Amorphous Solar Module for PV-T Collector for Solar Dryer

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***Abstract*—Solar thermal collectors generally convert sunlight into heat solely. However, if photovoltaic solar panels are used as collectors, the dryer system will get electricity in addition to the heat. The objectives of the present are to review the development of PV-T collectors and their use for solar drying. In addition, design and test a small scale solar dryer is carried out in this study by utilizing amorphous type photovoltaic-thermal (PV-T) as a collector. The heat obtained is used directly as a drying medium, while electrical energy is used for power supply for air circulating devices. The solar collector consists of 40 Wp amorphous solar panel, and covered with double glass at the top, while at the bottom and both sides are insulated to minimize heat loss. Heated air in the collector is then flowed to a chamber where the product to be dried the outlet. With the fixed position, it is found that the temperature of the outlet air from the collector varies from 35 – 50 ºC during the day with solar Irradiation of 300 – 1000 W/m^2. At the same time, the electric power output from the PV panel varies from 4 – 25 Watt.**

Keywords—solar dryer, PV-T, solar module, solar collector

I. INTRODUCTION

Drying is one of the essential processes in post-harvest for many kinds of agricultural products. Inadequate drying process would affect the productivity and the quality of a product. The traditional sun drying is still practiced in many places in Indonesia. A better way should be attempted for this situation. There are generally two ways to harvest solar energy, using photovoltaic (PV) systems to generate electricity and using solar thermal systems collect thermal energy. The two technologies are different and each has its advantages and disadvantages. PV systems generally are used only for converting a small fraction of the solar energy into electricity. Commercially modules, only about 17 % [1] of solar energy falling into the modules would be converted into electricity.The remaining portion is absorbed by the cells which result in higher cell temperature. On the other hand, when the cells temperature and the module increases, the efficiency decreases means less electricity would be produced. Solar thermal collectors system can produce energy in the form of heat with higher efficiency, however the solar thermal collectors are commonly more expensive in comparison with PV modules with a similar area of dimension.

The combination of electricity generation and generation of thermal energy in one single collector so-called Hybrid photovoltaic-thermal (PV-T) collectors is on way to increase the amount of harvested energy from solar radiation. This has the advantage that, in the most optimistic case, the PV module gets cooled by the extraction of heat and thus can operate with higher efficiency and the extracted heat can be used in any other heating purposes such as air heating.

The objectives of the studies in this paper are to review the development of PV-T collectors including their use for solar drying and review on test standards for solar dryers and PV-T air collectors. In addition a small scale PV-T solar dryer based on the Amorphous PV module was designed and constructed. The preliminary test was conducted and the results are discussed. The dryer is expected to use for drying of herbal material which is a part of studies in the faculty of pharmacy, University of Surabaya, Indonesia. The temperature for the drying process should not be more than 60 °C in order not to damage the herbal plants, on the other side the temperature should be above 45 °C as otherwise the drying process would take too long time. A PV-T air collector is assumed a good application for such purposes as the heated air directly could be used to dry the herbal plants and extra benefit electricity is produced which could be used in the production process to power a built-in system to control airflow and temperature in the drying compartment [2].

II. METHODS

The methods of studies in this paper are both by literature reviews and constructing and testing a small scale solar dryer. AS stated in the background that the literature review is done to review the development of PV-T collectors, as well as their application in solar drying. In addition, a review on test standards for solar dryers and PV-T air collectors are also discussed.

TABEL 1. SPECIFICATION OF SOLAR PV MODULE USED

Specifications	Unit/Number/T
Solar Panel Type	Amorphous
Maximum Power	40 Watt Peak
Current at max. power	1 A
Voltage at max	46 V
Open Circuit Voltage	61 V
Short Circuit Current	1 A
Maximum System Voltage	600 V
Dimensions	648x1253x37 (mm)

Fig.1. Schematic picture of solar PV-T collector

A small scale PV-T solar dryer based on the amorphous PV module was constructed. The solar collector consists of 40 Wp amorphous solar module, and covered with double glass at the top, while at the bottom and both sides are insulated to minimize heat loss. The specification of the PV module used as a solar collector is presented in Table 1, and schematic diagram is as shown in Fig 1. Heated air in the collector is then flowed to a chamber where the product to be dried the outlet. The photograph of the dryer is as shown in Figure xx. Preliminary tests, i.e.with out load, was conducted and the results are discussed.

III. Results and Discussion

A. Solar PV-T Collectors Review

There are a number of researches and studies had been done and published on the topic of PV-T air collectors. Some selected publications are reviewed in this section, and some of them are related to the solar drying application.

A review of the technologies development of PV-T was made by Chow [3] and Tyagi et al. [4]. Both reviews show that extensive research on PV-T technologies has been done during the last 30 years. They concluded that the hybrid PV collectors are promising devices for the future. A study on the electrical performance of mono-crystalline PV module under STC as a result of cooling by forced air ventilation was reported by Kim et al. [5].

The performance of a PV-T air collector system was studied by Aste, et al. [6] by comparing of theoretical model and the results from the real design. Employing double glazing cover on the top of the collector gives higher thermal efficiency due to lower heat losses. However, it would decrease electrical output by about 16 % due to losses by higher temperature operation [7].

On the other hand the electrical efficiency increases about 1.6% by cooling of the PV module in their PV-air collector in comparison to a free PV system module. It was also found that in order to increase the radiation heat transfer, the surface of the air channel opposite to the PV panel should be made of materials with high emissivity. A follow-up study [8] was made to investigate the possibilities of increasing the heat transfer into the air. A simple modification was made in the air channel like small fins on the surface, placing a thin metal sheet in the air channel or using small tubes (Fig.2). These modifications gave the increase the wall temperatures at the opposite air channel.

The effect of the air channel depth in the solar collectors was studied and reported by Farshchimonfared et al. [9]. Studies were made for different collector areas. The aims of the study were to find the optimum depth according to length/width ratio of the collectors. It was found that the size of the total area corresponds to optimum air channel. The result also showed that the optimum air mass flow rate per unit collector area is proportional to collector width. Persson [10] reported the effect of the airflow and heat transfer in the air gap behind PV cells. It was found that only a small amount of heat can be transferred from the PV cells to the air. The heat transferred was estimated varies 7 - 26 % depending on the velocity of the air.

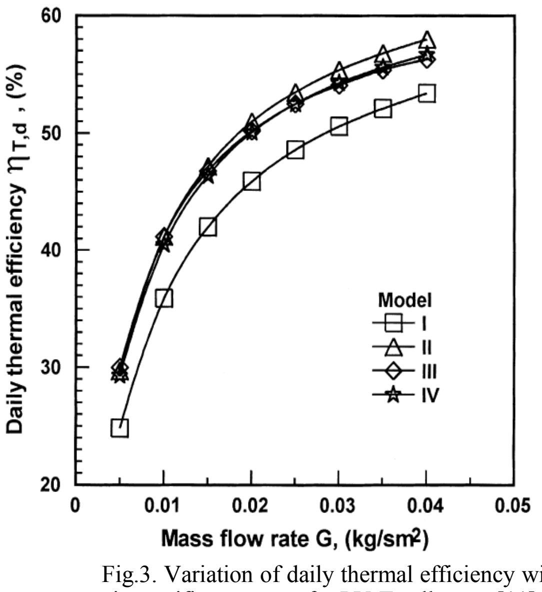

Fig.3. Variation of daily thermal efficiency with air specific mass rate for PV-T collectors [11]

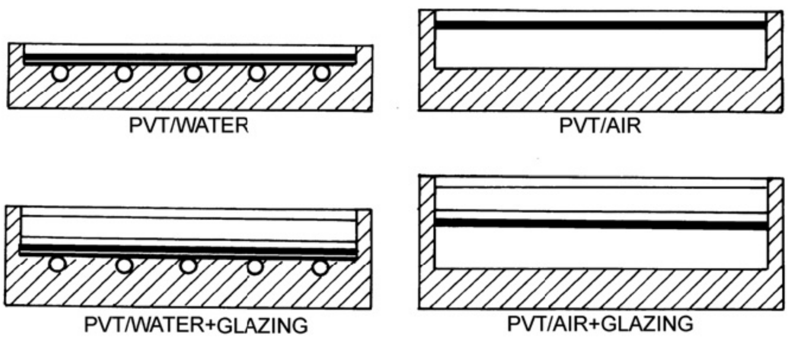

Fig.2. Cross-section of PV/T geometries, PVT/water (left) andPV-T/air (right), regarding unglazed (up) and glazed (down) types [8].

Fig.4. Photograph of solar dryer.

Hegazy [11] reported the performance of four different models of PV-T collectors. The optimum air mass flow was found around 0.02 to 0.03 kg/s m² as shown in Fig.3 The optimum of flow ratio (channel depth to length) for variable mass flow operation was reported about 2.5 x 10-3. Bambrook et al. [12] reported that additional energy from PV would exceed the power needed by fan with air flowrate in the range of 0.03 – 0.05 kg/s m².

B. Desain and Evaluation of a Small Scale PV-T Solar Dryer

Design and test a small scale PV-T solar dryer is carried out in this study using an amorphous type photovoltaic-thermal (PV-T) as a collector as schematically is shown in Fig 1.

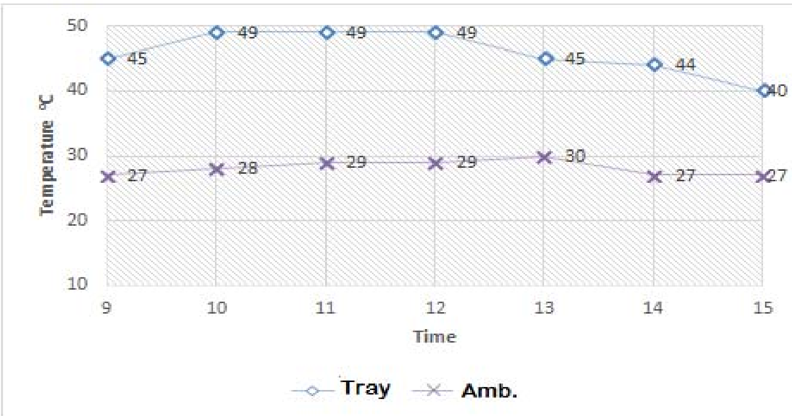

Fig. 5. Temperature in the drying chamber in comparison with ambient

Sharma, et al. [13] reported reviews of different technologies for solar drying. A similar review was presented by Belessiotis & Delyannis (2011). However, very limited studies on the implementation of PV-T technology for solar drying. Tiwari, et al. [14] analyzed the performance of a mixed-mode PV-T dryer under no-load condition. The module was used to supply electricity a fan in the drying system. Unfortunately, no appropriate research could be found in terms of replacing entirely a conventional absorber with a PV module in a solar drying system.

The solar collector consists of a 40 Wp amorphous solar module (Table 1), and covered with double glass at the top, while at the bottom and both sides are insulated to minimize heat loss. This type of PV cells was chosen for its less expensive (due to lower efficiency.

The collector is connected with a drying chamber using a PVC duct pipe. Drying chamber consists of a box with three trays inside, and employing 4 small DC fan on the top for air circulation. The heated air obtained from the collector is used directly as a drying medium, while electrical energy is used for power supply for air circulating devices. The photograph of the dryer is shown in Fig.4. Heated air in the collector is then flowed to a chamber where the product to be dried the outlet. The PV system electricity output is directly used by DC fan (without any storage).

Preliminary test to the dryer was carried out with no load. With the fixed position, i.e. solar collector facing north (in order to optimation solar irradiation according to astronomical possition of the testing location of Surabaya, Indonesia) it is found that the temperature of the outlet air from the collector varies from 35 – 50 ^oC during the day with solar irradiation of varies 300 – 1000 W/m^2. At the same time, the electric power output from the PV panel varies from 4 – 25 Watt. With this output power variation it was affecting the speed of circulating fan. Figure 5 shows the typical average air temperature in the drying chamber in comparison to the ambient, operating from 9.00 – 15.00. It can be concluded that the type photovoltaic-thermal works well as a solar collector for the dryer

CONCLUSIONS

Hybrid photovoltaic-thermal (PV-T) collectors combine of electricity and thermal energy generation of thermal energy in one single collector. This way would to increase the amount of harvested energy from solar radiation. The literature review and the real experiment in the present work show that the amorphous type of photovoltaic-thermal works well as a solar collector for solar dryer, particularly for drying product with low-temperature around 50^oC , such as many herbal and agricultural products.

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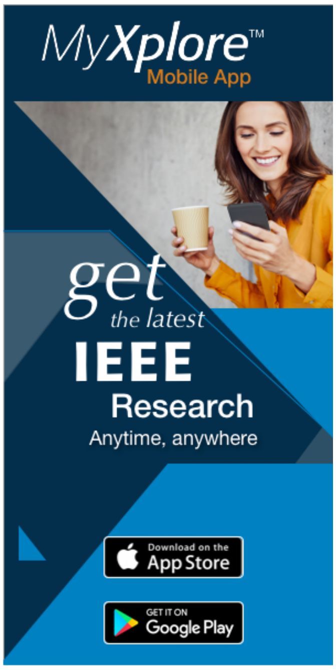

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