has been presumed between the glass envelope and stainless steel absorber. The thermal radiative interaction between those parts has been measured without constant temperature assumption ended with the glass envelope. the finite element method (FEM) and Solar ray trace (SRT) method founded numerical simulation technique is projected to solve the complex problem integrated with heat transfer , fluid flow and thermal stress in a CPC system. The distributions of the solar energy flux are designed by the SRT method, and the properties of the major operating parameters on the thermal performances of the receiver are numerically investigated.

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