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Research Article

PERFORMANCE ANALYSIS OF INCLINED SOLAR STILL WITH BIOMASS HEAT SOURCE AND SENSIBLE HEAT STORAGE MATERIALS

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ABSTRACT

In this analysis an inclined basin type solar was fabricated and tested for desalination of water with and without biomass boiler as heating source. An Inclined type Flat plate collector is designed in a conventional type solar still to act as collector. This collector was experimented in solar and biomass modes for comparison. The inclined flat plate collector tray was of dimension $1m^2$ and 3 mm thick G.I. Sheet was painted black and was attached with biomass boiler the inclination of the plate is 30°. Different water depths of 2cm, 3cm, were maintained in the conventional basin of the still and evaporation rates are analyzed. To enhance productivity of the still, sensible heat storage materials such as stone, iron scarps, sand were packed inside the wick and stretched at both ends and placed on the inclined flat plate collector. In order to improve capillary effects sponges of various sizes were placed on the inclined basin. Maximum evaporation rate was found for 2cm water depth 1530 kg/m^2 with The maximum evaporation rate for conventional still with 2cm depth was $680kg/cm^2$ For the various packing materials used highest evaporation rate is obtained for 2cm water depth with iron scarp packed inside the wick having $1400kg/cm^2$ Maximum productivity was achieved for still coupled with biomass heat source.

INTRODUCTION

Water is the main source for all the industrial and social activities. Many countries facing serious water problems. The economy of these countries depend on water. Many methods are available for solving water demand but the easy and economical solution to solve this problem is by desalination methods. Many desalination technologies were available of them our research is focused on solar stills. Fath and Hosny, (2000), analyzed the thermal performance of a single sloped basin still with an inherent built in condenser to improve condensation rate. Badran,(2009), studied the performance of a single slope solar still using different operational parameters experimentally. The results showed that daily productivity of the still can be increased by reducing the depth of the water in the basin. Vertical diffusion solar still coupled with flat plate reflector was designed by Tanaka and Nakatake, (2007), the distillate production rates were increased. Atikol *et al*,(2005), study inclined solar water distillation system and tested with three variants, base plate, black cloth, wick and black fleece wick. Nakatake,(2009) made a study, on increase in distillate productivity by inclining the flat plate external reflector of a tilted wick solar still in winter. The increase in fabricated a still which contains double slope, single basin. A thin layer of water is maintained in the still and many type of wick materials are used. They found that the production rate is a complex function of water, glass and its difference. Nassar *et al*,(2007), have successfully shown the effect of vacuum on the performance of the roof type solar still and conducted that the reduction in power required to produce 1 kg of fresh water will be 90.1% and water production rate is 20.11 kg/m2. Minasian and Karghouli,(1995), designed a wick type basin solar still and proved meet production of water increases by 85% than conventional basin. T.V. Arjunan and H.S. Aybar,(2005), analyse different heat storage medium and found meet blue metal store as a storage medium increases 5% productivity. Voropolulos *et.al*,(2004), experimentally investigated the hybrid still coupled with solar collectors the results showed that the productivity is doubled by coupling Muafag suleiman.K. and Tarawneh (2007) conducted the experiment on effect of water depth on still he also uses sprinkler for glass cooling to reduce glass cover temperature and improves productivity of

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14% more than conventional still. The main objective of this work is to investigate the performance of the inclined flat plate solar still integrated with and without biomass boiler along with sensible heat storage materials and evaporation material. A biomass boiler supply heat in to the still through heat exchanger. Various water depths of 2cm, 3cm were analyzed. Various combinations of sensible, evaporative materials were used in the still to increase productivity. Glass cover cooling is provided with the help of wicks and manual cooling at regular interval of time to increase condensation rate. To increase evaporative area sponges, wicks were used along with sensible materials. Materials such as sand, metal pieces, stones, were used as the sensible heat materials. The performances of still with biomass boiler are compared with performances of still without biomass boiler

Experimentation

The experimental set up (Fig.1) consists of the inclined flat plate collector and biomass heat source. The flat plate collector unit is enclosed in a wooden box of size 1.2 x 1.2m^2 and a height of 0.65m in one end and 0.5m in another end. The inclined flat plate collector and a conventional basin is of size 1m^2 made of G.I. sheet 4mm thick. The glass is fitted on the top of the wooden box to allow solar radiation. The thickness of the glass is 4mm. Thermocol is placed between the base surface and side walls of the tray to act as insulation materials. It prevents the bottom and side losses from the still a glass gutter is fitted at the bottom side of the glass to collect the desalinated water from the still. A measuring jar is placed outside the still to collect water from the gutter. Input tank is placed at height above the still which will supply saline water as a feed to the flat plate collector through a valve.

The biomass heat source having 133 mm external diameter and shell thickness 12 mm and height 550 mm made of cast iron. The lower segment of the heat source is known as the furnace where biomasses are sustained into the hummer through the fuel info entryway. The burnt ashes remains are collected at the lower end and evacuated intermittently. The lower end of flame tube is linked up to the heater and the upper end is joined with the heat exchanger. The boiler is supplied with biomass manually. The heat produced from biomass moves upwards there it transfer the heat to the water in the drum. The water gets heated and enter the still through heat exchanger tubes above the tubes saline water flows in the inclined flat plate collector which takes the heat and evaporated. One end of the heat exchanger is connected to circulation pump and other end to the boiler outlet. The circulation pump is operated at constant flow rate using external power supply. For solar mode the boiler was shutdown and still was exposed to solar energy only. Before starting the experiment, the glass cover is cleaned for removing dust using cotton cloths. The thermo couples are attached at the saline water storage tank, inclined flat plate collector and in a conventional basin to measure water temperature. Thermocouple is also attached at glass surface to measure glass cover temperature saline feed. The solar radiation enters through glass surface, evaporates the water, the evaporated water reacts the bottom surface of the glass cover. Condenses and due to change of phase water vapour becomes water. The distilled water gets collected in the glass gutter from where it is collected through output tank. The remaining brackish water is removed from still and collected at collection tank Experiments are first conducted by maintaining different water depths of 2cm, 3cm. For measuring temperatures, copper-constantan thermocouples indicator and selection switch are used. Solar radiations are measured using Kipp-Zonen Pyranometer. Wind velocity is measured by vane type digital anemometer. The beaker is used to collect and measure distilled water. This still is fabricated and tested at University College of Engineering, Ramnad, India during February 2017 to May 2017.

Fig 1 Experimental setup

Error Analysis

The degree of error analysis for various measuring instruments used in the experiments are shown in table 1. The error is calculated for thermo couple, solarimeter, Anemometer and collection tank. The minimum error occurred in any instrument is equal to be ratio between it’s least count and minimum value of the output measured.

Table 1 Accuracies and ranges of measuring instruments

Sl.No.	Instrument	Accuracy	Range	% error
1.	Thermocouple	$\pm$1ºC	0ºC to 100ºC	0.25 %
2.	Kipp-Zonensolarimeter	$\pm$1 W/m^2	0-5000 W/m^2	0.25 %
3	Anemometer	$\pm$0.1m/s	0-15 m/s	10%
4	Collection tank	$\pm$10ml	0-1000ml	10%

RESULTS AND DISCUSSIONS

Effect of water depths on productivity in inclined flat plate single basin in solar mode

The result of water depth in the still on the productivity is shown in Figure 2. It is evident that as the water depth increased, the productivity will be diminished. This is due to be increase of the heat content of the water in the basin, results, in lower water temperature in the basin leading to lower evaporation rate The 2cm water depth produces maximum output when compared to other water depths of 3 cm .The flat plate collector in solar mode produces lesser output than in biomass mode. In the biomass mode the output does not depend on solar radiation but depends on the heating value of the biomass. The flat plate with 2cm depth in solar mode has a productivity of 910Kg/m^2, and in biomass mode it produces1530 Kg/m^2. The 3cm depth produces 690,1120 Kg/m^2 in solar and biomass modes.

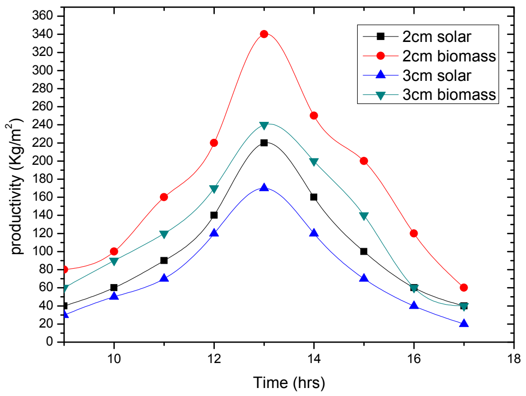

Fig 2 Productivity on water depth

Effect of solid sensible heat storage materials on productivity in flat plate collector

Some materials can store more amount of heat energy and increases the heat capacity of the basin in addition to increasing the basin absorption. These materials absorb energy during heating periods and released energy slowly during cooling. The Figure 3 shows the productivity of various solid sensible heat storing materials with time various materials such as metal, sand, stones were placed inside the still with 2 cm water depths and tested. The productivity ranges of the materials are 1580 Kg/m^2 for metals because it will absorb more heat than other materials. The productivity of other materials are 1200 Kg/m^2, for stone, 980 Kg/m^2 for sand. The basic property of sensible materials are high thermal conductivity, high specific heat capacity, non toxic, chemically stable. Non corrosive, easy availability with low cost.

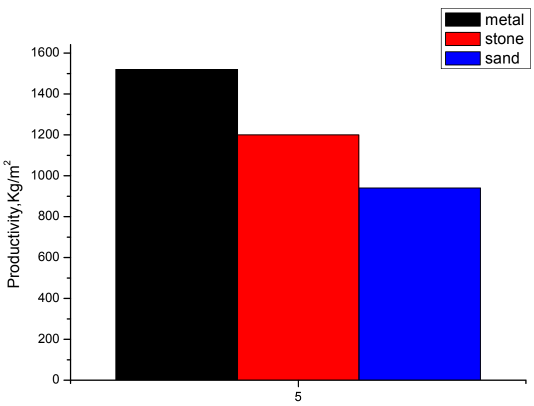

Fig 3 Effect of sensible material on productivity

Effect of evaporative surfaces on productivity

Due to capillary action sponge, wick absorb more water. Thus, exposure area is increased. This contributes to increase the evaporation rate in the still. As demonstrated in Figure4, productivity is increased by nearly 23% for wick and 17% for sponge Sponges and wick absorbs water by adhesive forces and serves to increase the productivity.

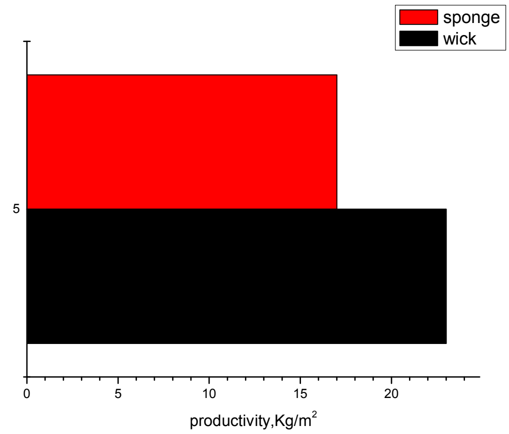

Fig 4 Effect of evoporatation material on productivity

Economic analysis

The overall fabrication cost operating cost of both conventional and modified still is Rs.8000 ($160). The cost of feed water is negligible. No maintenance cost. The cost per liter of distilled water is Rs.20. ($0.2) and the average productivity of the still is 3542 kg/m^2. The still produced an average of 1085 kg/m^2. Thus the cost of water produced per day is Rs.70 ($0.20) for modified still and Rs.20 for conventional still.

Net earnings for still with biomass boiler

=cost of water produced - maintenance cost
=Rs. (25-0) = Rs.25 ($ 0.25)
For still only it is Rs.20 and payback
Period = Investment / Next earnings per day
= 8000 / 70 = 114 days
Pay back period for conventional still =8000 /20 = 400 days
Taking biomass boiler into account,
For biomass boiler mode pay back period = 10000/90 = 114 days

As shown in Figure 5 about 71% of the days are saved in the modified still compared to conventional solar still.

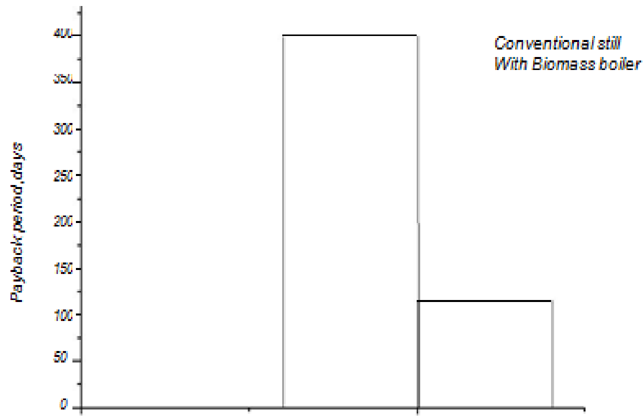

Figure 5 Economic Analysis for single basin still

CONCLUSION

The single basin inclined flat plate collector still with and without biomass heat exchanger was compared the results showed that,

- The still with biomass heater produces more output than conventional based still

The output in conventional still depend upon solar energy (radiation) which may vary from time to time. But in biomass heater energy can be increased by burning
More amount of natural fuels.

- The cost of fuel in biomass heater is low since they are easily available biomass wastes
- Concentrator requires special attention for focusing throughout the day
- The payback periods for biomass based stills were 142 days only as they produce more output. The payback for concentrator is 500 days.
- Lower water depth in the still produces more output in both the stills and higher depths produces lower output.
- Introduction of sensible heat storage materials increases productivity in both the stills. More output is from biomass based stills
- Using wax as latent heat material increases the productivity in both type of still but it was more on biomass heater type
- Porous materials increases the evaporation rate
- The average output from biomass based still was 5000lit/m^2/day and for conventional type it was 1500lit/m^2/day

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