Journal of Advanced Mechanical Sciences (JAMS)
ISSN: 2583-3790 (Online)
"J. Adv. Mech. Sci., vol. 1, no. 1, pp. 21-25, March 2022"

Studies on Solar Thermal Industrial Process Heating - A Review

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Article received: 01/03/2022, Article Revised: 21/03/2022, Article Accepted: 22/03/2022
Doi: 10.5281/zenodo.6482143

Abstract

As we all know the current dependency on nonrenewable resources is still around 85-90% worldwide. The nonrenewable resources which presently have less percentage contribution in power and heat generation have a great potential in the future. Many methods and techniques to harness the energy from these resources have already been developed and many yet are in progress. One of them is a solar energy which is present in abundance on our earth. The use of solar energy in power generation and process heating has vast applications ranging from residential to commercial sectors. The use of solar energy in industrial process heating can be utilized for many purposes depending on operating temperature ranges. Solar process heating is clean as it doesn't involve any fuel particles, dust, PM etc., and is also simple to construct and operate which ultimately leads it to one of the key options in power and heat generation throughout the world.

Keywords: *Thermal energy storage, Solar irradiation, Mathematical model.*

1. INTRODUCTION

There are many renewable energy resources present like wind, solar, ocean, geothermal, biomass, etc. The most popular of them is solar energy which we get directly from sun in terms of solar radiation. We all feel that when radiation strikes our body it causes our body temperature to rise because our body and cells absorb the energy associated with these sun rays. Similarly one can think of that how we can utilize this energy for process heating in industries or in our homes. As we all know that the industrial energy requirements are quite high for example in chemical industries the steam is required at around 350-400 °C. Another big example is of pulp and paper industries there also steam and hot water is required for making products from the rolls. The lots of steam and hot water requirements are majorly fulfilled by thermal a power plant which uses nonrenewable resources like coal, liquid fuel, etc. The steam after expanding in turbine is supplied to process plants which are further used for heating purposes. In other words we can say that the lot of heating demands of various industries in developing countries is still dependent on coal based power plant. Solar thermal is capable of fulfilling these requirements with added benefits like free availability, no pollution as it is clean energy, no dependency on geography, reliability, etc. The solar energy techniques in process heat is majorly grouped in three groups namely solar air collectors (SAC), solar water systems (SWS), and solar concentrators (SC). Air collectors find their applications mostly in food processing industries, solar water systems are generally used in residential applications operating in medium temperature around 80-90 °C and can be extended to industrial applications. Solar concentrators can give higher temperature around 400 °C and uses parabolic dish type collectors. The process usually involved heating a process fluid by means of the collector which further transfer heat by exchanger to process units to get hot water, steam etc. In developed countries nearly 50% of process heat requirement is covered by solar thermal. Despite all this still there is some challenges in integrating the systems with actual processes, optimizing the systems for major share, and deployment of systems for particular application.

2. EARLIER STUDY ON INDUSTRIAL PROCESS HEATING

Amendaet al. [1] in their studies focused on integrating methods in order to utilize maximum solar energy with minimum screen time, cost and other constraints. The pinch analysis for integration is used which focus on priori establishing objectives or variables before the design. In under different cases, they show how the cost and optimization both handled and simultaneously attained zero CO_2 emissions. Further study by [2] shows the use of parabolic trough reflector in process heat plant against load of 5mwt. The full technical, as well as economical analysis, is conducted to check plant performance and finally suggests solar thermal is best option as compared to natural gas plant. Neelesh et al. [3] points out the idea of storing thermal energy by use of storing system using mild steel block buried underground and circulation of CO_2 around it. The motive is to use this stored energy as a heat source especially in cold countries. The mathematical and numerical modeling is shown to evaluate the year round performance and its response characteristics under different loads. Shengqing et al. [4] analysed the selection of the best working fluid for heat pumps. The results are showed for heating applications greater than 20MW. The 2 configurations namely 2 stage compressions with an open flash economiser and low and high temperature cycles in series is analysed under the judging criterion of COP and suction side volumetric flow rate. The best working fluid is dependent on the heating load applications and availability of required properties is further which predicts the choice of working fluid.

Further studies [5] shown the use of baffle arrangement in evacuated solar tube collector to increase the thermal performance. The setup can provide the maximum temperature of 42.8 °C. The performance is analysed by varying parameters like flow rate, inlet temperatures, baffle geometry. Ultimately concludes that outlet temperature is strong function on inlet air temperature and baffle length increment show a good impact on performance but at a same time more pumping power. Willy et al. [6] in their studies shows the control strategies adapted under different solar collectors on a system integrated with TES in self-sufficient buildings. Minimum volume storage criterion for 100% solar fraction is taken for investigating numerically 3 systems namely HFC, LFC and VFC. The simulations shows LFC take less storage as compared to HFC and VFC. Thermal stratification and controller capabilities are proposed as reasons. Mingyang et al. [7] incorporated the phase change material in solar thermal system and experimentally analysed his performance and storage geometry. The test includes different amount of solar inputs by use of a controllable heater and investigates phase changing process of PCM. The result shows that at 85 °C temperature the PCM receives nearly stable heating power rate at around 6-8 kW.

Osama et al. [8] shows the comparison of solar collectors and solar photovoltaics to make selection easy for industries. The economical, technical and environmental point of view is considered and ultimately the solar mix design can be cost cutting as well as shows a reduction in carbon emissions. The literature gives the idea for industries to select a perfect balance mix as per their requirements. Fitsum et al. [9] lays the control and optimization framework which will help in decision making in industries incorporating solar energy. An experiment is conducted on dyeing industrial process to carry out the values of optimal variables under the constraint of payback time. Further studies [10] show the incorporation of solar steam boiler system which can replace the existing dependencies on fossil fuels or biomass. The solar steam boiler is analysed under 2 different thermal outputs at given average annual irradiation as per location. The solar steam production also serves economically under the geographical area having DNI of around 900Kwh/m^2. Fang and Xudong [11] studied the large scale seasonal borehole thermal energy storage system by using simulations and finally compared with real values. The whole system performance study requires clearly measuring the soil thermal properties. The exergy and temperature patterns are studied to identify the major cause of loss which ultimately affects the cycle efficiency. Further, proceed with sensitivity analysis to know the effect of various parameters on system design and found out that bore well geometry and flow circulation has a greater impact on performance. Lugo et al. [12] studied the numerical model of solar water heating system. The solar collectors, thermal storage tank and heating and other types of equipment are integrated as a part of setup to validate results experimentally. The statistical techniques are used to analyse the temperature variations, useful heat gain and various losses. The results showed that the major thermal losses are from connecting pipes that connect the storage tank to solar collector.

Kesari et al. [13] suggests the implementation of solar thermal heating in common industries like dairy, agriculture etc. In dairy hot water requirements for production as well as cleaning can be fulfilled by solar water heating systems like boiler. In agriculture the solar systems can be arranged as per different requirements like irrigation systems, domestic, feeding stock etc. Daniel at el. [14] proposes a method for sizing components for solar systems which have a seasonal thermal storage facility. With fewer inputs data like available climate data or annual average temperature the method gives underlying information regarding the aperture sizing and storage volumes. With no input data proposed interpolations techniques are used to determine the annual global and average solar radiation. Allouhi et al. [15] show the performance evaluation of compound parabolic collector. A mathematical framework is adapted to predict the performance equation. Many factors like output temperature, irradiation level, etc affect the performance directly. The test results are then compared with available standards. The deviation in performance is basically because of heat losses through manifold and piping, soiling of reflector, measurements errors and loss in a vacuum etc.

3. CONCLUSION

As a result, from the literature review discussed above the different areas that will be covered in this study are as follows.

- Solar thermal energy for process heating in industries is helping us in reducing carbon and other form of emissions.
- Depending on the heating load and temperature required various solar thermal systems designs can be modelled and also they can combine to get hybrid models.
- Performance evaluations under varying loads and operating conditions are done by using numerical techniques and simulation.

Acknowledgement/Funding Acknowledgement

The author(s) received no financial support for the research, authorship, and/or publication of this article.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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