An Extensive Review on Different Parameters of Parabolic Trough Collector

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Abstract: At present era of limited sources and pollutant type of conventional source of energy need to have energy which is abundantly available on earth and non-depletion in nature. Solar energy is best option which is available on globe on day time but greatest drawback of it that is scattered in nature so device called concentrator is required to harness and magnify intensity of solar insolation. Parabolic trough collector is widely used collector for industrial process heat and power plant. Many research have done for increasing efficiency and heat transfer of Solar PTC, in this review paper different parameters suggested by various researchers have reviewed for increasing efficiency of PTC.

Key words: Solar Energy, Parabolic Trough Collector, Design Parameter of PTC, Enhancement of heat transfer.

I. Introduction

Within last few decades, there is significant need of energy due increasing population, increasing consumption pattern of energy by mankind & Industry, increasing global pollution and limited source of fuel for conventional form of energy leads increasing to reduce the dependency on fossil fuel. Therefore need to have non convectional form of energy like ocean, wind, geothermal, and solar energy. Number of countries now centring on renewable energy. Among that solar energy is widely available across the globe also having great potential, it estimated that approximately an average $1000 W/m^2$ energy is available on earth surface. Solar irradiation could produce 85000TW compare to present need 15TW, there has been an increasing effort from governments, industry and academic institutions to harness scattered form of solar energy and to improve efficiency of collector. This, plus an ever growing pressure from different sectors of society to reduce carbon dioxide emissions, has motivates the development of emerging technologies to reduce the dependency on fossil fuels and the optimization of existing systems in order to minimize energy consumption.

There are two ways to gain electricity from the sun energy. First by using the concentrating solar thermal system. In this method heat from sun is focused to produce steam. The steam will run a generator to produce electricity. This type of configuration is typically used in solar power plants. In other way photovoltaic (PV) cell is used to convert heat to electricity.

II. DESIGN OF SOLAR CONCENTRATOR

Solar concentrator is a device that allows the collection of sunlight from a large area and focusing it on a smaller receiver or exit. For the past four decades, there have been a lot of developments involving the following designs of the solar concentrators. They are:

- Parabolic Concentrator
- Hyperboloid Concentrator
- Fresnel Lens Concentrator
- Compound Parabolic Concentrator (CPC)
- Dielectric Totally Internally Reflecting Concentrator (DTIRC)
- Flat High Concentration Devices
- Quantum Dot Concentrator (QDC)

III. PARABOLIC CONCENTRATOR

The two dimensional design of a parabolic concentrator is equals to a parabola. It is widely used as a reflecting solar concentrator. A distinct property that it has is that it can focus all the parallel rays from the sun to a single focus point, is not necessary to use the whole part of the parabola curve to construct the concentrator. Most of the parabolic concentrator employs only a truncated portion of the parabola. Currently, there are two available designs of parabolic concentrator. One is by rotating the two dimensional design along the x-axis to produce a parabolic dish, and the other way is by having a parabolic trough. Both of the designs act as reflectors and are used mostly in concentrating solar power system in big solar power plant. Although this concentrator could provide a high concentration, it requires larger field of view to maximize the sun energy collection. To obtain maximum efficiency, it needs a good tracking system, which is quite expensive. That is why this type of concentrator is not preferred in a small residential house.

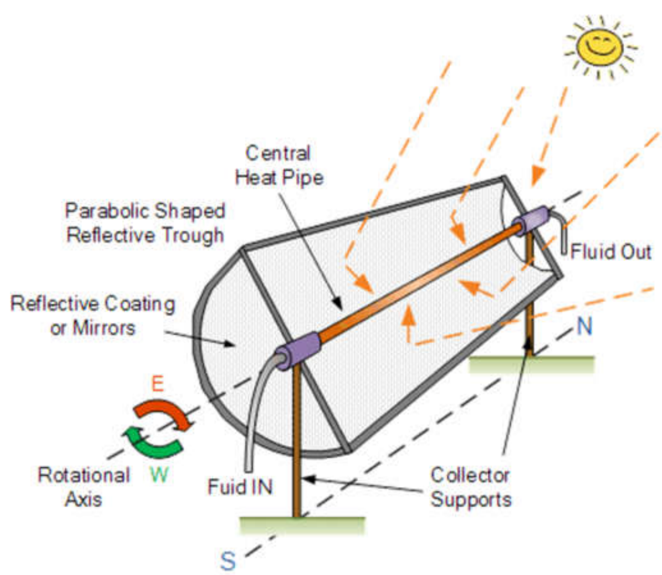

Fig. 1 Schematic of parabolic trough collector

The growing need for energy and the depletion of conventional fuel has forced the man kind to think in direction of non-conventional energy sources. One of the largest sources of non-conventional energy is Sun. A large amount of solar energy is available in thermal form. The collection and concentration of solar thermal energy on the object is done with the help of Parabolic Trough Solar Collector (PTSC) for the temperature range 60- 600°C. Solar flat plate collectors are available for temperature range lesser than 100°C.

IV. PART OF PARABOLIC CONCENTRATOR

Following are mail component of parabolic through collector. Assembling of all part to form PTC with providing heat transfer fluid at one end to gain concentrated heat from outer surface of absorber tube which is being reflected by reflective surface.

1) *Parabolic Shaped Structure*
2) *Reflective Surface*
3) *Receiver Tube or Absorber Tube*
4) *Support Structure or stand*

V. LITERATURE REVIEW

Hossein Mousazadeh, et al.[1] reported that using the designed sun-tracking system, the experimental tests illustrated that 30% more energy was collected in comparison to that of the horizontally fixed mode. Only 1.8% of all maximized energy is consumed by actuators of the designed tracking system.

Himanshu Tyagi, et al. [2] observed that the presence of nano particles increases the absorption of incident radiation by more than nine times over that of pure water. According to the results obtained from this study, under similar operating conditions, the efficiency of a direct absorption solar collector (DAC) using nanofluid as the working fluid is found to be up to 10% higher (on an absolute basis) than that of a flat-plate collector.

Accordingly Kawira M, Kinyua R., Kamau [3] the maximum temperature of steam obtained was 248.3ºC while average temperature of steam was produced was 150ºC. The absorber pipe was a copper tube which carried water as the heat transfer fluid. The concentration ratio of the solar concentrators was 128. The concentrator testing was carried out for each of the concentrators. When closed their efficiencies were: Aluminum sheet reflector PTSC; 55.52 %, Car solar reflector PTSC; 54.65 % and Aluminum foil reflector PTSC; 51.29 %. The open solar concentrator efficiencies were 32.38 %, 34.45 % and 27.74 % respectively

J F M Escobar-Romero, et al.[4] used the reflective surface of the solar parabolic concentrator prototype with following dimensions: 200, cm of length, 100 cm in width, and 50 cm focal length. On a clear day we can achieve temperatures above 200 ºC and pressures up to 12 Kg/cm^2.

J. K. Kaldellis, et al,[5] used the concept of combining photovoltaic (PV) power stations and energy storage systems comprises a promising solution for small scaled autonomous electrical networks, increasing the reliability of the local network as well.

C.E. Kennedy, H. Price, [6] mentioned that Improving the properties of the selective coating on the receiver represents one of the best opportunities for improving the efficiency of parabolic trough collectors and reducing the cost of solar electricity. Additionally, increasing the operating temperature above the current operating limits of 400^0C can improve power cycle efficiency and reduce the cost of thermal energy storage resulting in reductions in the cost of solar electricity. Current coatings do not have the stability and performance necessary to move to higher operating temperatures. The objective of this effort was to develop new, more-efficient selective coatings with both high solar absorptance ($\alpha \geq$

0.96) and low thermal emittance ($\varepsilon \leq 0.07$ at 400^0 C) that are thermally stable above 500^0C, ideally in air, with improved durability and manufacturability and reduced cost.

P. Sansoni et al.[7] parabolic trough collectors were investigated, applying the study results to a plant prototype installed in Florence (Italy) for residential supply. Ray tracing simulations examined optical characteristics and collection performance on the base of prototype geometry and functionality. The purpose was to control the realisation errors and overcome the difficulties arising in the development of the solar trough plant. The study summarises the results of several studies analysing the interactions between collection efficiency, angular misalignments, mirror deformations, sun tracking and trough placement. The mirror deformations are reproduced introducing an original procedure. The unusual subject of imprecision in trough axis placement is discussed.

Maria Dicorato et al., [8] noted that performances of a parabolic trough power plant of 100 kW size have been analysed. Two different types of one-axis solar tracking systems have been implemented, with horizontal and tilted rotation axis, to evaluate annual solar radiation. On the basis of simulations for analysing behaviour of sun-tracking parabolic collectors and statistical analysis of solar radiation data, annual electricity production has been calculated for both systems, showing notable advantage with respect to photovoltaic applications. Moreover, analysis on system with inclined rotation axis on the horizontal plane has yielded better results, comparable to those from biaxial sun tracking.

The PTC as per R. M. Muthusivagami, [9] has to be oriented in one of the existing tracking modes to track the beam radiation. The focused radiant energy from the sun is absorbed through the heat collection element and transferred to heat transfer fluid which flows through the absorber tube. In most of the tracking modes, the sun rays incident at an angle and will therefore come to the focus a little beyond the length of the absorber tube. Hence the absorber tube should be long enough to intercept the reflected solar radiation. The study helps in calculating the increase in absorber tube length on both sides to intercept about 95 % reflected solar radiation for smaller size parabolic troughs. This end effect study will be significant for pilot or small scale set-ups in obtaining consistent test results.

Kody M. Powell et al., [10] mentioned the results of simulations show that by increasing the size of the solar field and adding 8 hours of storage capacity, the solar share (the fraction of energy provided by solar) of the power plant can be increased by over 80% to levels as high as 0.78. With enough storage capacity, it would be possible for a plant to operate 24 hours a day on only solar energy. However, economics dictate that this is not a financially optimal scenario.

E. S. Quintal et al. [11] the evaluation of the economic and technical viability for the installation of a solar air conditioning system based on parabolic solar concentrators and adsorption technology, in an existent building. As case study was selected a university canteen located in the centre region of Portugal. Besides air conditioning, this system is also used for domestic hot water production. This solution enables the system use throughout the year in order to maximize the investment. Results show that the implementation of these systems is feasible for the Portuguese reality and the return of the investment can be achieved in 8 years without governmental financial support.

Yong Shuai et al., [12] the radial stresses are very small both for uniform and concentrated heat flux distribution conditions due to the little temperature difference between the inner and outer surface of tube receiver. The maximal axial stresses are found at the outer surface of tube receiver both for uniform and concentrated solar irradiation heat flux conditions. The axial stress has more impact on thermal stress compared to radial stresses. The temperature gradients and effective stresses of the stainless steel and Sic conditions are significantly higher than the temperature gradients and effective stresses of the aluminium and copper conditions. The stainless steel condition has the highest stress failure ratio and the copper condition has the lowest stress failure ratio. Adopting eccentric tube as the tube receiver for parabolic trough collector system can reduce the thermal stress effectively up to 46.6%. The oriented angle has a big impact on the thermal stresses of eccentric tube receiver. The thermal stress reduction of tube receiver only occurs when the oriented angle is between 90^0 and 180^0.

Emmanuel O. Sangotayo et al.[13]The parametric studies conducted investigating the heat transfer characteristics of fluids in the absorber in Cylindrical Parabolic Concentrating Solar Collector in Ogbomosho Climatic Conditions (lat 8º01', long 4º11'). Oil has highest heat transfer characteristics, Nusselt number values both with and without tape twist factor. It is observed that tape twist factor enhances the heat transfer characteristics of the fluids in cylindrical parabolic concentrating solar collector. The higher value of heat transfer characteristics is obtained with Nusselt number having tape twist factor (X = H/Di) in all the three fluids considered. This is due to the fact that high twisted tape inserted into the absorber increases the friction factor and pressure drop leads to higher pumping power. that the optimum design parameters are: length (L) is 1.30 m, mass flow rate is 0.036 kg/s, outlet and inlet fluid temperature is 0.505 with instantaneous collector efficiency of 47.38%.[30]

Also as per Emmanuel O. Sangotayo et al. [14] the energy equation for heat transfer of two dimensional fully developed fluid flow of the cylindrical parabolic trough collector have been considered and subsequently collector efficiency factor, F', collector heat removal factor, Fr and collector overall heat loss coefficient, U_l are used to analyse the thermal performance and to study the effect of mass flow rate ṁ, from 0 to 1.0 kg/s for the fixed value of incident solar absorbed flux, I_b of 186 w/m^2. The results revealed that the optimum design parameters are length, 1.30m, mass flow rate ṁ, 0.036kg/s, concentrator aperture width, 0.6 m, concentration ratio, 3.667, absorbed flux, 96.39, tilt angle, 8.2, fluid temperature, 0.05053 K and instantaneous efficiency, 47.4%. It is observed that performance of the cylindrical parabolic trough collector with twisted tape was enhanced appreciably.

S.K. Tyagi et al.[15] mentioned that the performance parameters such as the exergy output, exergetic and thermal efficiencies, stagnations temperature, inlet temperature, ambient temperature etc. are found to be the increasing functions of the concentration ratio but the optimal inlet temperature and exergetic efficiency at high solar intensity are found to be the decreasing functions of the concentration ration. On the other hand, for low value of the solar intensity, the exergetic efficiency first increases and then decreases as the concentration ratio is increased. This is because of the reason that the radiation losses increase as the collection temperature and hence, the concentration ratio increases. Hence, for lower value of solar intensity, there is an optimal value of concentration ratio for a given mass flow rate at which the exergetic efficiency attains its maximum value. Again it is also observed that the mass flow rate is a critical parameter for solar collectors and should be chosen carefully.

T. Yousefi et al.[16] has used Al_2O_3 water nanofluid, as working fluid, on the efficiency of a flat-plate solar collector was investigated experimentally. The weight fraction of nanoparticles was 0.2% and 0.4% and the particles dimension was 15 nm. Experiments were performed with and without Triton X-100 as surfactant. The mass flow rate of nanofluid varied from 1 to 3 Lit/min. The ASHRAE standard was used to calculate the efficiency. The results show that, in comparison with water as absorption medium using the nanofluids as working fluid increase the efficiency. For 0.2 wt% the increased efficiency was 28.3%. From the results it can be concluded that the surfactant causes an enhancement in heat transfer.

Balbir Singh Mahinder Singh, Fauziah Sulaiman [17] investigate that a rim angle of 90° is preferred as it gives an optimum intercept factor and allows the depth to be the focal point. The focal point, where the rim angle is set at 90° can be calculated by using the width value alone, Simulation for various concentrations until its maximum theoretical value of 212, the model's efficiency increased until the concentration ratio reached 10 for all three working fluids flowing in the receiver and then gradually decreased by at least 53 percent.

Tadahmun Ahmed Yassen [18] mentioned that the diameter was held at 0.03m so that the intercept factor γ has maximum value of unity. The rise of mass flow rate leads to high efficiency (40-65) % for the flow rate values (20.23-100) kg /hr. The efficiency starts from zero when the mass flow rate is zero because the heat removal factor is zero, and it increases quickly till it reaches about (62%) at mass flow rate of 40 kg/hr. That is, the increase of mass flow rate will decrease the absorber tube temperature so that the heat losses decreases and the heat removal factor is improved. The efficiency reaches a maximum at 40 kg / hr mass flow above which no more efficiency increase is observed.

VI. CONCLUSION

This include literature review of Solar Parabolic trough type collector that used for thermal and power production, analytical and experimental outcome of various reasearer summarized that;

1) Use of tracking system enhance the performance of system however this consume some power for it operation.
2) Use of Aluminum sheet as a reflecting surface will give more efficiency compare to other Car solar reflector and Aluminum foil reflector
3) Using proper selective coating on the receiver leads improving the efficiency of parabolic trough collectors.
4) Increase in absorber tube length on both sides to intercept maximum reflected solar radiation for smaller size parabolic troughs is advisable.
5) Properly designed PTC used for air conditioning as well as used for domestic hot water production.
6) For absorber tube the axial stress has more impact on thermal stress ccompared to radial stresses. The temperature gradients and effective stresses of the stainless steel and Sic conditions are significantly higher than the aluminium and copper conditions. Using copper as absorbing material is most suitable.
7) For lower value of solar intensity, there is an optimal value of concentration ratio for a given mass flow rate at which the exergetic efficiency attains its maximum value. Again it is also observed that the mass flow rate is a critical parameter for solar collectors and sshould be chosen carefully.
8) Comparison with water as absorption medium using the nanofluids as working fluid increase the efficiency.

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