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Experimental investigation on the performance of solar still augmented with pin-finned wick

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HIGHLIGHTS

- Performance of solar still with pin finned wick is investigated.
- Experiments are carried out at different weather conditions.
- Enhancement of system productivity up to 23% could be reached.
- System productivity is affected by weather fluctuation.

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ABSTRACT

This paper presents an experimental investigation on the performance of solar still augmented with pin-finned wick evaporation surface. The experimental system involves two identical solar stills, one of the stills is conventional and the other has an evaporation pin-finned wick surface. The fins are supported vertically on the basin of the still using steel wires. Outdoor experimental tests are conducted to investigate the effect of using pin-finned wick on the still productivity. Tests are carried out at wide range of ambient temperatures and solar radiation. Temperatures at different locations (glass surface, water in the still, wick surface and air–vapor mixture) as well as ambient temperature are recorded with time. Solar radiation as well as collected distillate are recorded during the experiments at different operating days. Experimental measurements indicate that the increase in distillate varies with ambient conditions. Enhancing the still productivity is proved when pin-finned wick is applied in the still. System efficiency of about 55% is recorded when pin-finned wick is used. An enhancement in the still productivity of more than 23% is recorded during this set of experiments.

1. Introduction

Investigation of solar still for water desalination has increased steadily during the past several years. From the viewpoint of the global environment and energy sources, these systems are considered as a good alternative for obtaining potable water. A comprehensive review and bibliography of the solar desalination can be found in literature [1–6]. Augmentation of productivity of solar still has been investigated by using different methods such as using tabular [7], heat-pipe [8] and thermoelectric module [9]. Numerical study to estimate the productivity of solar still as well as evaluate the convective heat transfer coefficient can be found in references [10,11] An improvement to the performance of solar still can be made by using porous black wicks to make what is now called the Wick-Type solar still [12–15]. The productivity of a solar still increases with increases in evaporation surface area. Enlarged areas by integrating fins with the solar still are investigated by Velmurugan et al. [16]. They found that the average daily productivity increased by 30%. In a fin type solar still with black rubber, sand, pebble or sponge immersed in brine; respectively, the productivity was increased by 58% to 70% [17]. Sponge cubes are placed in a basin solar still to increase the brine free surface and the evaporation rate [18]. It is reported that the increase in distillate production reaches 273% compared with the still without sponge cubes under the same condition. Floating tilted-wick type solar still is investigated by Janarthanan et al. [19]. The brine flow over an inclined surface paved with thin wicks. Compared with a basin solar still, less time is needed to get fresh water in a tilted wick type solar still at the beginning and the productivity can be enhanced by 16 to 50% [20].

Performance of basin type double slope solar still with different wick materials like light black cotton cloth, light jute cloth, sponge sheet, coir mat and waste cotton pieces is investigated [21]. It is reported that light black cotton cloth was the most effective compared with other wick materials. Aluminum rectangular fin covered with cotton cloth and arranged in lengthwise direction was more effective and gave slightly higher production than the light black cotton cloth.

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Nomenclature

A	area, m^2
I_t	total solar radiation, MJ/m^2day
I_s	solar radiation intensity, W/m^2
L	length, m; latent heat of evaporation, J/kg
m_d	mass of accumulated water, kg
T	temperature, °C
X	evaluated variable in error analysis

Greek symbols

η_D	daily efficiency

Subscripts

amb	ambient
b	basin
d	distillate
g	glass
t	total
wat	water
v	vapor

Shukla et al. [22] used jute cloth for increasing the evaporation rate. One end of the jute cloth was dipped into the water reservoir while the surface of the jute cloth was spread over the basin exposed to sunrays.

For increasing productivity of solar still new approaches are highly welcome. An attempt to improve the performance of solar still should include an investigation on the performance of new wick surface configurations. To the best of our knowledge, pin finned wick has not been investigated in the literature. In the present study it is objected to investigate the performance of solar still augmented with pin finned wick to enhance the evaporation surface. It is also aimed to evaluate the effect of ambient conditions on the still performance.

Table 1
Still design parameters.

Basin dimensions, cm.	80 × 125
Glass cover sloop, deg.	17
Glass thickness, mm.	4
Insulation thickness, mm.	50
Pin-fined wick height, cm.	9
Pin-finned wick diameter, cm	1
No of Pin-fined elements.	294
Water level in the basin, cm.	3

2. Experimental study

The objective of the experimental work is to study the performance as well as comparison between two solar stills; one of them is conventional still and the other is augmented with pin-finned wick. For this purpose, two identical solar stills are designed and fabricated at the Mechanical Power Department, Faculty of Engineering, Mansoura University. One of the two units is augmented with a pin-finned wick surface located at the basin of the still. The still is made of galvanized steel sheets (1.0 mm thick). Dimensions of the basin are given as 0.8 m and 1.25 m. The basin is covered with glass sheet of 4 mm thickness, inclined with nearly 17° to horizontal. The inclination angle of the glass cover is selected on the basis of previous studies, in which it is stated that the most efficient angle for El-Mansoura is around 15°. [23]. Rubber and Silicon are used for filling to prevent leakage from any gap between the glass covers and the still edge. All sides and the base are insulated by glass-wool of 5 cm thickness. The insulation layer is supported by aluminum frame. Still basin as well as the wick material are coated with black paint for good absorption.

The pin-finned wick (294 elements) of 9 cm height and about 1 cm diameter have 3 cm immersed in the water to have capillary action. The condensate flows downward on the inner surface of the glass cover towards a collecting V-trough, allocated at the lower end of the glass cover. The end of the V-trough is connected with a tube to the graduated flask. The tube exit and flask inlet are covered by plastic sheet to prevent

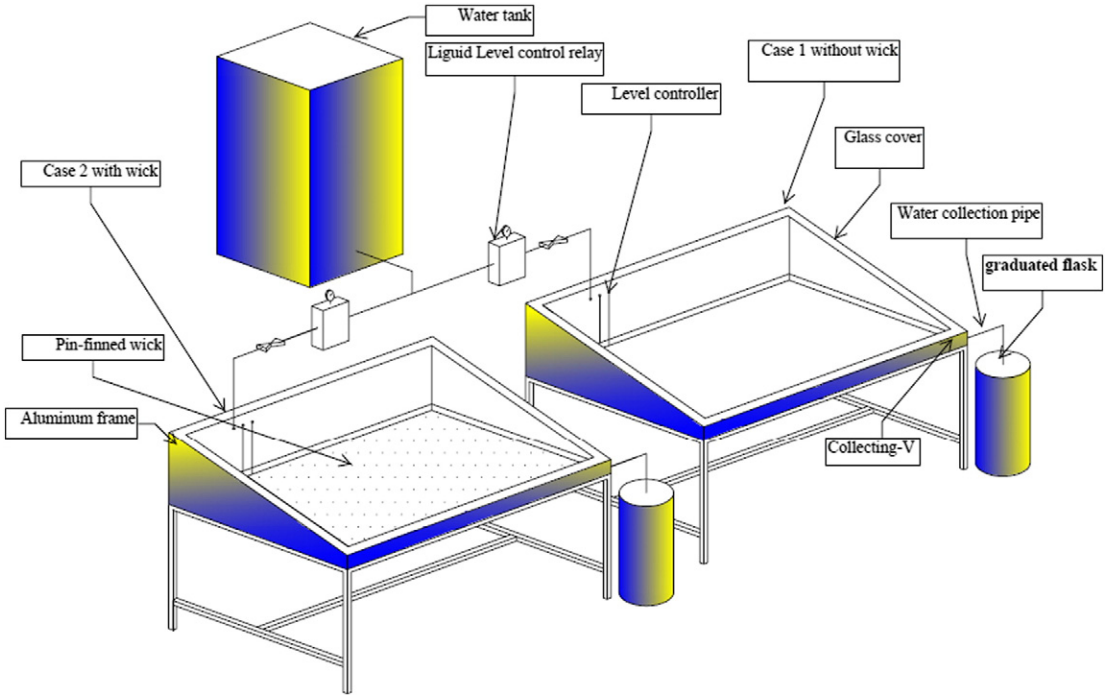

Fig. 1. Schematic of the experimental test unit.