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Performance comparison of single and double pass PV/T solar collectors integrated with rectangular plate fin absorber

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Performance comparison of single and double pass PV/T solar collectors integrated with rectangular plate fin absorber

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Abstract. Solar panel can act as a medium for transforming sunlight into electrical energy. Nevertheless, not all of the sunlight received on this device can be converted into electrical energy and the remainder will be dissipated into thermal energy. If a solar panel is continuously exposed to the sun, so its temperature will increase and thereby reduce its electrical efficiency. To deal with the issue, it may combine a PV panel with a thermal collector which is called a hybrid PV/T collector. Furthermore, in the present study the effects of fluid flow direction and mass flow rate on the thermal and electrical efficiency of the PV/T collectors are extensively analyzed. Single and double pass collectors with rectangular plate fin absorber were attached to backside of the PV panel. They were tested using a solar simulator with different flow rate ranging between 0.01 and 0.05 kg/s of the working fluid. The results show that the use of double pass PV/T air collector increase its performance compared with the single pass one. The highest values obtained from this type collector are found to be 73.23% in the thermal efficiency and 10.16% in the electrical efficiency with the working fluid mass flow rate of 0.048 kg/s.

Keywords: single, double pass, PV/T collectors, rectangular fin absorber

1. Introduction

PV/T collector is built by joining a PV cell and a thermal collector that produce thermal energy and electrical energy at the same moment. However, the electrical efficiency of PV/T collector decreases if the surface temperature of PV cell increases [1]. In general, a working fluid in the form of liquid and air can act as a coolant as reported in a comprehensive review by other [2]. The working fluid aims to absorb the heat waste of the collectors and reduce its surface temperature. In this type of the collector, the implementation of fins led an enhancement in the area of heat transfer and could be a better way to increase the thermal efficiency. Several researchers have conducted studies on the different geometry fins as reported in several literatures [3-6].

Furthermore, it has been also investigated that solar PV/T air collectors using v-grooved fins as a thermal absorber [7]. Air is circulated along the upper groove and returned in the counter flow direction along the lower groove. The results show that the use of an extended surface appearing as v-grooved fin give a significant impact on increasing the performance of the collectors. This is because of the working fluid absorb more waste heat through the fins attached backside the PV panel. Several other studies related to the improvement of collector performance, the effect of working fluid, fluid flow geometry and configuration have also been reported in the literatures. Since the air has lower heat capacity compared with water, so it is important to develop the performance of PV/T air collector as observed by other [8]

In addition, several other researchers investigated the performance of solar PV/T collectors for both single [9] and double passes [10-13] which were applied in various fin geometries. Meanwhile, a comparison research between the single and double passes of PV/T air collectors was carried out by others [13,14]. The results reported that better performance was obtained from the double pass design. Furthermore, the thermal efficiency of various PV/T air collectors associated with the double pass design is better than others because of uniform cooling for the surface temperature of PV panel, so enhance the electrical performance as investigated and reported by other [15]. Further study assumed that thermal efficiency of a trapezoidal corrugated plate thermal air collector [16]. This type collector was tested under the climate of Konya region (Turkey). There is the difference between outlet and inlet fluid temperatures up to 9^{o}C for the trapezoidal corrugated plate thermal air collector compared with the traditional thermal collector.

Based on the previous references reported from researchers as mentioned earlier, the impact on PV/T air collector performance may give various characteristics depend on several parameters. This makes the development of PV/T air collectors should be interesting to be explored in term of variations in geometries, materials and various test locations. In the present study, the performance of the single and double passes of PV/T air collectors combined with rectangular plate fin absorber is investigated. The inlet fluid temperature as a working fluid is based on the tropical climate of Lampung, Indonesia. Further, this new design of the proposed PV/T collector uses fins as absorber with a specific geometry. The material of fin used is aluminum which has good thermal conductivity and low density. Then, the two collectors were built in the form of single and double passes for flow arrangement of the working fluid. Furthermore, the influence of the mass flow rate of the working fluid on the performance of the two collectors is elaborated in the present work.

2. Design of PV/T collector

A photograph of the test installation is given in Figure 1. Solar simulator is the main component for simulating solar radiation energy. This device consists of 12 halogen lamps with a power of 300 W. Other's equipment are installed to measure data associated with radiation, temperature, fluid mass flow rate, current and voltage of the PV panel. Furthermore, the type of PV panel collector is polycrystalline PV 100Wp with dimensions of 1020 x 670 x 30 mm. The specifications of the PV panel tested are also presented in Table 1. Meanwhile, for circulating the working fluid along the rectangular plate fin, a blower is used.

Figure 1. Photograph of experimental setup.

Table 1. PV panel specifications (Polycristaline)

P_{max}	100 W
V_{mp}	17.6 V
I_{mp}	5.69 A
V_{oc}	2.85 A
I_{sc}	3.04 A
NOCT	45ºC±2ºC

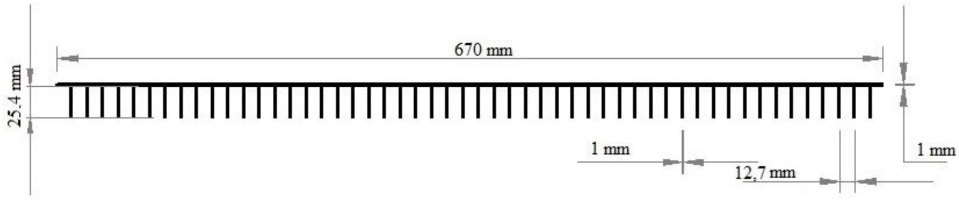

Figure 2. Dimensions of rectangular plate fin absorber.

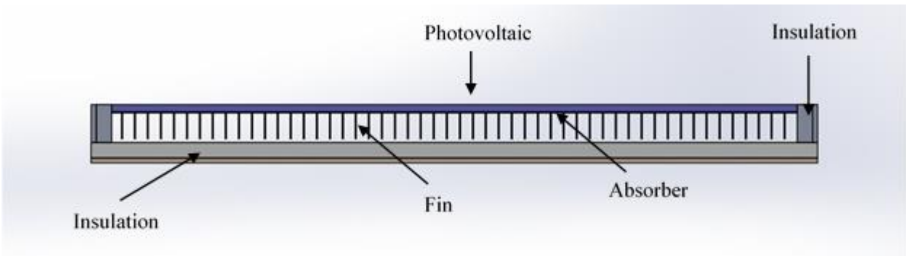

Figure 3. Front view of single pass collector

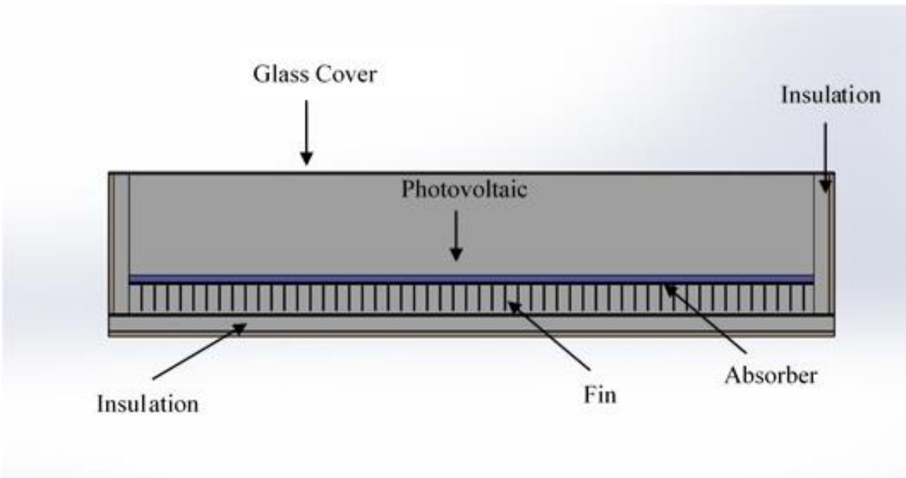

Figure 4. Front view of double pass collector.

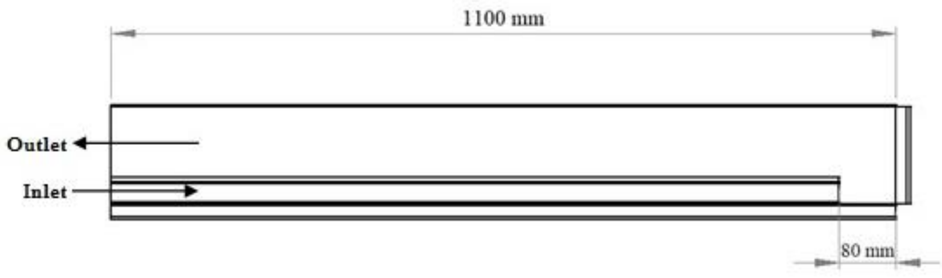

Figure 5. Side view and fluid flow direction of double pass collector

The PV/T air collector performed in the present work was combined by attaching the solar thermal collector to backside the PV cell surface. The dimensions of rectangular plate fin absorber fit the available surface of PV collector as seen in Figure 2. Fin height-space ratio setting is found to be 2:1. The differences between the two types of collectors are illustrated in detail in Figures 3 and 4, respectively. Besides, Figure 5 shows the side view of double pass collector which is developed from a single pass collector, where the outlet fluid of the single pass one is circulated back to the top of the PV collector surface.

3. Materials and Methods

The two types collectors were tested indoor by several halogen lamps as a substitute for solar radiation energy. The radiation intensity used was 860 W/m^2. In data collection, the collectors were exposed in direction perpendicular to radiation. The experiments were carried out in Bandar Lampung where is the capital of the Lampung Province (Indonesia). Bandar Lampung region has a typical tropical climate which is characterized as dry and rainy seasons. Air as a working fluid in this work acts as a cooling medium for rectangular plate fin absorber of PV/T collectors. It was varied in the range of 0.012, 0.024, 0.036 and 0.048 (kg/s), respectively, for the mass flow rate values. Furthermore, the performances of the two collectors were investigated and analyzed as described in the following sections.

3.1. Experimental procedures

A data acquisition system recorded every 10 s interval was implemented in the present study. The experimental data of the two collectors were taken such as inlet, outlet and ambient fluid temperatures, incident radiation, voltage and electrical current. Besides, the fluid temperatures and radiation intensity were measured using K-type Thermocouples and Solar Power Meter SPM 1116SD, respectively. The working fluid was regulated by using a valve for the *mass flow rate*. A power meter and electrical loading resistors were then installed to obtain the electrical data of the two collectors.

3.2. Characterization of PV/T solar collector

The thermal performance of the PV/T collectors was characterized referring to the working fluid and the surface temperature of the PV collectors. Furthermore, the experiments were also to determine the electrical efficiency of the two collectors. Moreover, the thermal performance in the form of instantaneous efficiency is associated with next equation:

$$\eta_{th} = \frac{\dot{m}\, C_p(T_{fo}-T_{fi})}{A\, G} \tag{1}$$

where the thermal efficiency is represented by η_{th} (%). Further, the specific heat of the working fluid and the mass flow rate are symbolized by C_p (W/m^{2}C) and $\dot{m}$ (kg/s), respectively. Then, the inlet and oulet of fluid temperatures, the absorber area and the intensity of radiation are given by T_{fi} (°C), T_{fo} (°C), A (m^2) and G (W/m^2), respectively.

Furthermore, testing electrical performance can use the following formula:

$$\eta_{el} = \frac{I\,V}{A\,G} \tag{2}$$

where the parameters of equation (2) namely electric current and voltage are represented by I(A) and V(V), then area of the PV surface and the intensity of radiation are given by A (m^2) and G (W/m^2), respectively.

4. Results and Discussions

The two types of the PV/T collector have been tested using several halogen lamps as a substitute for solar radiation. The experiments were carried out with a radiation intensity of 860 W/m^2 and various flow rate ranging between 0.01 and 0.05 kg/s of the working fluid. The ambient temperature in this work was implemented under the Bandar Lampung climatic (latitude 5°27′S and longitude 105°16′E). The experiment results are then analyzed and compared between the two collectors as described in the following paragraphs.

4.1. PV/T collector thermal performance

The results obtained from the experiments are presented in the form the temperature distribution and the thermal efficiency for the two collectors as illustrated in the Figures 6 and 7.

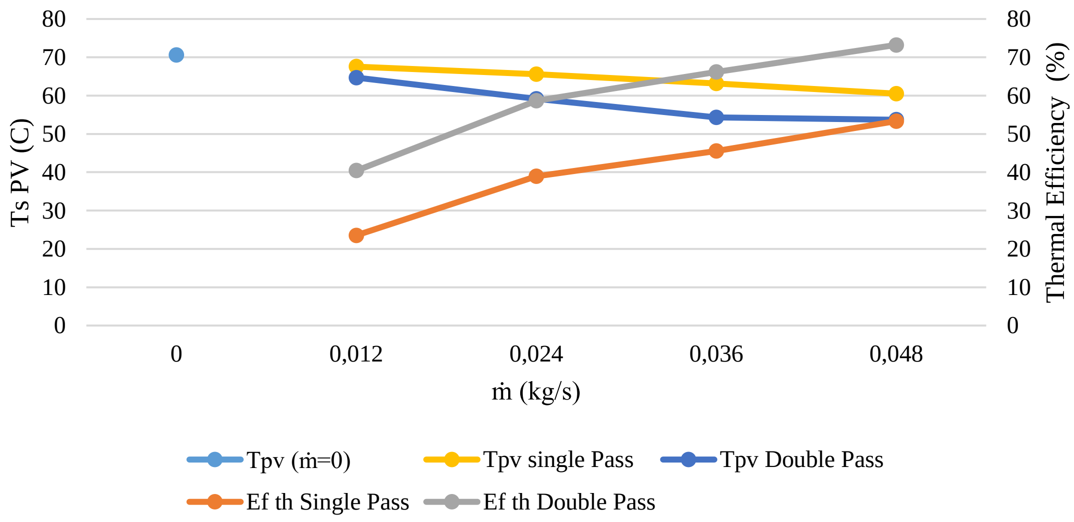

Figure 6. Thermal efficiency and PV surface temperature in accordance with mass flow rate of working fluid *without* ambient air speed (V = 0 m/s).

Figures 6 and 7 show the relationship between thermal efficiency and surface temperature of the two collectors associated with the mass flow rate of the working fluid. During the experimental tests, the two collectors were also performed *with* (velocity of 1 m/s) and *without* ambient air speed moving over the collector surface which was circulated by a fan. As for the cooling process, air as a working fluid supported by a blower was circulated through the rectangular plate fin absorber.

In general, from Figures 6 and 7 it is explained that the greater the working fluid mass flow rate, the temperature of PV surface will decrease and then the thermal performance enhances for the two types of the collectors. This is because the greater the working fluid mass flow rate of the collectors, the greater the waste *heat* absorbed by flowing air and move it to the outlet section, causing decreased the PV panel surface temperature. For this context, there is the difference in the temperature of PV surface for the double pass one (see the T_{PV} *double pass* curve) in Figure 7.

This condition is indicated by sharper curve than the others which decrease *the* temperature of PV surface around 10°C. The advantage of the double pass one, the outlet fluid of the first channel is circulated back to the top of the PV collector surface (second channel) may give the working fluid longer time to contact with the surface. Consequently, it can absorb more waste heat to improve the performance of the collectors in comparison with just a single pass one. Thermal efficiency is able to reach 73.23% at the working fluid mass flow rate of 0.048 kg/s for double pass one.

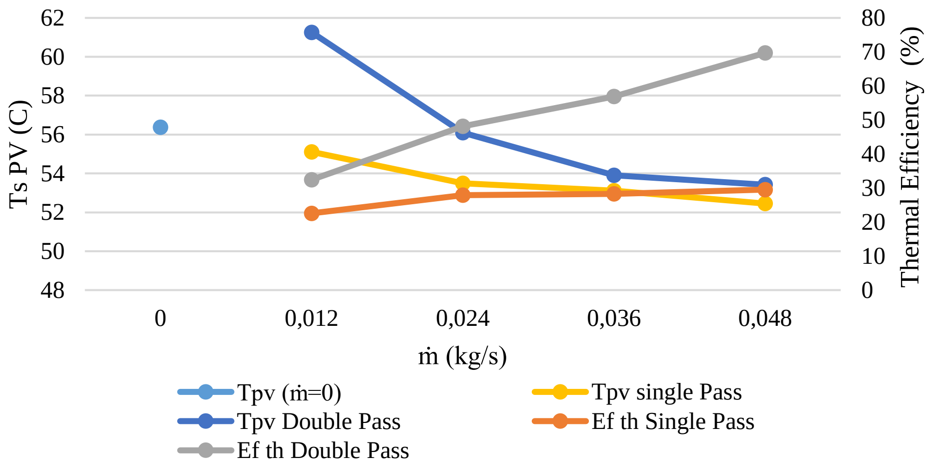

Figure 7. PV surface temperature and thermal efficiency in accordance with mass flow rate of working fluid *with* ambient air speed (V = 1 m/s).

4.2. PV/T collector electrical performance
To find out the electrical performance, the test procedure is similar to that of the thermal performance testing. The data obtained from experiments are then calculated and presented in the form of electrical efficiency and surface temperature of the collectors.

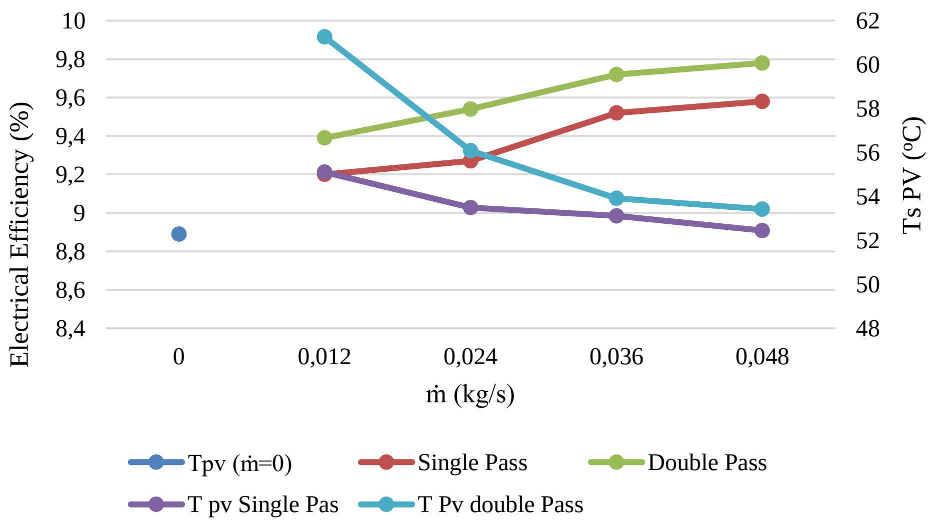

Figure 8. PV surface temperature and electrical efficiency in accordance with the mass flow rate of fluids *without* wind speed.

Figures 8 and 9 show impact of various flow rate of the working fluid on surface temperature and electrical efficiency of the two different types of PV/T collectors *with* and *without* ambient air speed.

Similar to that of the thermal performance characteristics, increasing the mass flow rate also enhance the performance of the PV/T collectors associated with the electrical efficiency and reduce the surface temperature for both types of the collectors. With the use of ambient air speed in the experimental tests, the surface temperature of the PV panel is lower than *the* results obtained from *without* ambient air speed. This is because in the testing *with* the ambient air speed, a convection heat transfer process occurs on the PV panel surface to ambient fluid flow. The waste heat of the PV panel surface will be absorbed by the ambient air moving over the collector surface.

That condition may be advantageous because a decrease in the surface temperature. It will enhance the PV/T collector performance related to the electrical efficiency. The graph of the impact of the mass flow rate for double pass collector as seen in Figure 9 provide the highest electrical efficiency value of 10.16% in the working fluid mass flow rate of 0.048 kg/s.

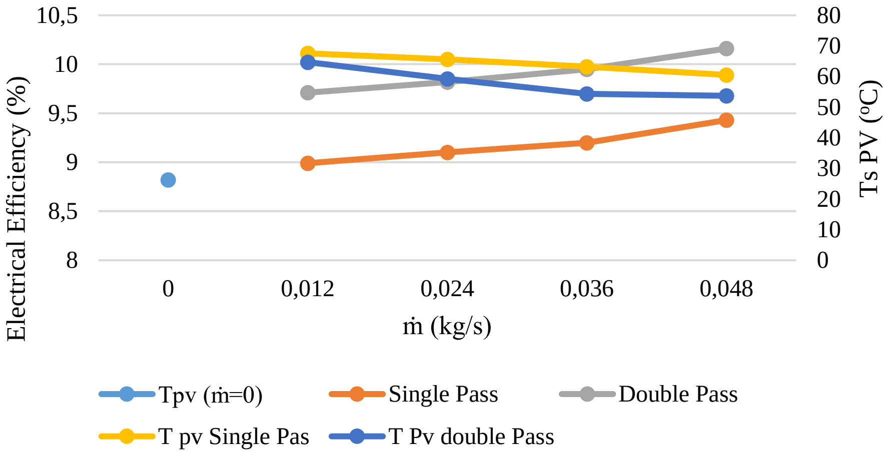

Figure 9. PV surface temperature and electrical efficiency in accordance with mass flow rate of fluid *with* wind speed.

5. Conclusions

The results have been obtained from this study indicate that thermal and electrical efficiency of the PV/T air collectors are affected by geometries, working fluid mass flow rate, flow arrangement and test locations (weather and climate). With fin height-space ratio setting (2:1) and different flow rate ranging between 0.01 and 0.05 kg/s of the working fluid and inlet fluid temperature (T_{fi}) under the tropical climate of Lampung (Indonesia), there is a different response of the two types of collectors. In general, the double pass PV/T collector has better thermal and electrical efficiencies than the single pass one. The highest values obtained from the double pass collector with the working fluid mass flow rate of 0.048 kg/s are found to be 73.23% in thermal efficiency and 10.16% in the electrical efficiency, respectively. Meanwhile, there is also an increase in electrical efficiency of 0.89% for double pass collector *with* the use of ambient air speed. The results of this study indicate that the use of double pass PV/T collector may have the potential to be developed in the tropical climate.

Acknowledgements

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