EFFECT OF FIN HEIGHT ON PERFORMANCE OF PASSIVE SOLAR STILL IN INDIAN COASTAL CONDITIONS

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ABSTRACT

In this paper the effect of fin height on the distillate output and performance of solar still have been presented for passive mode. The solar still has an effective basin area of 1m² and the fixed cover inclination of the still is 30°. The aim of the present paper is to study the effect of different heights of fin on the yield and distillation efficiency of passive solar still. Outdoor experiments have been conducted at the coastal town of Kakinada (16° 93'N/83° 33'E), Andhra Pradesh, India. The experiments were conducted for 24 hours during peak summer month of May 2019, with different fin heights of 3cm, 4cm, and 5cm for passive solar distillation system. It is observed that the yield and performance of solar still depends significantly on fin height. It is also shown that the internal heat transfer coefficients vary with respect to the fin height substantially. The results from the experimental data show that the combination of 4cm height of fin and the intensity of radiation for the coastal and summer climatic conditions of Kakinada leads to maximum yield and efficiency for the passive solar still.

KEYWORDS: Distillation Efficiency, Solar Still, Heat Transfer Coefficient, Fin Height and Optimization

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INTRODUCTION

Many Processes are available for obtaining purified water in which distillation is one of them. During the process water gets heated and evaporated. This evaporated vapour will be condensed and pure water is formed. The required heat for the process is powered from Sun, which one is a renewable energy source and its availability at any location on the earth.

In Indian coastal regions, pure water may not be available and the ground water is mostly used as drinking water. By considering the availability of solar energy and ground water, we studied the practical alternative, solar distillation of ground water especially in Indian coastal conditions.

This type of solar distillation never demands any hidden fuel costs and is eco-friendly. The solar radiation is available in very large areas compared to usage. So, the capacity of distillation can be raised by increasing the area of radiation.

DEFINITION OF THE PROBLEM

For the selected design, an attempt is made in this paper to find an optimum height of fin for maximum daily yield. A single basin solar still unit with a fixed 30° condensing cover inclination is considered at JNTUK Kakinada, Andhra Pradesh, India. Three different fin heights 3cm, 4cm and 5cm are considered for performance prediction of unit.

LITERATURE REVIEW

Review on the use of renewable energy in various types of desalination systems are found in references [1, 2, 3 and 4] Lilian Malaeb et.al [5] examined the effect of using a solar still with three different cover geometries of double-slope, single-slope and curved cover and the effect of cover design on the performance of the still in terms of measured temperature and productivity is considered. A.A.EI-Sebaiet.al [6] investigated the dependence of the still efficiency and productivity on the fin-configuration parameters such as the number, height and thickness was studied. A. Muthu Manokara et.al [7] shown that the amount of water produced from the still was increased by more than eight times by maximizing cooling of the condensation surface. R Bharadwaj et.al [8] studied the method of maximizing the water production by increasing the area of condensation surface for solar still. Mansoor Feilizadeh et.al [9] investigated the outdoor performance of a basin type multi-stage solar still as well as the effect of collector over basin area ratio on the distillate production. A .Jahanbakhsh et.al [10] shown that the collector water flow rate and evacuation of the glass cover tubes had little effect on the enhancement of the solar collector thermal performance. F.Saeedi et.al[11]the optimization of Photo Voltaic /Thermal active solar still has been carried out and values of mass flow rate and number of Photo Voltaic/Thermal collectors has been obtained. S.A. EI-Agouzet.al [12] suggested the productivity and efficiency of solar still are influenced by water film thickness, and velocity as well as wind velocity. Naga Sarada, et al[13] reported improvements in the efficiency of solar water distillation by using Phase Change Materials. Durkaieswaran, et al[14], reviewed the work on various special designs of single basin passive solar stills.

EXPERIMENTAL SETUP

Distillation Unit

The schematic line diagram of single-slope passive solar distillation unit is shown in fig. 1a, whereas fig. 1b is the photograph of the setup. The experimental setup consists of a passive solar distillation unit with condensing cover inclination 30°. The bottom surface of the still is painted Nichrome black for greater absorptivity. The height of lower vertical wall of still was kept at 0.30m to avoid the spilling of basin water into the distillate channel and to prevent the contact of distillation channel with the condensing cover as well as with the water level. The height of higher vertical wall was kept as 0.88m. The effective basin area of still is 1m x 1m and it is made of FRP of 6mm thickness, which provides insulation for heat flow. Condensing cover made of long plain glass of 4mm is fixed to the top of the vertical wall of the still using a rubber gasket. The yield from the still is collected through a channel, fixed at the height of the smaller vertical wall of the basin. A hose pipe is connected to this channel to collect the yield to a measuring jar.

Procedure

The experiments were performed in summer climatic condition of 2019 in JNTUK, Kakinada, Andhra Pradesh, India. May is usually the hottest month of the year in this region and typical results for 3 days during the period have been reported here. Experiments were conducted from 8.00 A.M. to 8.00 A.M. the next day for 3 different fin heights, namely 3cm, 4cm

and 5cm. The galvanized iron fins length and thickness are constant of 1m and 3mm respectively. Added 8 fins in the basin longitudinally and equal distances. The number of fins are constant for 3 cases. Sufficient care is taken for obtaining steady state condition during the experimentation. The inclination of condensing cover 30° and water depth in the basin 4cm are fixed for all experiments. The parameters, viz, glass outer and inner surface temperatures, vapour temperature, water temperature, ambient temperature, incident radiation, relative humidity (γ) inside still and distillate output are measured on 24 hr basis for all the 3 fin heights. Water, condensing cover and vapour temperatures were recorded with the help of calibrated copper constant thermocouples and a digital temperature indicator having a least count of 0.1°C .

Figure 1a: Schematic Diagram of Solar Still.

Figure 1b: Photograph of the Working Passive Solar Still.

A mercury thermometer was used to record the ambient temperature and outer glass temperature. The yield was measured using of a measuring flask at time intervals. A solarimeter was used measure the solar radiation intensity falling on condensing cover. The above measured parameters were used to calculate average values of each for further calculations. Table1 gives the measured parameters for a fin height of 4cm.

Free convection of water vapor takes place due to the density variations, which occur because of thermal potential difference.

Figure 1c: Photograph of Solar Still Basin with Fins Arranged Longitudinally.

DISTILLATION EFFICIENCY OF SOLAR STILL

The distillation efficiency (η_D) of the solar still has been defined as the ratio of distilled water produced to the total solar radiation energy received. Integration over a given period of time results in following distillation efficiency:

$$\eta_D = \frac{\sum m_{ew} L}{A_g \sum I(t)} \times 100 \quad (1)$$

Where, m_{ew} -Yield, L - Latent heat of vaporization of water, A_g - Area of glass cover and $I(t)$ - Hourly average of incident total radiation on solar still.

Present Work

In the present work, the effect of fin height on maximum yield and distillation efficiency for a single basin solar still are experimentally studied and the comparative performance of the solar still is also presented.

RESULTS AND DISCUSSIONS

In the present work, the performance of a single slope and single basin passive solar still with 30° condensing cover inclination for three fin heights of 3cm, 4cm and 5cm is reported. The measured values for a fin height of 4cm on a typical day are presented in Table 1.

The hourly water and inner condensing cover temperatures for various fin heights have been shown in figures 2a and 2b respectively. The temperatures rise in the morning, fall in the evening and variations followed similar trend for different fin heights. This is due to the variations in the intensity of sun radiation over the observation period. The variation of the hourly difference in temperature for water and inner surface of the condensing cover i.e. ΔT is shown in the figure 2c for the still with various fin heights. It can be concluded that during morning hours condensing cover encounters the radiation first and its temperature rises very fast when compared to the rise in water temperature and as a result, ΔT becomes negative. This will continue upto water temperature supersedes the cover temperature. It is seen from the figure 2c that for morning hours, the negative value of ΔT increases with increasing fin heights as the water temperature takes

more time to surpass the cover temperature. When the water temperature crosses the condensing cover temperature, it will continue higher till next sunrise. It was observed that, for a fin height of 3cm, ΔT becomes positive at around 10 am, whereas the same condition is attained for 4cm and 5cm fin heights after 11noon, i.e. 1 to 1.5 hrs later. After becoming positive, ΔT increases rapidly with increase in water temperature. Hence the ΔT plays an important role in optimizing the yield and ultimately the convective mass transfer coefficient and partial pressure difference as well.

For the fin height of 4cm, highest yield is obtained as shown in fig. 3a for the entire period of 24 hrs. Figure 3b shows the variation of the daily yield for the three fin heights. A maximum yield 1.771 kg is obtained at a fin height of 4cm whereas the yield is 1.325 kg for 3cm fin height and 1.627 kg for 5cm fin height respectively. It is clear from the above that the fin height of 4cm is the optimum fin height among the three. This is due to the reasons that less heat loss and more transmission of heat with the help of fins to water, which significantly increased the yield and gave higher efficiency also.

Figure 3c shows the variation of distillation efficiency for the three fin heights. The variation is similar to the daily yield, shown in fig. 3b. The efficiencies of still at 3cm and 5cm fin heights are 12.94% and 14.27% respectively. The maximum efficiency of 15.68% is obtained at the optimum fin height of 4cm.

Figure 2a: Variation of T_w with Fin Heights.

Figure 2b: Variation of T_d with Fin Heights.

Figure 2c: Variation of ΔT with Fin Heights.

Table 1

S. No	I(t) W/m ²	Time	T _w °C	T _{ci} °C	T _{co} °C	T _v °C	T _a °C	m _{ew} kg	γ % (Humidity)
1	510	8am	30.43	34.19	32.58	36.42	31.95	0.010	86
2	790	9	36.85	46.51	36.61	48.61	32.56	0.020	89
3	950	10	43.92	50.63	39.28	51.79	36.20	0.050	92
4	970	11	49.31	49.77	39.85	49.81	36.92	0.120	94
5	990	12	53.54	52.82	45.21	48.51	38.75	0.310	96
6	910	13	55.18	50.58	46.68	51.86	39.28	0.300	97
7	730	14	56.82	48.41	45.89	53.98	39.89	0.210	98
8	550	15	54.61	45.23	41.75	50.57	38.34	0.200	99
9	270	16	52.54	44.34	40.32	49.23	37.56	0.150	99
10	90	17	49.45	43.68	37.52	45.25	35.41	0.110	100
11	10	18	46.23	40.97	34.71	42.17	33.34	0.080	100
12	0	19	42.78	38.65	32.62	39.21	32.18	0.045	100
13	0	20	39.57	35.56	31.52	36.58	30.81	0.030	100
14	0	21	36.44	33.88	31.00	34.50	30.45	0.025	100
15	0	22	35.92	32.99	30.70	33.88	30.00	0.018	100
16	0	23	33.47	31.87	28.90	32.62	29.21	0.015	100
17	0	24	31.50	30.15	28.00	31.41	28.82	0.012	100
18	0	1	30.41	29.62	27.12	30.22	28.18	0.010	100
19	0	2	30.00	29.10	26.85	29.42	27.92	0.010	100
20	0	3	29.75	28.68	26.23	29.15	27.51	0.008	100
21	0	4	29.31	28.05	25.90	28.37	27.28	0.005	100
22	0	5	29.00	27.85	25.38	28.05	27.12	0.005	100
23	60	6	28.81	28.91	27.18	29.17	27.00	0.008	100
24	240	7	30.52	34.16	30.55	36.11	28.58	0.010	98
25	540	8	32.12	36.28	33.28	41.52	30.62	0.010	96

Figure 3a: Variation of m_{ew} with Fin Heights. Figure 3b: Variation of Σm_{ew} with Fin Heights. Figure 3c: Variation of η_D with Fin Heights.

CONCLUSIONS

The present experimental study is related to the optimization of the fin height for efficient distillation using a single slope, single basin passive solar still in Indian coastal climate in peak summer conditions. The important conclusions from the present work are summarized below.

- The highest yield and efficiency of the solar still are obtained at a fin height of 4cm. Hence 4cm fin height is the optimum height for the selected solar still. For fin height of 3cm, less yield and low efficiency are obtained due to less absorption area and less transmission of heat to basin water. For fin height of 5cm also, less yield and low efficiency are obtained due to more heat loss. The partial pressure difference between water temperature and condensing cover temperature is found to be highest for the 4cm fin height, which directly influences the yield.
- The distillation efficiencies of still at 3cm and 5cm fin heights are 12.94% and 14.27% respectively. The maximum efficiency of 15.68% is obtained at the optimum fin height of 4cm.
- A maximum yield of 1.771 kg is obtained at a fin height of 4cm whereas the yield is 1.325 kg for 3cm and 1.627 kg for 5cm respectively.
- The maximum yield and the distillation efficiency depend on the convection and the evaporation processes.
- The study will be useful for designing efficient solar distillation systems for the coastal climatic conditions.

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