MODELING OF "V" TYPE SLOPE SOLAR STILL USING ANSYS-CFD SIMULATION

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ABSTRACT

Among the planets of solar family, only earth is suitable for the humans to inhabit and also contains water. Most of the areas in the earth are occupied by water as compared to land. The palatable water is available in very less quantity and the brine water is present in large quantity. The Palatable water is not abundantly available in the earth, but humans are in need of it for drinking and domestic purposes. In the areas with hot climatic conditions and with defalcation of palatable water, conventional solar still is the only efficient solution. The still efficiency explicitly depends on its design specifications, such as the temperature of the glass, surroundings, water, radiation from the sun, and a yield obtained as an output. This paper was proposed in inspecting experimental validation and the still specifications using ANSYS CFD designing. The results obtained from ANSYS were compared with results obtained by conducting experiments in still. There is only a small variation obtained when comparing both the results were shown in this paper. ANSYS is best suited tool to check the still efficiency before designing it in real time. In contrast to other solar stills, the output of V type solar still is comparatively high due to large basin area. So V type solar still is preferred.

Keywords: ANSYS CFD (Computational Fluid Dynamics), V type solar still.

1 INTRODUCTION

It is of no doubt that palatable water is considered to be the nectar for human beings. Ninety seven percent of water available on our planet is brine water and contains harmful microorganisms and two percent is frigid in an iceberg. At last the remaining one percentage is being used by human for drinking and other domestic purposes. Due to change in climate condition and global warming the percentage of rainfall per year has been reduced. In the present situation scarcity of palatable water is the crucial problem for the living beings. The renewable energy obtained from the sun for the conversion of brine water to palatable water is one of the efficient techniques and it is zero polluting which is eco-friendly to the environment.

Experimental analysis of single basin single slope finned acrylic solar still was studied by manokar et al. [1]. They proposed the idea in which using aluminum fin as it has high thermal conductivity due to which water is heated and the vaporization process takes place. The evaporated water in the glass is collected in water collector. The daily productivity is the only 660 ml/0.5m^2. This type of arrangement is very simple and costs less. Modi et al. [2] have experimentally verified the two identical one slope dual basin solar still which consists of wick materials in the basin area. They used to wick materials, namely black cotton and jute cloth to improve yield with different depths. The distilled water of 0.91 and 0.771 L/m^2 was obtained by using the jute cloth and black cotton cloth with 0.01 m water depth, whereas distillate water of 0.8287 and 0.6823 L/m^2 was obtained with 0.02 m water depth. Arunkumar et al. [3] did the study using solar still with glass covering the basin is in the shape of a hemisphere and found that produced output depending on water used and temperature conditions. The maximum quantity of palatable water obtained was nearly 4.2 L/day with 10 ml/min brine water is given to still and amount of radiation obtained from the sun was increased due to effect of cooling by a factor of 1.25

Z. M. Omara et al. [4] had studied the use of internal reflectors in increasing the efficiency of stepped still. The yield obtained from stepping still with the presence and absence of internal mirrors is higher as compared to normal solar still which increased the previous value. The solar still in which basin is covered with sandy reservoir was studied by Tabrizi et al. [5] and observed that a heat in the sand keeps the basin always warm and so the overnight productivity of the still can be increased. The output of a solar still has been increased by using different material on stills such as black coated paint and asphalt and sprinkler on glass and wind speed [6]. Akash et al. [7] studied the evaluation of solar still which has one basin with double slopes and compared the water absorbing capabilities of various wick materials such as a black colored rubber mat, ink and dye to improve the distillate output, but crucial drawback is that it reduces the effective isolation area when increasing the distillate output. An evaporation process carried out using cable used concave wick surface improved the radiation from the sun and increased the area in which evaporation takes place. The distillate obtained is 4.0 L/m^2 with efficiency 45% and the cost for 1 litter production is 0.065 [8]. Comparison of various wick materials used in the basin to increase the still efficiency was done by Murugavel et al. [9] and they proved that the basin covered with black colored cotton cloth and containing the aluminum fin which is rectangular in shape was more effective than others.

Kumar et al. [10] designed a still with photovoltaic cells and still produces 2-7 kg output. This type of still produces output more than the others stills during the whole year. Mahdi et al. [11] fabricated solar still with tilted wick and they used charcoal cloth as a wick material to increase the productivity and experiments were done to observe the amount of inlet water flow and brininess on the solar still productivity. The efficiency of this type of solar still decreased linearly as salinity in the input water increases. Single slope, solar still was modeled and verified using Ansys CFX by Panchal et al. [12] and they compared simulated results with experimental results. The process of evaporation is carried out in ANSYS CFD by designing the solar still with dimensions from the experiment set up. The temperature obtained from various parts of the still and amount of radiations received from the sun in the experimental setup and in the still designed using ANYSYS gave more or less similar results The results obtained as a result of simulation does not show more variations as compared with experimental work [13]. Setoodeh et al. [13] used CFD for designing and estimation of heat transfer in a solar still with single basin. Panchal et al. used [15, 16] CFD for designing and estimation of hemispherical type still. Suneesh et al. [17] experimentally observed the working of V type solar still with wick material used and daily productivity is 2800 ml/m^2/day. They observed that the radiation received from the sun does not depend on basin area. The V type still with cotton was used as an absorbing material and it is used to study the air flow in the still. The quantity of water produced with the cotton overcooling effect is more than the palatable water produced without cotton overcooling effect [18].

2 EXPERIMENTAL SETUP

A'V' type solar still was designed and it was shown in the figure 1. The dimensions of the basin in a V type solar still consists of 2 m x 0.75 m x 0.05 m was designed and its heat absorbing has been increased by coating the basin with black paint. Water enters the still through an inlet pipe of dimension 13mm. The basin is covered with wooden case to avoid heat loss. The evaporated water is collected in the glass of thickness 3mm. The sawdust was used in the gap between the wooden case and basin to reduce heat loss at low cost. The glass cover was placed towards the middle of V type solar still and to reduce air leakage the cover was sealed by chemical adhesive (**Figure 2**). An outlet pipe acts as a conduit for the distilled water to pass through and an angle of 2° slope is maintained for the water collector for continuous flow of palatable water (**Figure 3**). The experiments were carried out in the time duration of 9 - 18 hrs. The digital thermometer is used to measure the temperature varying with time in hours. The basin in the still contains jute material to absorb water because it was available in abundant and not expensive. The temperature increases because the basin absorbs the radiations from the sun are refracted through glass cover. Solar energy collected by the basin is transferring the heat to the brine water. Palatable water is evaporated on the top glass cover and salt is deposited in a basin which is cleaned periodically. The motto of this work was to evaluate the performance of V type solar still using cotton as wick material and to calculate quantity of palatable water produced as a result of evaporation process carried out as a result of renewable eco friendly zero polluting solar energy. The crucial advantage of V type solar still is large quantity of brine water is converted into palatable water because of the large basin area. As a result the output palatable water is collected using a pipe in a measuring water collector so as to measure the quantity of output obtained as a result of evaporation of brine water. This setup is designed using ANSYS software to compare the results taken experimentally.

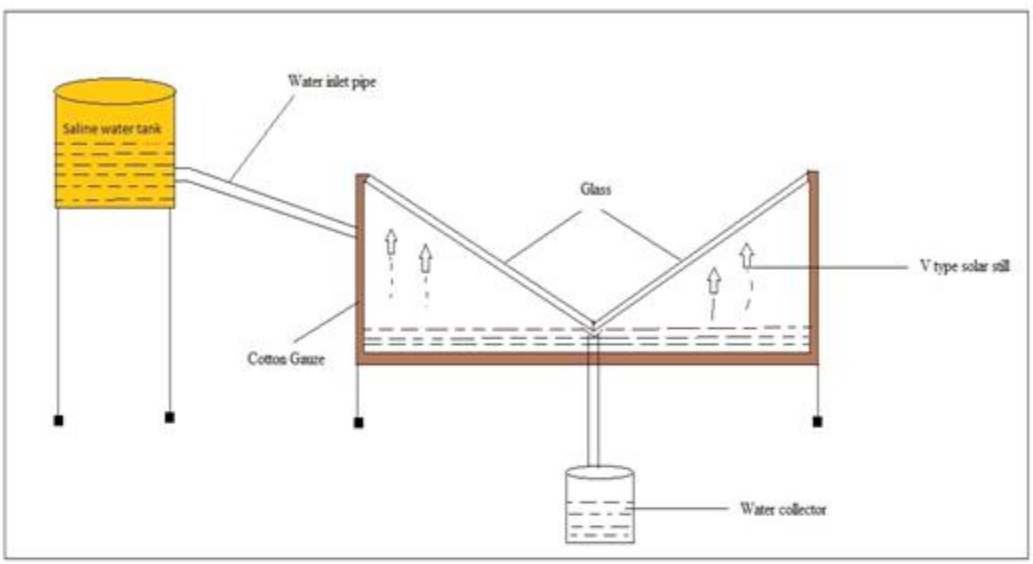

Figure 1.Schematic view of 'V' type solar still

3 OBSERVATIONS AND RESULTS

3.1 Experimental observations and results

Here, digital thermometer is a device used to measure temperature at different parts of V type still such as glass, surroundings and basin water. Temperature and amount of radiations received from the sun vary in accordance with time. There will be high temperature during noon hours and amount of solar radiations refracted through the glass and reaches the basin will be high. Thus more amount of palatable water will be obtained during noon hours. Hence the tabulation tabulates the readings of temperature, Ambient Temperature, Solar Radiation, yield. The readings were taken from experimental verification of in "V" type still with wick material [17].

Tabulation

S.No	Time(Hr)	Glass Temperature(^{0}C)	Ambient Temperature(^{o}C)	Solar Radiation(W/m^2)	Yield(ml/m^2/Hr)	Water Temperature (^{0}C)
1	9:00	30	29.8	590	0	30
2	9:30	32.5	31	625	75	38
3	10:00	40	31.5	740	100	47
4	10:30	42	32	875	125	52
5	11:00	45	32.6	1000	163	55
6	11:30	47	33	980	200	58
7	12:00	48	34	950	238	62
8	12:30	49	35	917	275	63
9	13:00	50	34	894	294	67
10	13:30	52	33.6	815	307	68
11	14:00	54	32	686	325	65
12	14:30	54	31.5	656	290	64
13	15:00	52	30.1	594	270	63
14	15:30	50	29.5	500	250	61
15	16:00	49	28.2	489	225	60
16	16:30	48	27	390	200	58
17	17:00	43	26	356	175	52

3.2 Simulation observations and Results

ANSYS CFD 17.2 is simulation software used for simulation of 'V' type solar still. To simulate the solar still, three dimensional xyz, two phase model is needed. There are two conditions used in this software they are steady state and transient condition. For the design of 'V' type solar still the steady state condition is best suited one as compared to transient state condition and so it is used. Figure 2 shows the design of 'V' type still developed in ANSYS Workbench. Figure 3 shows the Meshing design of 'V' type solar still in ANSYS. Figure 4 shows boundary condition of a 'V' type still. Figure no. 2 to 9 explains the procedure to design a solar still in ANSYS17.2.

'V' type solar still is, designed successfully using ANSYS 17.2 and the simulations were done. The results were obtained from this software. Both results obtained are plotted in the form of graph. The curves drawn by plotting the data obtained from both the simulation and experiment show less variation.

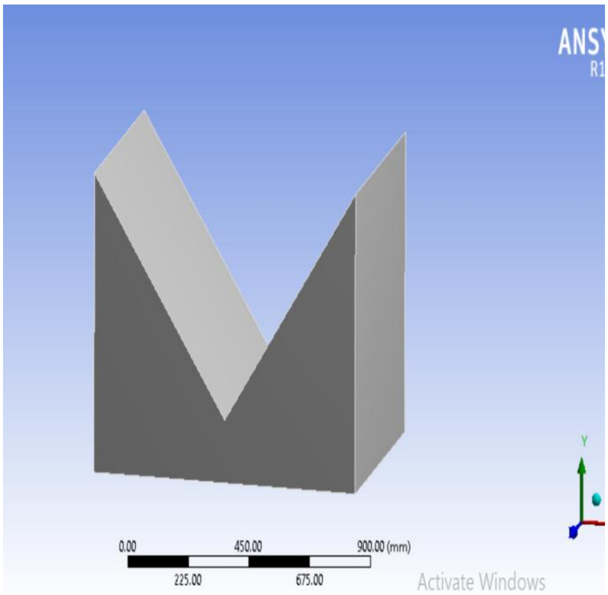

Figure2.Design of 'V' type solar still made in ANSYS Workbench

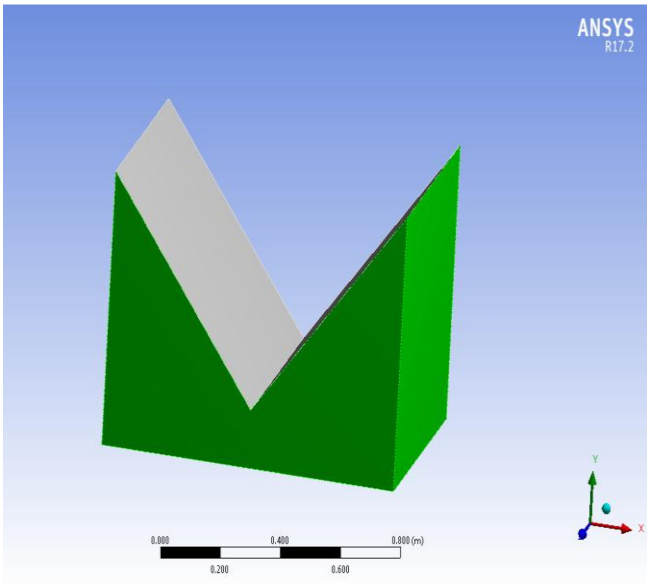

Figure4. Boundary condition of 'V 'type solar still

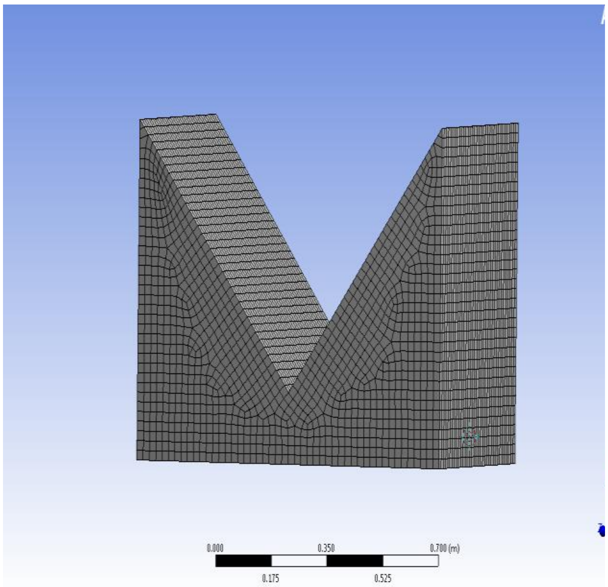

Figure3. Meshing analysis design of 'V' type solar still in ANSYS

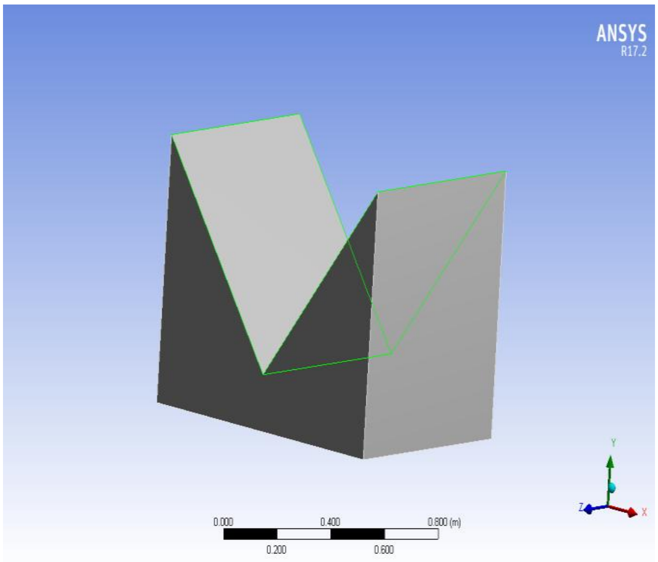

Figure5. Adiabatic condition between glass and wall

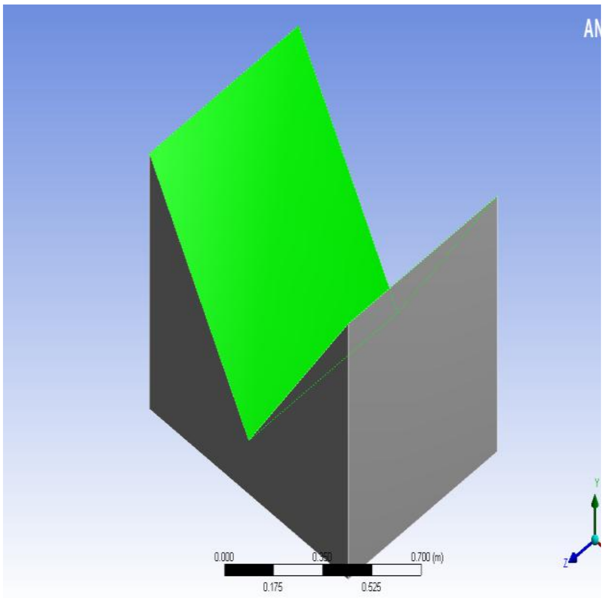

Figure6. View of solar radiation applied to glass of V type solar still

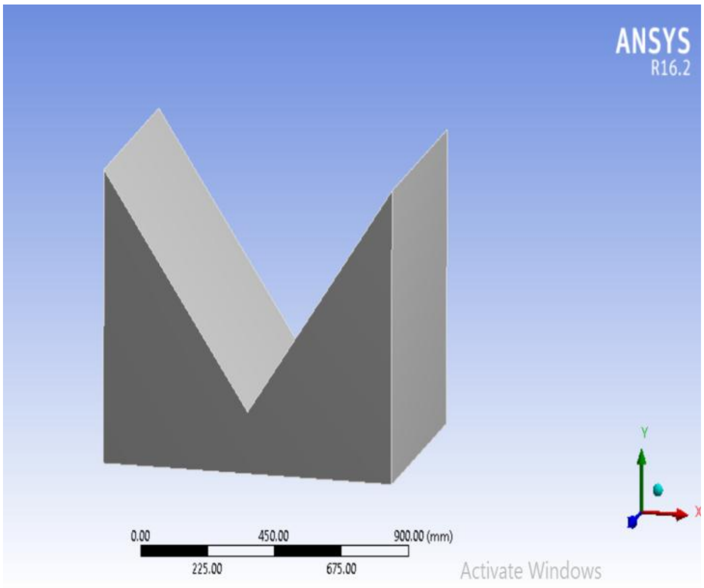

Figure7.total view of V type solar still with digital thermometer

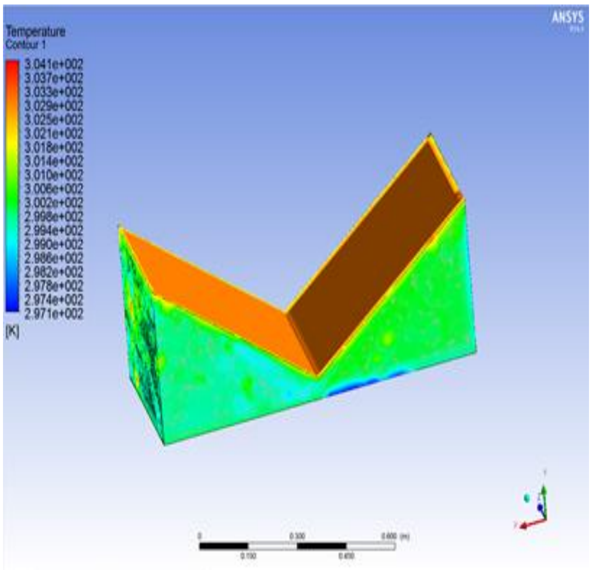

Figure8.Various temperature shown in various parts of 'V' type solar still

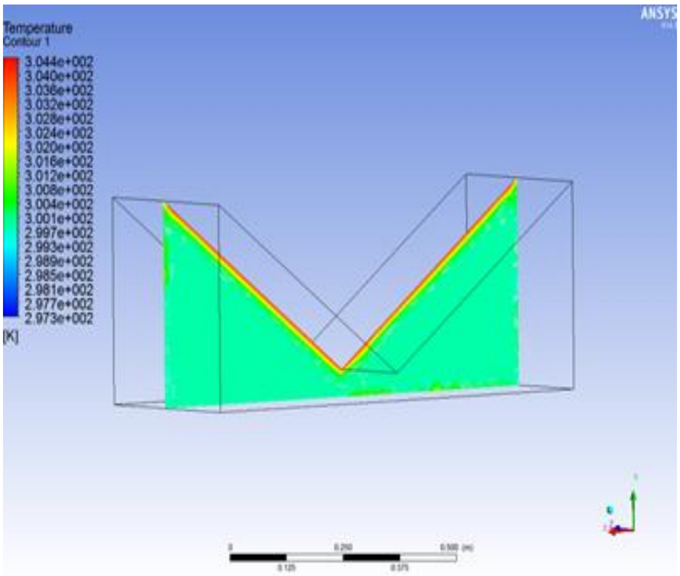

Figure9. Side view of various temperature in 'V' type solar still

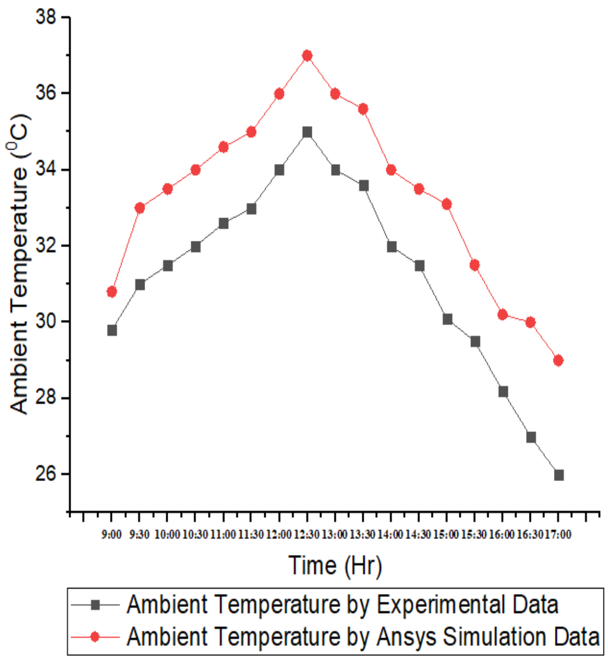

Figure10. Variation of ambient temperature with time from both results of V type solar still

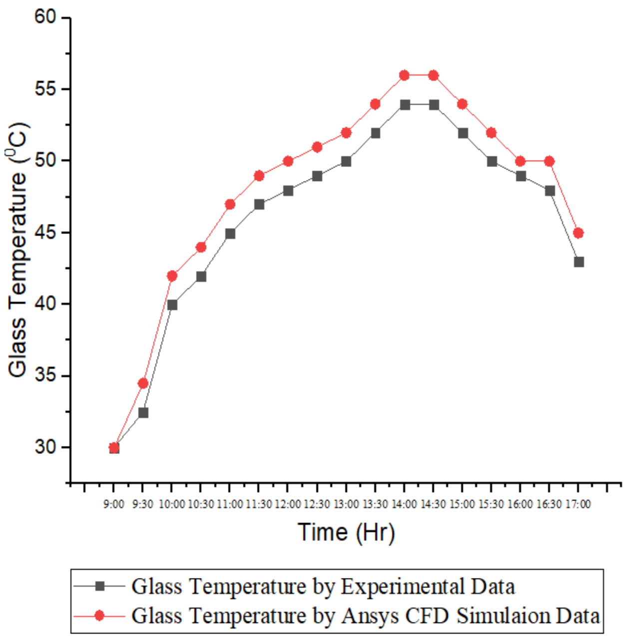

Figure11. Variation of glass temperature with time from both results of V type solar still

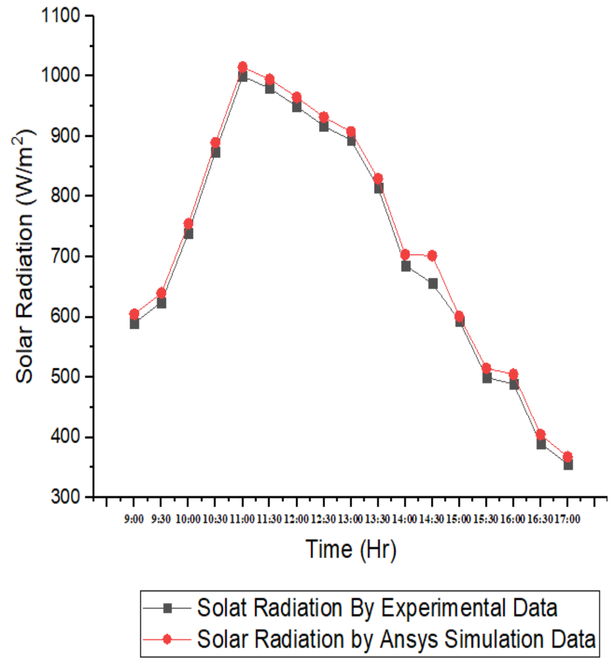

Figure12. Variation of amount of solar radiation with time from both results of V type solar still

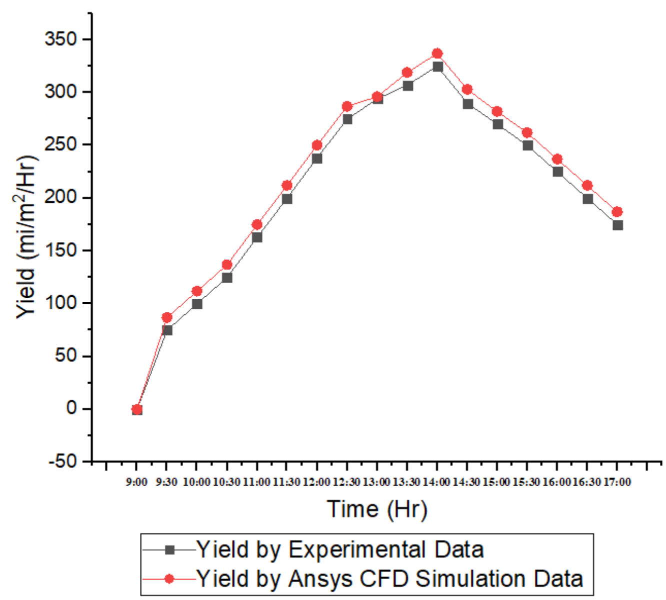

Figure13. Variation of yield obtained with time from both results of V type solar still

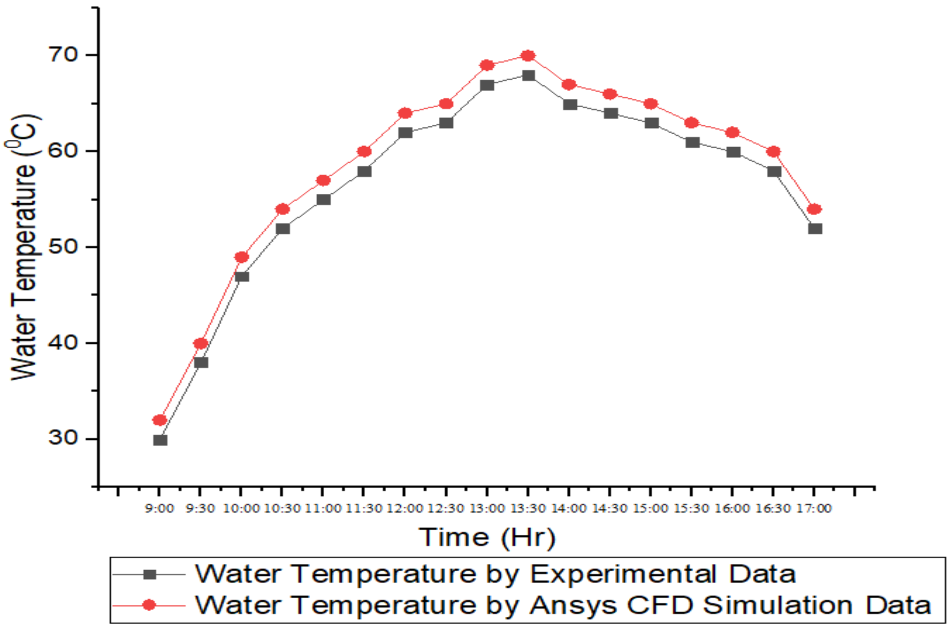

Figure14. Variation of water temperature with time from both results of V type solar still

Figure.10 this graph shows the comparison of ambient temperature readings obtained from experimental and simulation results. The ambient temperature reaches its maximum of 35^{o}c at12.30 hrs in the graph plotted for simulation setup and it reaches its peak of 37^{o}c at 12.30 hrs. The error between these two graphs is only 2%. Figure.11 shows the variation of glass a temperature of solar still obtained from simulation and experimental setup. The peak value of glass temperature is 54^{o}c which is obtained between 2.00 to 2.30 pm for experimental setup and from simulation results the peak value is obtained at 56^{o}c at the same time. This graph explains that the maximum output is obtained during this time because due to high temperature evaporation takes place at a higher rate due to which water gets evaporated at a faster rate and more amount of palatable water is obtained during these hours. Figure 12 shows the graph in which radiation from the sun is plotted against the time. The results from graph show that error between both readings from simulation and experimental setup is very less. Figure 13 represents the graph which shows the variation of output water obtained in contrast to the time. It is clear that the output produced starts from lower value rand reaches a maximum of 300-350ml of water is during 2.00 pm in both simulation and experimental results. The total quantity of yield obtained is 3.5 liters/day from experimental results and the distillate output obtained from simulation results is 3.69 liters /day. The difference between results obtained from both is nearly 169 ml. Figure 14 is the graph plotted for water temperature and time. The observations seen from the graph is the water temperature in the basin area reaches a maximum of 68^o-70^o c between 1.30-2.00 pm. From the comparison of both experimental and simulation results the observations obtained are the maximum output is obtained between1.30-2.30 pm and also the error between those two was very less. This comparison gave results with more similarities. This work done in ANSYS proves that the experiment done using ‘V’ type solar still was exactly correct because the results obtained from both has very less error percentage.

4 ECONOMIC ANALYSIS

There are many factors which affect the cost of the palatable water obtained from the desalination process takes place in different types of solar still. The factors that influence the total costs are the size of the still, feed water properties, product water required quality, qualified staff availability, etc.

The various types of parameters used in the economic analysis of a solar still are the Capital Recovery Factor (CRF), Fixed Annual Cost (FAC), Sinking Fund Factor (SFF), Annual Salvage Value (ASV), Average Annual Productivity (M), and Annual Cost (AC). Life cycle cost analysis of a single slope hybrid active solar still was studied by Kumar et al. [19]. Abdel et al. [20] made an experimental and theoretical study of solar still with solar concentrator and the cost per liter is around 0.05$/l. EL-Bahi et al. [21] have conducted an experiment using a double glass, solar still with a separate condenser. Abdallah et al. [22] designed sun tracking system for productivity enhancement of solar still and cost of palatable water per liter is 0.21$ which is more costly. El- Sebai et al. [23] conducted experiment using single basin solar still integrated with shallow solar pond. Desalination of effluent using fin type solar still was studied by Velmurugan et al. [24] and the CPL is 0.05$/l.

Velmurugan et al. [25] have studied single basin solar still with wick and fun for enhancing productivity because of usage of wick material the cost was raised to 0.06$/l. Transportable hemispherical solar still is designed by Ismail et al. [26] and the cost of palatable water per liter is 0.16$ which is the second highest cost among the comparison given in the table 2. Abdallah et al. [27] have studied the performance evaluation of modified design of single slope still and the annual cost is 60.44$. Sadineni et al. [28] have done an experimental investigation weir type inclined solar still. Velmurgan et al. [29] studied the solar stills integrated with a mini solar pond and the cost per liter are 0.07$.

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1} \quad (1)$$

$$FAC = P(CRF) \quad (2)$$

$$SFF = \frac{i}{(1+i)^n - 1} \quad (3)$$

$$ASV = S(SFF) \quad (4)$$

$$AC = FAC + AMC - ASV \quad (5)$$

$$CPL = \frac{AC}{M} \quad (6)$$

$$S = 0.2P \quad (7)$$

$$AMC = 0.15\,FAC \quad (8)$$

Table 2.

Type of Solar Still	P	CRF	FAC	S	SFF	ASV	AMC	AC	M	CPL
Single Slope [19]	250	0.163	40.75	50	0.073	3.65	6.11	43.21	343	0.13
With solar concentrator [20]	300	0.163	48.9	60	0.073	4.38	7.34	51.86	990	0.05
With separate condenser[21]	350	0.163	57	70	0.073	5.11	8.55	60.44	1116	0.05
With Sun tracking [22]	300	0.163	48.9	60	0.073	4.38	7.34	51.86	250	0.21
With a shallow solar pond [23]	320	0.163	52.16	64	0.073	4.67	7.82	55.31	1183	0.05
With fin type [24]	200	0.163	32.6	40	0.073	2.9	4.89	34.56	720	0.05
With wick and fin type [25]	250	0.163	40.75	50	0.073	3.65	6.11	43.21	737	0.06

Transportable hemispherical [26]	958	0.163	156.16	191.6	0.073	13.98	23.42	165.56	1026	0.16
Stepped with sun tracking [27]	350	0.163	57	70	0.073	5.11	8.55	60.44	958	0.06
A weir type [28]	280	0.163	45.64	56	0.073	4.08	6.85	48.41	1001	0.05
With sponge and pond [29]	350	0.163	57	70	0.073	5.11	8.55	60.44	837	0.07
V type solar still [present work]	200	0.163	32.6	40	0.073	2.9	4.89	34.56	803	0.04

The table compares the cost per liter of different solar stills. The cost per liter of V type solar still is 0.04$ which is less expensive than the fresh water obtained from other solar stills. The single slope, solar still with sun tracking system has the most expensive amount of cost per liter, which is 0.21$. The annual cost of a transportable hemispherical solar still is the most expensive one than the others which is 165.56 $. The capital investment cost for hemispherical still costs around 958 $ which is more and more expensive than others.

5 CONCLUSION

Condensation and evaporation are the most important phenomena in the process of conversion of brine water to palatable water in solar still. Using ANSYS ‘V’ type solar still is designed. The evaporation process is done in still designed using ANSYS. The temperature obtained from various parts of still and amount of radiations received from the sun in the experimental setup and in the still designed using ANYSYS gave more or less similar results The results obtained as a result of simulation does not show more variations as compared with experimental work. The total quantity of yield obtained is 3.5 liters/day from experimental results and the distillate output obtained from simulation results is 3.69 liters /day. The cost per liter of yield obtained is 0.04 $ which is less expensive than different types of solar stills. The results obtained from ANSYS is used to design a solar still with greater efficiency, improved performance. It is great simulation software for solar still design and leads to innovations of new types of solar stills to increase the output productivity.

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