

Article of Review on Computational Analysis on Performance of Solar Pond using Polycrystalline Material

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Abstract: The Solar pond is a pool of salt water stratified into 3 different layers, when radiations from the sun heats up the pond this heat energy gets stored in the lower most layers, thus making it as a heat source. Latent heat thermal energy storage is constantly an attractive method to store thermal energy due to because of its capacity to give high energy storage density and it also has a property to store heat at almost constant temperatures equivalent to the phase transition temperature of phase change materials (PCM). The aim of the thesis is to develop a CFD-based simulation analysis model of solar pond to analyze the double-diffusive nature of temperature and the saline concentration distributions, also to form a stable three-layer system of energy storage using computational fluid dynamics. The main objective of this study was to design solar pond modal with three layers in it and also to explore the effects of addition of material with high conductivity on the characteristics of heat transfer of pure PCM.

Keywords: Solar Pond, PCM, Conductivity, Thermal Energy, Computational Fluid Dynamics.

I. INTRODUCTION

A solar pond is a sort of a solar energy collector, generally, fairly large in size, that looks like a pond. This type of energy collector uses a large, salty lake as a kind of a flat plate collector that absorbs and stores the sun's energy in the lower most warm layers. These ponds can be natural or man-made, but generally the ponds that are in operation today are mostly artificial.

The main reason why the solar ponds function very effectively is due to the salt concentration gradient property of water. Due to this gradient, the water which is heavily salinated gets collected at the bottom and gradually the layers of the pond become cool and less salinated with fresh cool water at the top

of the pond. This layer at the bottom which is heavily salinated is known as "storage zone" whereas the top layer consisting of fresh water is known as "surface zone". The pond throughout is several meters deep, and storage zone is about one to two meters thick.

The ponds should be cleaned regularly for proper functioning, because if the water is murky the sun's radiation cannot penetrate through. When sunlight is incident on these ponds, most of the sunlight reaches the bottom and therefore the "storage zone" heats up. However, this newly heated water cannot rise and thus heat loss upwards is prevented. The salty water is heavy as compared to the water on the top layer which is fresh and thus the water from the bottom layer cannot rise to the top and thus the upper layer prevents convection currents from forming. Because of this, the top layer of the pond acts as a type of insulating blanket, and the main heat loss process from the storage zone is stopped. Without the loss in heat, the ponds bottom is warmed up to extremely higher temperatures - it can reach about 90°C. If the pond is used to generate electricity this temperature is high enough to initiate and run an organic Rankine cycle engine.

II. LITERATURE REVIEW

Panchal et al. (2020) [1] presented the experimental analysis of the single-basin solar stills which had attachments of fins which were porous on the absorber plate. Here, the experiments were conducted on single-basin solar stills with attachment and without attachments of porous fins. Generally speaking, fins are usually used in the solar stills in order to reduce the water's preheating time and achieve positive water and also to attain cover temperature of inner glass during morning hours for increase in the distillate output.

Adhikari et al. (2020) [2] introduced many approaches of ponds design and suggested use of Pond-In-Pond (PIP)

approach as a more apt design for the purpose of reusing, PIP is mostly the integration of two sorts of ponds

:- aerobic and anaerobic.

Anagnostopoulos et al. (2020) [3] Developed a CFD simulated model in its work in order to obtain an all over versatile which is practically applicable to most practical scenario. Also, they compared the results that were obtained using one dimensional MATLAB model and the two and three dimensional CFD models. These results developed in its work has also been carried out in order to increase the computational resources needed and to make a gain in the accuracy.

Sogukpinar et al. (2020) [4] introduced solar ponds temperature distributions numerical study in turkey and this investigation was compared with the experimental data for that district. For this, they considered the previously conducted experimental data and developed a prototype salinity gradient solar pond which had a square cross-sectional area and also had seven layers and then, they used a commercial software known as COMSOL to conduct a numerical method using finite element analysis.

Panchal et al. (2020) [5] presented the use of SP so that it improves the yield of solar still (SS) by providing hot water through the heat energy stored in it. in order to improve the yield they also mention the use of shallow SPs and mini-SPs with SS. Many future works on SS using SPs have been included in this paper. It has been concluded from the current research paper that SP increases the yield of SS.

Abu-Hamdeh et al. (2020) [6] An experimentally validated numerical simulation of the modified version of solar ponds employed with spiral piping systems was presented. The main part of the solar ponds that enhances its performance is the piping system in the solar ponds, so far has not been considered appropriately. To enhance this field, the spiral piping systems wall was grooved (this piping system is placed at the lower convective zone (LCZ).

S El-Sebaeya et al. (2020) [7] proposed a three-dimensional CFD model which is multi phased, it basically helps to predict the performance of a Solar Still without carrying out any experimental measurements, that depends on CFD (solar radiation) model. It then Generates Simulated results and is compared with the experimental values of water and glass cover temperatures and also the yield of fresh water in the climatic conditions of Sheben El-Kom, Egypt (with latitude 30.5° N and having longitude 31.01° E).

Yousaf et al. (2019) [8] They presented in this paper a Diffuser design for the developments of solar pond and it consists of an intricate study to overcome the effects of buoyancy in a stratified region and extended the range of plume emanated from the diffuser. Diffusers of varying designs and shapes including diffusers with round and rectangular outlets have been made to work in solar ponds over the past few years.

El Kadi et al. (2019) [9] presented that salinity and temperature gradients which are well established are the key points to achieve optimum efficiency for storage of heat. In this project, a higher-fidelity model is made to developed using the software of computational fluid dynamics (CFD) in order to simulate the behaviour of SGSP under hot climatic conditions or regions. This model has the ability to simulate the effect of double convective by solving Navier-Stokes equation and energy equation, side by side.

Rabhy et al. (2019) [10] proposed a new solar distiller which is fully transparent and it is designed in such a way so that it can be integrated into a roof of an agricultural greenhouse. It uses the excessive solar radiations in order to produce desalinated water for the irrigation of the plants. A numerical technique is normally presented so that the performance of the distiller can be analysed. This numerical technique consists of a lumped model based on transient mass and energy balance equations for different distiller components and is coupled with a computational fluid dynamics (CFD) model so that it simulate the flow, and heat transfer, and the phase change of a humid air and water with a free surface inside a distiller.

Murali et al. (2019) [11] In this research work numerical studies are carried out and then by simulating flow through a solar airborne heater the results are simulated and generated as continuous flow into a duct which is rectangularly shaped and has artificial ribbed bottoms surface. Ribs having dissimilar cross-sectional areas including triangular ones, semi-circular ones, rectangular and arc ones in shape. They are mainly considered for numerical analysis. At the bottom most surface of the duct which is shaped rectangularly, uses constant heat flux boundary conditions.

Balachandran et al. (2019) [12] presented an experimental validation and the still specifications using ANSYS CFD designing. The results that were obtained from ANSYS were mainly compared with the results obtained by conducting experiments in still. There is only a small variation obtained when comparing both the results were shown in this research paper. ANSYS is best suited tool to check the still efficiency before designing it in real time.

Passos et al. (2019) [13] They presented Two types of full-scale maturation solar ponds, at about different operational settings, it was modelled and proposed. This paper work was conducted to consider the gaps that exists in literature in regards with the CFD modelling in the ponds, such as the geometric conformations of the accumulated sludge at the bottom; also dynamic models that represents environmental conditions (like wind, solar radiations, and air temperatures), and the approximation of physical properties of the fluid to the real conditions, and buoyancy etc., all together in one unified model.

Nayak et al. (2019) [14] studied the dependency of the limiting values of the heat flux at the input for the thermoelectric

generators (TEG) which are solar assisted, on the Angle of Attack (AOA) and also winds direction of the heat sink of TEG. Recent study sets the limiting input of heat flux for TEGs with the hot side temperature of 150 °C which is to the allowable degree.

Mahizan et al. (2019) [15] filled the solar pond with saline water of increasing densities from top of the pond to the bottom of the pond as the solar radiation was absorbed at the bottom of the pond. This research work mainly focuses on the construction of a kind of a salinity gradient solar pond and propose the means to maintain the conditions of the solar pond. The parameters of water, such as the temperature, density and its pH value in solar pond, was obtained as a part of maintenance and stability of the pond.

El Kadi et al. (2018) [16] presents a numerical model using computational fluid dynamics (CFD). It acts as a first step in the designing and building of a solar pond which is located in Masdar City mostly for space cooling and desalination purposes. This model is mainly governed by species transport, continuity, energy and momentum equations of naturally convected, transient and non-isothermal flows.

Kasaeian et al. (2018) [17] concluded and studied the recent achievements in the development of solar pond. firstly, the novel salts and the additives for the improvement of the thermal properties of the solar pond solution were introduced. Secondly, the innovative designs and models for reduction of the heat losses from top and the bottom layers of the solar ponds are considered and presented in this paper.

Mashayekhi et al. (2018) [18] presented steady and laminar flow of the hybrid Al_2O_3 -Cu/water nanofluid. Research is done for the volume fraction of the solid nanoparticles which is around 0–2% in a double-layered microchannel containing sinusoidal walls.

El Mansouri et al. (2018) [19] presented A two-dimensional numerical model to simulate a solar gradient solar pond's behaviour having dimensions of $1*1*1$ m³. In this model, the numerical code takes into account a double-diffusive convection property in the pond, and also the absorption of solar radiation through the horizontal layers, this allows proper treatment of the boundary conditions at the free surface of the water. This transient evolution of SGSP's make up for the first five days of July 2011 under certain weather conditions of Marrakesh – Morocco.

Ding et al. (2018) [20] presented a research paper that reviewed the thermoelectric generators and established that thermoelectric is gaining more attention than the past decades. Generally speaking, the research conducted on thermoelectric generators, concentrate on the development of materials, development of numerical and mathematical models also the applications and uses of thermoelectric generators. For this paper, the main attention is mostly given to the research of applications of the thermoelectric generators.

Giestas et al. (2017) [21] presented a numerical model in which the solar gradient solar ponds dynamics is outlined in terms of pressure, velocity, concentration of the salt and temperature. This model is formed on the bases of Navier-Stokes equations for incompressible fluid, coupled with two advection-diffusion equations: one is for the temperature and another one is for the salt concentration. The density ρ of the fluid mainly depends on salinity and temperature and the Boussinesq hypothesis is considered. The variation in daily solar radiation and its attenuation along the depths of the solar pond are also taken into considered.

III. CONCLUSION

The solar pond is basically a pool of water that is sort out into three different layers namely the top convective zone (UCZ), non-convective zone (NCZ) the middle one, and lowermost convective zone (LCZ). This paper presents the review of the past works done on solar ponds using computational fluid dynamics (CFD). Almost every one of the examinations concerning heat transfer enhancement have recommended that utilization of high conductivity materials yet there is absence of research work about enhancement of heat transfer using polycrystalline materials. It can be an another path in terms of increase in the heat transfer rate of the HTF, also effectively utilizing the heat which is stored with the help of phase change materials(PCM).

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