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Experimental and CFD Analysis of Solar Water Desalination System

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Abstract
The thesis discusses the performance analysis of an active solar desalination system with boosting material. The variables used in this work are solar intensity, glass cover inlet temperature, glass cover outlet temperature, basin temperature. The fresh water output is increased considerably by using an active solar desalination system. ANSYS software are used to identifying flow variation on solar system. This paper deals with the thermal and CFD analysis of single basin single slope solar still. The modeling of still is done in Pro-E software and CFD analysis in ANSYS. Experimental and CFD analysis for different dates of solar irradiance was carried out. Maximum production rate and temperature distribution in the still is analyzed.
Keywords: *Solar, Radiation, CFD, Solar distillation*

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I. INTRODUCTION

Water is a gift of nature and it plays a key role in the development of an economy and in turn for the welfare of a nation. Non-availability of drinking water is one of the major problem faced by both the under developed and developing countries all over the world. Around 97% of the water in the world is in the ocean, approximately 2% of the water in the world is at present stored as ice in polar region, and 1% is fresh water available for the need of the plants, animals and human life. Today, majority of the health issues are owing to the non-availability of clean drinking water. In the recent decades, most parts of the world receive insufficient rain fall resulting in increase in the water salinity.

1.1. ACTIVE AND PASSIVE SOLAR STILLS

According to the type of input energy, the solar stills are classified into Passive and Active solar stills. In case of passive solar still, only solar energy is used for distillation purpose. In a passive solar still, the solar radiation is received directly by the basin water and is the only source of energy for raising the water temperature and consequently, the evaporation leading to a lower productivity. This is the main drawback of a passive solar still. Later, in order to overcome the above problem, many active solar stills have been developed. Here, an extra thermal energy is supplied to the basin through an external mode to increase the evaporation rate and in turn improve its productivity. The active solar distillation is mainly classified as follows:
(i) High temperature distillation—Hot water will be fed into the basin from a solar collector panel.
(ii) Pre-heated water application—Hot water will be fed into the basin at a constant flow rate.
(iii) Nocturnal production—Hot water will be fed into the basin once in a day.

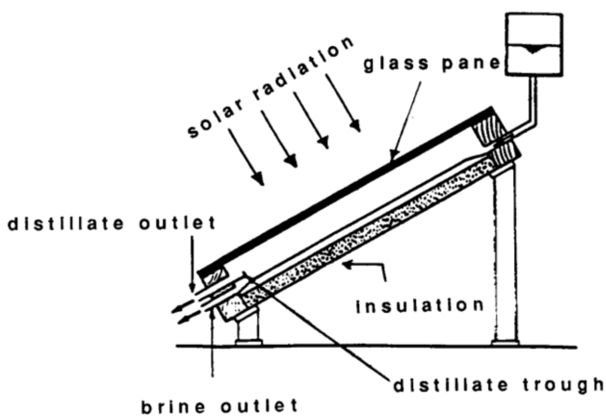


Figure 1.1 Inclined solar still

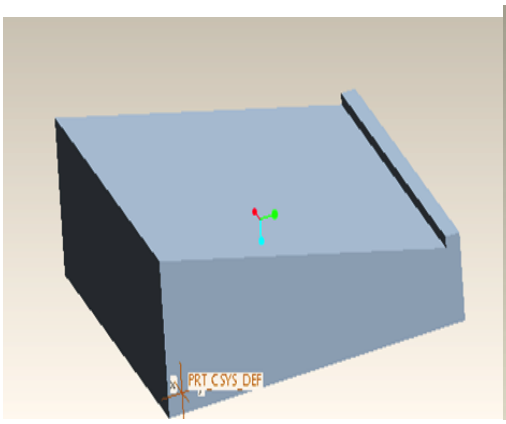
The major parts of a solar still are given below.

- Basin
- Black Liner
- Transparent Cover
- Condensate Channel
- Sealant
- Insulation
- Supply and Delivery System

II. MODELING OF SOLAR DESALINATION SYSTEM

2.1. MODELLING OF SOLAR SYSTEM

CAD modeling software is dedicated for the specialized job of 3D-modeling. The model of the solar system structures also includes many complicated parts, which are difficult to make by any of other CAD modeling as well as Finite Element software. CAD modeling of the complete solar system structure is performed by using PRO-E 4.0 software. PRO-E is having special tools in generating surface design to construct typical surfaces, which are later converted into solid models.



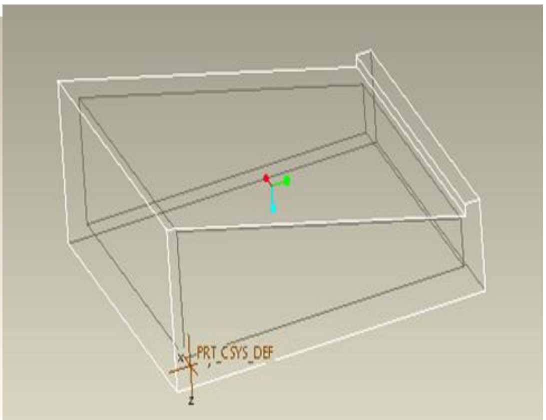


Figure 2.1.Shows the solid model of solar system. Figure 2.2.Shows the wire frame model of solar system.

III. EXPERIMENTATION

3.3.1EXPERIMENTAL SETUP

Experimental setup consists of single basin type solar still with inverted tapper type roof made up of plain glass. The basin of the still is made by wood and the side walls are made by wood and all the parts are painted black for better solar radiation absorption. The length and breadth of the solar still are 1 m and 1.0 m respectively. The side walls and the bottom of the still are well insulated by wood dust to minimize heat loss. An air pump is fitted and the outlet of which is connected to the holed pipe, which is fitted inside the basin. The top cover of the still is made by transparent glass with 3 mm thickness. A slope which is equivalent to that of the latitude (approximately 110) of the place is maintained for the roof. GI channels have been provided at the lower end of the glass cover to collect the fresh water. Two temperature absorbers are used (copper and aluminum west).They are used to improve output water.

Figure 3.1.shows the experimental setup model.

The still is made active by fitting an air pump of 2.5 l/min capacity. The output of the pump is connected to the still through a pipe which is fitted at the bottom of the basin and immersed in water. At the basin, the pipe is perforated to produce air bubbles, which made the still active. The still can be used as both active and passive by selecting the air pump in on and off position. Water is supplied to the still from the tank, which is fitted on a stand near by the still. The basin of the still is filled with water at a height of 5 cm. Pyrometer is used to collect the total solar radiation received on a region per unit area. It has a bulb like receiver at the top.

Readings

Table3.1.shows the water collection reading without any boosting material

DATE	TIME (HRS)	NORMAL TANK TEMPERATURE (^{0}C)	SOLAR SYSTEM TEMPERATURE (^{0}C)	COLLECTION OF PURE WATER (ML)
5/03/2021	9.00 am	28	41	0
	10.00 am	29	53	0
	11.00 am	29	59	0
	12.00 pm	29	61	200
	1.00 pm	29	63	230
	2.00 pm	29	62	200
	3.00 pm	29	57	0
	4.00 pm	29	49	0
Total water collection				630

Table3.2.shows the water collection reading with copper boosting material.

DATE	TIME (HRS)	NORMAL TANK TEMPERATURE (^{0}C)	SOLAR SYSTEM TEMPERATURE (^{0}C)	COLLECTION OF PURE WATER (ML)
10/03/2021	9.00 am	28	41	0
	10.00 am	29	53	0
	11.00 am	30	60	0
	12.00 pm	30	62.5	230
	1.00 pm	30.5	65	260
	2.00 pm	30.5	63.5	225
	3.00 pm	29	59	0
	4.00 pm	29	52	0
Total water collection				715

Table3.3.shows the water collection reading with aluminum boosting material.

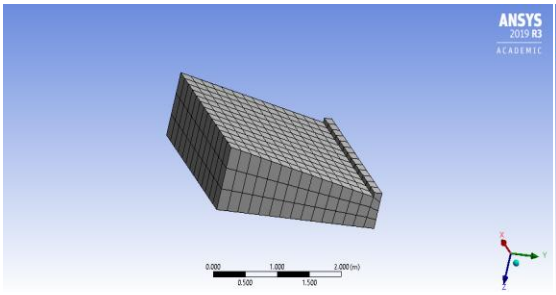
DATE	TIME (HRS)	NORMAL TANK TEMPERATURE (^{0}C)	SOLAR SYSTEM TEMPERATURE (^{0}C)	COLLECTION OF PURE WATER (ML)
15/03/2021	9.00 am	27	41	0
	10.00 am	28	52	0
	11.00 am	29	60	0
	12.00 pm	30	62	220
	1.00 pm	30	63.6	245
	2.00 pm	30	61.8	200
	3.00 pm	29	57.6	0
	4.00 pm	29	52	0
Total water collection				665

IV. CFD NUMERICAL ANALYSIS

4.1. MESHING ANSYS CFD & BOUNDARY CONDITION

Meshing technologies provide physics preferences that help to automate the meshing process. For an initial design, a mesh (Tetrahedral) can often be generated in batch with an initial solution run to locate regions of interest.

Initially, IGES files of air domain, single slope solar still can be imported to Ansys. The domain is meshed by using CFD with tetrahedral elements and the global element scale factor 1. In the mesh generation 35362 nodes, 170791 elements are generated. Near the wall of the solar still the elements were created so as to capture the fine boundary layers. Patch dependent method is used for meshing. After application of smoothing the mesh quality of 0.3 was obtained.



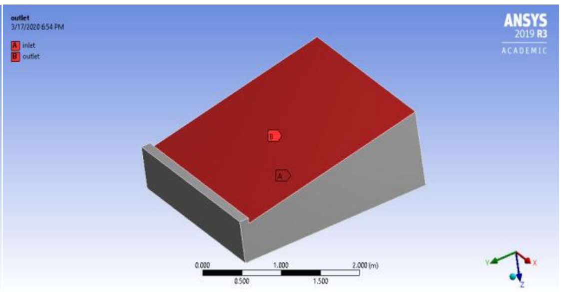


Figure 4.1.Shows the mesh model of solar system

Figure 4.4.Shows the boundary condition of solar system.

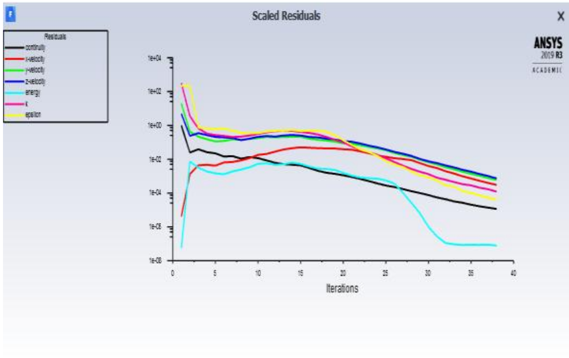


Figure 4.3.Shows the Iteration of solar system

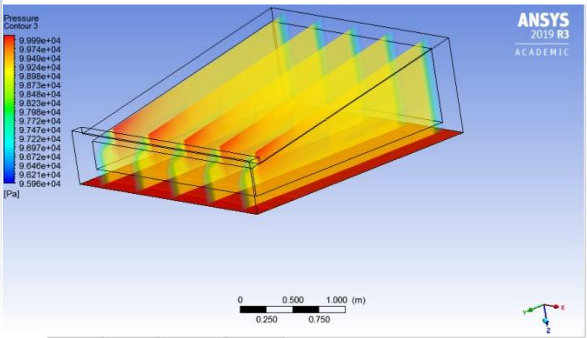


Figure 4.4.Shows the pressure distribution of solar system bottom area.

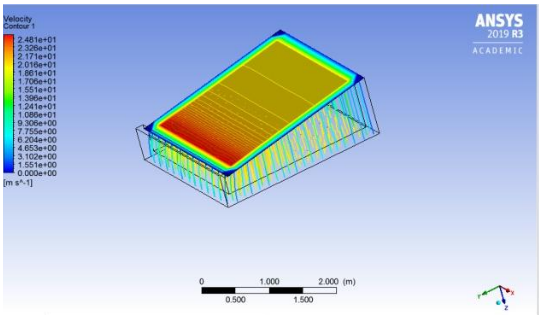


Figure 4.5.Shows the velocity distribution steam line of system bottom to glass.

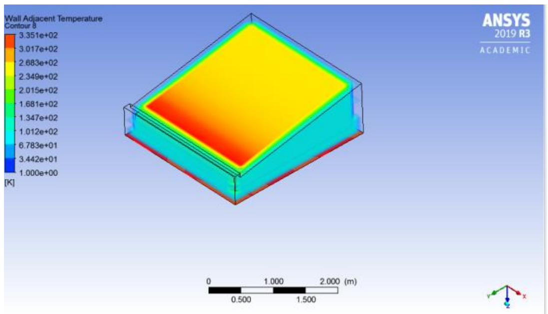


Figure 4.6. Shows the temperature distribution of solar solar system bottom.

V. RESULTS AND DISCUSSIONS

5.1. Computational Fluid Dynamic analysis.

Numerical results Computational Fluid Dynamic Simulations The performance of solar still depends upon the glass cover angle, depth of water, fabrication materials, temperature of water in the basin and insulation thickness which could be modified for improving the performance.

The flow patterns in solar still are shown in Figure with the help of velocity contour and vectors on vertical planes. The velocity vectors clearly show flow recirculation along with high velocity zones in the top and bottom portion with an intermediate low velocity region in the central portion. On the plane which is near the wall, the velocities are lower. The flow behavior can be considered suitable as the recirculating air will possibly drive / force the condensed water towards the distillate tray in the solar still device. The temperature contours in Figure shows variation of temperature in the vertical direction

This is due to high velocities as were discussed in Figure. The flow direction is mostly aligned with the two surfaces except near the corners (near the vertical surfaces) where the fluid takes a sharp turn. The flow seems two-dimensional as fluid movement is mostly in x-y plane. Heat transfer coefficient is found to be higher near the vertical wall with shorter height due to high temperature gradients as given in Figure.

Figure 5.3.Shows the static temperature in different position.

5.2. Experimental analysis.

The performance of still with boosting material and air pump is analyzed for the inverted single slop 'type solar still. The air pump increases the still output in case of active solar still. The air bubbles decreases the partial pressure ofwater and increasing the evaporation rate. The boosting material concentrates the incident radiation over the basin area and hence it causes the further increase of evaporation and water collection. The figure shows the variation of incident solar radiation received during the study as a function of time. The graph shows that the solar intensity increases with time and reaches a maximum at 12 .30 pm in all days and then decreases. Around 6 3.0 pm the solar intensity reaches a minimum as the sun drops at that time.

In case of passive solar stills (case 1 and 3) due to the boosting mirror the distillate output is increased. During night, the output remains same. The overall efficiency of the still is shown in below figures. The overall efficiency was obtained as 21.4 % and16.94 % for the passive still without and with the boosting mirror, and a similar experiment was carried out for the active still without and with the boosting mirror as 22.08 % and 13.11 % respectively. Though the yield was more, the efficiency was less for the still with the boosting mirror because the overall loss of this still was more due to the rise of the high temperature.

The variation of basin water temperature with time in each case. In the first day the basin water temperature reaches a maximum of 66.50 C at 4 30 pm. But in case of the system with air pump and booster mirror the maximum value reaches at 3 30 pm.Figure 5.4 shows the variations of temperature of the inner glass cover with respect to time.

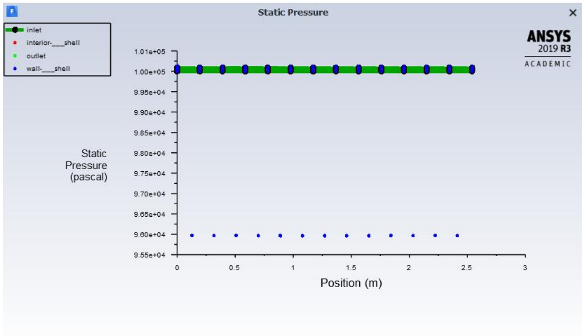


Figure 5.1.Shows the pressure in different position.

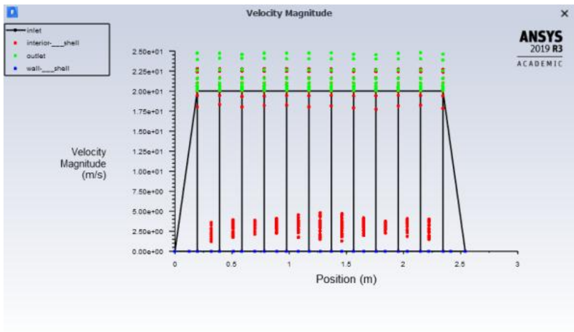


Figure 5.2.Shows the velocity magnitude in different position.

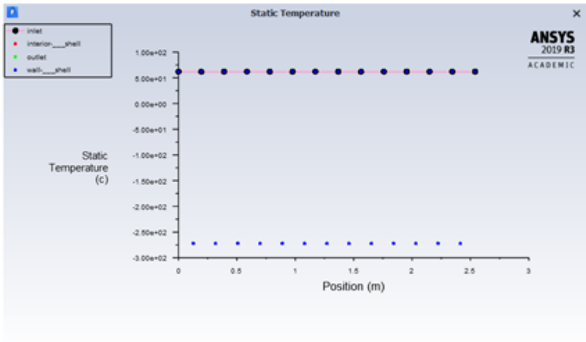


Figure 5.3.Shows the static temperature in different position.

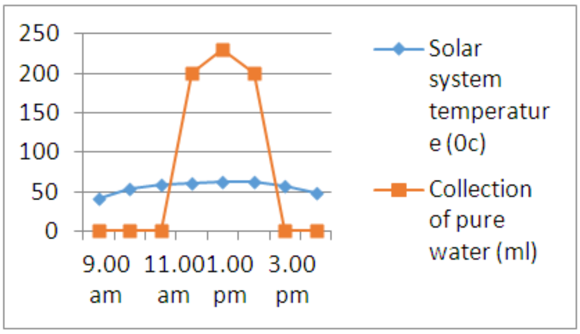


Figure.5.4.Shows the water collection without any boosting Material

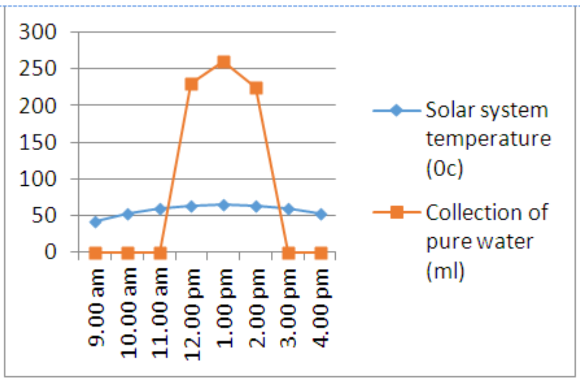


Figure.5.5.Shows the water collection with copper boosting material.

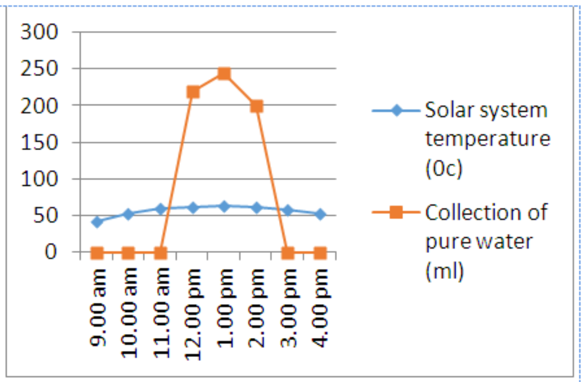


Figure.5.6.Shows the water collection with aluminum boosting material

VI. CONCLUSION

The experimental analysis of the passive and active solar stills with and without boosting mirrors is done in the climatic conditions of Tamilnadu in February. For the analysis same still is using boosting material.

The performance of the solar stills reanalyzed and their output water is also calculated. The various temperatures like basin water temperature, inside and outside temperature of the water and inside vapor temperature of the stills are recorded by using thermometer and the data is plotted. The solar intensity shows similar variation during the days of the analysis. Their average value shows a similar variation in these days. The inside vapors temperature for the stills with boosting material shows high value compared to the values without material. In this system the copper material using give the 715 ml outlet water at the time 11.am to 2.30 pm and it's the best result to compare others. The payback period of the experimental set up depends on the overall cost of fabrication, maintenance cost operating cost and cost of feed water. Different sets of simulation are done by varying the temperature of top and bottom according to experimental data. The behavior of phase change and temperature distribution is observed due to evaporation. The temperature of water obtained by CFD and mass yield is compared with the available experimental data. ANSYS CFD 19 R3 Software is use full for to identifying temperature, velocity and pressure variation in any area of solar system.

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