

Experimental Investigation of a Solar Still Modified with Fins

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Abstract

Today there is acute shortage of fresh drinking water in remote, coastal and rural areas of many countries. The only nearly inexhaustible source of water is the oceans. Their main drawback, however, is their high salinity. Therefore, it would be attractive to tackle the water-shortage problem with desalination of this water.

In the present work, effect of incorporating phase change material and fins on the performance of a single slope solar still is investigated. Experiments were performed on the still with and without incorporating fins. Daily yields of the still with and without fins were compared. It was observed that still daily yield was improved with the incorporation of fins. Energy and exergy analyses had also been carried out to assess the still's performance by incorporating fins. It was observed that, the daily thermal and exergy efficiencies of the still were increased with fins.

The efficiencies of the simple still and still with fins are found to be 21.26% and 22.26% respectively. The efficiency is increased by 4.70% with fins. Total yield of simple still and still with fins were found to be 1960 ml/m²day and 2052 ml/m²day.

Daily exergy efficiencies of the simple still and still with fins are 1.24% and 1.47% respectively. Exergy efficiencies of the still are very low compared to the energy efficiencies.

As the water depth increases, yield decreases. The reason may be the storage of more heat energy is required for the evaporation. But too low water depths are also not appreciable due to

the reason that salt accumulation decreases evaporation rate. Optimum water depth is found to be 2cm from the experiments.

Keywords: *Solar Still, Fins, Still with fins, Exergy efficiencies of the simple still.*

INTRODUCTION

There is only one thing that makes our small blue planet earth habitat for many life forms different from other planets in the solar system: liquid water. Without water no society can function. Of all the water in the world a mere 0.5-1% is fresh water available for the needs of all plant, animal and human life. Around 97% of the water of the world is in the oceans and approximately 2-2.5% of the water is in the ice stored in the glaciers and in polar ice, although global warming is reducing the reservoir of the fresh water.

Today there is acute shortage of fresh drinking water in remote, coastal and rural areas of many countries. The only nearly inexhaustible source of water is the oceans. Their main drawback, however, is their high salinity. Therefore, it would be attractive to tackle the water-shortage problem with desalination of this water.

Desalinize in general means to remove salt from seawater or generally saline water. Desalination processes require significant quantities of energy to achieve separation of salt from seawater. If desalination is accomplished by conventional technology, then it will require burning of substantial quantities of fossil fuels. Given that conventional sources of energy are polluting, sources of energy that are not polluting will have to be developed. Fortunately, there are many parts of the world that are short of water but have exploitable renewable sources of energy that could be used to drive desalination processes. Solar thermal energy is the most available renewable source of energy. India is a country which is blessed with abundant solar resources. There are about 300 sunny days in most parts of the country and on an average 4-7 kWh/m² day of solar radiation is incident which can be utilized for various applications.

The use of solar energy is a promising option for desalination of saline water. A single basin solar still is a very simple solar device. This can be fabricated easily with locally available materials. The maintenance is also cheap and no skilled labor is required. Because of its low productivity it is not popularly used.

In the conventional solar still there are many factors affecting the productivity and performance. Years of research in this field enable engineers to create modified solar stills based on the performance parameters. The performance varies with climatic conditions and operating conditions. The productivity of the still increases with incident solar radiation and lower ambient temperature. Wind improves yield; even low wind speed is better than zero wind speed. Palak Patel and Ajayraj Solanki [7] in their paper describes that as wind speed increases by convection more heat loss to ambient from the glass cover is achieved. The effect on sprinkling water or maintaining a thin film over the glass cover will increase productivity. Reducing the gap between glass cover and basin from 13 to 8 cm increases efficiency by 11%.

Dwiwedi et al. [8] reported that the productivity of single slope solar still is

greater than that of the double basin. Besides the gap between glass plate and basin the inclination of the glass plate is also an important parameter. Tiwari et al. [9] studied the variation of inclination angle and water depth. It was concluded from their study that summer and winter peak performances were optimized for glass cover inclinations of 15° or 45° respectively.

The conventional solar stills are simple and low cost, but their yield is very low. Raja seenivasan et al. [12] studied performance improvement on a single basin solar still with circular and square fins integrated in the basin. Circular and square fins result in almost the same performance and there is a minimum difference in distillate output. The highest productivity of 4.55 and 3.16 kg/m² day is obtained for the square fin covered with wick and conventional still respectively. Daily productivity of the still increases by 26.3 and 36.7% for circular and square finned stills. Research by Murugavel et al. [11] concluded that 29.6% productivity increased, when wick type solar still was used, 15.3% productivity increased when sponges were used and 45.5% increased when fins were used.

EXPERIMENT DETAILS

Fabrication of Solar Stills

Two stills of same dimensions are constructed. Basin of the still is made up of 0.0015 m thick (16 gauge) Galvanized Iron (GI) sheet with the dimensions: 0.64x0.59. The same is coated inside with black paint to act as an absorber. A glass cover of 0.66x0.59 m is mounted on the top of the basin. Inlet hole and outlet hole of diameter 127mm and 25.4mm, for the brackish water

are provided on the side wall and the bottom of the basin. Outlet hole for the pure water is provided at the end along the length of the still. Brackish water is supplied at regular intervals manually to maintain the desired water level in the still. Fins are used for increasing the area of the basin. Fins are made of hollow aluminium sheets and joined to the basin. 6 fins each having base cm and height .7 cm and length 64 cm is joined along the length of the still.

Table 4.1 Specifications of the still

Type	Single slope single basin
Area of glass cover	0.3894 m ²
Glass type	Ordinary glass
Glass cover inclination	15°
Area of the basin	0.3776 m ²
Length of the basin	0.64 m
Breadth of the basin	0.59 m
Basin material	0.0015 m (16 gauge) GI sheets
Collection trough material	Inch PVC
Insulation material	Expandable Poly-Styrene
Thickness of insulation	0.0254m

METHODOLOGY FOR MEASURING THE PERFORMANCE OF THE SOLAR STILL

Experiment is conducted after fabrication of single slope solar still with and without fins. Experiments were conducted on both stills by comparing the performance of the stills based on energy and exergy analyses and comparing the performance of the stills varying the water level in the basin.

Experiments were conducted in the terrace of a building during the month of March 2016. Experimental set up consists of a simple single slope solar still and a modified still with fins. Basin of the still was filled with water and it was varied as 1.5 cm, 2 cm and 2.5 cm. Brackish water was fed to the still manually at constant intervals. Water can be drained from the still through the outlet provided at the bottom. Constant water depth was maintained throughout all the experiment runs. Glass cover inclination was set as 15°. Still orientation was North-South during the entire experiment. The wind speed during experiment was 3-8 m/s. Glass temperature, water temperature, absorber temperature and yield are measured from 8 AM to 9 PM at the end of each hour for the simple still and still with fins using a digital thermometer in the

working range -50° C to 300° C with an accuracy of 0.1° C. A 500ml beaker and a test tube were used for measuring the yield.

Overall efficiency of the still was then calculated by ratio of productivity multiplied by latent heat of vaporization, to the cumulative solar radiation incident during the time period of interest (usually a day).

$$\text{Efficiency } (\eta) = \frac{M \times LH \times 100}{3600 \times \sum I}$$

Where,

M = Productivity (ml/m²)

LH = Latent Heat of Vaporization (2260 kJ/kg)

I = Hourly Solar radiation (W/m²)

RESULTS AND DISCUSSIONS

Cumulative yields for both stills were found to be maximum at 2cm water depth. The temperature values and yield are tabulated below and shown in table 1 and 2.

Table:1 Table of measured parameters-simple still

TIME	AMBIENT	AIR	GLASS	WATER	BASIN	YIELD	CUMMILATIVE
	TEMP	TEMP	TEMP	TEMP	TEMP		YIELD
9	30.8	37.1	35.9	32.9	33.1	0	0
10	32.9	42.1	39.4	38.9	39	0	0
11	35.5	51.4	48.9	52	52.3	80	80
12	37.1	59.1	57.6	58.5	58.8	160	240
13	39.3	61.5	57.2	63.2	63.8	240	480
14	39.7	62.1	58.9	64.5	64.9	320	800
15	38.1	56.7	52.2	62.3	62.6	280	1080
16	37.2	52.6	50.1	58.8	60	260	1340
17	35.6	52.3	47.8	51.6	51.8	220	1560
18	34.2	44.9	42.9	47.1	47.4	160	1720
19	32	38.3	37.1	42.9	43.2	40	1760
20	31.1	34.9	33.9	35.3	35.6	0	1760
21	30.1	32.2	31.1	32.8	32.8	0	1760
21-8						200	1960

Table: 2 Table of measured parameters-still with fins

TIME	AMBIENT	AIR	GLASS	WATER	BASIN	YIELD	CUMMILATIVE
	TEMP	TEMP	TEMP	TEMP	TEMP		YIELD
9	30.8	32	38.5	32.8	33.2	0	0
10	32.9	37.9	39.5	38.9	39.4	13.24	13.24
11	35.5	47.2	41	53.9	54.1	105.93	119.17
12	37.1	56.1	49	60.5	61.2	172.13	291.3
13	39.3	58.1	53.1	62.4	64.4	291.31	582.61
14	39.7	62.1	57.1	63.1	65.1	357.52	940.13
15	38.1	58.9	53.5	61.1	62	304.55	1244.68
16	37.2	51.3	47.9	55.1	55.2	264.83	1509.51
17	35.6	47.1	44.5	51.9	52.3	172.13	1681.64
18	34.2	46.2	40.5	47.9	48.2	92.69	1774.33
19	32	39.2	37.1	41.6	42.1	52.96	1827.29
20	31.1	33.1	32.3	37	37.2	13.24	1840.53
21	30.1	33.1	31.2	34.2	34.4	0	1840.53
21-8						211.86	2052.4

These tables represent the daily yield of simple still and still with fins. The cumulative yield/m² for simple still is 1960 ml and for still with fins is 2052 ml for a full day under same climatic conditions.

Theoretically it is said that yield increases as the temperature difference between water and glass surface increases. The graph between water and glass temperatures differences is plotted. below in Fig 1

Positive temperature difference of ($T_w - T_g$) between the water temperature and glass temperature is the main driving force for the evaporation of brackish water. In the case of both stills this is negative initially. Hence there is no evaporation of water during this period. It is clear that for both the stills ($T_w - T_g$) is higher during 12 PM to 2 PM.

See Figure 1

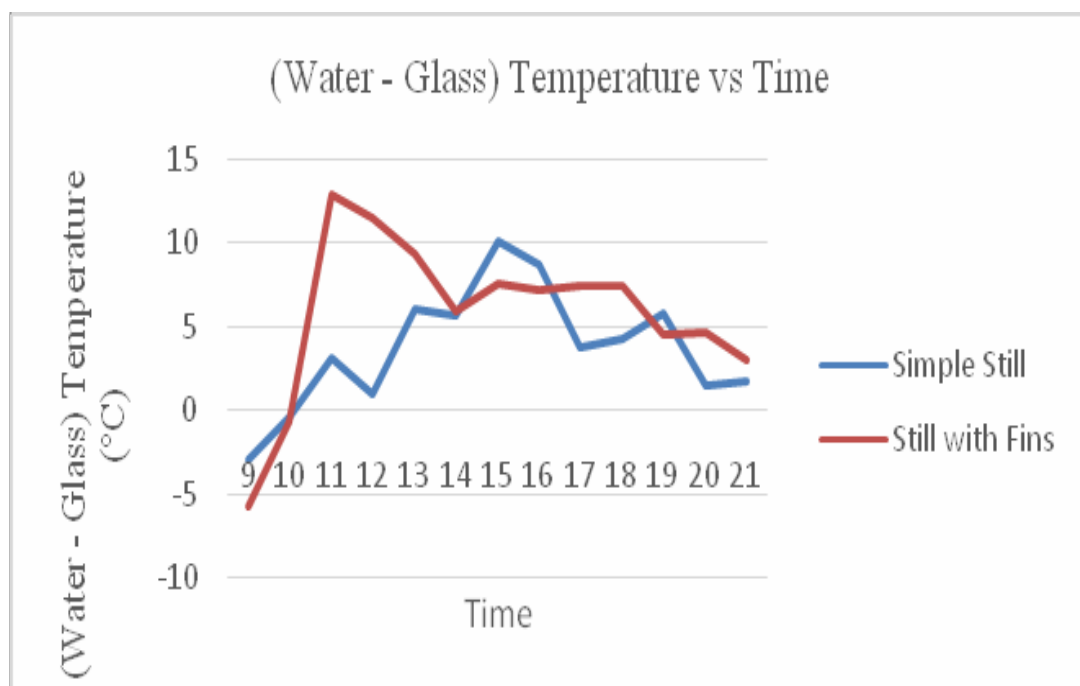


Figure 1. Variation of $T_w - T_g$ with time

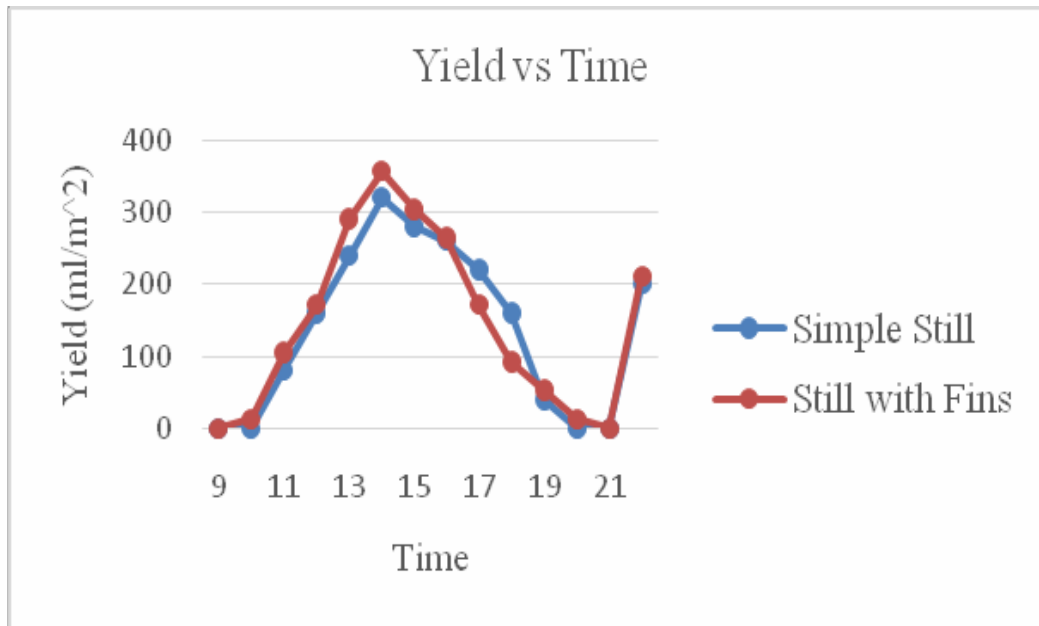


Figure 2 Variation of Yield with time

The variation of yield with time is shown in Fig.2. The yield is more for still with fins, but after 4 PM it decreases slightly due to the low intensity of the sun. Since there is no external power source yield is almost same for both stills. Fins are great for improving day time productivity, but there is not much change during night hours,

From the cumulative yield graph in Fig.3 between both stills, it can be seen that all the time still with fins has more yield than simple still even though basin area of both the stills are same. The effective area increase by using the aluminium fins which causes increased yield.

See Figure 3.

The experiment is conducted for water depths 1.5 cm, 2 cm and 2.5 cm. The maximum yield is for water depth 2 cm in both stills. For higher water depths the temperature will not be enough to heat up all the water. When the depth is too low initial yield will be high. As more water evaporates the mineral concentration increases in the still and the evaporation temperature needed will be more.

See Figure 4 and 5.

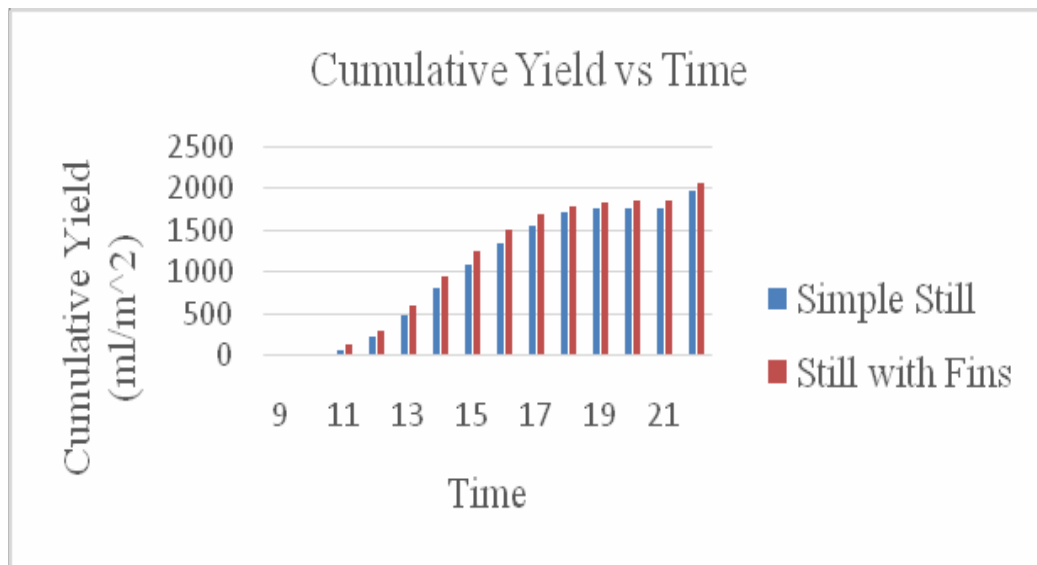


Figure 3. Commulative yield over time

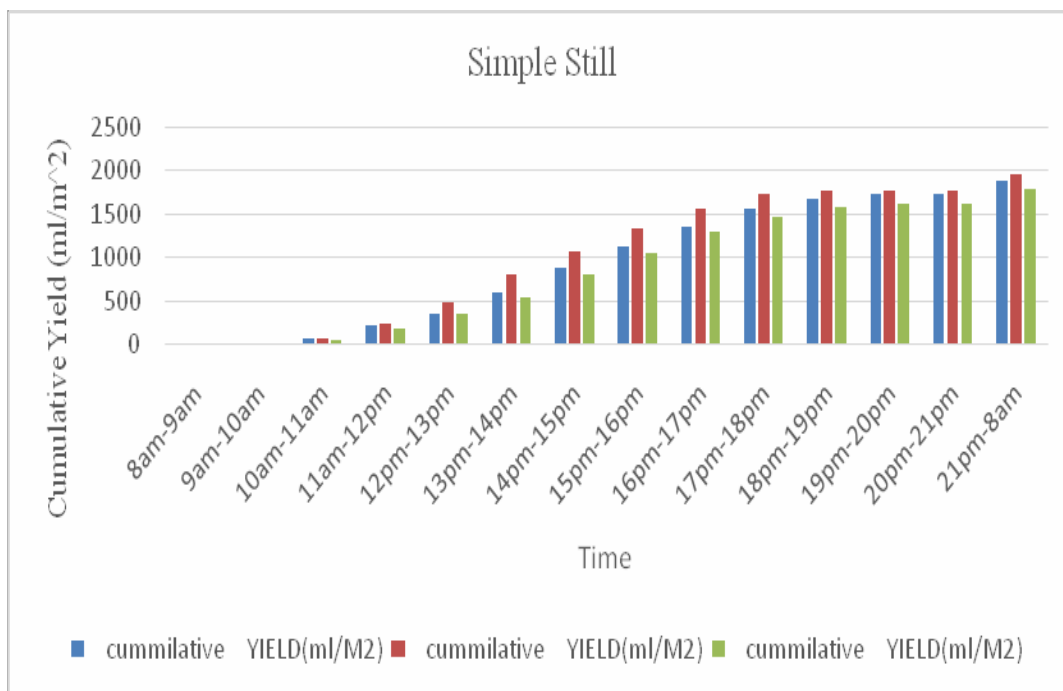


Figure 4: Effect of still height on the yield for a simple still

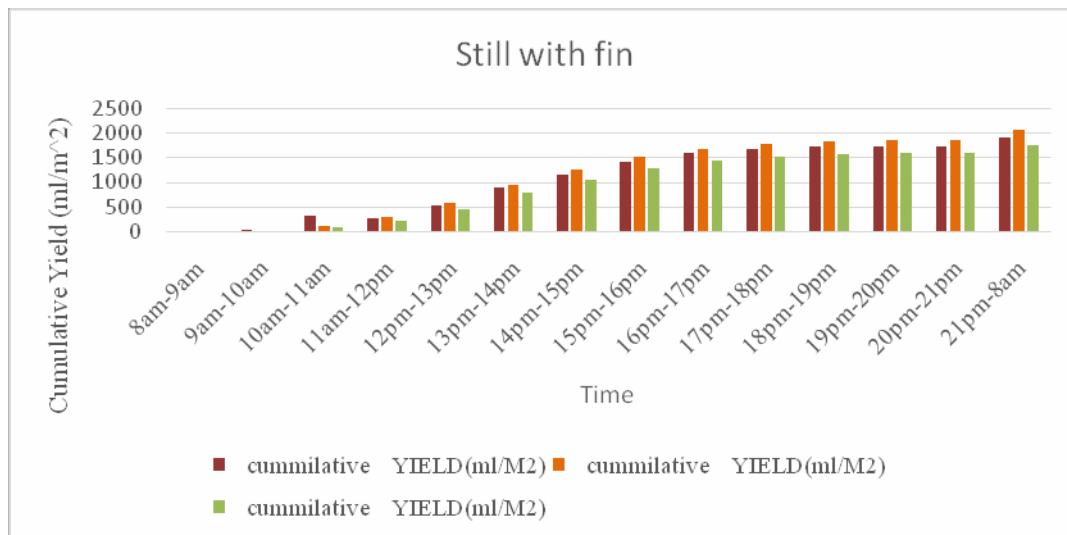


Figure 5 Effect of still height on the yield for a still with fins

The experiment is conducted for water depths 1.5 cm, 2 cm and 2.5 cm. The maximum yield is for water depth 2 cm in both stills. For higher water depths the temperature will not be enough to heat up all the water. When the depth is too low initial yield will be high. As more water evaporates the mineral concentration increases in the still and the evaporation temperature needed will be more.

CONCLUSIONS

Solar stills are relatively inexpensive, simple systems used for desalination. They produce distilled water without consuming energy from the conventional energy resources. They can supply the potable water needs of the remote and arid areas. However their low productivity is one of the

major limitations. Though, many works have been done to improve their productivity, still there is room for further innovations and improvements.

One of the methods to increase the day time productivity is to increase the basin area, but the still will be of large size. So another solution is increasing the effective basin area of the still by incorporating fins.

In the present work, effect of incorporating fins on the performance of a single slope solar still is investigated. It is observed that the still daily yield was improved by 4.7% with the incorporation of fins. Energy and exergy analyses had also been carried out to assess the still's performance by incorporating fins. The efficiencies of the

simple still and still with fins are found to be 21.26% and 22.26%. Daily exergy efficiencies of the simple still and still with fins are 1.24% and 1.47% respectively. Exergy efficiencies of the still are very low compared to the energy efficiencies.

Total yield of simple still and still with fins were found to be 1960 ml/m²day and 2052 ml/m²day for 2cm water depth. As the water depth increases yield decreases, because more heat energy is required for the evaporation. But too low water depths are also not appreciable due to the reason that salt accumulation decreases evaporation rate. Optimum water depth is found to be 2cm from the experiments.

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