A Review on Performance Evaluation of Parabolic Trough Collector

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ABSTRACT

Parabolic trough collector is solar energy conversion technology used for heat application. Solar energy incident on the reflector is reflected on the receiver which carries a fluid used for different application. Parabolic trough collector (PTC) generally used in an industrial application for thermal and power generation application. Parabolic trough collector consists of the reflector as a prime component which has a major impact on performance. Reflector with glass mirror has many limitations like high cost, difficult to manufacture, difficult to assemble, low curability etc. To tackle this problem reflector as a different polymer for the experimental application used. The different types of polymers having high specular reflectivity, thermal stability etc. like an Acrylic sheet, Vinyl, Aluminized Myler are used. Economically feasible parabolic trough collector constructed from the locally available material can be used as a solar device for the solar thermal application. The low-cost prototype parabolic trough collector used for domestic or industrial application deliver hot water at a temperature range of 55-65°C.

Keywords—Parabolic trough collector (PTC), Specular reflectivity, Thermal stability, alternative reflecting material.

1.INTRODUCTION

Solar energy is one of the promising sources of energy for survival and sustainability of human being. We can face issues like global warming with a clean source of energy like solar energy. It offers great chance to reduce pollution in an economical way. Commercial sources of energy harmful to the environment. So to prevent pollution and provide Sustainable environment it is necessary to improve the potential of renewable energy. The government set the target for renewable energy of 175GW which include 100GW for solar. Ministry of renewable energy started implementing and supporting various schemes to achieve the target. Solar energy is one of the prime sources of renewable energy which will be alternative to fossil fuels in the industrial and domestic application. [2]

Sun radiates energy at the rate of $3.8*10^{23}$KW out of which only small fraction i.e. $1.8*10^{14}$ reach to earth surface which is thousand times greater than current energy consumption. Solar concentrating devices reflecting solar energy from the reflector to focal point or focal line through which fluid is passed. These devices used for heat application and electricity generation now receive an attention. [4]

Solar energy technologies consist of solar photovoltaic cells, solar flat plate, and concentric collectors, solar towers etc. out of which concentrating solar power collectors such as Parabolic trough collector (PTC) are capable of producing hot water; steam can be further used for industrial process heat and power production. This is economically feasible solar energy technology used in domestic as well as in industrial application. [7]

2.LITERATURE REVIEW

The purpose of this literature review is to outline in some detail literature relevant to parabolic trough collector.

Prakash and Rai (2018) carried out experimental investigation by Taguchi method for performance optimization. Mass flow rate, Diameter of the receiver and material of receiver tube are design and operating parameters. The result shows that the parameters chosen in this study have a significant influence on response and validation of result shown significant improvement in performance characteristics. [1]Patil and Joshi (2018) took few parameters on which performance of parabolic trough collector depends. The result obtained shows that by increasing mass flow rate the value of outlet temperature decreases, at the same time value of useful heat gain increases and as the cross-section area of absorber tube increases, both outlet temperature and useful heat gain decreases. [2]Experimental study of parabolic trough collector with polymers as a reflector to reflect solar radiation towards receiver tube grey iron pipe located at focus line conducted by Syed Mohd. Yasir Arslan (2017). This experimental study includes design, construction and testing performance of parabolic trough at different parameters. [3]Faissal

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Abdel-Hady et.al (2016) carried out design, simulation, and manufacturing of integrated thermal photovoltaic closed parabolic trough collector using the composite material. This includes two flanges for supporting photovoltaic panels. Two cases are studied one with a glass cover over aperture area and another without it.Optical analysis is done and this shows that glass fiber is an ideal material for its high rigidity, low cost, and ease of manufacture. [4]Bhasme (2016) conducted performance analysis of solar cooking instruments based on their geometrical aspects. The main aim is to find out find out a best solar cooking device that can absorb heat reflecting from its surface.Peformance evaluation of parabolic trough and Scheffler type reflector in terms of its thermal efficiency and losses. Theoretical and simulated results over various conditions prove that the Scheffler reflector performs well compared to the parabolic collector. [5]Roy et al (2016) Performed parametric investigation of the effects of flow rate and absorbers water inlet temperature on collector thermal efficiency for a different level of insolation under the climate condition of Silchar, Assam, India. The result shows that the highest efficiency of about 0.46 is obtained at a water inlet temperature of 36.8°C for a solar insolation of 720 W/m^2 and the highest efficiency of about 0.51 is obtained at a mass flow rate of 4.8 kg/s for a solar insolation of 552 W/m^2. [6]Kumbhar, Shinde (2016) investigated the performance of parabolic trough collector integrated with latent thermal energy storage system. Instantaneous collector efficiency has been evaluated with and without incorporation of a thermal storage system with variation in mass flow rate of air from 0.0022kr/sec to 0.0044 kg/sec.The result shows that with latent thermal energy storage system improves collector efficiency by 17%.It gives better performance at low solar radiation intensity. Collector efficiency increases with increase in mass flow rate. [7]Design and manufacturing of parabolic trough collector with an experimental study performed by Savita Singh, Prashant Saini, and Mahesh Kumar (2016).GI sheet is used as a reflector. The structure was fabricated using the locally available material for rural application point of view. [8]Syad Mohd.Yasir Arslan, Earnest et al (2015) analyzed the performance of two parabolic trough collector for producing hot water with two different reflector materials one with acrylic mirror sheet and second with stainless steel sheet. The maximum instantaneous thermal efficiency obtained by the concentrator having acrylic mirror sheet is 13.67 %, and concentrator having stainless steel material is 15.85 %. [9]Fabrication and design of parabolic trough collector with locally available material for rural point of application by Tayade Mayur, Thombre and sub ratio Dutt(2015).The aluminum sheet used as a reflector. Performance evaluation of parabolic trough during the month of November and December at 19.95 degrees N and 79.3 degrees E longitude. [10]Kulkarni Hrushikesh bhujangrao (2015) conducted an experimental study of using top glass cover and without glass cover shows that top glass cover improves instantaneous efficiency 45.56% to 62.60% and overall efficiency by 10%. [11]An experimental study is carried for investigation of an absorber with twisted tape in solar parabolic trough collector to obtain optimum process parameters by K. Syed Jafar and B. Sivaraman (2015) using a statistical tool such as the design of experiments. From the results, it was observed that the significant increase augmentation in Nussle number and considerable friction factor can be obtained at high Reynolds number and low twist ratios parameters. Finally, from the experimental design and ANOVA using Design-Expert software, it was found that the twist ratio is the major parameter that influences absorber of parabolic trough collector performance. [12]Mr. Mohd. Rizwan et al (2014) carried out experimental analysis and verification of parabolic trough collector for water distillation. Parabolic trough collector was fabricated in a local workshop. They demonstrate the need to assess long-term system performance and possibilities of optimizing the optical efficiency or made it economically feasible by using new reflector materials and absorbing materials. The requirements for this specific design are a target for distilling water regularly with low maintenance. [13]Sri P. Mohana Reddy, Pathi Venkataramaiah and Devuru Vishnu Vardhan Reddy (2014) focused on selection of best materials for absorber tube and reflective surfaces of solar parabolic trough collector (SPC) using fuzzy logic, after analyzing the material data related to material properties such as price, thermal conductivity, density, temperature and corrosion. It is identified that Glass mirror and Aluminium tube are the best reflecting material and best absorbing material respectively. [14]Adel A. Ghoneim et al (2014) developed model to study the effect of different collector parameters and operating conditions on the performance of parabolic trough collector. The proposed model takes into consideration the thermal interaction between absorber-envelope and envelope-envelope for thermal radiation losses which have been neglected in existing model. Finally, the environmental impact of solar heating and cooling systems under Kuwait climate conditions is investigated. Present results indicate that convection loss from the absorber tube to supporting structures is the largest among the other losses (conduction and radiation). [15]Parabolic trough collector made of fiberglass-reinforced plastic with its aperture area coated by an aluminium foil with reflectivity of 0.86. Sagade, Atul A., Aher, Satish and Shinde Nilkanth (2013) Conducted experiment with mild steel receiver. From Indian condition, low cost FRP Parabolic trough system proves to be beneficial for industrial heating application as well as domestic heating. [16]Alok Kumar (2013) presented performance evaluation performance of solar isolation in terms of global solar radiation. On the basis of solar flux comparative study of the

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instantaneous efficiency of the solar parabolic trough is done. Comparative study of the instantaneous efficiency of the solar parabolic trough is done. Here four different type cover system is analyzed 1.single glass cover on the receiver, 2. Double glass cover on receiver, 3.single glass cover on aperture, 4.double glass cover on aperture. This report contains many graphs to illustrate the effect on instantaneous efficiency on the variation of primary parameter. [17]Pradeep Kumar K V et al (2013) conducted an experimental study of parabolic trough collector with different geometries and different types of reflecting and absorbing materials. Optical properties and degradation of different types of reflecting surface assessed. The experimental result shows that obtained characteristics of the tested Aluminum collector are considerably lower than that of a mirror collector. [18]Yadav, Kumar and Balram (2013) conducted experimental study and analysis of parabolic trough collector for air heater system air was used as working fluid which collects the heat from absorber tube. To enhance the performance of parabolic trough, a collector with a different type of reflectors were used. Efficiency by using the Aluminum sheet as reflector compared to Aluminum foil as a reflector is 18.98% more. [19]Experimental study on the model of Compound Parabolic Collector (CPC) system for the application of process steam generation conducted by Ajitkumar S. Guddekar et al (2013).It is easy for fabrication, operation and has a lower cost compared to other available concentrating solar collector systems with the further possibility of lowering the cost. The performance analysis of the system shows the potential of improving thermal efficiency up to 71%. [20]Design and fabrication of parabolic trough collector with aluminium sheet covered with cloth on which rectangular mirror strips by Singh S.K., Singh A.K., Yadav and S.K. (2013). Experiment conducted with two different absorber tubes were taken and the efficiencies of the plate where compared without glass cover on the absorber tubes. The efficiencies find that when without glass cover: aluminum tube receiver: 18.23%, copper tube receiver 20.25%. [21] Suple and Thombre (2013) designed and fabricated paraboloidal solar collector having aperture area 0.628 m^2, focal length 0.8, receiver area 0.015 m^2 and optical concentration ratio 40.Bi-axial tracking mechanism developed which can be operated from the kitchen. It can be tested for its thermal performance and cooking abilities. System was found useful in a variety of food material. [22]S. Umar et al (2013) Conducted experimental performance study of parabolic trough collector which was constructed and investigated under climatic condition of Dundaye at Sokoto Energy Research Center, Usmanu Danfodiyo University Sokoto, Nigeria. Collector was constructed using locally available material with focal distance 0.15m, 1.82m length of collector and depth of collector as 0.33m. The experimental test conducted to evaluate the collector showed that the maximum outlet water temperature attained was 110°C. [23] Sangotayo. E.O. et al (2012) reported a numerical investigation on the enhancement of thermal performance of solar air heater having cylindrical parabolic trough solar collector with twisted tape in weather conditions. Two dimensional fully developed fluid flow and heat transfer were studied. Instantaneous efficiency is finding 47.4% at optimal design parameters of 1.3m length and mass flow rate 0.036kg/s. At a high value of a Nusselt number, heat transfer coefficient is increased. Twisted tape in the absorber tube increases the thermal performance. [24]Operational performance and energy conversion efficiency of developed 15 KW solar chemical receiver/reactor for hydrogen production carried out by Jin H., Hong H. and Liu (2012).Solar receiver/reactor was tested at 200-300°C.They conclude that this temperature level was feasible for solar thermos-chemical process. [25]Yu Zitao et al (2012) designed a U-type natural circulation heat pipe system and experimentally investigated for generating mid-temperature steam. It was observed that thermal efficiency of the system was 38.58% at a discharge pressure of 0.5 MPa during summer time. This paper is based on the thermal performance of parabolic trough collector for heating of air. [26]Ansary and zeitoun (2011) performed a numerical study of the heat loss by conduction and convection from the half insulated annulus between two concentric horizontal cylinder receivers. It was observed that the addition of fiberglass insulation to the half of the annulus facing away from the parabolic trough has a positive impact on the reduction of convection heat losses by a maximum of about 25% compared to a conventional receiver. [27]Montes M.J. et al (2011) conducted experiment in which solar thermal the particular Integrated Solar Combined Cycle power plant proposed consists of a DSG parabolic trough field coupled to the bottoming steam cycle of a Combined Cycle Gas Turbine (CCGT) power plant. Hybridization between natural gas and solar power can be considered in two alternative ways. In this analysis, the solar thermal power plant performs in a solar dispatching mode: the gas turbine always operates at full load, only depending on ambient conditions, whereas the steam turbine is somewhat boosted to accommodate the thermal hybridization from the solar field. [28]Numerical investigation of performance of parabolic trough receiver with outer vacuum shell compared with non-evacuated shell receiver carried out by Yashwant J., Daniel and Das A.K. (2011).Performance of vacuum shell configuration performed better than non-evacuated tube without a selective coating and is better with selective coating. [29]Valentina A. (2010) performed work on Concentrated Solar Power and developed a solar parabolic trough in which medium temperatures is about 550°C. The synthetic hydrocarbon oil, which is flammable, expensive and unusable beyond 400°C, is substituted by a mixture of molten salts (sodium and potassium nitrate),

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widely used in the industrial field and chemically stable up to 600°C use as working medium. A storage tank is made of cone shape storage molten carbonate salts and combination with nitrate molten salts working at a maximum temperature of 565°C. [30]Garcıa A. Fernandez et al (2010) presented paper in which an overview of the parabolic trough collectors that have been built and the prototypes currently under development. It also presents a survey of solar system to supply thermal energy up to 400 °C, which is especially for steam power cycles for electricity generation. First commercial collectors used in U.S. Government's Sandia National Laboratories and Honeywell International Inc. Both collectors were quite similar in concept and were prepared to work at temperatures below 250° C. [31] Farooq and Raja (2008) made effort on effective solar coating resulted in enhancement of efficiency for the operation of solar apparatus. Increase in coating temperature radiation thermal losses may increases thus high thermal stresses in receiver tube. [32] Design and testing of fiberglass reinforced parabolic trough solar collector performed by Arasu and Sornakumar (2007).It was tested under a load corresponding to force applied by blowing wind with 34 m/s. They conclude that the deflection at the center of the parabola was only 0.95 mm with wind drag force load of 72 kg, which is considered adequate. [33]Loh Heng Chew et al (2016) perform the design, fabrication and monitoring system of a solar trough collector located in the energy park of the school of renewable energy technology at Naresuan University. A semi-analytical mathematical model developed for the collector also showed that simulated data had related closely with measured ones. [34]

3.DISCUSSION

The literature review reveals that researchers have conducted an experimental study on parabolic trough collector with different conditions. Researchers conducted experiments with different reflector materials, working fluids, tracking angles, solar insolation etc. Parametric investigation of different parameters on the performance of parabolic trough collector carried out. Some researchers fabricate the structure from the locally available material. These structures are used for rural point of view. Various software is used for performance optimization, Simulation. Comparative analysis of performance on basis of different parameters done. Performance optimization with or without thermal system was assessed. A trough with thermal system gave better performance.

Many researchers work for the selection of best material on the basis of material properties like thermal conductivity, reflectivity, density, temperature etc. Researchers used parabolic trough as a reactor for hydrogen production thermos-chemical process and for water distillation purpose with low maintenance. Some researchers used molten salt as working fluid alternative to synthetic hydrogen oil which is inflammable and expensive.

Some researchers used Fiber reinforcement plastic, polymers as an alternative to commercial materials like a glass mirror, aluminum etc. Manufacturing and fabrication of commercial materials are difficult. These materials are not economically feasible. Despite of giving high-performance material like glass mirror have no curability and it is difficult to assemble.

4.CONCLUSION

It is concluded that parabolic trough collector with a polymer as a reflector is economically feasible to design. The polymer can be used as alternative material to other conventional material. Hence there is need to test an alternative material which is economically feasible for the domestic and industrial application. A parabolic trough with the locally available material can be used as a solar thermal device in remote and local areas. It is environment-friendly solar energy conversion technology and suitable to use.

Also, there is scope to improve the thermal stability of polymer by using different reflector top coat for improving the thermal performance of the system.

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