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Design & Development of a Solar Pond and CFD Modeling

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Abstract- A solar pond is indeed a solar energy collector which resembles a pond and is often rather large in size. A form of solar energy collector are using a huge, saline lake as a flat plate collector, absorbing and stores solar energy in the pond's warm, bottom layers. Those pond images are fascinating. Solar ponds can be natural or man-made, although most of the ones in use today are artificial.

Keywords- Sali, solar energy etc.

I. INTRODUCTION

A salt-concentration gradient in the water is indeed a critical feature of solar ponds that allows them to function efficiently as solar energy collectors. This gradient causes intensely salivated water to concentrate at the pond's bottom, the concentration diminishing as it approaches the surface, resulting in cold, fresh water there at pond's top.

The bottom of both the lake has a collection of saline water known as that of the "The freshwater top layer was defined as the "surface zone," whereas the storage zone is recognized as the "storage zone." The "storage zone" is many meters deep in the overall pond "with a depth of one or two meters.

While sunlight could indeed reach to the pond's bottom if indeed the water is murky, these ponds should be clean in order to function properly. "As sunlight falls on these ponds, the majority of the incoming light reaches the bottom," heating up the "storage zone." "This newly heated water, on the other hand, cannot ascend, preventing heat loss upwards. Since saline water was heavier than that of the fresh water on the surface of the pond, this can rise, and thus the upper layer prevents convection currents from developing.

As a result, the pond's top layer works as just an insulating blanket, preventing the major heat loss process from of the storage zone. The bottom of the pond is heated to extraordinarily high temperatures - about 90°C - while losing any heat. This temperature is high enough just to start and run an organic Rank in cycle engine if the pond is now being utilized to generate electricity."

For order for such ponds to function, the salt concentrations and low temperature of both the top layer must be maintained. Winds plus heat loss from evaporation keep the surface zone mixing and chilly. Because the salt from the bottom layer diffuses across the saline gradient over time, the top zone must be flushed using fresh water on the regular basis to guarantee that no salt accumulates inside the top layer. In furthermore, to compensate for just about any upward salt losses, a solid salt or brine combination must be fed to the pond on a regular basis.

II. PAST STUDIES

Panchal et al. (2020) [1] "the experimental investigation of a single-basin solar always with porous fins attached to the absorber plate was given. Experiments were carried out on a single-basin solar still with and without the addition of porous fins. Fins are commonly employed in solar stills to shorten water preheating time and achieve positive water and inner glass cover temperatures during the morning hours, resulting in increased distillate yield.

Adhikari et al. (2020) [2] discussed several pond design ideas and advises the adoption of a Pond-In-Pond (PIP) strategy to reuse purposes, wherein PIP is the combination of two types of ponds—anaerobic and aerobic. The findings of recent studies that used

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Computational Fluid Dynamics (CFD) to analyse a flow-diversion mechanism, as well as performance data from current PIP systems, demonstrate that now the PIP is a viable idea for wastewater reuse systems.

Anagnostopoulos et al. (2020) [3] provided In just this study, a CFD simulation setup was constructed in order to generate a fully adaptable model that can be used to any actual circumstance. A comparison of the findings obtained using an existing one-dimensional MATLAB model and the two- & three-dimensional CFD models generated from this study was also conducted in order to assess the improvement in accuracy and processing resources required.

Sogukpinar et al. (2020)[4] "A numerical examination of the temperature distribution of solar ponds in Turkey were performed and the results were compared to experimental data for a particular district. For this, a prototype salinity- gradient solar pond with square cross- section with insulated wall and with seven layers was modeled by considering previously conducted experimental studies, and then, numerical method was conducted by using Finite Element Method with commercial software COMSOL. The data for temperature & sun radiation came from the General Directorate of Meteorology, where they've been measured since 1927.

Panchal et al. (2020)[5] suggested the need for an SP to increase the production of a solar still (SS) by supplying hot water via the heat energy stored inside of it. This also demonstrates how shallow and small SPs may be used with SS to increase yield. This report also includes a list of future research projects on SS utilizing SPs. According to the present review report, the SP boosts the yield of both the SS. Abu-

Hamdeh et al. (2020)[6] provided a numerical simulation of the improved spiral pipe system used in solar ponds, along with experimental validation. The much more essential component of both the solar ponds because affects its effectiveness would be its piping system, that hasn't been adequately examined thus far. Grooving the spiral piping system's wall to enhance this field (which is considered to be placed at the lower convective zone (LCZ))" was adopted as an improvement mechanism.

S El-Sebaeya et al. (2020)[7] "presented multi-phase, three-dimensional CFD model, which predicts the performance of the solar still without using any experimental measurements, Dependent here on CFD model of solar radiation. Simulated water and glass cover temperatures, but also fresh water output, are compared to experimental values in Sheben El-Kom, Egypt (latitude 30.5° N and longitude 31.01° E).

Yousafet al. (2019)[8] presented Diffuser design for evolution of solar pond and detailed research to overcome the effect of buoyancy in the stratified region and extend the range of plume emanated from the diffuser. Over the last few decades, diffusers of various designs and forms, including diffusers with round and rectangular outputs, have been used in solar ponds." Despite the fact that experts had found that semi-circular diffusers with rectangular slots are much more efficient, only limited study has been done using Computational Fluid Dynamics to corroborate those findings. The focus of the study is on diffuser designs and comparisons, as well as computer examination of the influence on the originating flow.

El Kadiet al. (2019)[9] "given the important criteria for achieving maximum efficiency levels are well-established salinity and temperature gradients. In the this work, a high-fidelity model based on computational fluid dynamics (CFD) is constructed to predict the behaviour of the SGSP in hot climate regions. The model can mimic the double convective effect by concurrently solving the Navier- Stokes and energy equations. Brines of various salinities (i.e. 10%, 15%, and 25%) were employed to examine their impact on the formed salinity/temperature gradients.

Rabhy et al. (2019) [10] revealed a novel entirely transparent solar distiller that is meant to be incorporated into in the roof of an agricultural greenhouse to create desalinated water for plant irrigation using surplus solar radiation. To analyse the distiller's performance, a numerical approach is suggested. This method combines a lumped models for various components of both the distiller depending on transient mass and energy balance equations with such a computational fluid dynamics (CFD) model to simulate the flow, heat transfer, and phase change of humid water and air with such a free surface within the distiller.

Muraliet al. (2019)[11] In simulating flow via a solar airborne heater and continuous flow into a rectangle

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shaped duct having artificially ribbed bottom least surface, numerical investigations have been carried out and findings are reported. The numerical analysis takes into account ribs with different cross-sections, such as triangular, semi-circular, rectangular, and arc in form.

At the bottom of both the rectangular shaped duct, a constant heat flux boundary condition was utilized. “Heat transfer rates for flow through a rectangular shaped duct with such a flat bottom most surfaces were compared to ribbed bottom least surface values.

III. RESEARCH METHODOLOGY

CFD is indeed a strong tool for predicting fluid motion in diverse conditions, allowing for correct design, thanks to developments in computer technology and accessible numerical methods. CFD is just a sophisticated method of analyzing not only fluid flow behavior but also heat or mass transport processes.

“The standard continuity equation for mass conservation, Navier–Stokes's equation for momentum conservation, and energy equations for forecasting conjugate heat transfer are the governing equations.

In this numerical analysis, the following assumptions are assumed:

- Steady fluid flow and heat transfer
- Incompressible fluid
- Turbulent flow
- Negligible radiative heat transfer

1. Model Description:

1.1 Physical Model:

At first a solid model of the solar pond without the three layers of the solar pond was designed. This model was created to see the thermal activity of the pond with fresh water and saline water so as to compare the thermal results with the double diffusive model of the solar pond with three different layers. Then the solid model with the three layers was created to see the fluid dynamics and the thermal analysis of the three zones.

This solid modeling was done to see the temperature distribution in the Lower Convective Zone and to analyze the temperature difference between the Lower Convective Zone and the Non-Convective Zone.

1.2 Description of the Solar Pond Geometry:

The dimensions assumed for this solid modeling are: [23]

- Length: 600mm
- Breath: 600mm
- Depth of UCZ= 200mm
- Depth of NCZ = 200mm
- Depth of LCZ = 200mm

Along with the solid modeling of the solar pond a 3-D model of the pipe. (assumed as SS 302 material) was also placed at the bottom of the solar pond to see the heat flux and the convective properties that might affect the temperature flow in the pond.

The dimensions of the pipe are, Length: 2.75mm

- Radius: 0.1m
- Depth at which it was placed: 1.3m

In case 1, the inlet and outlet of the tube are kept at same side of the solar pond. THE inlet temperature is increased from 300 k to 340 k in the steps of 20 and the outlet temperature is computed. The model consists of three zones, UCZ, NCZ, and LCZ. In this case, the both inlet and outlet of the tube are kept at same side.

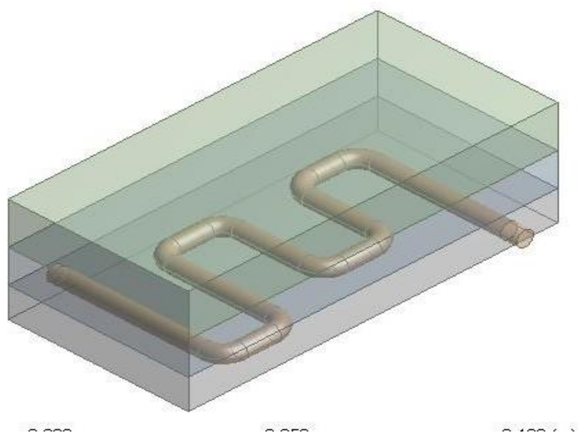

Fig 1. CFD Model.

1.2 Phase Change Materials (PCM):

“Latent heat thermal energy storage system utilizing phase change materials (PCMs) is an productive method for storing thermal energy and has lots of benefits of isothermal nature of the storage process density and high-energy storage density. Phase Change Materials have been broadly utilized for latent heat thermal storage systems for various application such as heat pumps, solar application, and spacecraft applications.

Although conventional PCMs offer high energy density, slower rates of melting and solidification limit the potential applications of LHTS systems in practical systems. This is due to the fact that all the conventional PCMs –both organic and inorganic possess very low thermal conductivity ranging from 0.1-0.6 W/m.K.

There is a list of thermal conductivity values along with latent heat values for few PCMs, which are generally used for investigation. [23]"

Table 1. **Text Here Your Table Title.**

Material	Thermal conductivity (W/m-K)	Latent Heat offusion (kJ/kg)	Specific heat (kJ/Kg-K)	Density (Kg/m^3)
Paraffin wax	0.224	118722	2345	789
PCM plus Al_2O_3	0.256	140000	2500	823

"Thermo physical properties of the PCMs and fin material are independent of temperature. But these properties are different for solid and liquid phases of PCM.

Following assumption should be considered before starting analysis work:

- PCM is initially in solid phase.
- PCM is homogeneous and isotropic.
- The mode of heat transfer is conduction only."

IV. RESULTS AND DISCUSSION

In this chapter details of computational model and analysis results are presented. Computational analysis includes evaluation of the following three characteristics of solar pond:

- ANSYS steady state thermal analysis without convection
- CFD thermal analysis flow and temperature with heat absorbing/collecting module for energy Storage and transfer for desalination plant.
- CFD coupled thermal and concentration analysis to evaluate double diffusive effect on the stratification of solar pond.
- Evaluate energy storage capability of the solar pond in LCZ and heating of the collection module for the desalination plant.

Heat transfer analysis has been used to obtain the heat balance analysis for such constructed pilot solar pond in just this study. THE inlet temperature is varied from 300 K to 340 K in the steps of 20 and the outlet temperature is computed for the two cases i.e with and without PCM.

Additionally, in each case, the position of the tube is changed and the temperature variation is tabulated.

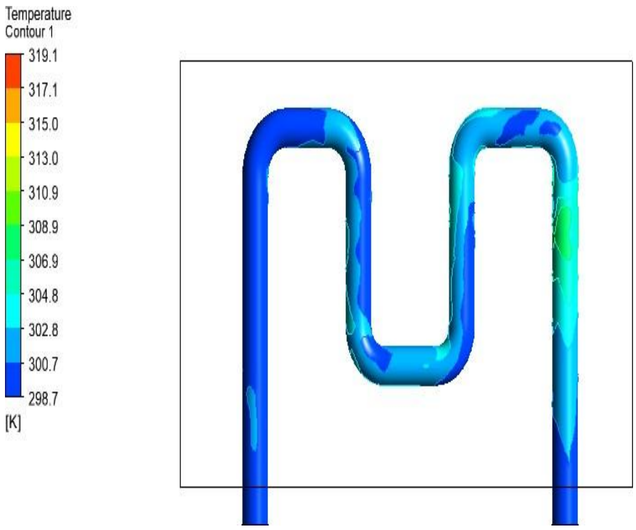

Fig 2. Temperature Contour for the pipe.

From the colour of the pipe in the above figure it is evidence that the outlet temperature (greenish colour) is greater than inlet temperature (blue colour). The temperature of the fluid is increasing while travelling from one end to another.

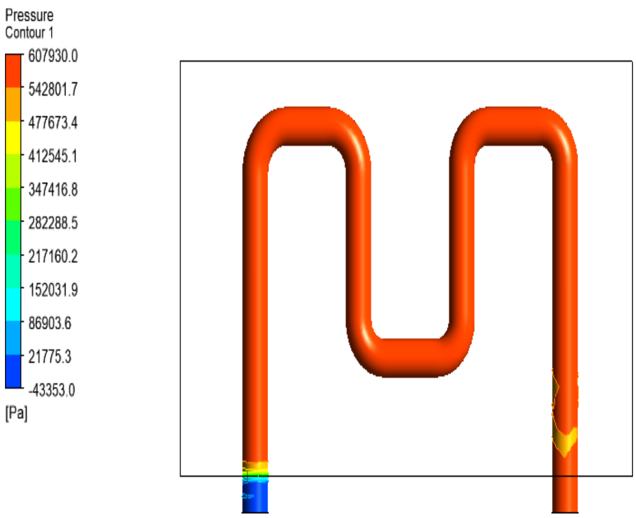

Fig 3. Pressure Contour for the pipe.

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From the colour of the pipe in the above figure it is seen that the pressure of the fluid is almost constant throughout the pipe. The maximum pressure achieved is 607 kpa.

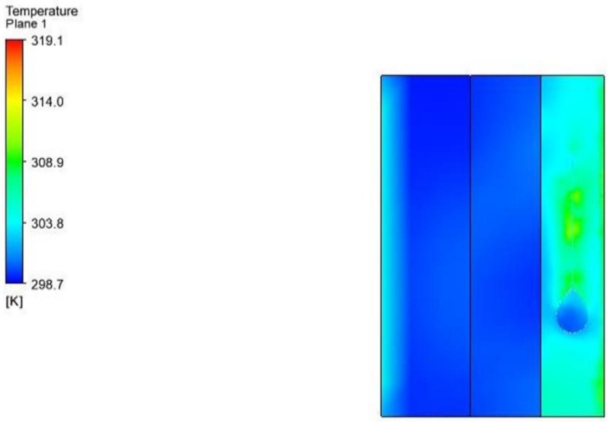

Fig 4. Total temperature of the water pond viewed from the Z-Y axis.

From the colour of the pond surface in the above figure it is seen that the temperature in the LCZ is maximum. Also the temperature at the top UCZ is also greater as compared to other zone. This is due to contact of the direct sunrays to water.

V. CONCLUSION

Solar pond and the heat from solar radiation heats up a pond, its heat energy is retained inside the lowermost layer, allowing it to function as both a heat source. From the literature review the following can be drawn as gaps in the current research work.

“Latent heat thermal energy storage is constantly attractive method to store thermal energy due to because of its capacity to give high energy storage density and its property to store heat at nearly constant temperature to the phase transition temperature of phase change material (PCM). The prime objectives of the study were to design solar pond with the three layers of the solar pond and to explore the effect of addition of high conductivity material on the heat transfer characteristics of pure PCM which are successfully achieved.”

In this study, the inlet temperature is varied from 300 k to 340 k in the steps of 20 and the outlet temperature is computed for the two cases i.e with and without PCM. Additionally, in each case, the position of the tube is changed and the temperature variation is tabulated.

In case when tubes are kept at same side, the performance of solar pond with PCM plus nano particles is better than solar pond with PCM by 3.76% when inlet temperature is kept at 300 K. When inlet temperature is increased by 340 K, performance is also increased by 43.59%.

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