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Experimental performance analysis of a modified single-basin single-slope solar still with pin fins absorber and condenser

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ABSTRACT

This work presents a modified solar still with pin fins absorber and external condenser. An experimental comparative study is carried out between the modified solar still with pin fins absorber and condenser, still with pin fins absorber and conventional still. This experimental study is conducted to evaluate the thermal behavior (evolutions of absorber and glass temperatures) and the water production performance of the modified solar still with pin fins absorber and condenser compared to other designs. All experiments are carried out under the meteorological conditions of the region of Gafsa-Tunisia during the days 01/26/2016, 01/27/2016 and 01/29/2016. Experimental results are presented, quantified and discussed to show the utility of the proposed modified solar still.

1. Introduction

The water still is a desalination device that permits to distill brackish water [1]. Due to the shortage in global freshwater resources, this device becomes more and more important [2]. The water still can be powered by low grade energy such as solar energy [3]. Solar still uses solar irradiance in order to create a greenhouse effect that permits to evaporate brackish water and then condensate it to obtain finally freshwater.

The use of solar energy to power water still permits to save fossil energy [4] and to be environmentally friendly [5] but at the expense of productivity. In fact, the productivity of solar water desalination is relatively low compared to other expensive water desalination technologies [6], such as vapor compression and reverse osmosis. The literature presents several research works carried out to improve the productivity of solar still. These works can be divided into 4 kinds.

The first kind of research works concerns the improvement of still productivity by studying the effect of absorber. The improvement of productivity and efficiency is experimentally investigated for a still having an absorber with pin-finned wick surface in [7]. The enhancement of performance is experimentally and theoretically studied for a solar still having a single basin with circular and square fins [8]. Performance analysis of solar still with modified basin, that incorporates multiple low thermal inertia porous absorbers, is carried out in [9]. Performance parameters are studied for solar still with corrugated absorber that uses double layer wick material and internal reflectors [10]. Theoretical and experimental work is conducted for double slope solar still with single and double basin. Experimental productivity study of double slope solar stills with single and double glass basin is carried out in [11]. An experimental and theoretical investigation is carried out in [12] for a stepped solar still having a reflecting mirror on the vertical side of each step. Experimental performance study are conducted in [13] for a single basin solar still that uses preheating of saline water by means of integrated flat plate collector arrangement. The influence of the amount and mode of input energy for a multi-stage solar still is investigated in [14].

The second kind of research work concerns the improvement of still productivity by studying the effect of reflectors and concentrators. A broad review of solar stills, using internal or external reflectors in order to improving water production performance, is presented in [15]. The influence of using reflectors inside a corrugated absorber solar still is, also, investigated in [10] in terms of water production performance. The effect of using internal mirror reflectors, installed on the vertical sides of each steps of a stepped absorber solar still is, also, studied in [12]. Design, fabrication and productivity evaluation are carried out for a stand-alone point-focus parabolic solar still in [16]. The water

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Nomenclature			
		b	Absorber
		cv	Convection
A	Area, m^2	D	Daily
I	Solar irradiance, $W.m^{-2}$	$evap$	Evaporation
L	Average latent heat of water vaporization, $J.kg^{-1}$	fw	Feed water
M	Hourly water production, kg	gls	Glass
T	Temperature, K	H	Hourly
U	Heat transfer coefficient, $W.m^{-2}.K$	p	Plate
		rd	Radiation
Greek symbols		sky	Sky
		w	Brackish water
η	Efficiency		
Subscripts			
amb	Ambient		

production performance of a compound parabolic concentrator tubular solar still is investigated experimentally in [17].

The third kind of research work concerns the improvement of still productivity by studying the effect of condenser. A solar still with photovoltaic system, external condenser and solar water and air collectors is investigated experimentally to evaluate the enhancement of its water production performance [18]. Experimental investigation is carried out on the influence of adding an outside passive condenser to a single-basin solar still with minimum inclination [19]. Numerical study of the influence of adding condensation cell to a single-basin double slope solar still is conducted in [20]. The influence of condenser on the productivity of single slope solar still is studied in [21].

The fourth kind of research work concerns the improvement of still productivity by studying the performance of hybrid solar still. A multiple effect diffusion hybrid solar still with dual heat sources (solar thermal energy and waste heat) is designed [22]. Also, its productivity is investigated experimentally in order to show the effect of operational parameters (inputted quantity of heat, feeding water flow rate and water level in the basin). A comparative experimental exergoeconomic and enviroeconomic study is carried out on a photovoltaic thermal flat plate collector solar still [23]. A hybrid solar desalination system composed of 4 solar stills and a humidification-dehumidification system is presented and investigated experimentally to show its high efficiency [24]. A numerical and experimental productivity study of a hybrid tube-type basin solar still with an air-gap membrane distillator is carried out [25].

In this paper, we aim to carry out an experimental comparative study between modified still with pin fins absorber and external condenser, modified still with pin fins absorber and conventional still. A detailed description for still design is presented in Section 2. The Section 3 is devoted to the experimental setup.The experimental results are presented and discussed in Section 4. Conclusions are elaborated in Section 5.

2. Solar still design description

The modified solar still (right) and the conventional one (left) is depicted by Fig. 1. A schematic diagram for the modified solar still is presented by Fig. 2. The absorber (box) of the solar still is manufactured by plywood and painted black in order to have a black body. This permits to absorb a maximum amount of solar radiation and to increase, so, considerably the amount of heat produced. Reflecting mirror is integrated within the still in order to reflect solar energy in the absorber. A glass cover is fixed on the top of the absorber with an inclination of 30°. Thus, a greenhouse effect is created, near the absorber,through the transparency of the glass to solar radiation (picked up by the absorber) and its opacity to infrared radiation (emitted by the absorber). The modified solar still have a pin fins absorber plate (Fig. 3) painted black and emerged in the brackish water within the basin. The pin fins are made of steel, painted in black, have a cylindrical form with a diameter of 3 mm and a height of 60 mm and placed 15 mm away from each other. A condenser is integrated to the modified solar still in order to enhance its productivity.

The greenhouse effect, within the still, permits to evaporate the brackish water. A part of the hot water vapor will be condensed on the inner surface of the glass cover through the temperature difference between the water vapor and the glass. The condensed distilled water will be collected using a condensate collection channel. The other part of hot water vapor will be moved by an air flow toward the condenser where it will be cooled and transformed in distilled water. All the heat flows components in the investigated still are depicted in Fig. 4.

3. Experimental setup

The experimental setup consists in 4 devices:

- Solar still combined to a condenser
- Compressor
- Thermometer
- Graduated bottle

The locations of the different devices used in the experimental setup as well as its installation are illustrated in Fig. 5.

The measuring instrumentations give, generally, experimental data slightly deviated compared to the exact ones. This is due mainly to the uncertainty of the measured phenomenon and the accuracy of the instrumentation itself. Solarimeter, thermometer and graduated bottle

Fig. 1. Modified solar still (right) and conventional solar still (left).